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Shengzhao Long
Balbir S. Dhillon
Editors

Man–Machine–Environment System Engineering

Proceedings of the 17th International Conference on MMESE

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Man–Machine–Environment System Engineering

Proceedings of the 17th International Conference on MMESE

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Xuesen Qian's Sky-High Estimation

Grandness Scientist Xuesen Qian's Sky-high Estimation for the Man–Machine–Environment System Engineering

龙升照同志：

我收到您主编的《人机环境系统工程研究进展（第一卷）》，翻看了之后，感到非常高兴，1985年秋提出的一个想法，现在8年之后已赫然成书，500多页的巨卷！而且研究范围已大大超出原来航天，内容涉及航空、航天、航海、兵器、电子、能源、交通、电力、煤炭、冶金、体育、康复、管理……等领域！你们是在社会主义中国开创了这门重要现代科学技术！

此致

敬礼！

钱学森

1993.10.22

Xuesen Qian's Congratulatory Letter

Grandness Scientist Xuesen Qian's Congratulatory Letter to the 20th Anniversary Commemorative Conference of Man–Machine–Environment System Engineering Foundation

龙升照同志:

你的来信已收到。欣悉人-机-环境系统工程创立 20 周年纪念大会暨第五届全国人-机-环境系统工程学术会议即将召开，我向你们表示最热烈的祝贺!

20 年来，你们在人-机-环境系统工程这一新兴科学领域进行了积极的开拓和探索，并取得了非常可喜的成绩，我感到由衷的高兴。

希望你们今后再接再励，大力推动人-机-环境系统工程理论及应用的蓬勃发展，为中国乃至世界科学技术的进步作出积极贡献!

祝

工作顺利!

钱学森

2001年6月26日

Preface

In 1981, under the direction of the great scientist Xuesen Qian, an integrated frontier science—Man–Machine–Environment System Engineering (MMESE)—came into being in China. Xuesen Qian gave high praise to this emerging science. In the letter to Shengzhao Long, he pointed out, "**You are creating this very important modern science and technology in China!**" in October 22, 1993.

In the congratulation letter to the commemoration meeting of 20th anniversary of establishing the Man–Machine–Environment System Engineering, the great scientist Xuesen Qian stated, "You have made active development and exploration in this new emerging science of MMESE, and obtained encouraging achievements. I am sincerely pleased and hope you can do even more to make prosper development in the theory and application of MMESE, and **make positive contribution to the progress of science and technology in China, and even in the whole world**" in June 26, 2001.

October 22, which is the day that the great scientist Xuesen Qian gave high praise to MMESE, was determined to be Foundation Commemoration Day of MMESE by the 2nd conference of the 5th MMESE Committee on October 22, 2010. On this very special day, the great scientist Xuesen Qian pointed out in the letter to Shengzhao Long, "**You are creating this very important modern science and technology in China!**" And the conference also determined that the Annual Conference on MMESE would be held from October 21–23 to cherish the memory of the great contributions that the great scientist Xuesen Qian had made to the MMESE!

The 17th International Conference on MMESE will be held in Jinggangshan, China, on October 21–23 of this year; hence, we will dedicate *Man–Machine–Environment System Engineering: Proceedings of the 17th International Conference on MMESE* to our readers.

Man–Machine–Environment System Engineering: Proceedings of the 17th International Conference on MMESE is the academic showcases of the 17th International Conference on MMESE joint held by MMESE Committee of China and Beijing KeCui Academe of MMESE in Jinggangshan, China. The *Man–Machine–Environment System Engineering: Proceedings of the 17th International*

Conference on MMESE is consisted of 99 more excellent papers selected from more than 500 papers. Due to limitations on space, some excellent papers have been left out, and we feel deeply sorry for that. Crudeness in contents and possible incorrectness are inevitable due to the somewhat pressing editing time and we hope you kindly point them out promptly, and your valuable comments and suggestions are also welcomed.

Man–Machine–Environment System Engineering: Proceedings of the 17th International Conference on MMESE will be published by Springer-Verlag, Germany. Springer-Verlag is also responsible for the related matters on index of Index to EI, so that the world can know the research quality and development trend of MMESE theory and application. Therefore, the publication of *Man–Machine–Environment System Engineering: Proceedings of the 17th International Conference on MMESE* will greatly promote the vigorous development of MMESE in the world, and realize the grand object of "**making positive contribution to the progress of science and technology in China, and even in the whole world**" proposed by Xuesen Qian.

We would like to express our sincere thanks to Springer-Verlag, Germany, for their full support and help during the publishing process.

Beijing, China
July 2017

Prof. Shengzhao Long

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He graduated from the Shanghai Science and Technology University in 1965, China. In 1981, directing under famous Scientist Xuesen Qian, he founded MMESE theory. In 1982, he proposed and developed Human Fuzzy Control Model using fuzzy mathematics. From August of 1986 to August of 1987, he conducted research in Man–Machine System as a visiting scholar at Tufts University, Massachusetts, USA. In 1993, he organized Man–Machine–Environment System Engineering (MMESE) Committee of China. He published "Foundation of theory and application of Man–Machine–Environment System Engineering" (2004) and "Man–Machine–Environment System Engineering" (1987). He edited "Proceedings of the 1st–16th Conference on Man–Machine–Environment System Engineering" (1993–2016). E-mail: shzhlong@sina.com

Dr. Balbir S. Dhillon is a Professor of Engineering Management in the Department of Mechanical Engineering at the University of Ottawa, Canada. He has served as a Chairman/Director of Mechanical Engineering Department/Engineering Management Program for over 10 years at the same institution. He has published over 345 (i.e., 201 journal + 144 conference proceedings) articles on reliability, safety, engineering management, etc. He is or has been on the editorial boards of nine international scientific journals. In addition, Dr. Dhillon has written 34 books on various aspects of reliability, design, safety, quality, and engineering management published by Wiley (1981), Van Nostrand (1982), Butterworth (1983), Marcel Dekker (1984), Pergamon (1986), etc. His books are being used in over 85 countries, and many of them are translated into languages such as German, Russian, and Chinese. He has served as general chairman of two international conferences on reliability and quality control held in Los Angeles and Paris in 1987.

Professor Dhillon has served as a consultant to various organizations and bodies and has many years of experience in the industrial sector. At the University of Ottawa, he has been teaching reliability, quality, engineering management, design, and related areas for over 29 years and he has also lectured in over 50 countries, including keynote addresses at various international scientific conferences held in North America, Europe, Asia, and Africa. In March 2004, Dr. Dhillon was a distinguished speaker at the Conf./Workshop on Surgical Errors (sponsored by White House Health and Safety Committee and Pentagon), held at the Capitol Hill (One Constitution Avenue, Washington, D.C.).

Professor Dhillon attended the University of Wales, where he received a BS in electrical and electronic engineering and an MS in mechanical engineering. He received a Ph.D. in industrial engineering from the University of Windsor. E-mail: dhillon@genie.uottawa.ca

Part I
Research on the Man Character

Validity Analyses of an Anthropometric Method Based on Computer Graphics

Xiaochao Guo, Lili Zhang, Yanyan Wang, Xueqian Deng, Duanqin Xiong, Jian Du and Qingfeng Liu

Abstract A comparative survey was conducted with 163 Chinese male pilots to build an anthropometric method based on computer graphics. 10 human body dimensions of point-to-point distance were gathered by extracted measurement based on computer graphic and traditional measurement in ISO7250 techniques. It was found that the extracted measurements were homogeneous with the traditional measurements in standardized Z scores, but there were systematic errors in raw data of the anthropometric method based on computer graphics. It suggested that the methodology based on computer graphics was well acceptable in views of ISO20685 because all mean differences were less than ±1.0 mm in 95% confidence interval after data correction by linear equation. Some factors were also discussed.

Keywords Anthropometry · Methodology · Computer graphics · Extracted measurement · Traditional measurement · Pilots · Validity

1 Introduction

There were 172 basic human body measurements for technological design in GB/T5703 [1] and totally 305 measurements which included 141 fundamental items and 164 recommended items in GJB4856 [2]. All data of human body measurements were collected by traditional methods with instruments such as the anthropometer, callipers or tape specified in ISO7250-1 [3]; therefore, more than 1.0–1.5 h was spent for every pilot's survey on working field and the duration of data collection was about two years for the databank of GJB4856. In fact, these measures can be gathered using a variety of instruments. For example, 3-D scanners could be used in

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laboratory [4] as well as photogrammetry to shorten waiting time of participants of pilots. An anthropometric method based on computer graphics was built in comparison with traditional anthropometric methods in the present paper.

2 Method

2.1 Selection of Measurements

There were 10 dimensions of anthropometry drawn from integration of GJB4856, GB/T5703 and ISO7250-1 which is defined as point-to-point distance in Annex A of ISO20685 [4]. The measurements listed in Table 1 could be representative of 201 linear items in GJB4856.

2.2 Methodologies of Data Collection

2.2.1 Extracted Measurement Based on Computer Graphics

Three classes of pictures were designed according to small, medium or large scale as listed in Table 1 for photography measurement based on data distribution of the 201 linear items in GJB4856 (see Fig. 1).

Table 1 Anthropometric items selected for comparative survey

No	Code in GJB4856	Items	Limits in GJB4856 (mm)			Class
			Range	Minimum	Maximum	
1	1.29	Mouth breadth	27	39	66	Small
2	4.10	Hand breadth at metacarpal	25	74	99	Small
3	1.12	Bizygomatic breadth	44	110	154	Small
4	1.3	Total head height	72	202	274	Small
5	2.57	Posterior interarmpit breadth I	135	278	413	Medium
6	2.51	Maximum shoulder breadth	128	386	514	Medium
7	3.22	Buttock–knee length, sitting	169	500	669	Medium
8	3.17	Arm reach from back	210	733	943	Large
9	3.1	Sitting height	179	843	1022	Large
10	2.1	Stature (body height)	342	1575	1917	Large

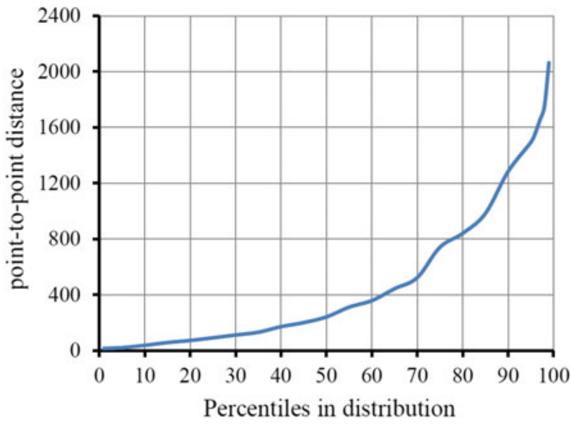

Fig. 1 Data distribution of GJB4856

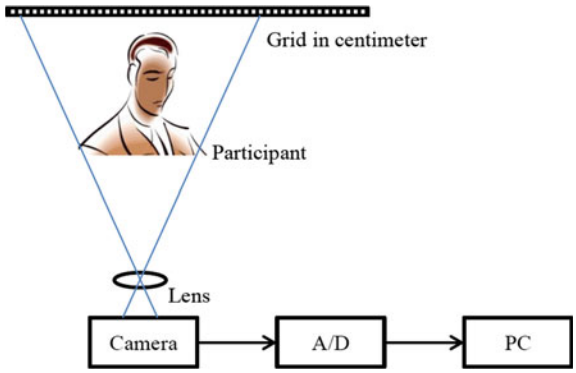

Fig. 2 Sketch of photography measurement

The pictures were photographed on grid in centimeters as close to participant as possible and stored in PC after digitalization as shown in Fig. 2.

An algorithm of computer graphics was programed to identify the anthropometric landmark on the surface of human body in digital picture as a point to be highlighted with jump in gray scale of image. The point-to-point distance could be computed as raw data of extracted measurement mentioned above in Table 1.

2.2.2 Traditional Measurement with Traditional Instruments

The traditional measurer was an expert trained and experienced in ISO 7250 techniques. All data were collected by direct measurement with traditional instrument precision of 1.0 mm in accordance with ISO7250-1 and GJB4856.

2.3 Participants

A total of 163 male pilots took part in the comparative survey to finish both tasks of extracted measurement and traditional measurement as paid volunteers.

3 Results

The data were listed in Table 2 by comparison.

Table 2 Statistic data of extracted and traditional measurements for 163 pilots (mm)

No	Code and item in GJB4856		Methodology	$\bar{x}$	s	Range	Minimum	Maximum
1	1.29	Mouth breadth	Extracted	52.2	3.8	23.3	44.4	67.7
			Traditional	51.7	3.4	17.5	44.5	62.0
2	4.10	Hand breadth at metacarpal	Extracted	84.1	4.3	22.7	72.6	95.3
			Traditional	84.8	3.5	18.0	76.0	94.0
3	1.12	Bizygomatic breadth	Extracted	125.5	5.8	31.1	112.6	143.7
			Traditional	125.0	5.5	27.0	114.0	141.0
4	1.3	Total head height	Extracted	236.6	7.2	35.2	219.9	255.1
			Traditional	235.4	7.5	44.0	213.0	257.0
5	2.57	Posterior interarmpit breadth I	Extracted	343.7	19.1	100.0	292.0	392.0
			Traditional	341.4	19.0	95.0	298.0	393.0
6	2.51	Maximum shoulder breadth	Extracted	445.7	18.2	112.9	390.0	502.9
			Traditional	446.3	17.9	105.0	394.0	499.0
7	3.22	Buttock–knee length, sitting	Extracted	600.2	49.4	191.1	524.8	715.9
			Traditional	602.7	49.8	192.0	526.0	718.0
8	3.17	Arm reach from back	Extracted	841.1	55.2	239.9	741.2	981.1
			Traditional	839.2	55.0	239.0	741.0	980.0
9	3.1	Sitting height	Extracted	923.8	23.7	113.0	869.7	982.7
			Traditional	924.4	23.8	113.0	871.0	984.0
10	2.1	Stature (body height)	Extracted	1712.4	46.8	240.0	1609.0	1849.0
			Traditional	1712.8	46.4	239.0	1611.0	1850.0

4 Discussions

4.1 Homogeneity of Two Subsamples of Data

All raw data were transformed into the standardized Z scores. It was suggested that the extracted measurements based on computer graphics were homogeneous with the traditional measurement in Table 2 by Levene's test of equality of error variances in SPSS repeated measures($F(1324) = 0.00$–0.42, $P = 0.58$–0.99). The anthropometric method of extracted measurement on computer graphics was same as the traditional anthropometric method in statistics.

4.2 Accuracy of Extracted Measurements

4.2.1 Systematic Error in Methodology

The analysis of mean difference was tested taking traditional measurement as norm in the light of ISO20685. It was found that there were systematic errors in the anthropometric method based on computer graphics as shown in Table 3.

4.2.2 Data Correction by Linear Equation

The correction of raw data was made by linear regression from extracted measurement to traditional measurement. All corrected mean differences were less than

Table 3 Mean difference between methodologies ($\Delta\bar{x}$, mm)

No	Code and item in GJB4856		$\Delta\bar{x}$	95% Confidence interval		Value of t-test	*P*
				Lower	Upper		
1	1.29	Mouth breadth	0.56	0.20	0.92	3.04	**
2	4.10	Hand breadth at metacarpal	−0.70	−1.09	−0.31	−3.54	**
3	1.12	Bizygomatic breadth	0.47	0.13	0.82	2.69	**
4	1.3	Total head height	1.24	0.69	1.79	4.48	***
5	2.57	Posterior interarmpit breadth I	2.29	1.77	2.81	8.72	***
6	2.51	Maximum shoulder breadth	−0.58	−1.12	−0.03	−2.09	*
7	3.22	Buttock–knee length, sitting	−2.48	−2.82	−2.15	−14.64	***
8	3.17	Arm reach from back	1.93	1.52	2.35	9.19	***
9	3.1	Sitting height	−0.62	−0.92	−0.32	−4.09	***
10	2.1	Stature (body height)	−0.37	−0.73	−0.01	−2.00	*

Note *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$

Table 4 Difference of two methodologies after data correction (mm)

No	Code and item in GJB4856		95% Confidence interval		Value of t-test	*P*	Allowable error
			Lower	Upper			
1	1.29	Mouth breadth	−0.30	0.34	0.15	0.88	1
2	4.10	Hand breadth at metacarpal	−0.28	0.36	0.24	0.81	1
3	1.12	Bizygomatic breadth	−0.39	0.27	−0.36	0.72	1
4	1.3	Total head height	−0.61	0.47	−0.26	0.79	2
5	2.57	Posterior interarmpit breadth I	−0.60	0.43	−0.33	0.74	4
6	2.51	Maximum shoulder breadth	−0.32	0.76	0.81	0.42	4
7	3.22	Buttock–knee length, sitting	−0.50	0.17	−0.97	0.33	5
8	3.17	Arm reach from back	−0.03	0.80	1.83	0.07	5
9	3.1	Sitting height	−0.05	0.55	1.64	0.10	4
10	2.1	Stature (body height)	−0.19	0.52	0.92	0.36	4

Note The maximum allowable errors are seen in ISO20685:2010

±1.0 mm in 95% confidence interval (Table 4), which was near to the precision of traditional instruments and presented the anthropometric method based on computer graphics same as the traditional methods in this paper.

4.3 Some Considerations in Methodology Developing

An accurate and fast method of anthropometry was desired in recent decades especially for human head and face, but results of studies were controversial. It was demonstrated that 3D anthropometry can be replaced with manual methods in South Korea with 10 hand measurements of 1700 teenager students [5], while it was found in USA that the mean aberration was 7.96 mm between 3D photography to traditional method ($P < 0.05$) although the mean diversity could be reduced to 1.33 mm after a cutoff of 10% extrema for calliper measurement data [6].

In China, Fang and Fang (7) revealed that the average error, maximum error and standard deviations are 1.70, 5.63 and 1.47 mm comparing computerized anthropometry to traditional method with 17 length measurements on head and face [7], which went beyond the maximum allowable error in ISO20685. Wu et al. [8] reported that the extracted measurements from 3D imagines were 1.9–8.0 mm more than traditional measurements in average with 14 linear dimensions ($P < 0.01$ or 0.05) except of mouth breadth, nose height, and nose breadth for 150 male pilots [8], which was partially acceptable by ISO20685.

Some factors should be emphasized in administration of comparative study for anthropometric methodology in consideration of influences such as:

- The trained and experienced measurer in both methodologies;
- The smallest and visible landmarks on surface of human body;
- Homogeneity test of errors between methodologies; and
- Accurate algorithm of computer graphics to identify the landmarks and correct raw data by regression versus traditional measurement.

It was also said that the skill of operators and the accurate positioning of landmarks would greatly influence the measurement [8].

The nonlinear dimensions could be curved by computerized algorithm or predicted by basic measurement in GJB4856 [9].

5 Conclusions

A total of 163 male pilots participated in a comparative study to set up an anthropometric method based on computer graphics. There were 10 items of point-to-point distance to be surveyed with extracted measurement based on computer graphic as well as traditional measurement with instruments such as anthropometer, callipers and so on. The results were found that the extracted measurements were homogeneous with the traditional measurements in standardized Z scores, but there were systematic errors in the anthropometric method based on computer graphics. All mean differences were less than ±1.0 mm in 95% confidence interval after raw data correction by linear equation which revealed that the methodology based on computer graphics was well acceptable in views of ISO20685.

Acknowledgements The authors are thankful to Mr Qichang Hou for his instruction of traditional measurement and Ms Xuan Qu for her computerized programming.

Compliance with Ethical Standards The survey was approved by the Academic Ethics Committee of Institute of Aviation Medicine PLAAF. All participants were volunteers with essential protection.

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Effects of Driving Experience and Hazard Type on Young Drivers' Hazard Perception

Long Sun, Ruosong Chang and Shuang Li

Abstract Young novice drivers are found to be poor at detecting and responding to hazards on the road. In this study, three groups of young drivers with 6, 12 and 18 month driving experience were asked to complete a hazard perception task and their eye movements were recorded using Tobbi T120 eye tracker. The task contained 20 video clips, and hazards in the clips were classified into overt hazard (continuous visibility) and covert hazard (interrupted visibility) according to their visibility of materialization. Results revealed that drivers reacted to overt hazards faster than covert hazards. The experience-related differences in reaction time of the three driver groups were due to the faster processing after the initial fixation. Drivers' mean fixation duration was influenced by hazard type, but not by driving experience. These findings suggested that hazard type was a key factor when it comes to hazard perception testing and training for young drivers.

Keywords Hazard perception · Driving experience · Hazard type · Young driver

1 Introduction

Crash rates are particularly higher during the first month of licensure and decline rapidly for about six months and then much more slowly for at least two years [1]. Among the factors that accounted for young drivers' crash involvement, hazard perception (HP) skill was a key factor. For example, young novice drivers' scores on a video-based HP test could predict their crash involvement in the next year following the test [2].

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When facing a specific hazardous situation, drivers are expected to detect the potential hazard earlier, and then, they evaluate the hazardous level of the hazard and decide whether a response is needed to avoid a collision [3]. This skill, naming hazard perception, was a multi-component driving skill that can be improved through training. However, some studies failed to find the differences of HP performance between young novice drivers and young experienced drivers [4, 5]. This may partially due to the hazard type used in the HP studies. Another reason was the experience-related differences in HP reaction time may derive from later detection of hazard or/and the longer processing time after the initial fixation [6].

Although many studies demonstrated that experienced drivers reacted to hazards faster than novice drivers, little was known about the influencing mechanism of hazard type on young drivers' different HP processes. Thus, in this study, three groups of young drivers with 6, 12 and 18 month driving experience were recruited. And their HP performance under two types of hazard was examined using a video-based HP task.

2 Methods

2.1 Participants

Forty-five young drivers agreed to participate in this study. Participants' ages ranged from 18 to 27 (mean = 23.20, SD = 2.18), and they have 6-, 12- and 18-month driving experience, respectively. Participants were classified into three groups (labeled as 6-month, 12-month and 18-month drivers) according to their driving experience since they obtained a valid driving license (see Table 1).

The three groups of drivers were significantly different in their total driving mileage. They were not significantly different in their male-to-female ratio, age and years of education. Participants had normal or corrected-to-normal vision. Each participant received ¥50 after he/she completed the HP task.

Table 1 Demographic and test scores

Demographic factors	Driver group			*p*-value
	6-month mean (SD)	12-month mean (SD)	18-month mean (SD)	
Gender ratio (M/F)	3/12	6/9	4/11	>0.05
Age (year)	22.53 (2.26)	23.00 (2.34)	23.40 (1.80)	>0.05
Total driving mileage/KM	887 (299)	2067 (1354)	3773(1877)	<0.01
Years of education	13.93 (2.40)	14.40 (2.02)	14.40 (2.03)	>0.05

2.2 Materials

A hazard perception task was used in this study. The task contained 20 dynamic video clips (lengths ranged from 9 to 20 s), and its discrimination validity was good [7]. All video clips were shot from drivers' perspective around Dalian urban area under fine weather. Each video clip showed a traffic situation where a potential hazard was developing slowly as the camera car was approaching. During the experiment, participants could see the front part (hood) of the camera car.

Hazards in the clips were split into two types according to the visibility of their materialization. Overt hazards were totally visible in the process of materialization in front of the camera car (e.g., a car was signaling to turn right on the next intersection). Covert hazards were partially or totally blocked during the process of materialization, and these hazards became visible at the very moment when a maneuver was needed to avoid a collision (e.g., a pedestrian was walking into the road from the other side, but he was blocked by a bus moving in the opposite direction with the camera car).

Ten video clips contained overt hazards, and ten video clips contained covert hazards. The ten hazards in the clips were triggered by cars (five clips), pedestrians (three clips) or riders (two clips). The clip length of videos that contained overt and covert hazards wasn't significant, $t = 1.12$, $p > 0.05$. The road types were counter-balanced under each hazard type to minimize the effect of local familiarity. The onset time and the location of hazards were also different from one clip to another. All the hazards contained a *hazard window*, which began at the earliest point where a hazard was detectable and ended at the point where drivers' avoidance response would no longer prevent a collision [5, 8].

2.3 Design

A 3×2 mixed design was employed. The between-groups factor was driving experience (6-month drivers, 12-month drivers vs. 18-month drivers). The within-groups factor was hazard type (overt hazard vs. covert hazard).

The dependent variables were response latency (RL), time to first fixation (TFF), reaction time (RT) and mean fixation duration (MFD). RL was divided into TFF and RT according to participants' first fixation on the hazard [4, 6]. RL was calculated as the time from the onset of the hazard to the moment when a maneuver was needed to avoid a collision. TFF was calculated as the time from the onset of the hazard to the moment when participants first fixated on the hazard. RT was calculated as the time from when participants first fixated on the hazard to the moment when they reacted to it. MFD was the mean amount of time in which participants fixated on the hazard.

2.4 Procedure

Participants first finished a demographic questionnaire, and then, they were fitted with the Tobbi T120 eye tracker, which samples at 120 Hz. The viewing distance was 65 cm from the screen. After calibrating their gaze points, participants took three practice clips. They were instructed to click the left mouse button quickly when they detected a potential hazard that forced them to slow down or change their driving course. Finally, 20 video clips were randomly assigned to each participant on a 17-inch monitor at a resolution of 1280 $\times$ 720. The experiment lasted about 15 min.

3 Results

3.1 Response Latency

A 3 $\times$ 2 analysis of variance (ANOVA) compared the mean RL of the three driver groups. The main effect of driving experience was significant (F (2, 42) = 13.42, $p < 0.01$, $\eta^2 = 0.390$). Post hoc revealed that 6-month drivers ($M = 3.05$, SD = 0.22) responded to hazards slower than 12-month drivers ($M = 2.79$, SD = 0.29) ($p < 0.05$) and 18-month drivers ($M = 2.48$, SD = 0.39) ($p < 0.01$). The main effect of hazard type was significant (F (1, 42) = 50.32, $p < 0.01$, $\eta^2 = 0.545$); drivers responded to overt hazards ($M = 2.56$, SD = 0.47) faster than covert hazards ($M = 2.99$, SD = 0.39). The interaction between the two factors wasn't significant ($F < 1$, $p > 0.05$).

3.2 Time to First Fixation

A 3 $\times$ 2 analysis of variance (ANOVA) compared the mean TFF of the three driver groups. The main effect of hazard type was significant (F (1, 42) = 36.25, $p < 0.01$, $\eta^2 = 0.463$); drivers detected overt hazards ($M = 0.21$, SD = 0.17) faster than covert hazards ($M = 0.40$, SD = 0.25). No effect of driving experience and its interaction with hazard type were found (Fs < 1, ps > 0.05).

3.3 Reaction Time

A 3 $\times$ 2 analysis of variance (ANOVA) compared the mean RT of the three driver groups. The main effect of driving experience was significant (F (2, 42) = 7.72, $p < 0.01$, $\eta^2 = 0.269$). Post hoc revealed that 6-month drivers ($M = 2.69$, SD = 0.26) and 12-month drivers (M = 2.52, SD = 0.32) reacted to hazards slower than 18-month drivers (M = 2.20, SD = 0.44) (ps < 0.05). The main effect of hazard type was significant (F (1, 42) = 8.47, p < 0.01, η^2 = 0.168); drivers reacted to overt hazards (M = 2.36, SD = 0.49) faster than covert hazards (M = 2.58, SD = 0.46). The interaction between the two factors wasn't significant (F < 1, p > 0.05).

3.4 Mean Fixation Duration

A 3 × 2 analysis of variance (ANOVA) compared the mean MFD of the three driver groups. The main effect of hazard type was significant (F (1, 42) = 24.64, p < 0.01, η^2 = 0.370); drivers fixated overt hazards (M = 0.44, SD = 0.24) longer than covert hazards (M = 0.37, SD = 0.19). The main effect of driving experience wasn't significant (F (2, 42) = 1.16, p > 0.05). The interaction between the two factors was significant (F (2, 42) = 3.43, p < 0.05, η^2 = 0.140). However, simple effect test showed that the three groups' MFD on covert hazards (F < 1, p > 0.05) and overt hazards (F (2, 42) = 1.67, p > 0.05) weren't significant.

4 Discussion

The present study examined the effects of driving experience and hazard type on young drivers' hazard perception performance. First, the three driver groups were only different in their total driving mileage. Thus, the relationship between young drivers' driving experience and their hazard perception performance could be better understood when the other demographic factors are well controlled.

Second, we found driving experience did affect drivers' response latency to hazards. The more driving experience a driver had, the faster he or she reacted to hazards. The experience-related differences in response latency were due to the faster processing time after the initial fixation. The three driver groups were not significantly different in the time to spot a potential hazard. One possible explanation for this was that participants haven't driven long enough to form flexible visual strategies. In addition, young drivers reacted to overt hazard faster than covert hazards. This indicated that how fast a young driver could react to the hazard, to some degree, depended on the salient nature of the hazard. Although drivers' HP processing mechanism on covert and overt hazards was similar, our data suggested that overt hazards were more effective in distinguishing the three driver groups than covert hazards. Overall, these findings provided some insight into why young novice drivers had poorer ability to address particular hazards.

Finally, no effect of driving experience on mean fixation duration was found in this study. Although the mean fixation duration of the three groups was similar, the reaction time of the two groups of less experienced driver was slower than drivers who had 18-month driving experience. This indicated that compared to more experienced drivers, when the similar amount of attention was given to a specific hazard, the two groups of less experienced drivers could not extract sufficient information from the stimuli, or at least, the efficiency of their information-to-action translation was worse [3].

Nonetheless, we found overt hazards were fixated more time than covert hazards. Due to the nature of covert hazards, it could be more beneficial for young novice drivers if their visual strategies on covert hazards get well trained. However, covert hazards used in the training should not be too difficult to detect because the task may require more attentional resources that young drivers may not have, especially when the training was conducted on a driving simulator.

Compliance with Ethical Standards The study was approved by the Logistics Department for Civilian Ethics Committee of Liaoning Normal University.

All subjects who participated in the experiment were provided with and signed an informed consent form.

All relevant ethical safeguards have been met with regard to subject protection.

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Role of Responding Time in Identifying False Results of Personality Tests Among Recruits

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Abstract In order to meet the need of modern army and war, the new recruits should pass systematic psychological selection and mental disorder assessment. Combined application of response time and relative mental tests could solve the problem of false psychological test results, validate the authenticity of the results, and strengthen the reliability and validity. This could be applied as efficient tests for new recruits of high stress condition during military training, and mostly abandon recruitments of mental disorders.

Keywords Personality tests · Recruits · Test error · False result · Responding time

1 Introduction

Mental health work in the military has been considered to be of great importance [1, 2]. In order to maintain the stability of the military, the staff working on military psychology must effectively conduct mental health work [3, 4]. For mental health of military personnel plays an important role in maintenance of military strength, prevention of mental disorders must be adopted by their early detection and treatment [5]. So development and promotion of efficient psychological evaluation is an important part of military mental work [6, 7].

This study aimed to explore the effect of words count of each question, personality factors, sexuality and majors on responding time of participants. Through these methods, we hoped to identify false results of personality tests.

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2 Participants and Methods

2.1 Participants

All 778 recruits were enrolled from some military colleges between September, 2004 and March, 2009. The participants provided permission to publish these features of their cases. And all subjects agreed to participate in the study.

2.2 DXC-6 Wireless Multiterm Group Psychological Testing Station (WMGPTS)

All participants were evaluated with the DXC-6 Wireless Multiterm Group Psychological Testing Station (WMGPTS) that was developed by the Fourth Military Medical University. This machine could evaluate basic ability and personality by series of scales. The instrument has been used in psychological evaluation of astronauts, pilots and new recruits, etc.

2.3 Cattell 16 Personality Factors Test

Cattell 16 Personality Factor Test (16PF) [8, 9] was carried out among military college students. WMGPTS automatically recorded four parameters for each question answered by the subject: the time to press key, the time to release key (the completion time), modifications of answers and the final answer, to analyze the relationship between the answer time and test results.

2.4 Statistical Analysis

Data were presented as mean ± standard deviation, and the responding time of participants among different sexual groups and majors was compared by Student's *t* test. And Pearson correlation and multiple liner regression were applied to analyze the relationship between average response time and personality factors. All analyses were performed with SPSS 21 (IBM Corp., US). Statistical probability (P) was determined based on hypothesis testing, with the level of statistical significance set at $P < 0.05$.

3 Results

3.1 Participants' Characteristics

In all 778 participants, 404 were men and 374 were female; 322 majored in humanities and 456 in natural science; their ages ranged from 17 to 25 with an average of (18.91 ± 1.08). To explore the sensitivity of time variables to individuals who pretend to be healthy or ill, the answer time of participants in the 16PF test was analyzed.

3.2 Results of Cattell 16 Personality Factors Test

Significant differences existed in the answer time of college students among the 16 factors ($P < 0.01$), of which factor B took the longest time, and factor G the shortest.

There was a significant positive correlation ($r = 0.522$, $P < 0.01$) between the average answer time for each question ($n = 778$) and the number of words (Table 1); the regression equation was: $Y = 0.325 + 0.193\ X1 + 6.209\ X2$ (Table 2). Y is the average response time of each question (in seconds), X1 the word count of the question, and X2 the proportion of factor B.

The total answer time of male students was 1464.51 ± 251.51 s and that of female students was 1396.43 ± 240.78 s. The independent sample test result of 3.86 ($P < 0.01$) suggested that there was a significant difference (Fig. 1). The total answer time among the humanities and natural science majors was 1512.11 ± 250.11 s and 1375.05 ± 231.53 s, respectively, which showed that natural science students answered significantly faster than humanities students ($P < 0.01$) (Fig. 2). The answer time reflected the performance of subjects to some extent, which would contribute to checking the authenticity of the test results.

Table 1 Correlation between average answer time and the number of words

Model	*N*	*r*	Sig. (2-tailed)
Pearson	778	0.522	<0.001

Table 2 linear regression model estimation

Model		Coefficients			Model summary		
		B	*t*	Sig.	*r*	*F*	Sig.
Linear	(Constant)	0.325	−2.284	0.048	0.619	15.917	<0.001
	X1	0.193	5.006	0.001			
	X2	6.209	3.333	0.009			

Note Dependent Variable: Y

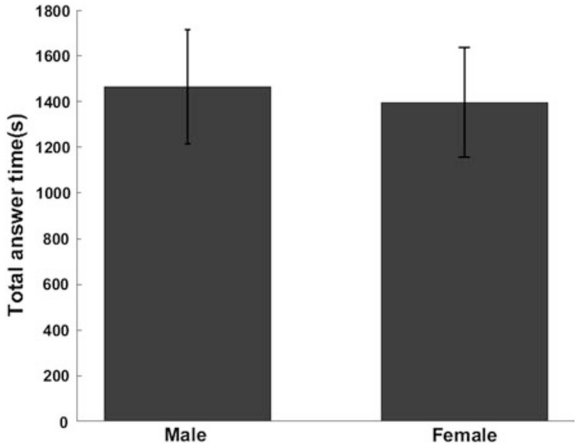

Fig. 1 Comparison of total answer time between male and female students

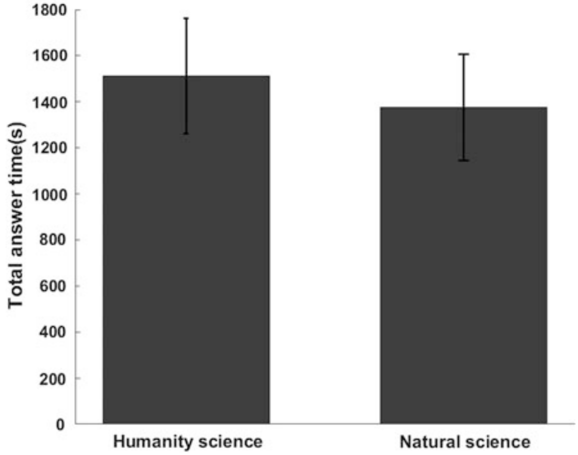

Fig. 2 Comparison of total answer time between humanity and natural science majors

4 Discussions

It was showed that mental illnesses primarily damages "sustained attention," then verbal and working memory, and seldom influences other abilities [10, 11]. The subject who performed poorly in all three of the abilities above would be in the high-risk group. In terms of personality and mental health tests, results vary greatly as the motivation of subjects is different, so we developed the WMGPTS that can effectively identify pretend health or illness. Because of a different motivation, voluntary soldiers would hide or exaggerate their suffering. Combining authoritative psychology scales and recording of answer time for each question, this new technology was developed to identify the seriousness of the subjects through time analysis.

5 Conclusions

Combined application of response time and relative mental tests could validate the authenticity of the results and strengthen the reliability and validity.

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Compliance with Ethical Standards The study was approved by the Logistics Department for Civilian Ethics Committee of the Department of aerospace medical equipment, Fourth Military Medical University. All subjects who participated in the experiment were provided with and signed an informed consent form. All relevant ethical safeguards have been met with regard to subject protection.

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Research on Pilot's Intention Reasoning Method Based on D–S Evidence Theory

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Abstract In order to improve the efficiency and accuracy of pilot decision-making in battlefield environment, a pilot intention reasoning method based on Dempster–Shafer evidence theory is proposed. Firstly, the D–S evidence theory is used to associate the pilot's action with the intention in the expert system database, and the credibility of the evidence is fused through the Dempster synthesis rule. The cockpit man–machine interface is dynamically changed according to the pilot intention. And then an example is given to demonstrate the effectiveness and feasibility of the proposed method, which provides a theoretical basis for the optimization of man–machine interface of fighter cockpit.

Keywords D–S evidence theory · Intention reasoning · Human–machine interface · Cockpit

1 Introduction

The operational intent of the pilot is that the pilot desires to achieve a certain state or purpose through a series of operations that most directly reflect of the pilot's tactical purpose, but the operational intent is difficult to measure directly or perceive by the device. In this paper, it is assumed that when the pilot's brain produces some operational intent, it requires a series of operational actions on the fighter, which are detected or collected by the airborne sensor.

Therefore, the cockpit man–machine interface can quickly and accurately show the pilot's intention, thus improve the decision-making efficiency of the pilot, by reversing the operator's action to indirectly infer the pilot's intention.

Intention reasoning includes strategic intention reasoning and tactical intention reasoning. By contrast, the judgment and decision made by the pilot in the battlefield environment are mostly specific, targeted and highly real-time, most of

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which belong to the tactical intention. This paper presents a pilot tactical intention reasoning method based on D–S evidence theory [1].

2 Basic Theory of D–S Evidence Theory

- Definition 1 Setting a non-empty finite set $\Theta = \{\theta_1, \theta_2, \ldots, \theta_N\}$, where the N elements are mutually exclusive, the set Θ is called the recognition framework. A set of all the subsets of the recognition framework Θ is called power set, as 2^Θ.
- Definition 2 Setting Θ as the recognition framework. The basic trust allocation function m is a mapping from the set 2^Θ to [0, 1], A represents any subset of the recognition framework Θ, as $A \subseteq \Theta$, and to meet $m(\varnothing) = 0$, $\sum m(A) = 1$, $m(A)$ is called the basic trust allocation function for event A, which indicates the degree of trust for A. For a subset A, then is called focal element as long as $m(A) > 0$.
- Definition 3 The trust function Bel is a mapping from the set 2^Θ to [0, 1], If A is any subset of the recognition frame Θ, as $A \subseteq \Theta$, and to meet formula

$$\mathrm{Bel}(A) = \sum_{B \subseteq A} m(B) \tag{1.1}$$

  Then, $\mathrm{Bel}(A)$ is called the trust function of A, it indicates the degree of trust that A is true [2].
- Definition 4 The synthesis rules of D–S evidence. Assuming that the framework Θ contains evidences E_1 and E_2, the basic trust allocation function corresponding to E_1 is m_1 and E_2 is m_2, then A_i and B_j are the two elements contained in the evidence [3].
  Setting $K = \sum_{A_i \cap B_j = \varnothing} m_1(A_i) \cdot m_2(B_j) < 1$, the rule of the two evidence is

$$m(A) = \begin{cases} \frac{\sum_{A_i \cap B_j = A} m_1(A_i) \cdot m_2(B_j)}{1-K}, & A \neq \varnothing \\ 0, & A = \varnothing \end{cases} \tag{1.2}$$

  In the formula, K reflects the degree of conflict between the various evidences, the coefficient $1/(1-K)$ is called the regularization factor [4]. The trust function given by m is called the orthogonal sum (also called straight) of m_1 and m_2, as $m_1 \oplus m_2$.

3 Pilot Intention Reasoning Model

At some point, through the pilot operation by the collected sensor data as input information, this information and expert system database associate, match, and screen through a certain rule of the model reasoning out of one or several pilot intentions that the expert system thinks that the most likely to occur. In this paper, the reasoning model and the matching method are combined with the expert system database and the intention of the pilot behavior prediction [5]. This combination method is helpful to optimize the fighter cockpit man–machine interface design to achieve the purpose of reasoning the operational intention through the pilot behavior.

3.1 Pilot Operation Intention Reasoning Model Structure

In order to facilitate the expert system to reason the pilot's intention, we must combine the operation of the pilot into a high-level combination of the sequence. The association of the pilot operations can effectively reduce the number and frequency of comparing with the expert knowledge database and improve the reasoning speed [6, 7]. At the same time, it is possible to increase the effective information of the operation sequence and make the connection between the operation and action more closely, and the associated operation intention is clearer. For the type of association, it can be defined according to the specific need. This paper only gives the definition of the operation event cleanup, repetitive action event compression, and operational intent to logical association.

3.1.1 The Operation Action Event Cleanup: $[a, p(a) \leq H] \rightarrow [\mathrm{nil}]$

a for a certain action, $p(a)$ for a property value of the action a, H is a valid value. Operation action event cleanup is the most widely used, and its role is to reduce the number of operational events to reduce the number of matching. If the value $p(a)$ of the attribute, such as the reliability, urgency, etc., by described in the operation action a is less than the system-defined valid value H, then this action will not produce an association effect or be temporarily stored in a log file. In the case of high complexity of the battlefield, you can also design a dynamic range H depending on the pilot and situation.

3.1.2 Repetitive Action Event Compression: $[a, a, \ldots, a] \rightarrow [a]$

The repetitive action event compression is a combination of operations that are repeated in a short period of time with a high number of operations, and only consider the intention of generating the single operation. The compressed operation is basically the same as the effect of a single operation. However, in a short time, the operation information will be repeatedly written on the log file.

3.1.3 Operational Intent Logic/Match Association: [*a*, *b*, …, and, or, not] → [*c*]

a for the operation of action, *and*, *or*, *not* for the logical relationship, *c* for the result of reasoning. Operational intent logic/matching association is a more complex way of matching by using Boolean operations. Through a large number of original simple operational action or sequences that are matched to the expert system database to be associated with operational intent. Since the previous database is represented by the frame structure, then the intention it should also have is the corresponding structure. The intention frame structure of this paper is as follows (Fig. 1).

For Fig. 1, it is worth noting that the reservation slot contains the relationship value among the different intentional identification frameworks, which indicates the relationship among the different intentions; the serial slot is the intent number of the intentions in the entire expert system database; operation–intention association slot is the focus of this framework, it directly describes the degree of operation associated with this intention, its side 1, side 2 that is the name of each different operation, value 11 and value 21 correspond to the credibility of the operation; the threshold slot is the degree of association between the operation and the intention, and the value is the discriminant threshold, which is the fixed value by given directly by the expert system.

Fig. 1 Intent frame diagram

Intention name		
Imperative slot	Value	
Serial number slot	Value	
The enemy sign slot	Value	
Intent type slot	Value	
Hierarchical Type Slot	Value	
Operation - intention association slot	Side 1	Value 11
	Side 2	Value 21
	……	
Threshold slot	Value	

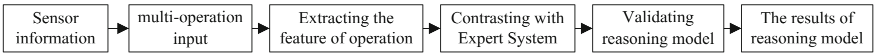

Fig. 2 Pilot's operating intent inference step

The pilot operation intention reasoning process is divided into five steps, as shown in Fig. 2.

Assuming that the current sensor input pilot action has 11, respectively, for the push throttle stick, sharp turn, roll, rollback, dive, quickly pull up, separate S maneuver, into the helmet flight mode, weapons online preparation, radio silence, and infrared interference bomb preparation [8, 9]. The property slot of each action of the framework has three attribute values which can determine the authenticity of the action and repeat or not. After action cleaning and compression, eleven actions are combined into seven actions, respectively, action 1, 2, 3, 5, 7, 9, 11. And actions 4, 6, 8, 10 are merged or cleared temporarily. The seven effective actions are input expert system to match to operate intended, finding that five operation intentions intend to be associated with the above seven actions, respectively, five intentions to match and compare. It can be seen that the operational actions 1, 2, 5 are associated with intent 1. Operational actions 2, 3, 9 are associated with intent 2. Operational actions 5, 7 are associated with intent 3. Operational actions 1, 9, 11 are associated with intent 4. Operational actions 2, 5, 9 are associated with intention 5. Through the confidence value of the operation–intention, the corresponding slot is calculated and then compared with the discrimination value of the discrimination threshold slot; we can get the possibility of occurrence. Finally, the possible intention is pooled into the intent concentration to carry out the collision detection. If the conflict is found, the intention will be synthesized. Otherwise, the result of intention reasoning will be stored in the expert system combined with the method of the pilot's online modification [10]. Meanwhile, the cockpit man–machine interface displays information corresponding to the current intention. The pilot reasoning model is shown in Fig. 3.

The following gives a detailed reasoning process based on the expert system of the pilot operating intention reasoning model in the fighter cockpit:

1) According to the distributed sensor to detect the operation of the pilot, enter the $E_i, i = 1, 2, \ldots, k$ operation action. Clean up, compress and integrate the pilot operation, and construct the recognition frame $\Theta : \Theta = \{E_1, E_2, \ldots, E_K\}$;
2) According to the operator's current operation to compare the intention set of the expert system database and intention $I_n, n = 1, 2, \ldots, N$ which is able to match as a focal element, to associate with the operation-intention, and construct the same basic allocation function $m_k(A_n), k = 1, 2, \ldots, K;\ n = 1, 2, \ldots, N$ as structure of the database. The basic trust allocation function is determined by the following formula: $m_k(A_n) = \mathrm{CF}_K \times W_K$, where CF_k is the trust value of operation E_k and match intention A_n, and W_k is the corresponding weight.
3) Continuous synthesis of $m(A)$ by the two–two evidence ladder synthesis method, and finally the trust function $\mathrm{Bel}(I_n)$, if $\mathrm{Bel}(I_n) \geq \mathrm{Th}(I_n)$ ($\mathrm{Th}(I_n)$ for the

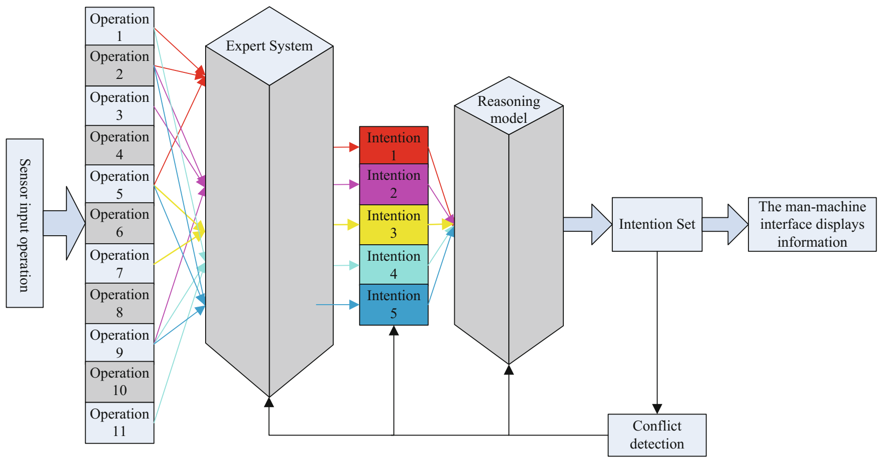

Fig. 3 The pilot reasoning model

expert system database on the intent I_n of the predetermined threshold), this operation corresponds to intention I_n and dynamically changes the man–machine interface. Otherwise, the current interface doesn't change or asks the pilot to make assistance changes.

4 Case Analysis

In this paper, it is assumed that the current sensor has received three effective actions A, B, C. Action A means that the pilot increases throttle. Action B means that the pilot frequently increases the turning angle for emergency maneuvers and into the helmet flight state. Action C means that the main channel of active phased array radar has detected the enemy's proximity information and tracks the target. Through the above three actions compared to the intention of the expert system set, it is associated with two different intentions I_1, I_2, I_1 on behalf of my fighter into a positive defense of the maneuver flight mode, I_2 on behalf of being ready to fight back air and air missile filling information tips. The above three movements are in line with the framework of the expert system structure which has three sides, three actions, and two intentions. The credibility and weight are as follows.

For I_1 there are: $E_{A1}(\mathrm{CF}_{A1}(0.2, 0.6, 0.2)), W_{A1} = 0.4$

In the formula, E_{A1} represents the degree of correlation between the operational action A and the intention I_1, CF_{A1} is the reliability of the three sides of the operational action A, and W_{A1} represents the relevant weight of the operational action A and intention $I_1 : m_{A1} = (0.08, 0.24, 0.08), m_{A1}$ indicates that the operational action A assigns a function to the basic trust assignment of intention I_1, that is, the action A shows evidence of intention I_1 through three sides.

Similarly:

$$E_{B1}(\mathrm{CF}_{B1}(0.5, 0.4, 0.1)), \quad W_{B1} = 0.3,\ m_{B1} = (0.15, 0.12, 0.03)$$
$$E_{C1}(\mathrm{CF}_{C1}(0.7, 0.2, 0.1)), \quad W_{C1} = 0.2,\ m_{C1} = (0.14, 0.04, 0.02)$$

For I_2 there are:

$$E_{A2}(\mathrm{CF}_{A2}(0.6, 0.2, 0.2)), \quad W_{A2} = 0.2,\ m_{A2} = (0.12, 0.04, 0.04)$$
$$E_{B2}(\mathrm{CF}_{B2}(0.6, 0.2, 0.2)), \quad W_{B2} = 0.2,\ m_{B2} = (0.12, 0.04, 0.04)$$
$$E_{C2}(\mathrm{CF}_{C1}(0.3, 0.4, 0.3)), \quad W_{C2} = 0.5,\ m_{C2} = (0.15, 0.20, 0.15)$$

According to the Dempster synthesis rule of D–S evidence theory, it is necessary to synthesize the operation A and related intention first. It is necessary to note that there are three values in m_{A1}, m_{B1}, m_{C1}, m_{A2}, m_{B2}, m_{C2}, which can be understood as the three different sides to the three basic trust assignments of intention, for example, $m_{A1} = (0.08, 0.24, 0.08), m_{A1}(a_1) = 0.08$, $m_{A1}(a_2) = 0.24, m_{A1}(a_3) = 0.08$ it can be understood as representing the degree of support for the associated intention I_1 and option A of the sides a_1, a_2, and a_3, respectively.

$$m_{A1} = (0.08, 0.24, 0.08), \quad m_{A1}(D) = 1 - (0.08 + 0.24 + 0.08) = 0.6$$
$$m_{B1} = (0.15, 0.12, 0.03), \quad m_{B1}(D) = 1 - (0.15 + 0.12 + 0.03) = 0.7$$
$$K = \sum_{i \neq j} m_{A1}(a_i) \cdot m_{B1}(b_j) = 0.0768$$

The following is the synthesis of m_{A1} and m_{B1}: $m = m_{A1} \oplus m_{B1}$, where m is the intermediate state evidence formed when m_{A1} and m_{B1} are synthesized.

$$\begin{aligned} m(a_1) &= \frac{1}{1-K}[m_{A1}(a_1) \times m_{B1}(b_1) + m_{A1}(a_1) \times m_{B1}(D) + m_{A1}(D) \times m_{B1}(b_1)] \\ &= 0.171 \end{aligned}$$

Similarly, $m(a_2) = 0.291$, $m(a_3) = 0.083$, $m = (0.171, 0.291, 0.083)$, m and m_{C1} combination.

By $m = (0.171, 0.291, 0.083)$ get $m(D) = 0.455$;

By $m_{C1} = (0.14, 0.04, 0.02)$ get $m_{C1}(D) = 0.8$;

$$\begin{aligned} K' &= 0.171 \times (0.04 + 0.02) + 0.291 \times (0.14 + 0.02) + 0.083 \times (0.14 + 0.04) \\ &= 0.07176 \end{aligned}$$

The following m, m_{C1} synthesis: $M = m \oplus m_{C1}$, where M is the final evidence after the synthesis of m, m_{C1}.

$$M(a_1) = \frac{1}{1 - K'}[m(a_1) \times m_{C1}(c_1) + m(a_1) \times m_{C1}(D) + m(D) \times m_{C1}(c_1)] = 0.242$$

Similarly, $M(a_2) = 0.283, M(a_3) = 0.083$, $\mathrm{Bel}(I_1) = \sum_{i=1}^{3} M(a_i) = 0.608$.

$\mathrm{Bel}(I_1)$ indicates that the operational actions A, B, and C have a trust level of 0.608 for the association intention I_1, under the three sides of the recognition frame.

Assuming that the intent threshold defined in the expert system database is $\mathrm{TH}(I_1) = 0.6$, and $\mathrm{Bel}(I_1) > \mathrm{TH}(I_2)$, it is assumed that intent I_1 is about to occur when action A, B, and C occurs. At this point, my aircraft should be transferred to the active defense of the mobile flight mode, the man–machine interface should be displayed or prompted to open the infrared missile jammers, platinum/infrared interference bombs, and other images.

Similarly, $\mathrm{Bel}(I_2) = 0.63$, assuming that the intent threshold defined in the expert system database is $\mathrm{TH}(I_2) = 0.7, \mathrm{Bel}(I_2) < \mathrm{TH}(I_2)$, it means that I_2 does not occur when the operation action A, B, C occurs; if $\mathrm{TH}(I_2) = 0.6, \mathrm{Bel}(I_2) > \mathrm{TH}(I_2)$, the man–machine interface should display the information of the air-to-air missile filling information. The helmet display is the received signal, immediately transferred to the launch state screen.

When the conflict is detected, the two intentions I_1, I_2 are likely to occur. At this time, $\mathrm{Bel}(I_1) < \mathrm{Bel}(I_2)$, the display of the man–machine interface should be mainly the intention I_2, and the relevant screen of the intention I_1 should be small screen display or aid tips display. Similarly, when multiple intentions are likely to occur, they should also follow the display mode where the most likely intention is the main screen.

5 Conclusion

In this paper, the problem of pilot intention reasoning is described systematically. The pilot reasoning is divided into three levels: intention, operation, and state level, and then the method of intention reasoning based on pilot action is put forward. The D–S evidence theory is chosen as the algorithm in the reasoning model. The algorithm validates the rationality of the expert model recognition framework of operation-intention matching, and provides the theoretical basis for the optimization of the man–machine interface of the cockpit.

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Pressure Effects of Compression Garment on Muscle Fatigue in Upper Limb in Men's Basketball

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Abstract The purpose of this study was to investigate compression garments' pressure effects on muscle fatigue in upper limb in men's basketball. Twenty male college basketball players, wearing compression garment of different pressures, completed dribbling, layups, and shooting with surface EMG signals measured during exercise. After data processing by MATLAB 7.0, correlation analysis and multiple comparisons were conducted. The properties of sEMG signal were significantly related to muscle fatigue in upper limb, especially in biceps and brachioradialis. The result showed pressure effects of compression garment on muscle fatigue in upper limb, which appeared mainly on the middle and later stages of exercise. Moderate pressure was able to relieve muscle effectively and consecutively, while high or low pressure could not help drop fatigue but accelerating tired feeling. The research finding of this paper could be taken as a reference for the development of compression garment of basketball players.

Keywords Pressure · Compression garment · Basketball · Muscle fatigue · Surface electromyography · Correlation

1 Introduction

Basketball is now very popular for its function of body-building and pleasure in watching. After one hundred years of development, the intensity and antagonism of game have been improved a lot. This may cause muscle fatigue and damage easily in high-intensity exercise [1]. In basketball, actions, such as steals, stops, jump shots, dunk, and blocked shots, are all mainly completed by upper limb. The muscle of upper limb enables it to move by contraction and relaxation. Of all the ball games by touching hands directly, basketball has the most strongly dependence on upper limb [2].

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The purpose of wearing clothes is to package body, protect body from injury, meet the needs of physiology and security of human body, and adapt to the surroundings [2, 3]. Sports compression garments can be comfortable to wear [4], and help to decrease sports injuries [5], protect muscles, delay muscle fatigue. They are now very popular in basketball games [6]. World sports brands (e.g., CYCFIT, Adidas) have already developed compression garment for basketball for a time, and now lining begins to dip into this area. However, both at homeland and abroad, the mechanism research and experimental analysis of muscle fatigue during basketball exercise are still inadequate. The aim of this paper was to investigate compression effects of sports garment on muscle fatigue of upper limb and find the proper compression that could ease muscle fatigue, combined with the subjective evaluation.

2 Methods

2.1 Participants and Garment Information

Twenty athletes were recruited from basketball teams of five universities in Hangzhou for this study [mean (SD) age, 22 (3) years; height 1.75 m; upper arm girth 32(33) cm]. All participants were healthy and recreationally trained for a week before taking part. Before the experiment, all athletes were trained for standardized actions required.

Upper body seamless compression garment was used in this study. The garments were knitted by 85% nylon and 15% elastane. The illustration of garment is given in Fig. 1.

Each participant was allocated three sizes of garments—170/88A, 175/92A, and 180/96A, which will compress upper limb tightly, moderately, and loosely. These three sizes were numbered as 1, 2, and 3, and the specifications are given in Table 1.

Fig. 1 Illustration of garment, both front and back sides

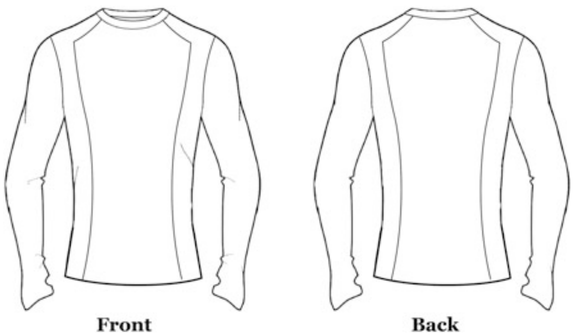

Table 1 Specifications of garment in each size

Number	Chest circumference	Upper arm circumference	Sleeve opening	Sleeve length from shoulder	Center back length
1	84	29	14.5	66.5	64
2	88	30	15.0	68.0	65
3	92	31	15.5	69.5	66

2.2 Experimental Procedures and Measurement

Upper limb muscles include shoulder, arm, forearm, and hand muscles. Shoulder muscle mainly includes deltoid muscle. Bicipital muscle is the strongest among arm muscles. Forearm muscle includes brachioradialis, palmaris longus muscle, which control the contraction of joints of upper limb. Based on the research of muscle fatigue [7] in basketball [8], take three test points represented as M1, M2, and M3, respectively—the most raised points in the central section of deltoid muscle, bicipital muscle, and brachioradialis, which were shown in Fig. 2. The specific locations of three points were given in Table 2.

And based on the research of muscle fatigue test by Karthick and Ramakrishnan [9], Bueno et al. [10], and Naeem [11], this experiment took three indicators to evaluate muscle fatigue—two of time-domain analyses: RMS (root-mean square amplitude) and iEMG (integrated electromyography), one of frequency-domain analysis: MPF (mean power frequency). The evaluation criteria were given in Table 3.

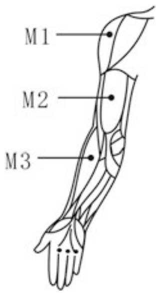

Fig. 2 Three test points in upper limb represented, respectively, as *M1*, *M2*, and *M3*

Table 2 Specific location of test points in upper limb

Test point	Specific location
M1	The most prominent point in shoulder, 5 cm below shoulder point
M2	Above elbow joint, the anteromedial upper arm
M3	Below elbow joint, the outmost forearm muscle

Table 3 Evaluation criteria of sEMG signal for muscle fatigue

Indicator	Evaluation criteria
RMS	All the root-mean-square value in a period of time, describing features of mean sEMG change—the higher the value, the more muscle fatigue
iEMG	Total area of time-domain curves per unit of time, indicates the strength change as time goes on—the higher the value, the more the muscle fatigue
MPF	The frequency of going through orthocenter of power spectrum curve with higher stability and sensitivity—the lower the value, the more the muscle fatigue

Experimental trials were conducted in an environmental chamber under the controlled conditions of 24 (2) °C and 68 (5)% RH, wind speed under 1 m/s. Participants were asked to wear compression garment and enter the laboratory to sit quietly for 30 min until physical condition became stable. Three test points were disinfected by medicinal alcohol with EMG sensors attached. Participants started to make basketball actions for 120 s, including dribbling, shooting, layup. The total time was equally divided into 8 time periods—each 15 s, represented by T1, T2, T3, T4, T5, T6, T7, and T8. After changing into another garment, participants would rest for an hour. The final test result was the average value of 20 participants. In each session of experiment, participants were asked to score the feeling of muscle fatigue, and the criteria were as follows: not tired at all scored 1, slightly tired scored 2, tired scored 3, very tired scored 4, and exhausted scored 5.

3 Results and Discussion

3.1 Correlation Between sEMG Signal and Muscle Fatigue

The values of RMS, iEMG, and MPF were calculated by MATLAB 7.0, according to surface EMG signals via smooth denoising. Correlation analysis was conducted, and the result in Table 4 indicated that in moderate pressure garment, sEMG signals of all three muscles showed a significant correlation with subjective feelings of muscle fatigue, M2 and M3 at the 0.01 significant level and M1 at the 0.05 significant level. In high-pressure garment, signals of M2 and M3 showed correlation, but M1 did not. In low-pressure garment, RMS and iEMG of sEMG signals of all

Table 4 Correlation analysis of sEMG indicators and subjective fatigue evaluation

	1			2			3		
	RMS	iEMG	MPF	RMS	iEMG	MPF	RMS	iEMG	MPF
M1	0.942	0.639	−0.551	0.727*	0.791*	−0.199*	0.441*	0.785*	−0.780
M2	0.793**	0.461*	−0.431*	0.674**	0.732**	−0.975**	0.357*	0.543*	−0.489*
M3	0.893*	0.459*	−0.613*	0.913**	1.44**	−1.223**	0.801*	0.419*	−0.971*

**means $p < 0.01$; *means $p < 0.05$

three muscles showed significant correlation and as for MPF, M2, and M3 showed correlation at the 0.05 significant level, while M1 did not.

The analysis results indicated that RMS, iEMG, and MPF of sEMG signals were all able to reflect the extent of muscle fatigue, especially for bicipital muscle and brachioradialis. In basketball exercise, bending arms mainly depend on bicipital muscle, and actions, like shooting and passing, are completed mainly by contraction of brachioradialis. Meanwhile, deltoid muscle only plays a secondary role.

3.2 Correlation Between Compression Garment Pressure and Muscle Fatigue

Consistency test was conducted to measure the features of sEMG signals change in M1, M2, and M3 during eight intervals—rs > 0.8 means strong positive correlation. The result showed that sEMG signals of all three test points had strong positive correlations, which meant that all three sEMG indicators had a high concordance with each other. So considering sEMG indicators of all three points in each interval as dependent variable, comparison test of one-way ANOVA was conducted.

The result indicated, in Table 5, that in garment 1, mean value of RMS started to show significant difference from T6. In all three garments, the value of iEMG started to show significant difference from T4, and the value of MPF started to show significant difference from T6. All the results suggested that the pressure effects on muscle fatigue were improved as garment pressure increased, which mainly appeared in the middle and later stages of exercise, and the significant level of the effects decreased from garment 1 to 3.

For intervals with great pressure effects of compression garment, the increasing and decreasing rates of sEMG indicators change were drawn in histograms, which were shown in Fig. 3. In garment 1, the rate of RMS and iEMG increased steadily as time went by, while MPF decreased. In garment 2, the increasing rate of RMS

Table 5 One-way ANOVA comparison test result

	RMS			iEMG			MPF		
	1	2	3	1	2	3	1	2	3
M1–M2	0.976**	1.000**	0.929**	1.000**	1.000**	1.000**	0.927**	0.998**	1.000**
M1–M3	0.952**	1.000**	0.929**	1.000**	1.000**	0.912*	1.000**	1.000**	1.000**
M2–M3	0.881**	1.000**	0.929**	1.000**	1.000**	0.971**	1.000**	1.000**	1.000**

**means $p < 0.01$; *means $p < 0.05$

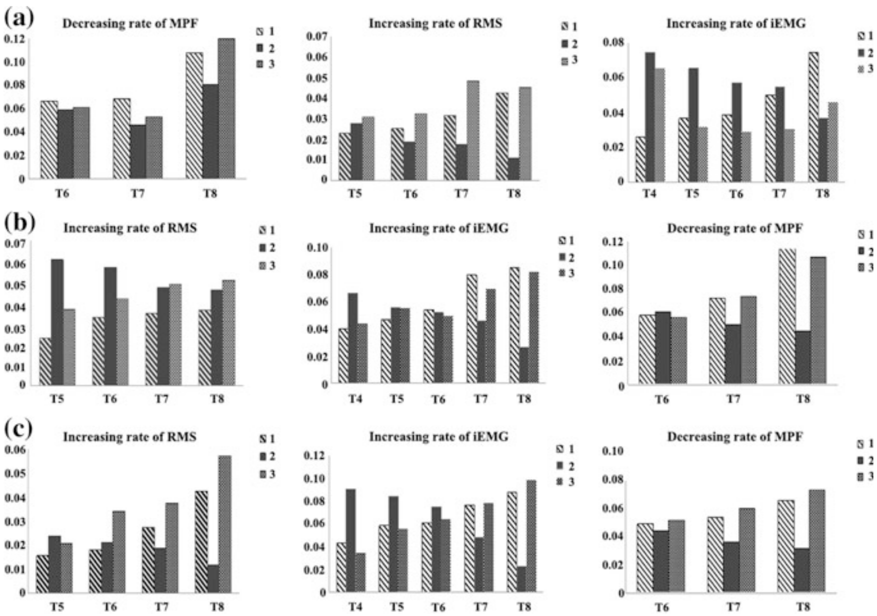

Fig. 3 Increasing and decreasing rates of sEMG signal indicators in **a** M1, **b** M2, and **c** M3

and iEMG, as well as the decreasing rate of MPF, went down gradually as time went on. In garment 3, the rate of RMS and iEMG increased with slight fluctuations as time went by, while MPF decreased.

In the middle and later stages of exercise, comparison of sEMG signal indicators among all three garments showed that garment 2 brought increasing and decreasing rates of indicators down, garment 1 raised rate of indicators, and garment 3 did not perform well but in a trend of rising overall. Combining the results in Table 5, it suggested that moderate pressure was able to relieve muscle effectively and consecutively, high pressure could not help drop fatigue but accelerating tired feeling, and low pressure did not have the function of easing muscle fatigue.

The reason why pressure effects appeared was that compression could help support body to make movement, but impose restrictions on body as well, which decreased energy consumption of muscles [12]. Moderate pressure was able to stimulate nerve cells and promote proprioceptive sensation, which helped improve athletes' attention and therefore made the body adjusted to the environment [13].

The reason why pressure effects appeared was that compression could help support body to make movement, but impose restrictions on body as well, which decreased energy consumption of muscles. Moderate pressure was able to stimulate nerve cells and promote proprioceptive sensation, which helped improve athletes' attention and therefore made the body adjusted to the environment. When pressure was over-high, blood flow might get blocked and human body would raise oxygen consumption to maintain sports intensity. And this could cause muscle fatigue immediately. Over-high pressure would also restrict microcirculation of blood capillary partly, which might lead to the anoxia of muscle, accumulation of metabolic waste, such as lactic acid, and accelerate the process of muscle fatigue [13]. Meanwhile, low pressure was not able to reduce the vibration of muscle due to lack of compression with energy consumption. In order to output the same amount of energy, muscle would increase discharge capacity and get tired quicker.

4 Conclusions

In basketball exercise, indicators of sEMG signals and muscle had significant correlation, which could help evaluate muscle fatigue. And, pressure effects were more efficient for bicipital muscle and brachioradialis than deltoid muscle, and mainly appeared in the middle and later stages of exercise. Moderate pressure was able to relieve muscle effectively and consecutively, while high or low pressure could not help drop fatigue but accelerating tired feeling. The research finding of this paper could be taken as a reference for the development of compression garment of basketball players.

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Compliance with Ethical Standards The study was approved by the Logistics Department for Civilian Ethics Committee of Zhejiang Sci-Tech University.

All subjects who participated in the experiment were provided with and signed an informed consent form.

All relevant ethical safeguards have been met with regard to subject protection.

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Measurement of a Walker's Movement Parameters by a Monocular Camera

Yang Shang

Abstract This article elaborates on the theory of monocular measurement for a walker and uses experiments to validate this approach. This new monocular approach for measuring the movement parameters of a walker allows for the 3-D pose and position of the walker to be obtained using at least two endpoints on the target, the walker's vertex and heel, and then other point's position on the walker can be calculated. If the walker's stature is not known, there is a coefficient of proportionality between the measured result and the true result. When the walker's stature is known, the movement parameters of the walker can be measured in this way by a monocular camera, which can be used to study a person's movement or to monitor person's action in public places by monitor video.

Keywords Anthropometry · Monocular measurement · Walker's movement parameters

1 Introduction

One of the tasks of human engineering is to measure the structure or movement of a person. To measure an object's structure or movement parameters is important work in computer vision and photogrammetry. When the measurement system is made up of many cameras, the three-dimensional stance and position can be obtained by having the cameras intersect at no fewer than three characteristic points on the target's surface [1, 2]. The three-dimensional stance and position can be calculated when at least three characteristic points in the body's coordinate system are known. Three-dimensional structure and movement can be rebuilt on the basis of single camera sequence images when the target has more disoperative characteristic points

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[3–5]. Many methods have been applied to measure the three-dimensional stance of targets such as missiles, including the axis method, the ellipticity method, the length–width ratio method, and the spiral method [6, 7].

This article elaborates on a method of monocular measurement for a walker, which is a translation-only one-dimensional target. The approach can be used to measure the 3-D pose and position parameters of the walker by using two end-points. Then, any other point's position on the target can be calculated. If there is no known distance between any two endpoints, a coefficient of proportionality will be left for the results. The movement parameters of the walker can be measured in this way when the distance between two points, the walker's vertex and heel, is known, and thus, the true result is obtained.

2 Measurement Method

Adopting a center perspective projection-imaging model. Take the camera reference as a reference coordinates, so the camera lens is the origin and camera's rotating matrix $\mathbf{R}$ is identity matrix. $\mathbf{M} = [X \quad Y \quad Z]^{\mathrm{T}}$, whose augmented matrix is $\widetilde{\mathbf{M}} = [X \quad Y \quad Z \quad 1]^{\mathrm{T}}$, is the target's coordinate in the reference coordinates and $\mathbf{m} = [u \quad v]^{\mathrm{T}}$, whose augmented matrix is $\tilde{\mathbf{m}} = [u \quad v \quad 1]^{\mathrm{T}}$, is the target's image coordinate. The imaging relation is:

$$s\tilde{\mathbf{m}} = \mathbf{A}[\mathbf{R} \quad \mathbf{T}]\widetilde{\mathbf{M}}$$
$$\text{with} \quad \mathbf{A} = \begin{bmatrix} \alpha & \gamma & u_0 \\ 0 & \beta & v_0 \\ 0 & 0 & 1 \end{bmatrix}, \quad \mathbf{R} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}, \quad \mathbf{T} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix} \tag{1}$$

where (u_0, v_0) is the main spot coordinate of the image, α and β are the transverse and lengthways imaging equivalent focal lengths. γ is image reverse factor.

As shown in Fig. 1, two end points on a one-dimensional target are considered. And, the target is translation-only. The camera coordinate *S-XYZ* is the reference coordinate, and the image plane is *I*. The target's characteristic points are A_i and B_i at time i ($i = 0, 1, \ldots, m - 1$). The distance from A_i to B_i is L. The image points corresponding to the characteristic points are a_i and b_i.

Suppose the positions of the target's characteristic points A and B are $\mathbf{M}_{A0} = [X_{A0} \quad Y_{A0} \quad Z_{A0}]^{\mathrm{T}}$ and $\mathbf{M}_{B0} = [X_{B0} \quad Y_{B0} \quad Z_{B0}]^{\mathrm{T}}$ at time 0, and that their positions at time i are $\mathbf{M}_{Ai} = [X_{Ai} \quad Y_{Ai} \quad Z_{Ai}]^{\mathrm{T}}$ and $\mathbf{M}_{Bi} = [X_{Bi} \quad Y_{Bi} \quad Z_{Bi}]^{\mathrm{T}}$. The translation vector of the position at time i corresponding to the position at time 0 is $\mathbf{T}_i = [T_{Xi} \quad T_{Yi} \quad T_{Zi}]^{\mathrm{T}}$. Thus

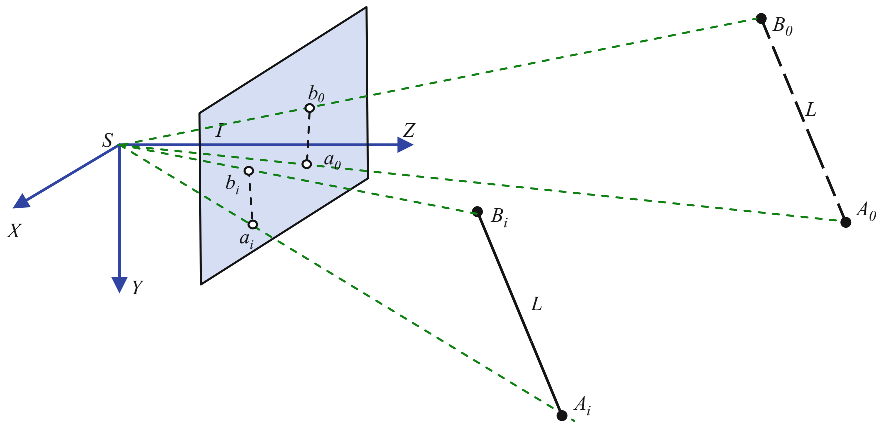


Fig. 1 Imaging relation of a translation-only one-dimensional target

$$\begin{cases} \mathbf{M}_{Ai} = \mathbf{M}_{A0} + \mathbf{T}_i \\ \mathbf{M}_{Bi} = \mathbf{M}_{B0} + \mathbf{T}_i \end{cases} \quad (i = 1, 2, \ldots, m-1) \tag{2}$$

Suppose the image coordinates of A and B are $\mathbf{m}_{Ai} = [\,u_{Ai} \quad v_{Ai}\,]^{\mathrm{T}}$ and $\mathbf{m}_{Bi} = [\,u_{Bi} \quad v_{Bi}\,]^{\mathrm{T}}$ at time i.

According to Formula (2), the imaging relation of the target's characteristic points A and B can then be expressed as:

$$\begin{cases} s_{A0}\tilde{\mathbf{m}}_{A0} = \mathbf{A}[\,\mathbf{R} \quad \mathbf{T}\,]\widetilde{\mathbf{M}}_{A0} \\ s_{B0}\tilde{\mathbf{m}}_{B0} = \mathbf{A}[\,\mathbf{R} \quad \mathbf{T}\,]\widetilde{\mathbf{M}}_{B0} \\ s_{Ai}\tilde{\mathbf{m}}_{Ai} = \mathbf{A}[\,\mathbf{R} \quad \mathbf{T}\,]\left(\widetilde{\mathbf{M}}_{A0} + \widetilde{\mathbf{T}}_i\right) \\ s_{Bi}\tilde{\mathbf{m}}_{Bi} = \mathbf{A}[\,\mathbf{R} \quad \mathbf{T}\,]\left(\widetilde{\mathbf{M}}_{B0} + \widetilde{\mathbf{T}}_i\right) \end{cases} \quad (i = 1, 2, \ldots, m-1) \tag{3}$$

$\tilde{\mathbf{m}}_{A0}, \tilde{\mathbf{m}}_{B0}, \tilde{\mathbf{m}}_{Ai}, \tilde{\mathbf{m}}_{Bi}, \widetilde{\mathbf{M}}_{A0}, \widetilde{\mathbf{M}}_{B0}$ and $\widetilde{\mathbf{T}}_i$ are augment matrix of $\mathbf{m}_{A0}$, $\mathbf{m}_{B0}$, $\mathbf{m}_{Ai}$, $\mathbf{m}_{Bi}$, $\mathbf{M}_{A0}$, $\mathbf{M}_{B0}$. $s_{A0}, s_{B0}, s_{Ai}, s_{Bi}$ is the scale. $\mathbf{A}$ is the inner parameters of camera and $\mathbf{R}$ is the 3×3 identify matrix, $\mathbf{T}$ is 3×1 zero vector.

Take the middle variables as:

$$\begin{cases} g_0 = X_{A0}/Z_{A0}, g_1 = Y_{A0}/Z_{A0} \\ g_2 = X_{B0}/Z_{A0}, g_3 = Y_{B0}/Z_{A0}, g_4 = Z_{B0}/Z_{A0} \\ g_{5,i} = T_{Xi}/Z_{A0}, g_{6,i} = T_{Yi}/Z_{A0}, g_{7,i} = T_{Zi}/Z_{A0} \end{cases} \quad (i = 1, 2, \ldots, m-1) \tag{4}$$

So we can set up the linear equation related to g_0, g_1, g_2, g_3, g_4 and $g_{5,i}$, $g_{6,i}$, $g_{7,i}$. Suppose the distance between A and B is L, then

$$(X_{B0} - X_{A0})^2 + (Y_{B0} - Y_{A0})^2 + (Z_{B0} - Z_{A0})^2 = L^2 \tag{5}$$

Therefore,

$$Z_{A0} = L \Big/ \sqrt{(g_2 - g_0)^2 + (g_3 - g_1)^2 + (g_4 - 1)^2} \tag{6}$$

Furthermore, we can obtain results for other parameters

$$\begin{cases} X_{A0} = g_0 Z_{A0},\ Y_{A0} = g_1 Z_{A0} \\ X_{B0} = g_2 Z_{A0},\ Y_{B0} = g_3 Z_{A0},\ Z_{B0} = g_4 Z_{A0} \\ T_{Xi} = g_{5,i} Z_{A0},\ T_{Yi} = g_{6,i} Z_{A0},\ T_{Zi} = g_{7,i} Z_{A0} \end{cases} \quad (i = 1, 2, \ldots, m-1) \tag{7}$$

When the exact distance between A and B is known, the positions of A and B at any point in time can be solved with precision (that is, the initial position and the translation vector at every time).

However, if the distance between A and B is not known, a coefficient of proportionality will exist between the measured result and the true result. In practice, if the distance between each target point and the camera is known, the true result can also be calculated. The pose of one-dimensional target can be solved if the characteristic points target coordinates are known [8]. When, we need not to know the scale information.

3 Experimental Validation

The target to be measured is a person walking steadily in front of the camera about 100 m. The medial axes of the person are taken as the one-dimensional target. The calvarias and the intersect point of the medial axes with the two touchdown points connect line are chosen as the starting point and the end point. The camera remains stationary on the floor and takes images, some of which are shown in Fig. 2. The small circle points are the projection on the image plane of position's result of the end characteristic point of the walker. The big circle points are the current result. All of the results at different time are figured in every image. The triangle is the calculated result of pate and projects it to image plane. All the result's projection can accordant with the current target's pose and position.

Let the person stays at every measured position. At the same time of taking images, getting the 3-D coordinates depending on geosystems. On the reference coordinate's XZ, the true trajectory and calculated trajectory are shown in Fig. 3, in which the real line represents the true trajectory and the broken line represents calculated trajectory.

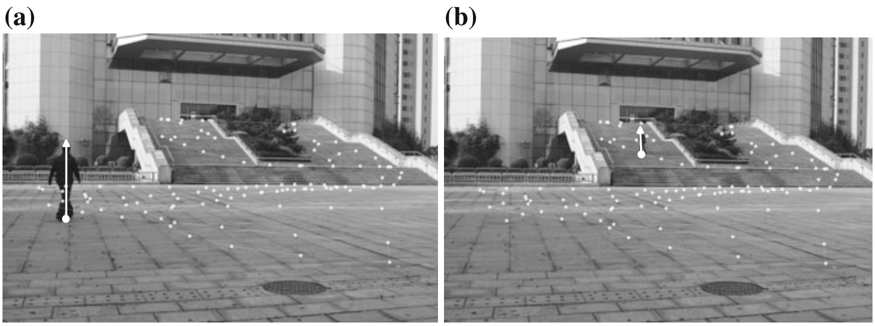
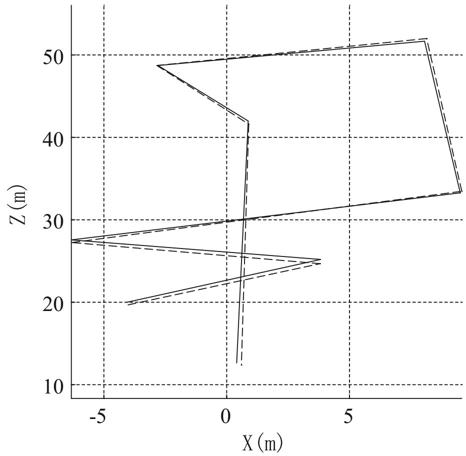


Fig. 2 Measurement of the position and stance of a person walking steadily and the projection of calculated results

Fig. 3 Statistical error of measured result of the walker that the true result is known



4 Conclusion

This article elaborates on the theory of monocular measurement for a walker, a translation-only one-dimensional target, and uses practical experiments to validate this approach. By this approach, a single camera is employed to take at least two images and make use of at least two characteristic points on the target to measure the walker's movement parameters. Provided the distance or another measurement between two characteristic points is known, the three-dimensional position and stance can be calculated. Except the two characteristic points, other point's position on the target can also be calculated. If no measurement information is available, there will be a coefficient of proportionality between the measured result and the true result.

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Compliance with Ethical Standards The study was approved by the Logistics Department for Civilian Ethics Committee of the National University of Defense Technology.

All subjects who participated in the experiment were provided with and signed an informed consent form.

All relevant ethical safeguards have been met with regard to subject protection.

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Evaluation on Crew's Information Processing Capability Based on Grey Relational Analysis

Binhe Fu, Weiping Liu, Yi Jin and Bo Yang

Abstract With the improvement of informative level of special vehicles, the primary operation type of special vehicle crews has been turned into knowledge-based operations, which sets a high demand on crew's information processing capability. Based on grey relational theory, an evaluation model of crew's information processing capability was established and an evaluation method of crew's information processing capability was presented. First, evaluation indicators of crew's information processing capability were presented. Then, the crew's information processing capability was evaluated and ranked with the calculation of the degree of grey correction. The evaluation result of one example is in good agreement with that of expert discussion, which proves the feasibility and validity of this method and provides guidance and reference for crew's selection and training.

Keywords Special vehicle · Information processing capability · Grey relational theory

1 Introduction

Crews acquire information by the sense of sights, and then, brain makes a judgment promptly during the process of information processing operations. If a crew cannot distinguish information in time, or reacts falsely, the situation would turn out to be disadvantageous rapidly. The higher the speed of analysing information and making judgments is, the higher the odds of accomplishing tasks successfully would be. Special vehicle crews are required to perform tasks both accurately and quickly, which sets a high demand on crew's information processing capability.

The current study on special vehicle crew's information processing capability remains in its early stage and lacks effective evaluation methods at present.

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Therefore, based on grey relational theory (GRT), an evaluation model of crew's information processing capability was established and an evaluation method of that was presented in this paper to evaluate and compare information processing capability of different crews.

2 Features of Information Processing Operations and Its Evaluation Indicators

2.1 Analysis of Operation Features

Special vehicle crews have to complete a series of operations about information processing when performing tasks: situation observing and information inputting, instruction receiving and equipment manipulating. By analysing the process of information processing operations of special vehicle crews, the feathers of it are concluded as follows.

(1) Significant increment of knowledge-based operations
Information processing operations of special vehicle crews are involved with varieties of tasks, such as message preparation, map recognition, equipment manipulation, which are of informative content and complicated manipulation. Concrete manipulation coming from random combination of different functions would be even more complicated. Compared with the physical labour, information processing operations are embodied in basic manipulation, such as selecting, inputting and identifying, and knowledge-based operations are taken the principal position.

(2) Strong randomness of tasks
Rapid reaction after receiving information is very important for task performance because every single second is precious for crews. The large amount of real-time interaction and the high speed of information update lead to the strong randomness of information processing tasks, which demands crews recognize and react promptly to carry out relevant functions immediately. Information processing operations set a high demand on crew's speed of reaction and manipulation.

(3) Large amount of information monitoring
Task situation varies from minute to minute, so special vehicle crews need to concentrate on operations in hand to guarantee the speed and accuracy of task performance. Crews have to deal with multitask, which means that while processing information, crews are supposed to observe the change of real-time information update at the same time. The amount of information crews have to monitor is so large that they should allocate attention to multiple tasks properly during task performing to make sure all aspects of information accepted.

2.2 Presenting Evaluation Indicators

Information processing capability is a comprehensive reflection of several types of basic capability without effective evaluation method. It cannot be measured or evaluated with one single index quantitatively, so it needs several indicators to evaluate comprehensively. Evaluation indicators selected should be able to evaluate information processing capability comprehensively and accurately, and help analyse the reason for the performance difference of crews [1].

Based on human information processing model and the feathers of information processing operations of special vehicle crews, the evaluation index system of information processing capability can be concluded as five aspects of basic capability, that is, discriminative reaction (DR) capability, choice reaction (CR) capability, short-term memory (STM) capability, spatial position memory (SPM) capability and working memory (WM) capability.

3 Evaluation Model of Information Processing Capability Based on Grey Relational Analysis

Grey system theory (GST) is a new method of study on uncertainty in less data and incomplete information with the uncertain system as the object of study in which part of the information is unknown. By studying the known part of the information, valuable information is obtained to describe and monitor the operating process and the changing rule of the whole system accurately and effectively [2].

The basic method of grey relational analysis (GRA) is to convert the observed value of discrete behaviours of system objectives into piecewise continuous function by linear interpolation to build models of the relational grade of measure based on the geometrical characteristics of functions. The closer the geometrical shape of functions appears, the higher the relational grade between sequences would be [3].

Grey relational analysis (GRA) method was employed to establish an evaluation model of information processing capability of special vehicle crews in this paper. The basic procedure includes selecting and preprocessing indicators, building analysis matrix, calculating grey relational coefficient and grey relational grade, analysing the evaluation result.

3.1 Preprocessing Indicators

Different performance data of different dimensions cannot be measured and compared by a common standard. Before comparing and analysing, different indicators should be preprocessed with dimensionless method to construct membership functions for each indicator. Indicators are divided into two types, “the smaller, the better” and “the larger, the better”. Dimensionless method of two types of indicators is given as follows [4].

(1) Membership function of “the smaller, the better” type of indicator is

$$u_i = \begin{Bmatrix} 1 & x_i \leq m \\ \frac{M-x_i}{M-m} & m < x_i < M \\ 0 & x_i \geq M \end{Bmatrix} \tag{1}$$

(2) Membership function of “the larger, the better” type of indicator is

$$u_i = \begin{Bmatrix} 1 & x_i \geq M \\ \frac{x_i-m}{M-m} & m < x_i < M \\ 0 & x_i \leq m \end{Bmatrix} \tag{2}$$

where x_i refers to actual value of indicators, M and m refer to maximum and minimum values of x_i respectively, and u_i refers to membership of indicator.

After preprocessing, performance data is turned to membership ranging from 0 to 1 according to membership functions. All the indicators are turned into “the larger, the better” type.

3.2 Building Analysis Matrix

Analysis matrix is built with n evaluation objects and m evaluation indicators, where X_0 is the system characteristic sequence and X_i is the correlative factor sequence ($i = 1, 2, \ldots, n$).

$$(X_0, X_1, \ldots, X_n) = \begin{bmatrix} x_0(1) & x_1(1) & \cdots & x_n(1) \\ x_0(2) & x_1(2) & \cdots & x_n(2) \\ \cdots & \cdots & \cdots & \cdots \\ x_0(m) & x_1(m) & \cdots & x_n(m) \end{bmatrix}_{m \times (n+1)} \tag{3}$$

The optimal sequence G and worst sequence B of system are defined as follows.

$$\begin{aligned} G &= (g_1, g_2, \ldots, g_m) \\ &= (x_1(1) \vee x_2(1) \vee \cdots \vee x_n(1), x_1(2) \vee x_2(2) \vee \cdots \vee x_n(2), \ldots, x_1(m) \vee x_2(m) \vee \cdots \vee x_n(m)) \end{aligned} \tag{4}$$

$$\begin{aligned} B &= (b_1, b_2, \ldots, b_m) \\ &= (x_1(1) \wedge x_2(1) \wedge \cdots \wedge x_n(1), x_1(2) \wedge x_2(2) \wedge \cdots \wedge x_n(2), \ldots, x_1(m) \wedge x_2(m) \wedge \cdots \wedge x_n(m)) \end{aligned} \tag{5}$$

where $\vee$, $\wedge$ are operators of maximum and minimum, respectively.

3.3 Calculating Grey Relational Coefficient and Grade

Calculate absolute value sequence of difference value.

$$\Delta_{0i}(k) = |x_0(k) - x_i(k)| \tag{6}$$

where $i = 1, 2, \ldots, n$; $k = 1, 2, \ldots, m$. From this, absolute difference value matrix Δ_{0i} can be obtained.

$$\Delta_{0i} = (\Delta_{0i}(1), \Delta_{0i}(2), \ldots, \Delta_{0i}(m)) = \begin{bmatrix} \Delta_{01}(1) & \Delta_{02}(1) & \cdots & \Delta_{0n}(1) \\ \Delta_{01}(2) & \Delta_{02}(2) & \cdots & \Delta_{0n}(2) \\ \cdots & \cdots & \cdots & \cdots \\ \Delta_{01}(m) & \Delta_{02}(m) & \cdots & \Delta_{0n}(m) \end{bmatrix}_{m \times n} \tag{7}$$

Maximum $\Delta(\max)$ and minimum $\Delta(\min)$ difference is as follows, respectively.

$$\Delta(\max) = \max_i \max_k \Delta_i(k) \tag{8}$$

$$\Delta(\min) = \min_i \min_k \Delta_i(k) \tag{9}$$

Relational coefficient can be calculated as follows.

$$\gamma_{0i}(k) = \frac{\Delta(\min) + \varepsilon\Delta(\max)}{\Delta_{0i}(k) + \varepsilon\Delta(\max)} \tag{10}$$

where $\varepsilon \in (0, 1)$ is resolution ratio, and usually $\varepsilon = 0.5$. Then, relational coefficient matrix can be obtained as follows.

$$[\gamma_{01}, \gamma_{02}, \ldots, \gamma_{0n}] = \begin{bmatrix} \gamma_{01}(1) & \gamma_{02}(1) & \cdots & \gamma_{0n}(1) \\ \gamma_{01}(2) & \gamma_{02}(2) & \cdots & \gamma_{0n}(2) \\ \cdots & \cdots & \cdots & \cdots \\ \gamma_{01}(m) & \gamma_{02}(m) & \cdots & \gamma_{0n}(m) \end{bmatrix}_{m \times n} \tag{11}$$

Relational grade can be calculated as follows.

$$\gamma_{0i} = \frac{1}{m}\sum_{k=1}^{m}\gamma_{0i}(k) \tag{12}$$

3.4 Analysing the Evaluation Result

In common analysis of grey relational grade, either the optimal or the worst sequence is employed to calculate the relational grade. However, sorted results of the relational grade from two methods may not reach a consensus, which could cause errors of evaluation result. Therefore, combined the optimal with the worst relational grade comprehensively, the error problem can be solved by calculating comprehensive relational grade [5].

Comprehensive relational grade can be calculated as follows.

$$u_i = \frac{1}{(1 + \gamma_{0i\max}/\gamma_{0i\min})^2} \tag{13}$$

where $\gamma_{0i\max}$, called the optimal relational grade, is the relational grade between X_i and the optimal sequence, while $\gamma_{0i\min}$, called the worst relational grade, is the relational grade between X_i and the worst sequence. The final evaluation result is $u = (u_1, u_2, \ldots, u_n)$.

At last, the rank of comprehensive relational grade can be obtained. The larger the comprehensive relational grade u_i is, the better information processing capability the corresponding crew would have.

Table 1 Performance result of crew's information processing operations

No.	DR time (ms)	CR time (ms)	STM range	SPM range	WM error
1	532.33	663.40	11	5	0.5
2	463.50	579.21	9.66	9.33	0.5
3	676.0	654.37	9	5.33	0.3
4	580.56	756.80	8.66	5.66	0.3
5	509.33	650.40	6	4.66	0.8
6	673.33	720.80	7.66	4.66	0.7
7	648.33	675.80	6.33	6.66	0.3
8	736.11	739.80	8	5	0.4
9	564.00	753.05	7.33	5.66	0.6
10	724.45	719.40	6.33	4.66	0.7

4 Example Analysis

Ten participants were selected to complete five aspects of experiments including DR capability, CR capability, STM capability, SPM capability and WM capability. The performance result of crew's information processing operations as Table 1 was analysed to evaluate crew's information processing capability.

The performance data was preprocessed with the dimensionless method. The DR time, CR time and WM error rate were "the smaller, the better" type of indicators, while the STM range and SPM range, "the larger, the better" type. The membership result of each basic capability performance after preprocessing is shown in Table 2. The larger the membership is, the better the corresponding basic capability appears.

The correlative factor matrix is as follows.

$$(X_1, \ldots, X_n) = \begin{bmatrix} 0.748 & 1 & 0.221 & 0.571 & 0.832 & 0.230 & 0.322 & 0 & 0.631 & 0.043 \\ 0.526 & 1 & 0.577 & 0 & 0.599 & 0.203 & 0.456 & 0.096 & 0.021 & 0.211 \\ 1 & 0.732 & 0.6 & 0.532 & 0 & 0.332 & 0.066 & 0.4 & 0.266 & 0.066 \\ 0.073 & 1 & 0.143 & 0.214 & 0 & 0 & 0.428 & 0.073 & 0.214 & 0 \\ 0.6 & 0.6 & 1 & 1 & 0 & 0.2 & 1 & 0.8 & 0.4 & 0.2 \end{bmatrix}$$

The optimal sequence can be obtained.

$$G = (g_1, g_2, \ldots, g_m) = (1, 1, 1, 1, 1)$$

The worst sequence can be obtained.

$$B = (b_1, b_2, \ldots, b_m) = (0, 0, 0, 0, 0)$$

Table 2 Membership result of each basic capability performance

No.	DR time	CR time	STM range	SPM range	WM error
1	0.748	0.526	1	0.073	0.6
2	1	1	0.732	1	0.6
3	0.221	0.577	0.6	0.143	1
4	0.571	0	0.532	0.214	1
5	0.832	0.599	0	0	0
6	0.230	0.203	0.332	0	0.2
7	0.322	0.456	0.066	0.428	1
8	0	0.096	0.4	0.073	0.8
9	0.631	0.021	0.266	0.214	0.4
10	0.043	0.211	0.066	0	0.2

From this, the relational coefficient matrix between correlative factor matrix and the optimal sequence can be obtained.

$$[\gamma_{01}, \gamma_{02}, \cdots, \gamma_{0n}]_G = \begin{bmatrix} 0.664 & 1 & 0.391 & 0.538 & 0.748 & 0.394 & 0.424 & 0.333 & 0.576 & 0.343 \\ 0.513 & 1 & 0.542 & 0.333 & 0.555 & 0.385 & 0.479 & 0.356 & 0.338 & 0.388 \\ 1 & 0.651 & 0.556 & 0.517 & 0.333 & 0.428 & 0.349 & 0.455 & 0.405 & 0.349 \\ 0.350 & 1 & 0.369 & 0.389 & 0.333 & 0.333 & 0.466 & 0.350 & 0.389 & 0.333 \\ 0.556 & 0.556 & 1 & 1 & 0.333 & 0.385 & 1 & 0.714 & 0.455 & 0.385 \end{bmatrix}$$

The relational coefficient matrix between correlative factor matrix and the worst sequence can be obtained.

$$[\gamma_{01}, \gamma_{02}, \cdots, \gamma_{0n}]_B = \begin{bmatrix} 0.401 & 0.333 & 0.694 & 0.467 & 0.375 & 0.685 & 0.608 & 1 & 0.442 & 0.921 \\ 0.487 & 0.333 & 0.464 & 1 & 0.455 & 0.712 & 0.523 & 0.839 & 0.959 & 0.704 \\ 0.333 & 0.406 & 0.455 & 0.484 & 1 & 0.601 & 0.883 & 0.556 & 0.653 & 0.883 \\ 0.873 & 0.333 & 0.777 & 0.700 & 1 & 1 & 0.539 & 0.873 & 0.700 & 1 \\ 0.455 & 0.455 & 0.333 & 0.333 & 1 & 0.714 & 0.333 & 0.385 & 0.556 & 0.714 \end{bmatrix}$$

The optimal relational grade is as follows.

$$\gamma_{0i\max} = (0.617, 0.841, 0.571, 0.555, 0.461, 0.385, 0.544, 0.442, 0.432, 0.360)$$

The worst relational grade is as follows.

$$\gamma_{0i\min} = (0.510, 0.372, 0.545, 0.597, 0.766, 0.742, 0.577, 0.730, 0.662, 0.845)$$

The comprehensive relational grade is as follows.

$$u = (0.300, 0.481, 0.262, 0.232, 0.141, 0.117, 0.235, 0.142, 0.156, 0.089)$$

So, if the optimal or worst relational grade is employed to compare crew's information processing capability, the rank results would not reach a consensus, which will bring problems to the evaluation. The comprehensive relational grade combined with the optimal and worst relational grade could help solve this problem. It is concluded that the rank of information processing capability of the ten crews is 2 > 1 > 3 > 7 > 4 > 9 > 8 > 5 > 6 > 10, which is consistent with panel's perspective.

5 Conclusion

Grey relational analysis (GRA) method was employed to establish an evaluation model of information processing capability of special vehicle crews. An evaluation method was presented to compare information processing capability of different crews. The computational process of this method is easy to realize, and the reliability of the result is high. This method provides guidance and reference for crew's selection and training with a view to information processing capability.

Compliance with Ethical Standards The study was approved by the Logistics Department for Civilian Ethics Committee of AAFE.

All subjects who participated in the experiment were provided with and signed an informed consent form.

All relevant ethical safeguards have been met with regard to subject protection.

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Computer-Aided Visual Function Assessment Using Subjective Image Quality Evaluation Metrics

Haoting Liu, Beibei Yan, Ming Lv, Junlong Wang, Xuefeng Wang and Wei Wang

Abstract A new computer-aided visual function assessment method is proposed. In contrast to the traditional methods, our method can realize an elaborated subjective state analysis of visual function. The subjective image quality evaluation metrics (IQEMs) are utilized to implement the visual function assessment, and they include the image brightness, the image brightness uniformity, the colour image contrast, the image edge blur, the image colour difference, the image noise, the image saturation, and the integrated evaluation. An ergonomic experimental software is developed, and the typical experimental datasets are also built. After the implementation of the visual function assessment experiment, some statistic features of IQEMs can be calculated. By developing the proposed visual function evaluation technique, it can be used for the disease diagnosis and healing.

Keywords Visual function · Assessment system · Image quality evaluation · Ergonomic experiment · Statistic feature

1 Introduction

The visual function [1] can not only reflect the healthy state of ocular system but also indicate the development states of other diseases in human body [2], such as the brain disease, the nerves disorder, the diabetes, or even the tumour growing. Currently, the diagnosis of visual function uses the standard visual chart, the colour blindness chart, and other visual field measurement device to evaluate the visual function state of patient. The patient is asked to observe the typical images or graphs and speak out his or her subjective cognition states of them when using these methods above. Traditionally, the diagnoses of each vision function index are

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independent to each other. The integrated analyses of them are only performed by the individual experiences of doctor. These methods above have been utilized extensively in past, because the applications of them are convenient, cheap, and flexible.

Many related works have been done in the visual function assessment research fields in recent years. In [3], the authors presented a system which used the camera, the image processing module, and the neural electrical stimulator to assist patient to realize the visual function loss restoration. In [4], a method for generating observation target of contrast sensitivity and colour difference inspection was proposed. In [5], an autostereoscopic display was developed to recover the binocular vision performance of strabismus or amblyopia patients. After an extensive comparison of these evaluation methods, it can be found these methods still have some shortcomings: first, the investigated data are limited which means they cannot reflect the integrated performance of ocular character of human eyes. Second, the data processing and analysis of them are also oversimple.

In this paper, a new computer-aided visual function assessment method is proposed. In contrast to the traditional methods, we use the colour image, which has the abundant detail information as the evaluation target [6], and employ the image quality evaluation metrics (IQEMs) to denote the visual function characters of human eyes [7]. The IQEMs include the image brightness, the image brightness uniformity, the colour image contrast, the image edge blur, the image colour difference, the image noise, the image saturation, and the integrated evaluation. To verify the correctness and the effectiveness of proposed method, the typical image datasets are built, a series of human-involved experiments are carried out, and the corresponding data features are computed. The primary experiment results have shown the proposed method can represent the visual function of subjects; and the evaluation method also behaves better than some traditional ones.

2 Proposed Visual Function Assessment System and Method

The proposed visual function assessment system and method is shown in Fig. 1. Figure 1a shows the proposed assessment system, and Fig. 1b shows the experiment flow chart of proposed method. From Fig. 1a, it can be seen the visual function evaluation system includes the typical image dataset, the image display and subjective score software, the PC, and the projector. The image display and subjective score software are installed in the PC, and it also can play the typical image dataset in screen. The projector plays the image in a wall, and then the subject can watch the corresponding images. From Fig. 1b, the experiment flow chart can be described as follows: first, the experiment designer selects the typical image dataset according to the corresponding experiment purposes. Second, after a primary training of subjects, the experiment designer announces the start of the

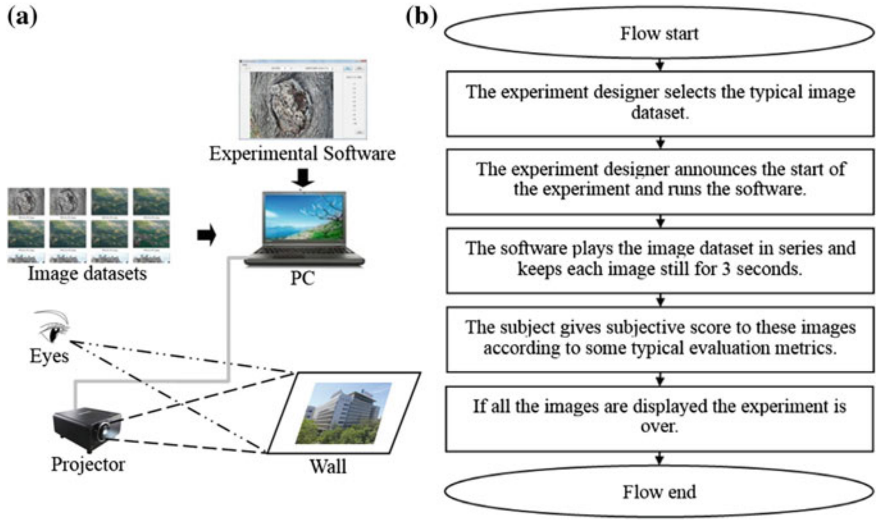

Fig. 1 Proposed visual function assessment system and method

experiment and runs the software. Third, the software plays each image in series and keeps it still for 3 s on the wall. Fourth, the subject gives the subjective score to these images according to some typical evaluation metrics, such as image illuminance or image contrast. Finally, if all the images are displayed, the experiment will be over.

3 Visual Function Evaluation Indexes

Eight subjective IQEMs are utilized to evaluate the visual function in this paper, and their definitions and descriptions are shown in Table 1. From Table 1, it can be seen these indexes can reflect the visual function of human completely comparing with the traditional measurements; they cover lots of visual function information including the image colour, the image detail, and the image difference. A kind of 10-degree score method is employed to classify the visual function. Here, the score "1" means the weakest evaluation result, while the score "10" means the strongest assessment result. For example, regarding the image brightness index, the score "1" means the image brightness is low, while the score "10" indicates the image brightness is high; regarding the image colour difference index, the score "1" means the colour distortion is low, while the score "10" manifests the colour distortion is high; and regarding the integrated evaluation result, the score "1" means the worst evaluation result, while the score "10" is the best evaluation result of the integrated imaging quality.

Table 1 Definitions and descriptions of the visual function evaluation indexes

No.	Name	Descriptions
1	Image brightness (M_{IB})	The luminance of the entire image region
2	Image brightness uniformity (M_{IBU})	The uniform distribution degree of image luminance
3	Colour image contrast (M_{CIC})	The intensity discrepancy degree of image region
4	Image edge blur (M_{IEB})	The edge sharpness or spread degree of image
5	Image colour difference (M_{ICD})	The colour distortion between the true colour and the degraded colour
6	Image noise (M_{IN})	The contamination degree of the additive noise
7	Image saturation (M_{IS})	The fresh degree of image colour
8	Integrated evaluation (M_{IE})	The integrated imaging effect evaluation including colour, detail, and distortion

After the implementation of the visual function evaluation experiment, some statistic features can be computed. In this paper, the following statistic features are utilized: the arithmetic mean, the median, the mode, the variance, the range, and the variation coefficient. The statistic feature can reflect the change laws of visual character if the experiment times are large enough. Among these features, the arithmetic mean, the median, and the mode can reflect the concentration of observed data, while the variance, the range, and the variation coefficient can represent the discreteness of data. In future, other data feature analysis techniques can be used, such as the *k*-means method, the balanced iterative reducing and clustering using hierarchies method, or the density-based spatial clustering of applications with noise method.

4 Experiments and Discussions

4.1 Experiment Data and Subjects

Lots of typical image datasets are built for the visual function assessment experiment in this paper. Figure 2 shows the related image samples. From Fig. 2, it can be seen the typical image datasets include the images captured from nature scene and the images captured under different indoor lighting conditions. The first dataset can be downloaded from the website: http://www.vcl.fer.hr/quality/vclfer.html. And the second dataset is made by us. This dataset is captured in a darkroom of the visual function laboratory in the Astronaut Research & Training Center of China.

Eight subjects (male, ages from 25 to 35; heights from 165 to 175 cm; weights from 60 to 75 kg) participate in the visual function evaluation experiment. This experiment is implemented in the darkroom of the department of ophthalmology of the General Hospital of the Chinese People's Armed Police Forces. After a primary

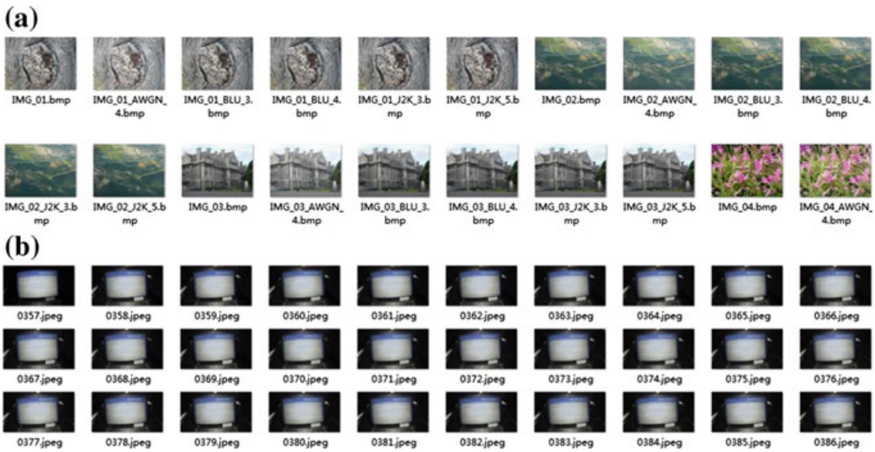

Fig. 2 Experiment data samples

ocular examination, none of the subjects have any ophthalmopathies; their uncorrected eyesight are better than 0.8. Before the subjects participated in this evaluation experiments, the entire experiment procedures should be declared to them clearly. After the authorization by the Ethics Committee of the General Hospital of the Chinese People's Armed Police Forces, this experiment can be carried out.

4.2 Experiment Software

A visual function evaluation software is developed in this paper. It is written by C++ and MATLAB. The basic software interfaces are shown in Fig. 3: Fig. 3a is its function region partition and Fig. 3b shows its application case. Regarding the visual function evaluation task, this software has five functions: first, it can select the image dataset and display them in its image display region. Second, it can select the subjective image quality evaluation index; the indexes are shown in Table 1. Third, it can set the evaluation response time of subject. The response time is the maximum evaluation time of each image. Fourth, it can score the subjective evaluation result. The maximum evaluation degree is 10. The user can also use it with a small evaluation degree, such as 5 or 3. Fifth, it can record the assessment details and results in a text file. The storage path can be set by the user. If the user misses to assess some images during experiment, this software can reset a new experiment for these missed images.

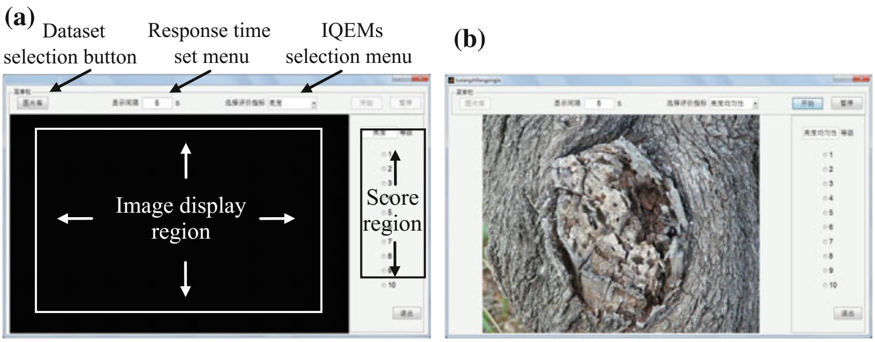

Fig. 3 Software interface design and its application

4.3 Experiment Results

Figure 4 shows the image quality evaluation result samples of the experimental dataset in Fig. 2. In this experiment, the 10-degree evaluation method is utilized. Figure 4a shows the evaluation result sample of the first image in Fig. 2a, while Fig. 2b shows the assessment result sample of the first image in Fig. 2b; the horizontal coordinate in Fig. 4 is the subject's ID and the vertical coordinate is the subjective evaluation results of different IQEMs. From Fig. 4, it can be seen that the evaluation results of different subjects approximately have the distribution consistency; in addition, these results can cover the subjective cognition of subject after using a subjective questionnaire; as a result, the subjective visual function can be described quantitatively by this experiment.

Table 2 gives out some statistic computation results of the subjective image quality evaluation in Fig. 4a. Eight subjects are asked to perform the evaluation experiment for 12 times in different days; thus for each image, we can get 12×8 evaluation results. In Fig. 2, the degraded images are created by the digital image processing techniques or by the environment lighting setting of camera. That means

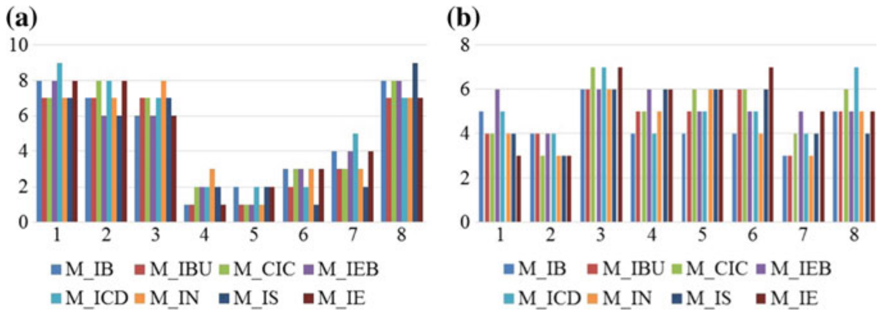

Fig. 4 Result records of the subjective image quality evaluation experiment

Table 2 Statistic results of the subjective image quality evaluation indexes

		Subjective image quality evaluation indexes							
		M_{IB}	M_{IBU}	M_{CIC}	M_{IEB}	M_{ICD}	M_{IN}	M_{IS}	M_{IE}
Statistic indexes	Arithmetic mean	7.625	7.125	6.75	1.75	1.5	2.5	3.5	7.625
	Median	7.5	7.0	7.0	2.0	1.5	3.0	3.5	7.5
	Mode	7.0	7.0	7.0	2.0	1.0	3.0	3.0	7.0
	Variance	0.5536	0.6964	0.5	0.5	0.2857	0.5714	0.8571	0.5536
	Range	2.0	2.0	2.0	2.0	1.0	2.0	3.0	2.0
	Variation coefficient	0.0976	0.1171	0.1048	0.4041	0.3563	0.3024	0.2645	0.0976

the experiment designers have the primary knowledge about these results. For example, if the original high-quality image is processed by the image definition degeneration technique, the experiment designer will know the subject will give a low score when they assess the image edge blur index. From Table 2, we can find the corresponding calculated results have the distribution consistency with the experiment designer's prior knowledge; thus, it indicates these results should be correct.

4.4 Discussions

The visual function assessment has extensive application needs for both the scientific research purpose and the clinic diagnosis purpose. As we have stated above, the visual function can not only reflect the ocular state of subject but also indicate other disease-caused lesion of human eyes. Thus, it can be a kind of direct or indirect medical processing measurement for many diseases. In future, the visual function assessment can be both a kind of disease diagnoses measurement and a rehabilitation evaluation method for the typical disease if the corresponding experiences are accumulated elaborately.

Comparing with the traditional visual function assessment technique, the advantages of proposed method are apparent. First, the proposed method can reflect the integrated healthy state of patient. Second, the automation capture and processing ability of the proposed method are good. That means the accumulated data can be stored and analysed by a computer system effectively. Third, many data processing methods can be used to analyse the features of these high-dimensional data. The correlativity analysis or the association analysis can be performed by using these data in future.

The proposed method also has some shortcomings. For example, comparing with the standard visual chart-based method, the proposed method does not have any medical standard currently which can limit its implementation in practice. Another shortcoming is the experiment processing costs too much time comparing with the traditional method. The patients still do not admit this method as the diagnosis measurement in some cases. In future, with the accumulation of the experiment data and data distribution laws, the proposed technique can become enforceable definitely.

5 Conclusion

A computer-aided visual function assessment system and method is proposed. The typical image datasets are used as the observation target; some IQEMs are employed to assess the visual function of subject. After the application of proposed system and method, the visual function change laws of typical image dataset can be accumulated by the IQEMs and their statistic features. In future, the proposed method can be regarded as a kind of supplemental measurement of the traditional visual function assessment method to realize the precise analysis of human visual function or other corresponding diseases.

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Experimental Study on Ergonomic Form of Handsaw Handle

Xiaohu Xu, Siyong Guo, Ran Yan, Haifeng Zhang and Ping Zhang

Abstract Using the basic theory of human factors engineering, the author discusses whether various handles affect the human arm and shoulder muscles or not, while observing the work efficiency and accuracy by designing controlled experiment. According to Man-machine analysis of the hand tools, the paper studies on handle tool usage method, and creates a kinds of Z-shaped handle handsaw. The control experiments of new handle were conducted by sEMG measurement, and the author tries to understand and evaluate the effect on efficiency and accuracy. This study finds that fatigue degree is different between I-shaped and Z-shaped to arms and shoulders. Z-shaped handle handsaw is slightly better than I-shaped handsaw on the working efficiency, but Z-shaped has obvious advantages in accuracy which has an important enlightening effect on designing the tool handle.

Keywords Handsaw · Ergonomic form · I-shaped and Z-shaped handles · sEMG

1 Introduction

Recently, although automation technology develops rapidly [1], human manual operation has not been completely replaced by automation. For example, handsaws are characterized by simple and easy application and low price. So there is still vast development space about the traditional handsaw. The application or design of hand tools without considering the human body conditions or human operation state may cause inappropriate exertion or poor working posture and lead to low efficiency, even an accident or the occurrence of musculoskeletal injuries [2].

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The present paper we studied is mainly concentrated on the effect of handle modeling on hand muscles, hand load, etc. Without involving arms and shoulders. The effect of the shape on efficiency and accuracy was not studied. According to the ergonomic design and evaluation of handsaw (Pao-Hung Cheng from National Yunlin University of Science & Technology), in order to improve the load and action of hands while using traditional handsaws, the author applies ergonomics, considering aesthetic and convenience, and discusses the important factors of handsaws such as size, material, angle, handle shape, point of application. Through analyzing the structure and biomechanics of the palm, the handle is designed to meet the human palm size and surface, and the thrust experiment of various new handle as well as sEMG measurement was conducted to put forward the design principle of hand tools. The ergonomics research on hand tools mainly focused on hand position, but did not involve the impact on the forearm and shoulder.

This paper is aimed at creating a Z-shaped handle by studying anthropometry and biomechanics of hands and arms. By sEMG measurement on the I-shaped and Z-shaped handles, the author discusses whether various handles affect the human arm and shoulder muscles or not, while observing the work efficiency and accuracy. In order to improve the operation posture of the handsaw, decrease the load of the arm and shoulder. Finally, based on the study, the designer may develop some kinds of handsaw with higher efficiency and accuracy.

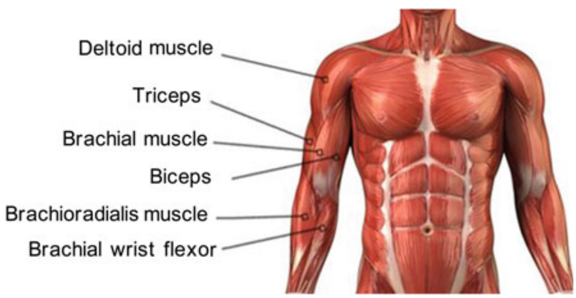
2 Form Design of Handsaw Handle Based on Ergonomics

2.1 Analysis of the Hand Tools on Ergonomics

The tool must meet the following basic requirements to ensure efficiency and health: achieving the function of hand tools, in addition to improving work efficiency; the size of the hand tool must take into account the size and structure of the hand [3]; it should be natural, comfortable, and keep your wrist straight when using tools [4]; reducing muscle static load; avoiding repeated bending of the fingers and excessive fatigue.

In terms of anatomy, the wrist has more than ten muscles and this part of the muscle can provide many operating states by changing postures [5]. Human arm

Fig. 1 Arm muscles



muscles affected in the operation of hand tools include deltoid, triceps, brachialis, biceps, brachioradial muscle, brachial carpal muscle flexor [6]. This part of muscle fatigue degree will affect the work efficiency and accuracy (Fig. 1).

2.2 Analysis of Application of Handsaws

When operating the handsaws, the operator may meet such problems: break blades or askew saw kerf. There are several reasons for the saws broken.

1. The workpiece clamping position is unreasonable or the clip is too loose. As a result, there is not enough support at the sawing spot.
2. Sawing too fast or heavily.
3. After the sawing slanting, the force is adjusted to make the blade side and workpiece change to produce pressure.
4. When the saw blade is locked in the workpiece, the operators do not lift it while continuing to pull.
5. When the blade is nearly broken, the operator did not try to relieve pressure, which leads to the impact on the workbench.

The reasons of the saw kerf skewing are as follows:

1. The operator saw the workpiece in a skew way at the beginning.
2. The blade is not clipped tightly, swaying around, or the nuts are loosening.
3. When using the handsaw, the operator’s posture is incorrect and the work piece is not aligned with the workpiece.
4. The frequency of the handsaw operation is so fast that the saw kerf is narrow and skewed.
5. The operator’s sawing amplitude is too large.

2.3 Designing of the Handsaw Handle

1. The side of the handsaw handle is like Z-shaped. The angle between the handle and the saw blade plane is 10°. When a right-handed user saws a piece of wood up and down with a handsaw, his arm moves to the outside of the body involuntarily and the handsaw tilts to the right which could lead to a skew kerf. If forced to correct at this time, it may cause dorsal flexure, hand fatigue, and an uneven kerf. Therefore, designing a Z-shaped handle by clockwise tilting the existing I-shaped handle 10°to compensate for the deviation of the saws from the outside of the arm (Figs. 2, 3, and 4).

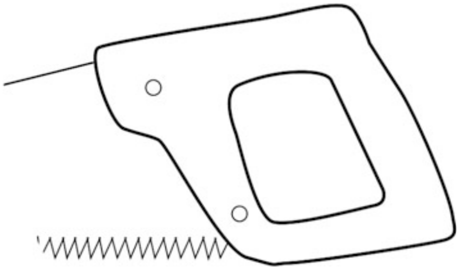


Fig. 2 Front view

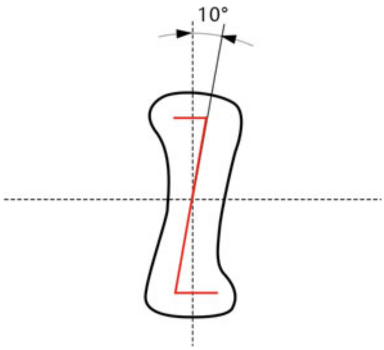


Fig. 3 Side view of Z-shaped

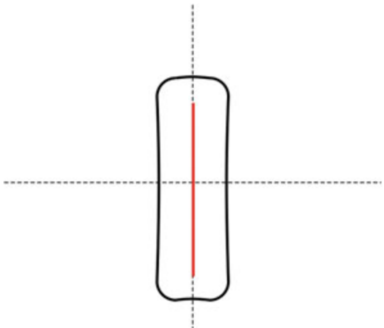


Fig. 4 Side view of I-shaped

2. There is a bulge in the lower side of handle to give the thenar muscles upward support force. The upper part is sag, and the thumb can hold the handle naturally. Between the palm and the handle, there is a little gap, so that the pressure of the first webspace (the space between the thumb and the index finger) is right.
3. The cross section of handle is designed into curve which can be effortless and comfortable. The bending angle of finger joints is moderate about 45°. That means it is easy to grasp and reduce the extrusion.
4. Composite: The handle is made by engineering plastics covered with rubber pad. The rubber pad could relieve the pressure at the position of hypothenar muscles and finger dorsal interosseous muscles (Fig. 5).

Fig. 5 Physical models

3 Experimental Evaluation of Handsaw

In order to examine whether the handsaw shape has an effect on the degree of muscle fatigue in the arm and shoulder. The paper conducts sEMG experiments and contrast experiments on the I-shaped handle and the Z-shaped handle. Exploring the impact of fatigue on the arm and shoulder, which differ from the I-shaped handle to Z-shaped handle, and observing the operation process and results to compare the working efficiency and accuracy between the two handsaws.

Experiment 1: Handsaw measurement by sEMG

1. Facilities: stopwatch; 60 mm * 8 mm batten; I-shaped handsaw; Z-shaped handsaw
2. Process: A subject uses one I-shaped and Z-shaped handsaws to saw a piece of batten within 120 s, respectively, and the experimenters collect the sEMG data of post-deltoid, triceps, biceps, and brachioradial of the right arms (Figs. 6 and 7).
3. Data analysis

Studies show that the sEMG signal frequency characteristic can be changed with the change of the muscle functional status in the process of muscles work. The

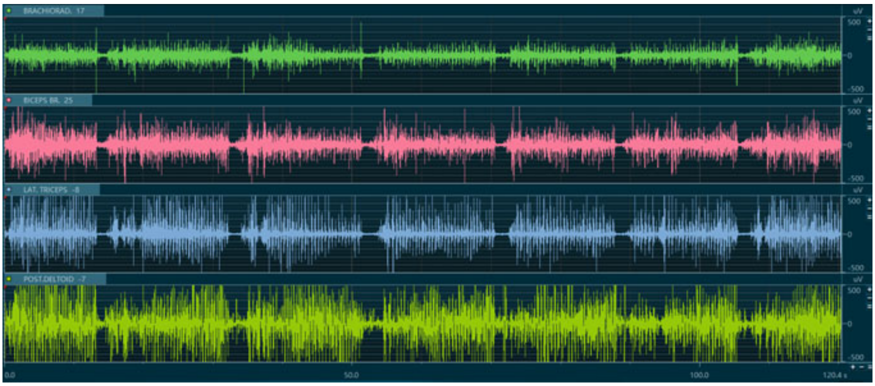


Fig. 6 Post-deltoid sEMG data

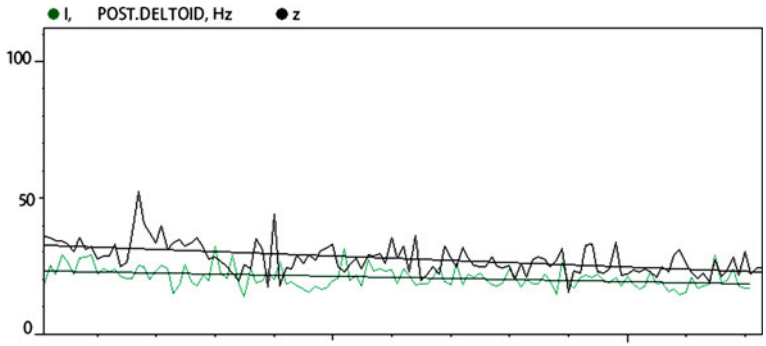


Fig. 7 Mean power frequency

frequency characteristics of the sEMG signal are the mean power frequency (MPF) and the center frequency (FC). The fatigue value of the muscle is obtained from frequency domain analysis of the EMG data. Using the time domain diagram mean frequency of muscles to make a comparative analysis of the operation of the different handsaws. During the study of muscle continuous working to fatigue, the spectrum of the electromotor signals shifts to the left as the degree of fatigue deepens, which means the mean power frequency reduces. The conclusion can be reflected from the curve which the smaller the intercept of the curve is relatively labor-saving action and the smaller the slope means uneasy fatigue. The fig. 7 shows the time domain diagram mean frequency of the post deltoid. The figure shows the I-shaped handle is recorded as a green curve and the Z-shaped handle is recorded as a black curve. The former intercept is slightly smaller than the latter, and the absolute slope is slightly smaller than the latter either. It means that the post-deltoid feels more labor-saving and tireless when operator is using the Z-shaped handle handsaw. Table 1 is the intercept and slope of the curve which represent the subjects' four groups of muscles, and the results show the fatigue degree of the other three muscles.

Analyzing the mean power frequency (MPF) chart of the muscle with different handsaw. The conclusion is shown in Tables 2 and 3.

Table 1 Part of the data slope and intercept of MPF

	Slope	Intercept
I (post-deltoid)	−0.0405	23.3
Z (post-deltoid)	−0.0837	32.8
I (triceps)	−0.183	37.7
Z (triceps)	−0.173	46.2
I (biceps)	−0.213	39.6
Z (biceps)	−0.1359	37.6
I (brachioradial)	−0.118	62.3
Z (brachioradial)	−0.219	73.3

Table 2 More effort type of handsaws

	Post-deltoid	Triceps	Biceps	Brachioradial
Subject 1	I	I	Z	I
Subject 2	I	I	I	I
Subject 3	I	Z	I	Z
Subject 4	Z	I	I	I
Subject 5	I	Z	Z	Z

Table 3 Uneasily to fatigue type of handsaws

	Post-deltoid	Triceps	Biceps	Brachioradial
Subject 1	I	Z	Z	I
Subject 2	Z	I	Z	Z
Subject 3	I	Z	I	Z
Subject 4	Z	I	Z	Z
Subject 5	I	Z	I	Z

4. Conclusions: According to the sEMG table, the effect of different handsaws on muscle fatigue is not significant. And there is not significant correlation between the type of handsaws and the fatigue of the muscles. The reason may be the limits of uncontrollable factors. Such as the limitations of number of subjects and sawblade inconsistency.

Experiment 2: Testing of sawing efficiency of handsaws

1. Facilities: Stopwatch; 120 mm * 30 mm batten; I-shaped handsaw; Z-shaped handsaw
2. Process: A subject uses I-shaped or Z-shaped handsaw to saw two same pieces of batten within 120 s, respectively, and we record the number of sawed batten pieces. After having finished, the subjects have a 20-min rest. The experimental data of 10 groups are recorded, respectively.
3. Records (Table 4):
4. Discussions:

   The I-shaped average number of batten: $I = 6.65$ pieces
   The Z-shaped average number of batten: $Z = 7.05$ pieces
   The Z-shaped working efficiency is slightly higher than the I-shaped.

Experiment 3: Sawing accuracy of the different handsaws (Fig. 8)

1. Facilities: Triangle; 280 mm * 300 mm batten; I-shaped and Z-shaped handsaws.
2. Process: Let the subject use the I-shaped handsaw, vertically sawing the board until the saw kerf reaching 100 mm, and horizontally measuring the maximum offset. 20 min later, using Z-shaped handsaw to carry out experiment in the same way.

Table 4 Testing work efficiency

Subject number	I-shaped handsaw/pieces	Z-shaped handsaw/pieces	Subject number	I-shaped handsaw/pieces	Z-shaped handsaw/pieces
A	7	6	A	6	7
B	4	5	B	5	7
C	9	8	C	7	8
D	7	7	D	6	7
E	5	6	E	5	7
F	8	9	F	7	8
G	6	7	G	6	7
H	8	8	H	7	8
I	6	7	I	6	8
J	5	5	J	5	6

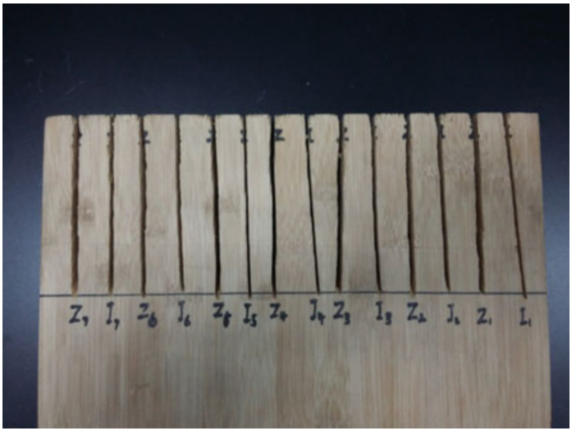


Fig. 8 Experimental results

3. Records (Table 5).

   Sample deviation
   The I-shaped average deviation: $I = 3.39$ mm
   The Z-shaped average deviation: $Z = 1.29$ mm

4. Discussions:

   1. The saw kerf has a tendency shifting to the right during the process of using handsaw with right hand.
   2. The sawing accuracy of Z-shaped handle handsaw is more than twice that of I-shaped handle handsaw in the case of vertically sawing wood.
   3. The tilt angle of the Z-shaped handsaw can be designed slightly bigger, which contributes to the accuracy.

Table 5 Offset data

Subject number	The deviation of I-shaped/mm	The deviation of Z-shaped/mm	Tester number	The deviation of I-shaped/mm	The deviation of Z-shaped/mm
A	+6	+1	D	+6	+1
A	+3	0	D	+3	0
A	+2	−3	E	+2	−1
A	+5	+1	E	+5	+1
B	+3	+2	E	+3	+2
B	+3	+1	E	+3	+1
B	+2	+1	F	+2	+1
B	+4	+2	F	+5	+1
C	+3	+2	F	+2	+2
C	+5	+1	F	+3	0
C	+2	0	G	+2	+1
C	+3	+3	G	+4	+2
D	+4	+2	G	+3	+1
D	+3	−1	G	+4	+2

"+" means right offset, "−" means left offset, calculating the deviation by the absolute value of the data

4 Conclusions

Through making comparison between the I-shaped handle and the Z-shaped handle in the aspects of work effectiveness, cutting accuracy, and the fatigue degree with the sEMG experiment, the paper comes to the following conclusions: During the process of handsaw operation, different handle shapes have an impact on the fatigue degree of brachioradial, and the handle with Z-shaped side can alleviate the fatigue of this part muscle; the Z-shaped handle's cutting efficiency is more efficient than the I-shaped handle's cutting efficiency; in most cases, the saw kerf has a tendency shifting to the right during the process of using handsaw with right hand, and the sawing accuracy of the Z-shaped handsaw is more than twice that of the I-shaped handsaw in the case of vertically sawing wood, so the tilt angle of the Z-shaped saw kerf can be designed slightly bigger, which contributes to the accuracy. In repeated mechanical movement conditions, Z-shaped handle applications can be extended to many other tools. A small inclination can bring great progress.

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Study on Mental Attributes of Aged Test Pilots

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Abstract Mental ability will decline by ageing while the experience accumulating. It is important to study the mental attributes of aged test pilots in order to maximum professional span and ensure flight safety. Methods A total of 35 experts including test pilots and aircraft design engineers were interviewed on the issues of the mental ability of aged test pilots through completing a questionnaire about the issue. A battery of mental ability test and 16PF were used to examine 37 test pilots who were divided into three age groups (age above 45 year, $n = 16$) and control group (age below 45 year, $n = 21$). Results Most important mental attributes of older test pilots were related to professional spirits, flying expertise (judgment) and personality. The firstly aging abilities were cognition and psychomotor ones. Scores of Detecting special graph, Distinguishing direction and Distracted listening were lower than those of control group ($P < 0.05$), which were negatively correlated to age ($r = -0.335, -0.411, -0.409$, $P < 0.05$). Conclusion Mental abilities related to reaction speed decline earlier. Although the expertise may compensate for the decline, routine aptitude test will benefit the increasing need for test pilot and aviation safety.

Keywords Test pilot · Aging · Mental attribute

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1 Introduction

Mental ability and human performance will decline after the peak age, but the change pattern of different type ability varies. In aviation occupation, an air carrier flight pilot must retire from pilot job upon reaching their 60th birthday, commonly referred to as the Age 60 Rule [1], which was implemented by the Federal Aviation Administration (FAA) in 1959. Since then, the relationship between pilot age, piloting performance, and safety has inspired much debate and many questions.

Pilot incapacitation and performance factor are the most important concerns. Age-related decline in the pilot ability includes rapidly reaction, resisting fatigue, applying experience and judgement in emergency situations [2]. But in November, 2006, the International Civil Aviation Organization (ICAO) revised the maximum age for pilots from age 60 to age 65, and the United States followed in December 13, 2007 [3]. This may spire the concerns of aviation safety and expertise compensation in aged pilots. Although retired age of test pilot for fighter is far lower than 65, it is important to study the mental attributes of them because the high demand of fighter flying.

According to fluid and crystallized intelligence theory, originally identified by Cattell [4], fluid intelligence is the capacity to reason and solve problems, independent of any knowledge from the past. It typically peaks in young adulthood and then steadily declines. This decline may be related to local atrophy of the brain in the right cerebellum [5]. Crystallized intelligence is the ability to use skills, knowledge, and experience. This improves gradually with age, and stays relatively stable across most of adulthood, and then begins to decline after age 60, even age 80 [6].

Many researcher concerns about aged pilots ability since it is a high cognition demand job. Wu et al. [7] used seven cognitive test to investigate the age difference in the basic cognitive ability of fighter pilots and its influence upon flying training. The results show that pilot cognitive ability of the age 26–28 was higher than younger and older age groups. The age difference were significant between age groups, but did not influence upon flying performance. Hardy [8] also pointed out that there was only weak evidence that age-related differences in cognition influence pilot performance. But Yesavage [9] revealed that pilot performance on several flight tasks declined significantly with age. Quinn Kennedy [10] also found that older pilots' (41+ year) decision making ability and flight control performance were lower than younger pilots, but expertise could attenuated an age-related decline in flight control.

Flight skills, expertise and, special knowledge are essential to test pilots. Most test pilots became mature after their age 40. So it is important to study the age effect on their cognition. In this study, subject matter experts (SMEs) and psychological test were combined to study mental attributes among aged test pilots.

2 Subjects and Methods

2.1 Subjects

A total of 35 subject matter experts were investigated, including test pilots (TP), and aircraft design engineer (ADE).

There were 37 flying qualified test pilots, 35–56 year of age, who completed the study. All pilots were sub grouped into two age ranges: 45–53, 35–45, named older group and control group respectively. There were 16 older group members (average age 47.94 year) and 21 control ones (average age 41.43 year).

The experimental protocol was approved by the Beihang University Human Ethics Committee. All subjects signed informed consent to attend the experiment and their rights to withdraw at any time.

2.2 Tools

2.2.1 Mental Attributes Questionnaire of Aged Test Pilots

We compiled a questionnaire of 29 mental attributes that were essential to test pilot according to literature and test flying work context and job activities. The subject was asked to evaluate the importance of each item with 1–5 scale. The test pilots were asked to identify the top 10 mental attributes which were most important to old test pilot and top 10 which were most influence by age (Table 1).

2.2.2 Psychological Test

A test battery for measurement of mental attributes of fighter pilots developed by Wu [11]. The test battery include Sixteen personality Factor (16PF), Detecting special graph (DSG), Comparing simulated scales (CSS), Distinguishing direction (DD), Dual task (DT), Distracted listening (DL). According to the according to literature and test flying work context and job activities, Growth capacity (GC) and Innovation ability (IA) in 16PF were adopted in the study.

The test was completed on Lenovo Y460 notebook computer with 15 in. LED screen resolution of which was set at 1024 $\times$ 768.

2.3 Statistical Analysis

The IBM SPSS statistical software package 20.0 was used for data analysis, all test data were expressed as Mean $\pm$ SD ($\bar{x} \pm$ s). Pearson correlation test and t-test was

Table 1 Mental attributes questionnaire of aged test pilots

No.	Mental attributes	Importance evaluation (1–5)	Top 10 important	Top 10 age declined
1	Interesting in test flying			
2	Curiosity			
---	---			
28	Harmonious interpersonal relationship			
29	Sense of discipline			

used for statistical analyses. An alpha-level of 0.05 was used as threshold for significance.

3 Results

3.1 *Survey on Mental Attributes of Aged Test Pilots*

Top 5 most important mental attributes evaluated by ACG are 80% (4/5) similar to those of TP. Top 5 most important mental attributes evaluated by TP are 80% (4/5) similar to those selected by TP. Top 5 mental attributes which are influenced by age are different to those most important ones except agility of thinking Table 2.

3.2 *Psychological Test Results*

DSG, DD, DL scores of elder group are significantly higher than those of control group (P = 0.008, 0.008, 0.020) Table 3. There are negative correlation between

Table 2 Mental attributes of aged test pilots

No.	Top 5 evaluated by ACG	Top 5 evaluated by TP	Top 5 selected by TP	Top 5 influenced by TP
1	Decisiveness	Rigorous	Interesting in test flying	Agility of arms and legs
2	Interesting intest flying	Interesting in test flying	Decisiveness	Long memory
3	Judgment complicated situation	Decisiveness	Agility of thinking	Agility of thinking
4	Divided attention	Divided attention	Divided attention	Perception ability
5	Space orientation	Judgment complicated situation	Rigorous	Curiosity

Table 3 Comparative of mental attributes of test pilots between two groups

	Older group (N = 16)		Control group (N = 21)		t	P value
	M	SD	M	SD		
DSG	5.06	2.86	8.43	4.43	2.797	0.008**
CSS	13.06	5.08	16.19	4.76	1.907	0.066
DD	6.31	5.50	12.19	7.14	2.829	0.008**
DT	71.09	41.70	86.64	35.70	1.195	0.242
DL	30.81	6.08	35.38	4.81	2.473	0.020**
GC	22.80	4.66	25.89	3.95	1.253	0.249
IA	78.80	5.26	80.78	5.04	0.684	0.513

Note $*P < 0.05$; $**P < 0.05$

Table 4 Correlation between age and mental attributes of test pilots (r)

	DSG	CSS	DD	DT	DL	GC	AI
Age	–0.335*	–0.323	–0.411*	–0.208	–0.409*	–0.269	–0.286

Note $*P < 0.05$; $**\ P < 0.05$

age and mental attribute test. The correlation between age and DSG, DD, DL test are significant ($r = -0.335, -0.411, -0.409$) Table 4.

4 Discussion

The essential mental attributes of pilots including excellent ability of perception, memory, thinking, attention, psychomotor and personality character. With the development of aviation technology, automation gradually replaced many traditional piloting skills such as stick and rudder control. But test pilots still need the skills since the automation is not always on work. They must understand the inner work of the increasingly complicated aviation system besides piloting. The occupation character distinguish the mental attribute from traditional pilot [12]. The USAF have set the special TP requirement of flying ability, technical ability and professional competence [13]. But the study on mental attributes of test pilots is rare.

In our survey, the most important mental attributes of older test pilots are related to professional spirits, flying expertise (judgment) and personality. The psychomotor abilities which rely on neural system function, are less important and would decline early with aging.

The psychological test results is accordance with the survey results. The older test pilots' cognition and perception ability decline as aging since three sub test scores are lower than younger group. There are no significant difference between two group in personality test. Dual task test is more complex than other tests, and is done on a simulated radar interface which is similar to pilot work activity, so is not sensitive to aging effect and can compensated by expertise.

Many studies [14] on general pilots aging and cognition ability or simulation flight performance found that the relationship between increased age and decreased flight performance was significant. But other factors are also important for the older pilots performance [15]. Expertise may attenuate an age-related flight control decline [16] and that expertise effects were most evident in the accuracy of executing aviation communications [17], but many performance may not benefit from experience.

In our study, many test pilots' cognition and psychomotor ability is above the average level of younger groups. The individual difference is evident. Many older test pilot between 45 and 56 years feels the cognition ability decline themselves. Although they thought that can be compensate by expertise and have no crisis for safety, it is never too enough to be careful. David [18] examined the effect of age on aircraft pilots' cognition with a variety of neuropsychological tests. The results show that age was significantly related to test performance except immediate verbal recall or recognition. 95% scores lower than 2SD occurred in pilots over age 40 which may also mean a gradual cognition decline. Individual difference was an importance factor for flying requirement of aged pilots. Tsang [19] reviewed psychological literature about age effects on four cognitive abilities essential to pilot performance and also concluded that 40 is the declining age. Pilots over age 40 should be evaluated by ability test annually.

With the development of aviation industry, there are increasing demand for test pilots, either in general or military aviation. The occupation character determines that the test flying expertise is important to be a qualified test pilot. Routine aptitude test will benefit the need for test pilot and aviation safety.

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Eye Movement Characteristics Research on Pilots of Different Experience Background During Aircraft Cockpit Display Image Visual Search Task

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Abstract The purpose of the study was to find visual search characteristics on cockpit man–machine interface by the pilots with different flight experiences and different ages. *Methods* Test objects were 44 men; they were divided into three groups according to different aircraft cockpit experiences with large screen display or different age groups. The completely randomized block test was used. The instrument for recording eye movement was adopted in the process of eye-target search. *Results* Among 14 parameters for eye movement, 13 parameters were statistically significant ($P < 0.05$). Significant differences existed between groups of different experience background. There were seven indicators showed that the novice group was more than the expert group, the expert pilot group was greater than the mature group. The results of different age groups were as follows: Significant differences existed among three groups of different ages. Eight eye movement indicators showed that the values of 40–45-year-old group were more than that of 25–35-year-old group; the values of 25–35-year-old group were more than that of 35–40-year-old group. *Conclusion* The novice group was least familiar with screen layout and therefore search target took longer time and more fixation points. The expert pilot group is the most experienced in three groups, but they took more time to search targets than the mature group. The reason might be that "no error" thought forced them to confirm on the same issue repeatedly, resulting that the search efficiency was lower. Data of different age groups showed that the older the ages were the worse eye movement data were. This shows that as the increase of age the eye's capture and search ability fall. But for some other indicators, 35–40-year-old group was better than that of 25–35-year-old group, indicating that

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there were interactions between the experienced background and ages because there were more novice pilots in 25–35-year-old group, familiarity of the picture can make up for the lack of physical reaction speed.

Keywords Eye tracking · Human computer interaction (HCI) · Pilots · Visual features

1 Introduction

As the direct media of pilot controlling aircraft, human–machine ergonomics of cockpit display interface directly affect the aircraft controlling effect, the outcome will directly decide the flight performance. Abroad in the 1960s, researchers began to study the scanning mode of pilot, many research models are based on eye movement data or search for support of eye movement data. Using the eye movement data to evaluate instrument scanning behavior of the pilot, in the three-dimensional space understand the process of the pilot controlling aircraft posture, location and movement rate and information was obtained from the meter. After entering the 1980s scanning analysis has been developing rapidly, the analysis technology and control technology together with aircraft flight parameters evaluate display design. Bellenkes et al. [1] found difference lies in each phase of the flight scanning mode. Schriver et al. [2] by verifying relationship of attention and action (attention-action) to examine the differences in making decision skilled personnel and flight trainees. Previous research is basically done in actual flight of simulator, there are few research comparing different experience background of pilots when in observation of design elements of cockpit display interface, Guo et al. [3] did not use eye tracking technology during his ergonomic experiment of cockpit display interface such as HUD speed, altitude and heading, flight instruction format. Therefore, it is necessary to compare visual search characteristics of pilot groups with different flight experiences and ages using flight cockpit man-machine interface so as to provide the crucial information for the design of man-machine interface.

2 Methods

2.1 Test Object

Subjects were a total of 44 people aged between 26 and 49, (average age 36, SD = 6), flight hours 221–7455.20 h, (average 2142, SD = 1723). According to different experiences for the aircraft cockpit large screen display, three groups are divided: novice group, mature, the experts. The novice group consists of 23 people, aged 26–46 years old, (average age 33, SD = 5), flight hours 221–4580 h, (1282 on average, SD = 980). Mature group has 7 people, aged between 35 and 43, (averages age 38, SD = 3), all flight hours 1338–3366 h, 2169 on average, SD = 777). Expert group has 14 people, aged 34–49 years old, 40 on average, standard deviation 5), flight hours 1772–7455 h, (3541 on average, SD = 2121). Experiment scheme has gone through the review by the ethics committee; the participants signed informed consent before test.

2.2 Test Conditions

2.2.1 Test Environment

Illumination: intensity daylight saving mode illumination intensity since 8:00–17:00 of the day (20–220 lx)

2.2.2 Equipment

The instrument used in this experiment is Model D6 Eye View Monitoring Systems by Applied Science Laboratory. Sampling rate of the equipment is 60 Hz. Record the participants: eye movement trajectory diagram, eye movement time (including fixation time, regression time, DE time, saccadic distance, the pupil diameter, etc.).

2.3 Test Design

Test use completely randomized block test paradigm. Test program used is self-programming, participants were asked to found position in the original accordingly in the fastest time according to the given target images. The test programming was self-compiling. The design elements were extracted from ARJ-21 and seven aircraft cockpit typical images were used. The “target pictures” with significance was intercepted from the pictures for searching. The typical picture were divided artificially into twelve quadrants, each quadrant can involve a target. In the test , “target figure” appeared firstly, and then “target figure” disappeared, then a with “target figure” appeared, the participant was asked to locate the “target figure” in the larger figure as fastest as he could. Each image rendering time is 200 ms. Eye movement data accuracy and reaction time are recorded in background. Questions compiled are randomly appeared. Because given “target” used, thus problems of different participants experience background are eliminated.

2.4 Test Procedure

The participants were told of test purpose and matters needed attention before the test.
Trial begins:

(1) The participants adjust sitting position, the program uses eye movement apparatus to scale for the participants. Double-click to start testing.
(2) "Instructions" appeared; click "next" into practice after understand.
(3) Exercises are a total of three, if all right formal test can be started.
(4) The official start, the "target" to be tried to find appeared first, the participants remember it and then click the blank space key to continue.
(5) A larger figure with target appears.
(6) After the participants have moved eyes to search the location of the target figure in the larger image, click the mouse button to confirm.
(7) Then a calibration image(red "+") is inserted and the eye tracker calibrates automatically (see Fig. 1). After the calibration the next trail will begin. Loops (4)–(6) step until the end of the test.

2.5 Data Statistics

The use of SPSS statistical software package for data processing, all test data are expressed with mean +/− standard deviation ($\bar{x} \pm s$). Fourteen of eye movement indices from the ASL-D6 eye movement apparatus were analyzed, and the set $P < 0.05$ for the threshold with difference significance in statistic. After inspection, 14 of eye movement data variance are uneven; therefore, multiple independent samples nonparametric test was adopted (k independent samples test).

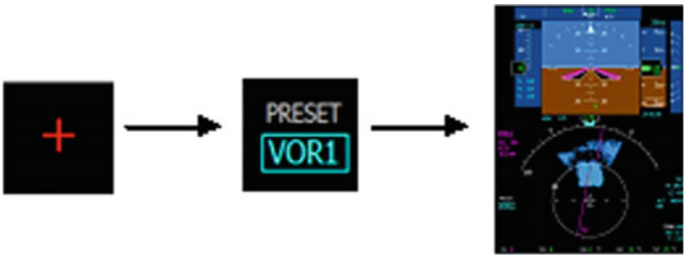

Fig. 1 "Automatic scaling figure," "Target," "A larger figure with "target figure""

3 The Results

3.1 *Eye Movement Indices Statistics Analysis Results of Different Experience Background Pilots*

3.1.1 Eye Movement Indicators Descriptive Statistics Analysis Results of Pilots of Different Experience Background

See Table 1.

3.1.2 Eye Movement Indicators Statistical Analysis Results Different of Pilots of Experience Background

Fourteen eye movement data as independent variables name different experience background as "novice group," "mature group," "experts group" as the grouping variable for the single factor variance analysis, the results are shown in Table 2.

According to the average rank further conclude that the eye movement index "Spent time in AOI," "Fixation points," "Total fixation duration," "Fixation points in AOI," "Number of times regression in AOI," "Average fixation duration in AOI," "Average fixation duration" seven indicators data results showing that the new group is more than the experts, the experts are more than the mature group. "First pass time

Table 1 Eye movement indices descriptive statistical results of pilots of different experience background

Content	The pilot group of different experience background		
	The experts	The mature	The novice
Spent time in AOI	3.71 ± 4.90	3.09 ± 3.71	3.58 ± 4.69
Fixation points	18.33 ± 24.11	15.90 ± 20.30	17.67 ± 23.26
Total fixation duration	2.92 ± 3.79	2.45 ± 3.06	2.81 ± 3.55
Fixation points in AOI	3.39 ± 2.40	2.64 ± 1.58	3.17 ± 1.96
Number of times regression in AOI	1.44 ± 1.02	1.21 ± 0.54	1.30 ± 0.74
First fixation duration in AOI	0.18 ± 0.13	0.19 ± 0.11	0.18 ± 0.12
First pass time in AOI	0.50 ± 0.34	0.42 ± 0.24	0.51 ± 0.37
Average fixation duration in AOI	0.21 ± 0.11	0.21 ± 0.10	0.22 ± 0.11
Fixation duration in AOI	0.68 ± 0.51	0.51 ± 0.30	0.66 ± 0.44
Average fixation duration	0.17 ± 0.04	0.16 ± 0.03	0.17 ± 0.04
Average saccade distance	117.57 ± 48.71	127.80 ± 56.92	121.86 ± 60.21
Average saccade time	0.05 ± 0.01	0.05 ± 0.02	0.05 ± 0.02
Average saccade speed	2044.51 ± 541.77	2178.90 ± 591.44	2109.25 ± 673.17
Average pupil diameter	34.87 ± 6.03	36.40 ± 8.13	37.32 ± 7.88

Table 2 Eye movement index *K* inspection statistical analysis results of pilots of different experience background

Sequence number	Dependent variable	df	χ^2	Sig.
1	Spent time in AOI	2	23.11	0.00**
2	Fixation points	2	16.95	0.00**
3	Total fixation duration	2	30.48	0.00**
4	Fixation points in AOI	2	86.82	0.00**
5	Number of times regression in AOI	2	7.11	0.03*
6	First fixation duration in AOI	2	3.18	0.20
7	First pass time in AOI	2	26.44	0.00**
8	Average fixation duration in AOI	2	13.94	0.00**
9	Fixation duration in AOI	2	102.49	0.00**
10	Average fixation duration	2	14.91	0.00**
11	Average saccade distance	2	18.48	0.00**
12	Average saccade time	2	5.98	0.05*
13	Average saccade speed	2	36.82	0.00**
14	Average pupil diameter	2	160.54	0.00**

**$P < 0.01$;*$P < 0.05$

in AOI," "Fixation duration in AOI" two indicators, the experts are greater than the novice group, novice group is greater than the mature. "Average saccade distance," "Average saccade time" two indicators suggest that mature group greater than the experts, the experts are greater than the novice group. The results for "Average pupil diameter": average pupils diameters of the expert group are less than the mature group, and the mature group is less than the novice group.

3.2 *Eye Movement Indices Statistics Analysis Results of Different Age Pilot*

3.2.1 Eye Movement Indicators Descriptive Statistics Analysis Results in Different Age Groups

See Table 3.

3.2.2 Pilot Eye Movement Indices Variance Analysis Results in Different Age Groups

Use 14 eye movement data as independent variables, different age groups as the grouping variable, multiple independent samples nonparametric inspection has been done; the results are shown in Table 4.

Table 3 Different age group pilot eye movement indices descriptive statistical results

Content	Pilots in different age groups		
	25–35 years old	35–40 years old	40–45 years old
Spent time in AOI	3.43 ± 4.01	3.48 ± 4.85	4.19 ± 5.39
Fixation points	16.91 ± 19.91	17.58 ± 24.76	19.82 ± 25.41
Total fixation duration	2.72 ± 3.08	2.73 ± 3.76	3.23 ± 4.07
Fixation points in AOI	3.20 ± 1.96	2.97 ± 1.99	3.73 ± 2.49
Number of times regression in AOI	0.28 ± 0.62	0.28 ± 0.66	0.40 ± 0.81
First fixation duration in AOI	0.19 ± 0.13	0.18 ± 0.11	0.19 ± 0.15
First pass time in AOI	0.53 ± 0.39	0.44 ± 0.27	0.55 ± 0.41
Average fixation duration in AOI	0.22 ± 0.11	0.21 ± 0.10	0.22 ± 0.13
Fixation duration in AOI	0.68 ± 0.45	0.58 ± 0.41	0.77 ± 0.53
Average fixation duration	0.17 ± 0.04	0.16 ± 0.04	0.17 ± 0.04
Average saccade distance	114.99 ± 48.05	127.55 ± 63.17	120.74 ± 54.00
Average saccade time	0.05 ± 0.01	0.05 ± 0.02	0.05 ± 0.01
Average saccade speed	2042.43 ± 590.17	2155.30 ± 634.46	2104.08 ± 714.83
Average pupil diameter	38.84 ± 6.41	35.87 ± 7.33	30.23 ± 8.59

Table 4 Eye movement index *K* inspection statistical analysis results of different age group pilot

Sequence number	Dependent variable	df	χ^2	Sig.
1	Spent time in AOI	2	25.75	0.00**
2	Fixation points	2	14.54	0.00**
3	Total fixation duration	2	30.42	0.00**
4	Fixation points in AOI	2	71.09	0.00**
5	Number of times regression in AOI	2	17.35	0.00**
6	First fixation duration in AOI	2	0.93	0.63
7	First pass time in AOI	2	35.81	0.00**
8	Average fixation duration in AOI	2	24.22	0.00**
9	Fixation duration in AOI	2	106.60	0.00**
10	Average fixation duration	2	43.98	0.00**
11	Average saccade distance	2	42.66	0.00**
12	Average saccade time	2	11.64	0.00**
13	Average saccade speed	2	44.10	0.00**
14	Average pupil diameter	2	537.81	0.00**

**$P < 0.01$

According to the average rank further conclude that the eye movement index "Spent time in AOI" and other 7 index results: 40–45-year-old group more than 25–35-year-old, 25–35-year-old group more than 35–40-year-old group. "Average fixation duration in AOI" result showed that: 25–35-year-old group more than 40–

45-year-old group, 40–45 more than 35–40-year-old group. “Average saccadic distance,” “Average saccadic time” and “Average saccadic speed” three indicators results: 35–40-year-old group more than 40–45-year-old group, 40–45-year-old group more than 25–35-year-old group. According to the results of “Average pupil diameter” ,the order from big to small is: 25–35 year-old group, 35–40 year-old group, 40–45 year-old group.

4 Discussions

From the data results it can be seen that different groups of eye movement data generally show novice and expert groups take longer time, get more fixation points and lower search efficiency when searching target. Analysis reason is that the novice group was less familiar with screen layout and lead to low search efficiency. Though expert group was the most experienced in three groups, the searching time was longer than mature group, the reason was that “no error” thought forced them to confirm on the same issue repeatedly, resulting that the search efficiency was lower. This phenomenon was convinced by the eye movement data. “AOI first processing time”, “AOI fixation time” of expert group were the longest in the three groups and “AOI regression times” was the most, which indicated that the experts have done more confirmation after they have found the target. Sibert [4] argues that regressive number is associated with significant number of clues, but it must rule out experience factors, this study due to the same search target, clues meaning is the same, so the number of regression should come from the subjects, and its search decision strategy differences in the test. Expert and novice AOI first fixation time is better than that of mature group, but the first processing time is than mature team, proving that expert and novice have fast recognition to perception characteristics search target. But for the target to confirm taking is a long time. Analysis reason, for newcomers, uses a “bottom-up” mode of perception, perception characteristics of concrete are the first focus, and consolidation process (pattern recognition) is easy to be influenced by experience, thus slower. But experts always are based on careful characteristic in the process of task; therefore, they are inclined to integrated application of perceptual characteristics and pattern recognition, confirming the target is beneficial to feature recognition, but hindered the graphics integrated identification process.

Pupil size is associated with mood changes [5], to be able to response effort level and work load of the participants in the test [6], the previous research results show that in the same task the pupil diameter of specialist subjects on average is the smallest, and the pupil diameter of the novice group is the biggest, tension, load, etc., causes pupil diameter increasing of the novice group participants [7]. The results are consistent with this, it also indicates that the search performance of expert group is lower than the mature performance; the reason for this is not a big task load, but need to reconfirm the result repeat for cautious decision making.

In dynamic task, eye scanning characteristic and the static image search task showed different characteristics in the subjects of different experience background, Kasarkis and Stehwien [8] found that in the process of the plane's landing simulation, visual scanning rules of different experience pilots are quite different. Experts watch frequently than novice, residence time is shorter, total fixation point number is more. Experts have a clear scanning mode, and fixation point total number of pilots of precise landing is more, watching residence time is shorter. Jacob and Karn [9] study found that in the static image search task, more fixation point number shows lower search efficiency, the target is not confirmed; this is the same with the results of this study.

With the increase of age, adult visual system function and visual search ability decline, visual perceptual speed and eye movement speed is reduced; many studies are focused on this problem. Results confirmed are, Abel [10] study found that with increasing age, saccadic incubation period increases, Ross [11] study found that smooth tracking ability is reduced, In the three groups in the study, 40–45-year-old group visual search efficiency is lower than the other two groups, showed by the fixation point quantity and fixation time increased, consistent with previous results. But in processing efficiency in stimulating target, 35–40-year-old group is better than the other two groups, showed by short processing time in the interest area. There may be two reasons for analysis: One is the cognitive abilities gradually decline with age, different cognitive abilities have different rates of cognitive declining, David [12] studied 220 pilots aged 28–62 years old, showing that, most of the cognitive performance has negative correlation with age, but the correlation coefficient is low; but the individual of single poor cognitive performance is generally between the ages of 43–62. Another reason is, the vast majority of 25–35-years-old group are novice, using a bottom-up mode of perception, familiarity of target is low, leading to low machining efficiency, and 35–40-year-old group perception ability has yet to reach down a turning point, and has relatively rich experience using a top-down mode of perception for target, so the machining efficiency is high. Also show that interaction between age and experience background, because 25–35-year-old group has more novice participants, familiarity of images can make up for the lack of physical reaction speed.

5 Compliance with Ethical Standards

The study was approved by Beihang University Human Ethics Committee.

All subjects who participated in the experiment were provided with and signed an informed consent form.

All relevant ethical safeguards have been met with regard to subject protection.

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Visual Characteristics Study of Traditional Round-Backed Armchair Based on Eye-Tracking

Yun Liu, Yi Zhou, Hanzhou Qiu and Liming Shen

Abstract With the pictures of the traditional round-backed armchairs being the sample, TOBII Eye-Tracker is adopted for the eye-tracking experiments, followed by the study of several key issues based on the Semantic Differential Five-Level Quantitative Scale surveys. The results suggest: the visual highlight of the round-backed armchair lies in the upper part of the chair. The arch enclosure virtual plane enhances the layering of the furniture, but lowers the visual stability. A proper supplement of embellishment and supports (Ya Tou) with classic pictures could cultivate users' recognition for the traditional round-backed armchair and elevate the overall preference and intent to purchase the round-backed armchairs.

Keywords Classic round-backed armchair · Visual characteristics · Aesthetic cognition · Eye-tracking · Intent to purchase

1 Introduction

As an important category of the Chinese traditional chairs, the round-backed chair has formed unique characteristics along its long-term development. With the major feature of lines, the overall shape is simple, elegant and full of dynamics, combined with its profound cultural intension, explaining its popularity in the furniture market [1]. Whether the aesthetics of traditional round-backed chairs could be accepted by consumers depends on whether they could obtain the aesthetical recognition from the visual features of the product, which could influence their perception for the product and the intent to buy [2]. It is revealed in a study that 80–90% of the

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external information is received by human through eyes [3]. Therefore, this study adopts the eye-tracking experiment and the semantic differential method (SD method) scale survey to study the visual characteristics of traditional round-backed chairs and the possibility of purchase.

2 Method

2.1 Testee

Twelve volunteers, all teachers and students, were recruited from the Nanjing Forestry University, including six males and six females, and all aged between 22 and 35. The health condition was found normal without the symptom of colour blindness or weakness. The naked or corrected visual acuity was all above 1.0. No expose to the television or the computer was ensured within the 6 h before the test. No discomfort occurred to the eyes. Females were required to remove the eye make-up.

2.2 Experiment Instruments and Materials

Based on the ClearView 2.7.0 software system, the Sweden TOBII Eye-Tracker was used to record the eye tracks of the testees. The test was located in the perceptual engineering laboratory in the Shaw's Building of the Nanjing Forestry University.

Two classic round-backed armchairs were chosen in the test [4]: Chrysanthemum pear round-backed armchair and rosewood Ruyi round-backed armchair, the experimental images as shown in Figs. 1 and 2. The discoloration mode and the size remained consistent, and the background adopted 35% grey, to avoid the visual fatigue of testees.

2.3 Experimental Indicator Selection

The experiment purpose is to explore the visual effects of the traditional round-backed armchairs, namely the testees' sight distribution and the attention mode of different parts. The round-backed armchair was separated into three areas of interest (AOI): backboard, back-hoop and legs. The total fixation duration, fixation points, average fixation duration and combined heat map of each AOI were adopted as the eye-tracking indicators.

Fig. 1 **Chair1**: Chrysanthemum pear round-backed armchair

Fig. 2 **Chair2**: Rosewood Ruyi round-backed armchair

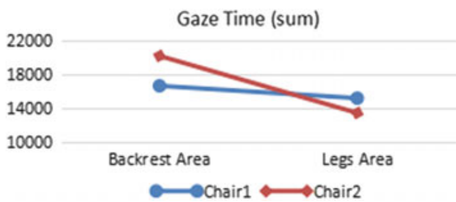

Fig. 3 Line chart of the total fixation duration of the traditional round-backed armchair

2.4 Experiment Flow and Methodology

After explaining the tasks to testees, they were placed about 600 mm away from the screen to follow the eye calibration procedure. Then each testee would watch the pictures of the round-backed armchairs, where each picture would be shown for 10 s [5]. Subjective reviews were completed right after watching, including stability, sense of fashion, decoration level, sense of layering, overall appearance rating and intent to purchase. The final form is presented with the semantic differential five-level scale.

3 Results and Discussion

3.1 Results and Analysis of the Eye-Tracking Data

3.1.1 Charts and Analysis of the Eye-Tracking Data

Table 2 and Fig. 4 show that the total fixation points of the two round-backed armchairs are approaching the same. But compared to the legs, the back of the chair with more designing elements receives more attention, revealing a finding that the visual highlight of the round-backed armchair lies in the upper part of the chair. As shown in Tables 1 and 3, the attention values of the back-hoop and legs do not vary a lot between the two types of round-backed armchair. But the legs with the arch enclosure apparently receive longer fixation duration than QuanKou. Moreover, the standard deviation of the Chrysanthemum pear round-backed armchair is obviously higher than that of the other, suggesting a larger dispersion of the fixation times of testees. For the back of the chair, due to the hollowed-out embellishment on the backboard, the rosewood Ruyi round-backed armchair earns a noticeably larger fixation duration. The slopes of the two lines in Figs. 3 and 5 have indicated that a longer fixation duration is distributed to the back rather than legs for rosewood Ruyi round-backed armchair compared with the Chrysanthemum pear round-backed armchair, with the visual highlight moving up.

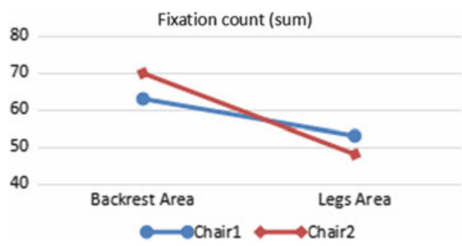

Fig. 4 Line chart of the fixation points of the traditional round-backed armchair

Table 1 Total fixation duration of the traditional round-backed armchair (unit: ms)

AOI	Backboard	Back-hoop	Legs
Chair 1	5879 (610.66)	10782 (1094.93)	15209 (1145.17)
Chair 2	9053 (621.30)	11124 (800.25)	13476 (1009.45)

Note Standard deviation is presented in the brackets in the table

Table 2 Fixation points of the traditional round-backed armchair

AOI	Backboard	Back-hoop	Legs
Chair 1	23 (2.58)	40 (4.82)	53 (4.45)
Chair 2	25 (1.67)	45 (1.41)	48 (2.90)

Note Standard deviation is presented in the brackets in the table

Table 3 Average fixation duration of the traditional round-backed armchair(unit: ms)

AOI	Backboard	Back-hoop	Legs
Chair 1	255.61	269.55	286.93
Chair 2	362.12	247.20	280.75

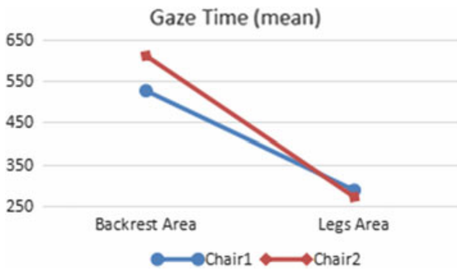

Fig. 5 Line chart of the average fixation duration of the traditional round-backed armchair

3.1.2 Analysis of the Combined Heat Map

It could be inferred from Figs. 6 and 7 that the attention of the testees is distributed along the linear components of the armchair and focused on the joints and decorations of the components. By comparing the heat maps of the chairs, the hot areas (red zone) of the rosewood Ruyi round-backed armchair are larger but fewer in amount and more concentrated on the upper part, while the hot areas of the Chrysanthemum pear round-backed armchair are smaller, more in amount and more evenly distributed, indicating that testees need more fixation points to look for the interesting targets.

3.2 Analysis of Subjective Reviews

The subjective reviews respond to the "aesthetic recognition" and "intent to purchase" of testees. The results are shown below.

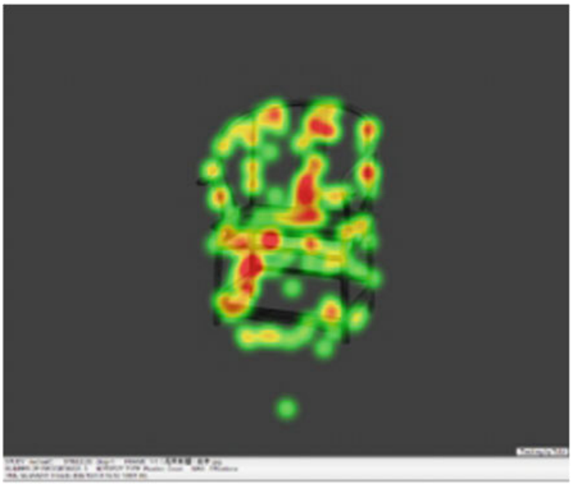

Fig. 6 Combined heat map of the Chair 1

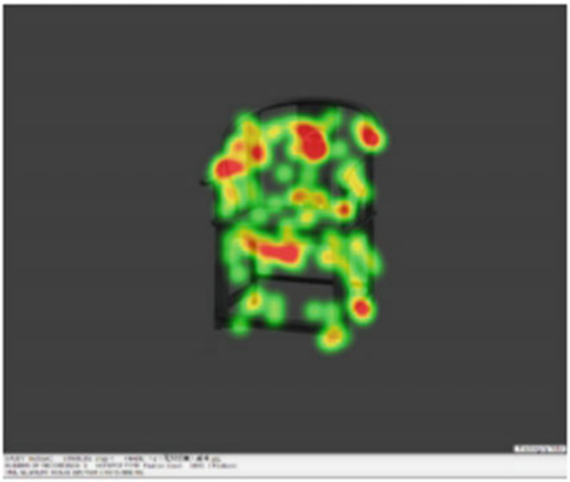

Fig. 7 Combined heat map of the Chair 2

Table 4 and Fig. 8 show that: (1) in terms of the visual stability, the linear components like the arch enclosure and Ai Lao on the legs of the Chrysanthemum pear round-backed armchair have formed multiple virtual planes, which seem more empty compared with the other type of chair, leading to a lower visual stability; (2) as regards the sense of fashion, the traditional taste delivered by the two is at the same level; (3) by the decoration level, the backboard of the rosewood Ruyi round-backed armchair adopts the Ruyi pattern cavity. Both sides of the upper back-legs are decorated with long supports. QuanKou surrounds the space below the chair-board on three sides. The overall decoration level is obviously higher than the Chrysanthemum pear round-backed armchair; (4) by the sense of layering, there are multiple virtual planes overlapping on the Chrysanthemum pear round-backed

Table 4 Subjective reviews for the traditional round-backed armchair

	Stability	Sense of fashion	Decoration level	Sense of layering	Overall appearance rating	Intent to purchase (%)
Chair1	1.27	−1.18	−0.45	0.82	7.27	60
Chair2	1.36	−1.18	0.18	0.64	7.90	64

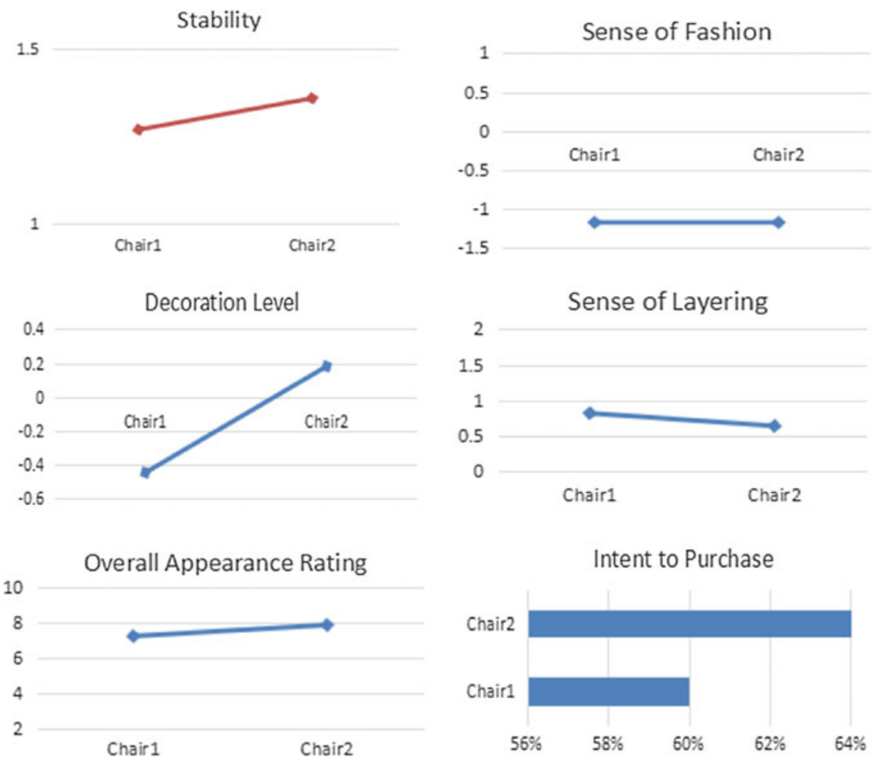

Fig. 8 Tables of the subjective review data of traditional round-backed armchairs

armchair, whose sense of layering is higher than the other; (5) the aesthetic perception of the two chairs is basically on the same level, but testees apparently prefer the rosewood Ruyi round-backed armchair considering the intent to purchase.

To explore the relationship between the aesthetic indicators, overall appearance perception and the intent to purchase, the follow correlation analysis is conducted. Table 5 demonstrates that the maximum correlation coefficient of the stability and overall appearance perception of the Chrysanthemum pear round-backed armchair is 0.665, as the uncorrelated probability remains smaller than 0.05. The appearance with a strong sense of layering arrests testees' attention on the stability, which is the consideration for the functionality. The maximum correlation

Table 5 Correlation analysis of the subjective review indicators, overall appearance and intent to purchase

Chair			Stability	Sense of fashion	Decoration level	Sense of layering	Overall appearance rating	Intent to purchase
Chair1	Overall appearance rating	Pearson correlation	0.664*	−0.293	−0.232	0.350	1	0.817**
		Sig. (bilateral)	0.026	0.382	0.492	0.291		0.002
		N	11	11	11	11	11	11
	Intent to purchase	Pearson correlation	0.531	−0.159	−0.339	0.230	0.817**	1
		Sig. (bilateral)	0.093	0.641	0.308	0.497	0.002	
		N	11	11	11	11	11	11
Chair2	Overall appearance rating	Pearson correlation	0.310	−0.125	0.900**	0.013	1	0.640*
		Sig. (bilateral)	0.353	0.715	0.093	0.969		0.034
		N	11	11	11	11	11	11
	Intent to purchase	Pearson correlation	0.218	−0.280	−0.087	−0.075	0.640*	1
		Sig. (bilateral)	0.520	0.405	0.800	0.827	0.034	
		N	11	11	11	11	11	11

Note *Sig. correlated on the level of 0.05 (bilateral). **Sig. correlated on the level of 0.01 (bilateral) coefficient of the decoration level and the overall appearance perception of the rosewood Ruyi round-backed arm chair is 0.90, with the uncorrelated probability remaining smaller than 0.01, representing that the hollowed-out Ruyi embellishment in the traditional Chinese culture has the largest influence on the overall appearance perception. The correlation coefficient of the intent to purchase with stability, sense of fashion, decoration level and sense of layering remains all low, but is large when it comes to the overall appearance perception, showing a positive correlation.

4 Conclusion

(1) Users distribute more attention on the upper part of the traditional round-backed armchairs than on the lower part. The distribution is along the "linear" components of the hair, which also reflects the leading effect of the "lines". Meanwhile, lines creating many enclosed virtual planes might lead to users' consideration for the stability.
(2) Users' attention would be focused on the joints of "lines" and the embellishment of "points" when watching the traditional round-backed armchairs. So, the location of "point" embellishment matters a lot to the visual highlight. Using the classic embellishment, image could extend the universality of user perception. Meanwhile, it could be learnt from the subjective surveys that the location of visual highlight and the perception of the visual stability leave no influence.
(3) For traditional round-backed armchairs, the intent to purchase is strongly correlated with the overall appearance perception. The better the appearance perception, the higher the intention to purchase.

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Compliance with Ethical Standards The study was approved by the Logistics Department for Civilian Ethics Committee of Human Ergonomics Research Institute of Nanjing Forestry University.

All subjects who participated in the experiment were provided with and signed an informed consent form.

All relevant ethical safeguards have been met with regard to subject protection.

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Physiological and Psychological Selection for High-Performance Fighter Pilot Based on Analytic Hierarchy Process

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Abstract *Objective* To construct an evaluation model of physiological and psychological selection for high-performance fighter pilot based on analytic hierarchy process (AHP), and apply the model in candidate pilot selection. *Methods* The hierarchy structure model of high-performance fighter pilot physiological and psychological selection was constructed firstly. According to the consulting results of 20 aeromedical experts, judgment matrix was built and consistency was checked. Then, the weights of 23 evaluation indexes were calculated, and the examination results of physiological and psychological indexes for 16 candidate fighter pilots were evaluated. *Results* An AHP evaluation model of physiological and psychological selection for high-performance fighter pilot was constructed successfully, and the ranking result of the candidate pilots was obtained. *Conclusion* Method and reference were provided for high-performance fighter pilot selection. Data and experience were accumulated for research on future evaluation methods for pilot selection.

Keywords Pilot selection · Analytic hierarchy process · Evaluation model

1 Introduction

US F22 or F35, Russia T-50, and China J-20 were considered as the representatives for a new generation of high-performance fighters, all of them having the characteristics of super maneuverability, stealth, supersonic cruise, and superior avionics for battle awareness and effectiveness. The improvement of the cockpit interface

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and operation procedure increased the workload significantly, which will put forward higher requirements on the long-haul flight endurance, anti-G, space orientation, and cognitive and decision-making ability. In addition to strict physical examination, aeromedical selection for high-performance fighter pilot will focus on physiological and psychological ability. The evaluation indexes of traditional selection method for fighter pilot can hardly meet the requirements for high-performance fighter pilot selection.

The analytic hierarchy process (AHP) [1] is a kind of multi-index comprehensive evaluation method based on the theory of the operational research, with a relatively stronger theoretical basis and objective analysis. With the advantages of being concise and efficient, AHP was widely used and extensively researched. Based on the study of physiological and psychological selection indexes for high-performance fighter pilot, this paper aims to construct an evaluation model of physiological and psychological selection for high-performance fighter pilot based on AHP. And the evaluation model was preliminarily applied in fighter pilot selection.

2 Method

2.1 Subjects

Physiological and psychological indexes were examined on 16 male fighter pilots (age 27.5±4.2 years) whose clinical physical examination results meets the relevant pilot physical examination standards.

2.2 Analytic Hierarchy Process Model

2.2.1 Construction of the Hierarchical Structure Model

Based on extensive literature and documents investigation, we studied the requirements for the physical and mental diatheses of high-performance fighter pilot. As shown in Table 1 an evaluation index system including 5 first level and 23 second level indexes was developed. According to the general approach on the construction of the hierarchical structure model, the first step was to set the goal for solving the question, that was to select the suitable pilots. Then, all the relating aspects or factors of the goal were classified, i.e., all the evaluation indexes were classified hierarchically. The last step was to set the alternatives, i.e., the candidate pilots under selection.

Table 1 Evaluation index system for high performance fighter pilot selection

First-level indexes	Second-level indexes	First-level indexes	Second-level indexes
Basic physiological function(A)	Cardiovascular function (A1)	Mental ability (D)	Basic cognitive ability (D1)
	Respiratory (lung) function (A2)		Spatial orientation ability (D2)
	Vestibular function (A3)		Dynamic operation capability (D3)
	Brain function (A4)		Decision-making ability (D4)
	Visual function (A5)	Physical fitness and Ergonomics (E)	Basic body condition (E1)
	Autonomic nervous system (A6)		Exercise cardiopulmonary function (E2)
Flight physiological endurance(B)	Anti-G ability (B1)		Strength and endurance (E3)
	Vestibular stability (B2)		Agility (E4)
	High Altitude endurance (B3)		Flexibility (E5)
	Ear pressure adjusting ability (B4)		Ergonomics and size suitability (E6)
Psychological basis(C)	Level of mental health (C1)		
	Personality traits (C2)		
	Motivation level (C3)		

2.2.2 Construction of the Judgment Matrix

To construct the judgment matrix, questionnaires were distributed to some experts of aviation medicine. The experts would make decisions on the relative importance between indexes of one level to an upper level index with 1–9 scale (Table 2). According to the experts' judgment results, the judgment matrix could be constructed.

To ensure the logical rationality of judgment matrix and avoid the error of experts, we need to check the consistency of the judgment matrix and calculate the consistency ratio C.R. (consistency ratio).

$$\text{C.R.} = \frac{\text{C.I.}}{\text{R.I.}}, \quad \text{C.I.} = \frac{\lambda_{\max} - n}{n - 1} \tag{1}$$

Table 2 Meaning of 1–9 scale

Significance scale	Meaning
1	Indicates that the two indexes are of equal importance
3	Indicates that the former is slightly more important than the latter
5	Indicates that the former is strongly more important than the latter
7	Indicates that the former is significantly more important than the latter
9	Indicates that the former is absolutely more important than the latter
2, 4, 6, 8	Represents the intermediate value of the above judgment
Reciprocal	If the ratio of index i and j is a_{ij}, the ratio of index j to i is $a_{ji} = 1/a_{ij}$

Table 3 Average random consistency index (R.I.)

Matrix order	1	2	3	4	5	6	7	8
R.I.	0	0	0.52	0.89	1.12	1.26	1.36	1.41

Among them, C.I. is the consistency index. R.I. is the mean random consistency index, $\lambda_{\max}$ is the maximum eigenvalue of judgment matrix. n is the order of the matrix. R.I. is shown in Table 3, depending on the order of the judgment matrix.

When C.R. <0.1, it is considered that the consistency of the judgment matrix is acceptable. When C.R. >0.1, it is considered that the judgment matrix does not meet the requirement of consistency, and the expert is required to revise the judgment matrix.

2.2.3 Calculation of the Index Weights

After the construction of the judgment matrix and the verification of its consistency, hierarchical single-level sorting and hierarchical total-level sorting were calculated. The relative weights of the second-level indexes for pilot physiological and psychological selection were obtained.

Hierarchical single sorting was to calculate the relative weights of indexes in each judgment matrix. The eigenvector for the maximum eigenvalue $\lambda_{\max}$ of judgment matrix was normalized (the sum of each element in the vector was equal to 1) to get the weight vector of the all the indexes in the judgment matrix.

Hierarchical total sorting was to calculate the relative weight of each index in a certain criteria level for the goal level. The weight was calculated from top to bottom and synthesized level by level.

Assuming that the relative weight of index m indexes in $k-1$ level to the goal level was $w^{(k-1)}$, then

$$w^{(k-1)} = \left(w_1^{(k-1)}, w_2^{(k-1)}, \ldots, w_m^{(k-1)}\right)^T \quad (2)$$

To the j-th index in $k-1$ level, the hierarchical single sorting weights of n indexex in the k level was $p_j^{(k)}$, then

$$p_j^{(k)} = (p_{1j}^{(k)}, p_{2j}^{(k)}, \ldots, p_{nj}^{(k)})^T; \tag{3}$$

if an index in k level had no relationship with j-th index in k-1 level, $p_{ij}^{(k)} = 0$, i=1,2,...n.

The hierarchical total sorting of n index in k level could be calculated as follow,

$$w_i^{(k)} = \sum_{j=1}^{m} p_{ij}^{(k)} w_j^{(k-1)}, \quad i = 1, 2, \ldots, n. \tag{4}$$

2.3 *Examination of Physiological and Psychological Indexes*

Physiological and psychological examinations were carried out for all pilots, including five categories, with a total of 23 indexes.

1. The basic physiological function examination. The examination included dynamic ECG, echocardiography and vascular elasticity for the cardiovascular function examination, pulmonary function test, dynamic balance, EOG check for the vestibular function examination, dark adaptation, phoria, contrast sensitivity for special visual function examination, and orthostatic tolerance (tilt) test.
2. The flight endurance examination. The examination included centrifuge anti-G endurance test, vestibular autonomic reaction stability examination, hypoxia endurance, and ear pressure adjustment check.
3. Psychological basis of examination. The examination included psychological scale measurement, projection measurement, EMG and evoked brain potentials, heart rate and other physiological signal acquisition activities, observation, interviews and other objective examination, and subjective evaluation.
4. Mental ability examination. The examination included the use of paper and pencil test, single or complex tasks under specific flight simulation environment evaluation, and spatial orientation simulator.
5. Physical fitness and ergonomic examination. The examination included assessment of development and nutritional status, physical characteristics, exercise ability, cardiopulmonary exercise test, muscle strength and endurance test, visual and oral reaction, body coordination ability tests, joint range and extent, three-dimensional human body size and cockpit fitment, etc.

Clinical physical examinations were carried out before the above physiological and psychological examinations. The clinical physical examination results of all the pilots meet the relevant pilot physical examination standards. The relevant instruments and equipment used in the examination of physiological and psychological indexes are approved by the state or the army.

2.4 Evaluation on the Indexes

To make the AHP model for pilot selection more objective and minimize the influence of human factors, questionnaires were distributed to 20 aeromedical experts. Each expert made his decision or judgment on the relative importance of various indexes, basing on their knowledge and experience. Since professional knowledge, experience, and motivation preferences of the experts were different, the judgment matrix was not necessarily the same. Therefore, we used the group decision-making method to solve this problem. We used the expert self-assessment score (1–5) on familiarity and professional expertise in the questionnaires to determine the expert weights. The modified weights of all the indexes were obtained by expert weighting and averaging on the ranking vector. Final scores can be calculated by weighting on the physiological and psychological examination results of the pilots. By ranking of the final scores, we could select the most suitable high-performance fighter pilots.

3 Results

3.1 Analytic Hierarchy Structure Model

Hierarchical structure model was composed of three levels:

1. The goal level, which refers to goal to solve the problem, which was to select the most suitable high-performance fighter pilot.
2. The criteria level, which refers to indexes needed consider as decision criterion to achieve the goal. Here was the pilot physiological and psychological selection index system, which consists of two levels.
3. The alternative level, which refers to the alternatives to achieve the goal, namely, the candidate pilots to be selected.

The hierarchy structure model is shown in Fig. 1.

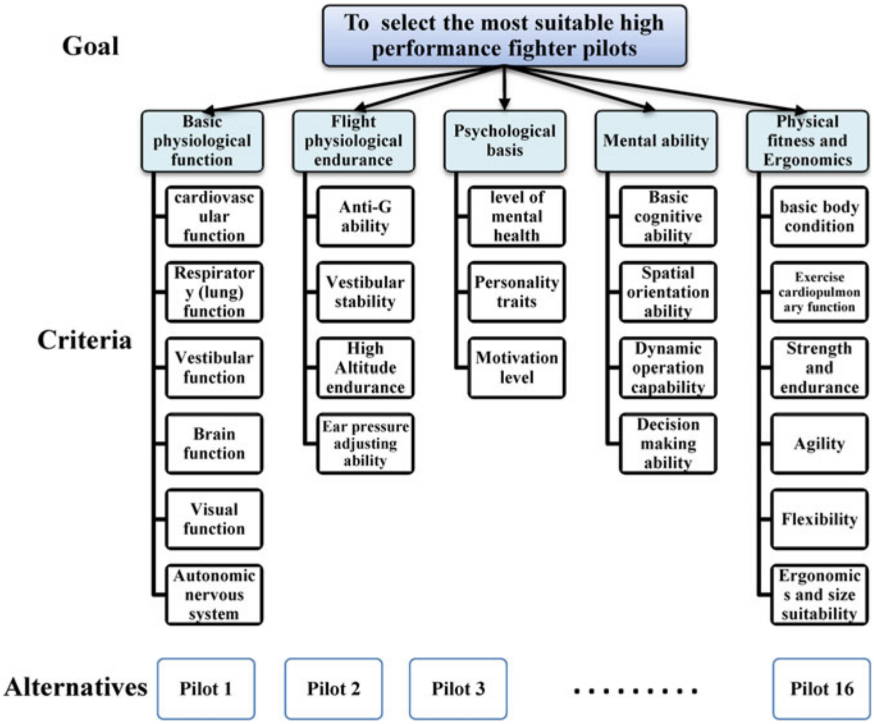

Fig. 1 Hierarchical structure model for high-performance fighter pilot physiological and psychological selection

3.2 Judgment Matrix

Aviation medicine experts made their decision or judgments on the relative importance between every two index, either in the five first-level indexes or in the second-level indexes related to one upper level index, according to their knowledge and experience. The relative importance between indexes to an upper level index was marked with 1–9 scale.

The judgment matrix of one expert was constructed and is shown as an example in Table 4.

The consistency ratio was 0.0001, 0.0273, 0.0039, 0.0088, 0.0116, and 0.0088, respectively, which were less than 0.1. Therefore, the judgment matrix passed the consistency check.

Table 4 Judgment matrix of one expert

	A	B	C	D	E		A	A1	A2	A3	A4	A5	A6		C	C1	C2	C3
A	1	1/2	1	1/2	2		A1	1	1	1/2	1/4	1/4	2		C1	1	2	3
B	–	1	2	1	4		A2		1	1/2	1/2	1/4	3		C2	–	1	2
C	–	–	1	1/2	2		A3	–	–	1	1/2	1	4		C3	–	–	1
D	–	–	–	1	4		A4	–	–	–	1	1/2	5					
E	–	–	–	–	1		A5	–	–	–	–	1	6					
							A6	–	–	–	–	–	1					
D	D1	D2	D3	D4		B	B1	B2	B3	B4		E	E1	E2	E3	E4	E5	E6
D1	1	1/2	1/3	1/4		B1	1	2	1	3		E1	1	2	3	4	5	6
D2	–	1	1/2	1/3		B2	–	1	1/2	2		E2		1	2	3	4	5
D3	–	–	1	1/2		B3	–	–	1	3		E3	–	–	1	2	3	4
D4	–	–	–	1		B4	–	–	–	1		E4	–	–	–	1	2	3
												E5	–	–	–	–	1	2
												E6	–	–	–	–	–	1

3.3 Index Weights

First of all, the expert weights were determined by normalization of the expert self-assessment score on familiarity and professional expertise. The weights of all the indexes were modified by weighting and averaging with the expert weights.

By calculation, the relative weights of the five first-level indexes were: 0.1728, 0.2241, 0.1785, 0.2891, and 0.1355, respectively.

For the second-level indexes, the weights of 6 second level indexes related to basic physiological function were 0.1839, 0.1201, 0.2083, 0.1968, 0.1600, and 0.1308; the relative weights of 4 second level indexes related to physiological endurance were 0.3240, 0.2611, 0.2049, and 0.2100; the relative weights of 3 second level indexes related to the psychological basis were 0.3089, 0.3417, and 0.3494; the relative weights of 4 second level indexes related to mental ability were 0.1253, 0.2233, 0.2635, and 0.3879; the relative weights of 6 second level indexes related to fitness and ergonomics were 0.1283, 0.2102, 0.2041, 0.1831, 0.1031, and 0.1712. The relative weight of each individual index of second level was calculated by Eq. (4).

3.4 Comprehensive Evaluation

Assuming S_i was the comprehensive evaluation result for the ith pilot, [$A1_i$ $A2_i$ … $E6_i$] was the physiological and psychological indexes evaluation score vector of the ith pilot, where $i = 1, 2, \ldots 16$. w_j was the relative weight of jth single index, where $j = 1, 2, \ldots 23$. Comprehensive evaluation results vector of 16 pilots was calculated with Eq. (5).

$$[S_1, S_2, \ldots S_{16}]^T = \begin{bmatrix} A1_1 & A2_1 & \cdots & E6_1 \\ A1_2 & \cdots & \cdots & \cdots \\ \vdots & \vdots & \vdots & \vdots \\ A1_{16} & A2_{16} & \cdots & E6_{16} \end{bmatrix} [w_1, w_2, \ldots w_{23}]^T \quad (5)$$

Then, the suitable high-performance fighter pilot can be selected by ranking comprehensive evaluation results of the pilots in a high to low order.

4 Conclusion

Super maneuverability of the high-performance fighter makes pilots have to withstand higher acceleration and acceleration growth, facing more frequent acceleration stimulation and push–pull effect. The big amount of the data information and processing demands increase the decision-making and cognitive workload significantly. All these put forward higher and special requirements for the physiological function, mental ability and physical ability. As Linder and Tielemans [2] had suggested, in addition to the existing selection criteria, a new generation of super agility aircraft pilot selection should focus on the visual and vestibular, hearing, respiratory, cardiovascular, skeletal muscle, cognitive, and neural system. Lafortune [3] indicated that the major issues for the F35 pilots will be information management, sensor fusion and management, flying with might-aided visual systems, and the safety in high G-force flight.

As for the comprehensive evaluation method for pilot selection, multivariate statistical methods [4] were often used by the US and European countries [5, 6]. The US air force is using the PCSM (Pilot Candidate Selection Method) system in pilot selection [7] since 1993. And the PCSM uses the comprehensive evaluation model based on multiple regression analysis [8].

To improve the objectivity of multi-index comprehensive evaluation method for high-performance fighter pilot selection, this paper constructed a comprehensive evaluation model basing on the group decision AHP method and preliminary applied it in a high-performance fighter pilot psychological selection and assessment task. AHP makes the thinking process of expert decision hierarchically and quantitatively and provides quantitative and mathematical basis to analysis, decision, forecast, or control. The analysis on the nature of the problem, factors involved in the problems, and the internal relation of AHP was thorough and clear. AHP is also very simple and easy to use. The weights of the 23 selection indexes well reflected the relative importance of the physiological and psychological indexes on high-performance fighter pilot selection.

In this paper, a more objective comprehensive evaluation method for high-performance fighter pilot selection was tested. The correlation of the physiological and psychological indexes and the prediction efficiency of current AHP evaluation model still need to be studied and optimized basing on the real pilot training result. In this research work, a large amount of physiological and psychological examination data were also accumulated. Basis and reference were provided for future research on the high-performance fighter pilot selection.

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Research of Operating Posture of Shoulder-Mounted Equipment

Zhaofeng Luo, Honglei Li, Yu Jin, Ruifeng Zhao, Qi Ma, Zhibing Pang and Cheng Jin

Abstract The purpose of this paper is to increase the scientificalness of shoulder-mounted equipment operator's training. A research on shoulder-mounted equipment operator's body force stress in standing and kneeling positions qualitatively points out that operator should strengthen the training of some body parts. Training these relative parts is of much pertinence to improve the training effect. Based on the simplified model of human body and static analysis method, the main stressed parts in two different training states are found—in standing position and in kneeling position. In this way, the methods of how to strengthen the training after confirmed the main stressed parts of operator in different training states are pointed out. The main stressed parts of shoulder-mounted equipment operator in standing and kneeling positions are presented, and corresponding training methods provide strong support for operator's scientific training.

Keywords Shoulder-mounted equipment · Operator · Operating posture

1 Significance of Research

For operator's training, we use the feeling of fatigue after static training to get the purpose of standard training generally, because muscle can "remember" the operating posture due to this kind of fatigue. In practice, we find that some operators may feel overtired easily if we only increase the amount of time spent on training, and this may cause a deviation of posture and harm operator's health. So we want to make a preliminary research on operator's body force stress in different postures through stress analysis and provide the theoretical support to enhance the level of training. There are three significances.

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1.1 To Enhance the Scientificity of Training

More stressed body parts in different positions by the operating posture static analysis method are found out. The pertinence of the training of these body parts in preparatory phase is enhanced to lay a foundation of formal training. We expect the training will be more scientific.

1.2 To Prepare for the Quantitative Analysis

Qualitatively point out the main stressed body parts of shoulder-mounted equipment operator in different positions can make preparation for the future research and training. Then analyze quantitatively through data collection and grouping comparison to make the more accurate research on operating posture.

1.3 To Promote the Study of Human

Posture and action are at the center of the study of human; through analysis we can obtain the operator's body force stress of main stressed parts in different positions and present the key stressed parts of shoulder-mounted equipment operator in different positions qualitatively. It is based on quality development, aimed at enhancing the man–machine integration and to promote the in-depth study of human [1].

2 Analysis of Operating Posture

For the shoulder-mounted equipment, the fatigue and stressed body parts of operator are so many. Through questionnaire and statistic methods [2], we find out these parts. There are more than 20 parts such as neck, shoulders, the right hand, and waist. There exist obvious differences in different operating posture. Hereby, this paper made an analysis on two typical postures.

2.1 Standing Position

Standing position means that when people is standing on his feet the angle of upper body flexion is smaller than 30° [3], as shown in Fig. 1. Standing posture has some advantages such as wide range of field of vision, big space for operating and full

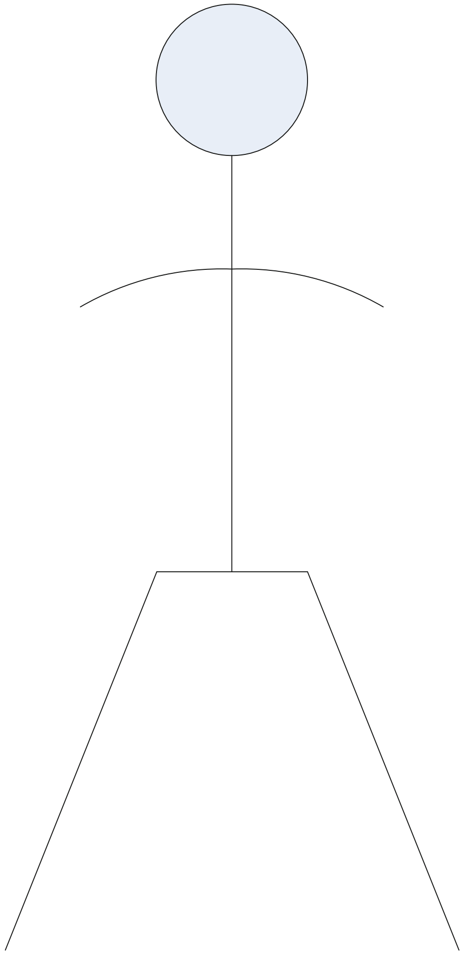


Fig. 1 Front view of operating in standing position

power output. But its disadvantages are also obvious: Muscle needs the stronger power output to support the weight, operator may feel tired easily, and especially when standing for a long time, the fatigue may cause broken veins.

From the article Experimental Research of Shoulder-mounted Portable Equipment Operator's Foot Spacing in Standing Position [4], we can find the analysis of operator's body force stress in standing position [5, 6], and this article focused on the variable part—the benefit of changing foot space on operating stability.

After analyzed the foot, we can find out the other main stressed parts through transmission law of force: They are neck, right shoulder, waist, both legs and both feet. Because the equipment is handheld portable equipment, and operator's left big arm, right-hand palm, right forearm and right big arm exceed the comfortable operating area when operating the equipment, these parts may feel uncomfortable easily. The operating has very high demands for eye and ear also. Above all, the main stressed parts are (1) eye, (2) ear, (3) neck, (4) right shoulder, (5) arm, (6) palm, (7) waist, (8) leg, (9) foot.

(1) The eye should have fast vision response speed and sensitive visual orientation ability except the good congenital vision.
(2) The ear should have auditory localization ability and auditory response speed.
(3) Neck should be kept straight and curved properly with flexible movement which means that neck should be kept straight firstly to ensure the normal operating but neck also should be curved properly so that different operator can adapt to the equipment. Keeping proper curve can maintain the stability of man–machine integration. “Flexible movement” means that neck can rotate flexibly.
(4) Right shoulder should have certain endurance and support force to keep steady and square. “Steady” means that operator should keep two shoulders relatively stable without swing and moving; “square” means that operator should keep two shoulders relatively horizontal to realize the exact operating.
(5) Arms and hands should have endurance and push–pull effort. If it is not necessary to operate the equipment during operating, operator should use the endurance of arms and hands to support the front of the equipment and keep the stability of equipment; if operator needs to operate the equipment, he should use the push–pull effort of arms and hands to do the action rapidly and accurately.
(6) Palm should provide steady support to operating, so the operating has very high demands for the endurance of palm and flexibility of fingers.
(7) Waist should meet the requirements of “stand up straight and upright” and “rotate smoothly and steady.” “Stand up straight and upright” means that when operator is standing, his waist is straight, and his upper body is upright; “rotate smoothly and steady” means that waist should cooperate with feet to move during operating.
(8), (9) Legs and feet should have endurance and push–pull effort to support and assist the rotary movement of waist. Especially in standing position, the stable support of legs and feet is the base for operating.

2.2 Kneeling Position

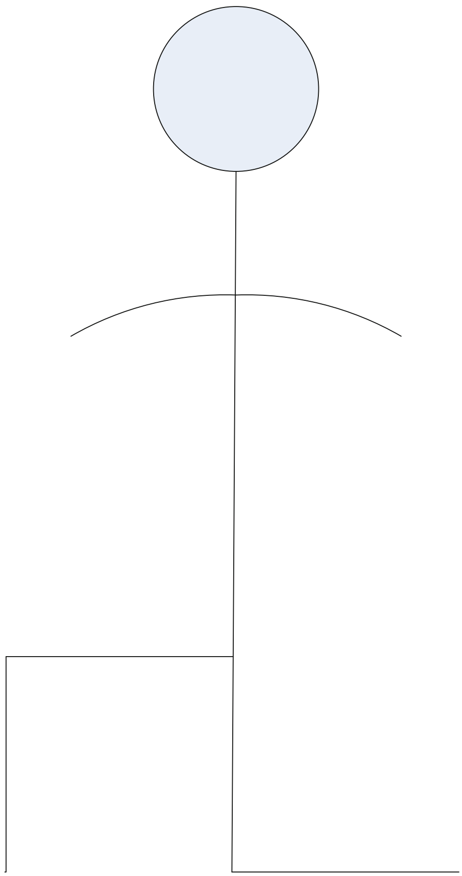
Kneeling position means that the operator kneels down on his right knee, the angle between right calf and right thigh is about 90°, body center of gravity is on right leg, left leg is in front of body, and the angle between left calf and left thigh is about 90°. Posture of upper body in kneeling position is same as that in standing position.

Kneeling position has advantage of good stability. But compared with standing position, it has more disadvantages: Field of vision is not wide enough, space for operating is small, and operator is not able to play a full strength. In kneeling position, operator may feel tired easily because huge portions of weight all press on right knee, even pain and numb. In kneeling position, the main stressed part is right knee, as shown in Fig. 2.

In kneeling position, the posture is relatively fixed. We can find out the other main stressed parts through transmission law of force: They are neck, right shoulder, waist, right knee, right thigh and both feet. In operating, operator's left big arm, right-hand palm, right forearm and right big arm are dangling so these parts may feel uncomfortable easily. Above all, the main stressed parts are (1) eye, (2) ear, (3) neck, (4) right shoulder, (5) arm, (6) palm, (7) waist, (8) right thigh, (9) right knee, (10) foot.

The requirements for main stressed parts (1)–(8) in kneeling position are same as those in standing position.

Fig. 2 Side view of operating in kneeling position



(9) The function of right knee is to support the weight, so requirements for this part are higher. It should have a stable and enduring endurance to support the weight, especially when operating time is long.

(10) During operating, forefoot and heel of left foot and right knee are three points which can maintain the stability of operator's body. So, left foot is required to provide enough endurance.

3 Pertinence Training

Based on the questionnaire and force analysis result, we should do pertinence and adaptive training for key parts so that operators can master standard action. The training time and training content are shown as follows:

3.1 Training Opportunity

Before training, preparation is an effective method to reduce fatigue, so operators should do proper warm-up. Warm-up can promote blood circulation, each organ of human body can change from rest state to motion state due to warm-up, and temperature of muscle, ligament and joint also can be increased. For some key parts, physical vitality will be improved.

During training, operators should keep moderate relaxation after one set of training to relief training fatigue and prepare for the next set of training.

After training, operators should do some relaxation exercises to eliminate tiredness.

3.2 Training Content

To determine pertinence training content according to main stressed parts, the two operating postures are needed.

(1) With computer simulation technology, we can improve vision response speed and sensitive visual orientation ability through virtual training. (2) Auditory localization ability and auditory response speed of ear can be trained by auditory orientation training system. (3) Neck can be trained by stretching exercises and rotation motion. (4) Before operating, operator can make preparation for muscle, ligament and joint of shoulder through circle annulus movement. (5), (6) Dumbbell can be used to do some training for improving the endurance of arm muscle. (7) Sandbags carrying exercise and sit-ups can be used for improving waist and abdominal muscle strength. (8) For training of legs, long-distance running and

high-step stretch of legs are good methods to improve the endurance and strength of legs. (9), (10) Squat thrust exercise is a good training way to develop endurance and support strength of knee and feet.

Besides, armor can be used for shoulder and knee to avoid injuries in training because shoulder and knee have less muscle, and this can also provide favorable conditions for continued training.

4 Conclusion

Stress demands in different positions of shoulder-mounted equipment operator through statistic analysis are found, the main stressed parts through force analysis are pointed out, the corresponding training content and training time are presented, basis for experimental research is provided, and the foundation for improving training quality and future research is laid.

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The New Requirement of the Development of Weapons and Equipment to the Quality of Military Talents

Nan Men, Zhibing Pang, Pengdong Zhang, Shuai Mu, Zhaofeng Luo and Ming Kong

Abstract *The purpose* through the research in the future weapons development tendency and military professional's necessary quality, and lay a theoretical foundation for cultivating integrated new military talents. *The method* by applying the basic theory and analytical method of Man–Machine–Environment System Engineering, consults the documentation and correlation data, carries on the summary to the new request that the military professional quality set to the future weapons development tendency. *The result* the weapons' development presents the informational, unmanned, intelligent and stealth tendency and sets the new request in the physical ability, skill and intelligence to the military professional. *The conclusion* in order to adapt to the needs of the future high-tech local war and to meet the challenge of the informationization, unmanned, intelligent, stealth military weapons and equipment, we must create a new type of integrated military personnel.

Keywords Development of weapons and equipment · Tendency · Quality · Integration

1 Introduction

Published in May 2015 white paper on "China's military strategy" clearly pointed out: The world revolution in military affairs (RMA) is proceeding to a new stage. Long-range, precise, smart, stealthy and unmanned weapons and equipment are becoming increasingly sophisticated. Outer space and cyber space have become new commanding heights in strategic competition among all parties. The form of war is accelerating its evolution to informationization [1]. This is the forecast and basic assessment of the development characteristic of weapon equipment of world in current and future certain time. With the development of weapons and equipment

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that presents a new trend, the quality of military personnel also put forward new requirements. The cultivation of new military talents should focus on enhancing physical ability, improving skills and developing intelligence.

2 New Tendency of Development of the Weapons and Equipment

2.1 Informationization

With the application of information technology in weapons and equipment, its high degree of integration and extensive penetration of the characteristics of weapons and equipment increase the tactical technical performance and combat effectiveness unprecedented, resulting in the improvement and research of weapons and equipment use information technology increasingly, and the development of weapons and equipment has shown a general tendency of information.

Modern main battle platform, precision-guided weapons, space warfare weapons and other equipment have been equipped with a large number of information technology devices, such as satellite positioning navigation equipment, fire control systems and electronic countermeasure devices. And with the development and application of cloud computing and Internet of Things and other emerging information technology, combat equipment or support equipment will further improve its tactical technical performance, making weapons and equipment more and more information, so that make big influence on the future war.

2.2 Unmanned

With the rapid development of military high-tech, on the one hand makes the war attack more accurate, the war conditions more cruel, the combat operations more dangerous, on the other hand also strongly promote the development of unmanned combat platform, may say that the unmanned combat platform conform to the need of development of future war.

In the future high-tech battlefield, with the gradual improvement in the ability of the precise strike, long-range engagement and mass destruction, there will be more and more professional soldiers, especially those who bear the dangerous and heavy, complicated and hard mission and will shift from the combat to the front of computer terminal; in some cases, the traditional task completed by the warfighters can be borne by the unmanned system, the needs of the development of war form, and support provided by scientific basis is bound to keep this trend becoming a reality rapidly [2]. At the same time, unmanned combat platform without casualties, a high degree of integration of technology, low life-cycle cost and other advantages, as well as the fast-growing strong driving force and inner drive.

2.3 Intelligent

With the use of information technology as the core of high-tech applications in the military field, weapons and equipment have gradually become the agent which, as a core of artificial intelligence, can automatically search, identify, track, judge and destroy the target, and present the intelligent trend gradually.

Intellectualization of weapons and equipment through the weapons system with those who have a similar person's senses organ (various sensors), the central nervous (information data transmission equipment), the brain (automatic command and control system) and limbs (in a variety of missile-borne, vehicle-mounted, airborne, shipboard man–machine combination structure of precision strike weapon) and other components of the multi-integrated weapons system to achieve [3]. Intelligent embodied in three aspects: the battlefield perception, intelligent decision-making and precision strike of the weapons and equipment. Intelligent precision-guided weapons can carry out their own combat mission planning, automatic discovery and identification of targets and automatically select the attack path and implement combat.

2.4 Stealth

Due to the development of radar technology, the battlefield transparency enhances unprecedentedly, the penetration and attack are even more difficult, and therefore the weaponry stealth technology obtains development unprecedentedly. As an effective means to improve the survival, penetration, especially the deep strike capability of the weapon system, it has become the most important and effective tactical technique in the six-dimensional modern warfare of land, sea, air, sky, electricity and magnetism [4].

In recent years, infrared stealth, radar stealth, visible stealth and other stealth technology have been widely used in aircraft, missiles, ships and other existing weapons and equipment improvements and the development of new weapons. At the same time, low RCS shape technology, radar absorbing materials, plasma technology and other modern stealth means develop rapidly toward the "thin, wide, light, strong" direction [5]. New stealth mechanism and technical means and the development of new stealth materials will bring a breakthrough in the development of stealth technology.

3 New Requirement of the Quality of Military Talents

Modern war shows not only the material force confrontation, but also a contest of human physical ability, skills and intelligence.

3.1 Enhance Physical Ability and Lay the Foundation of Talent Quality

Physical ability is the general level of physical quality, is the basic support of military combat winning mechanism and is the basis of modern military quality [6].

Physical ability has six elements, including cardiovascular endurance, muscle strength and endurance, flexibility, agility, strength and balance. For the military, the physical ability combine with combat missions, tactical background and battlefield environment, enhancing the military physical ability should highlight the specific on the basis of the six elements, and carry out closely with actual combat.

Looking back on the history of human war, physical ability has always played a vital role as a constant component of combat effectiveness. In cold weapons era, physical ability is the core elements of combat effectiveness, the way of transformation from physical ability to combat effectiveness is direct, the process is simple, the effect is obvious, and physical ability determines the operational capacity of an army. Under the condition of modern information warfare, with the increase in heavy load of individual soldier, expansion of battlefield space, upgrade of fighting and killing, increase of war rhythm, refined division of labor of the arm of the services, the requirements of military physical ability get higher and higher, the physical ability is still the important basis essential factor of combat effectiveness [7].

3.2 Improve the Skills and Consolidate the Quality of Talent

Military skills are the main body of overall development of modern military comprehensive quality, are the necessary skills and ability of serviceman who apply knowledge and experience to complete a task in the military activities and are a comprehensive embodiment of mental skills and action skills [6, p 238].

Military skills consist of two parts, the tactical and technical skill. Tactics include tactical thinking and tactical implementation. Technology includes the theoretical knowledge and operation of weapons and equipment.

With the rapid development of information technology and artificial intelligence, the trend of weapon equipment development is more obvious, but the master of these weapons is always people, and people in the modern war still plays a key role about the success or failure of the war. Even if the weapons and equipment how advanced, if we want to control high-tech war, the key and fundamental is improve the operation and command skills of military and the ability to adapt to weapons and equipment.

3.3 Develop Intelligence and Strengthen the Core of the Quality of Talent

Intelligence is relative to the physical ability and skills and refers to learning, memory, thinking, understanding of objective things and the ability to solve practical problems [8]. Intelligence is the integrated embodiment of its knowledge, intelligence and talent and is the core of modern military qualities.

Intelligent military professional has the following several essential factors: courageous judgment ability, scientific thinking ability, keen insight, clever strategy ability, strong cohesion, nimble handling ability, fast adaptiveness, excellent operational command capability, decisive decision-making ability, super foresight ability, strong communication ability, wise coordination ability, exuberant innovation capabilities as well as the highly effective memory.

Future high-tech war is a war that the knowledgeable serviceman uses weapons and equipment and network command and control means, and one of the important characteristics is intelligence against becoming an operational style that relates to success or failure of war [6, p 238]. The traditional wisdom must combine with the new technology, promote each other and give each other new vitality, only then achieve the organic combination of both, can shorten the technical gap between the enemy and achieve the purpose of victory.

4 Conclusions

In short, in order to adapt to the needs of the future high-tech local war and to meet the challenge of the informationization, unmanned, intelligent, stealth military weapons and equipment, we must create a new type of integrated military personnel. In the integration of development, physical ability is the foundation, skills are the main body, intellectual is the core, the three have different contents and interaction and complement each other. The coordinated development of physical ability, skill and intelligence is the direction of our military's high-quality personnel training. It is consistent with the development of the whole national education in the direction of totalization and integration. Only by cultivating such integrated military personnel can we adapt to the national and military modernization construction and future war's need [6, p 239–240].

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A Study on the Method of Human Observation and Software Design

Jiang Wu, Qiqing Su, Hongyan Ou, Honglei Li, Chuanyin Ji and Chenhui Li

Abstract The observational test of human is to quantify human's observation by certain means. It is based on the existing theories. With the advancement of science and technology, the method of observational test is changing every day. Through compiling the software of human's observation and the existing observational test theories, we can develop software of human's observational test, which is based on the data base. This testing method written in the software not just puts the traditional paper testing in the computer, but also adds new testing means based on theory. If a lot of people use this observational testing software, then we can build a data base of different human observation levels for the next statistical analysis. Meantime, we tried to add the training module in the software to improve the observers' level of testing.

Keywords Observation · Test method · Database · Statistical analysis

1 Introduction to Observation and Testing Status

Observation is a combination of multiple senses. There are individual differences in human observation, and these differences with the innate quality and acquired practice and training are closely related. There are three important indicators of observation, namely breadth: refers to a person in the acquisition of specific external information and the amount of data can be extracted in the scope, type, quantity, etc.; precision: that people can get the accuracy and precision of information; speed: refers to the speed of access to information the extent of people [1].

Human observation as an important psychological indicator can be judged by some methods, such as by the quantitative things to respond to determine the time,

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through the identification of things to determine the degree of property and other methods. People have also made a number of test functions with the system, and methods to determine the quality of human observation are mainly divided into two types: the first is more in the laboratory of professional testing system, mainly used in scientific research. This system is relatively accurate test results, but the system is huge, expensive, and difficult to debug operation; the second method is constantly in the process of practice to explore the universality of some of the test means and the application of these tools is simple, Interference by the external environment is small, but the accuracy is not very high.

Now many social positions in the selection of human observation have certain requirements, but due to the lack of compliance with the requirements of the observation test method, the more choice is through the second method of some simple means to select the qualified personnel; however, this method is usually based on paper media as the carrier, and the test process that is not tightly organized will lead to inaccurate test results. The computer software with its irreplaceable superiority and its powerful data analysis and processing power can make up for these shortcomings, so the design of observation test software is very important.

People's observation is not innate, but in the latter part of learning and training in practice, the late learning and practice often take a long process and sometimes have to pay some unnecessary costs. On the other hand, the observation of the test itself is a training to improve the process, therefore, in the same system will combine testing and training, can greatly enhance the efficiency of the system and practical performance.

2 The Typical Method of Observational Testing

Through the analysis of the definition of observing power and its determinants, as well as combining the existing test methods, we selected four relatively wide ranges of methods as software testing and training methods.

2.1 Bai li tiao yi

A fixed interface is randomly divided into 100 randomly shaped small pieces; each set a small range of 1–100 random numbers, by detecting the number of subjects used to find the time to determine the quality of its observation.

The specific situation is shown in Fig. 1. This method focuses on the observation of the speed and breadth of the observed two qualities, the use of subjects on the understanding of the laws of digital logic and observes the speed and breadth of things to be tested.

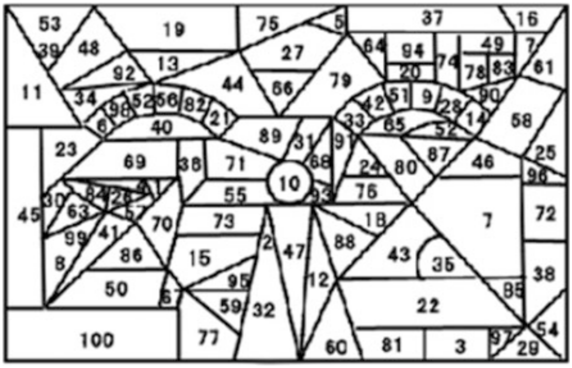

Fig. 1 Bai li tiao yi [2]

Fig. 2 Huo yan jin jing

2.2 *Huo yan jin jing*

The subjects observed a number of test images within a certain range to find a different picture of all the test pictures that were slightly different from the others. By calculating the subjects completed a series of reactions to determine the time spent watching its good or bad, the specific situation shown in Fig. 2. This method focuses on the observation of the speed and breadth of the observed two qualities, the use of the color and line combination of the differences in understanding to observe the picture, and to respond. We can use the reaction time to quantify the level of observation of the subject.

2.3 *The Public to Find Him*

Set the two batches of pictures, the second batch of pictures in the first batch of pictures on the basis of some minor adjustments (for example, the picture on the 1–3 picture content replaced with other forms), so that subjects observed a picture

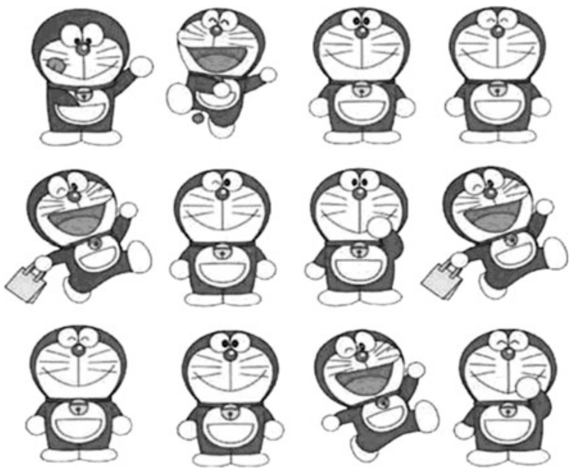

Fig. 3 Huo yan jin jing

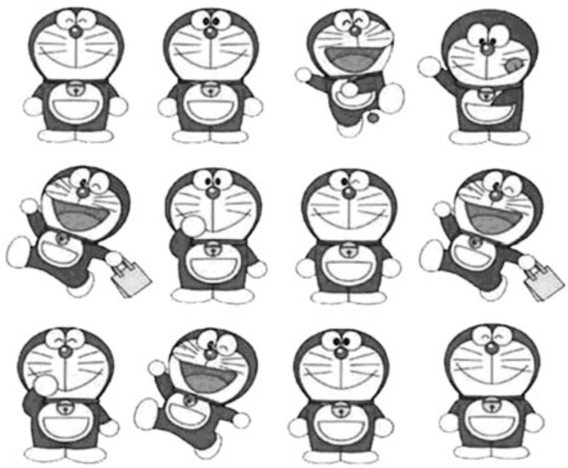

Fig. 4 Huo yan jin jing

of the first picture Time, and then converted into the second batch of pictures. By calculating the accuracy of the subjects to adjust the identification and completion of a series of reactions to determine the time required for observation of good or bad. The specific situation is shown in Figs. 3 and 4. This method on the subjects observed the speed, breadth and accuracy of the three qualities are reflected, the main use of people to observe the degree of sophistication, comprehensiveness and speed to be measured.

2.4 Excellence

Set up a complex pattern composed of triangles, and let the subjects count the number of all the triangles, and according to the number of triangles and the reaction time to measure the level of their observation, the specific situation is shown in Fig. 5/RTI & gt; This method focuses on the quality of observation accuracy, but also reflects the speed of this quality. The use of people in the observation of things when the degree of sophistication and the speed of conversion between different objects to be intuitive to quantify.

3 Software Design

3.1 Software System Flow Diagram

If the above method is realized by software, it not only can improve the efficiency of testing and training, but also can effectively avoid the waste of resources. For the design of software, we have the spirit of science, practical, broad principles, as well as multi-functional, modular requirements, and strive to comprehensive and focused. Software design process is shown in Fig. 5.

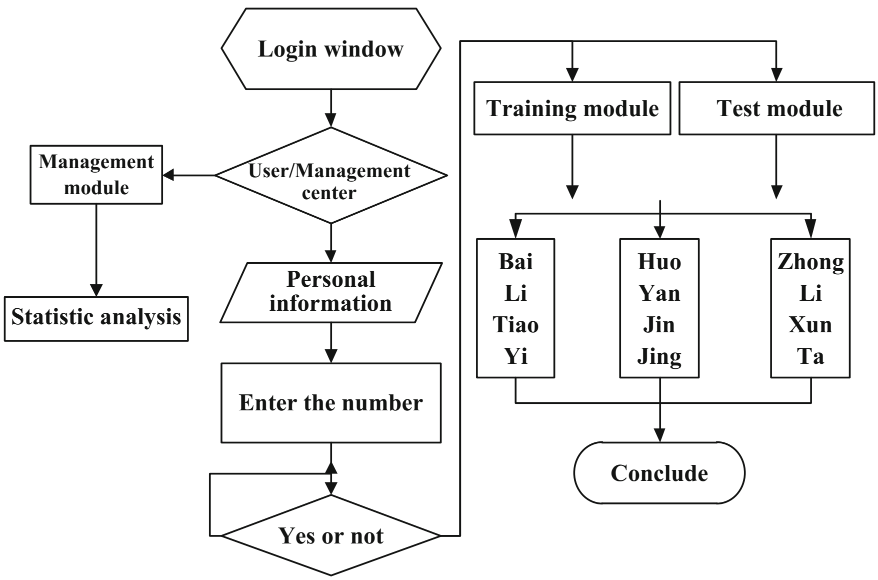

Fig. 5 Flow chart

3.2 Test Method Implementation Module

Test method to achieve through the human–computer interaction interface to display, according to the test idea, requiring continuous testing process, that is, all types of test methods to complete a test, the software then record the total score, the following is a specific method Module:

3.2.1 Barry Pick One

This module contains the timer, buttons, enter the text box, display text box and other controls. By using the idea of object-oriented programming, the relevant events are added to the button to start the source code, and the starting order of the button is edited through the functional logic relationship. The purpose of each test content is reached. Tester in the testing process, the front interface timer shows the time changes, the system record the location of its click, and record each of its number of time-consuming and accurate degree. According to the test method for multiple program operation, and debugging and upgrade the program.

3.2.2 Eye Gold Eyes

This module contains the timer, buttons, and pictures, enter the text box, display text box and other controls. In the database into a large number of pictures for testing, add the button to read the picture source code, through the edit button to bring up the database image (the picture appears random); the tester during operation, the system will record its time, while recording click accuracy. Through the trial debugging to modify and upgrade the program.

3.2.3 Find Him in the Public

The module also contains buttons, pictures, display text boxes and other controls. In the database into the test picture, through the button to control the transformation of local pictures, clicked by the tester to change the location of the picture, the system automatically records the number of clicks, click on the accuracy or not, and display its use of time. According to the test process several tests, find out, and debug and upgrade the program.

3.2.4 Excellence

Software implementation: This module contains buttons, pictures, display text box and other controls. In the database into the test image, by displaying the cursor coordinates check triangles, and set the program and deposit all data types, to avoid duplication of results.

Above a brief introduction to the four test method implementation module, the corresponding can also set the test module. Training module is still the essence of the test method, so the training module is also divided into a hundred miles, one eye, the public looking for him and excellence of four sub-modules, modules independent of each other, as a training module; the tester can choose their own training types and the corresponding difficulty level, and the system will automatically save the training results.

3.3 Other Expansion Modules

3.3.1 Data Import and Export Module

Data import and export module refers to the personnel to use the software for observational testing and training, the software needs to first access the Access database, the test training data into the software, test and training results will be stored in the database, can be derived into other types The data. Its import principle is sql statement and source code using Delphi integrated ADO control channel, control data import. For the export of data is to use the same data into the principle of the inverse of the principle of the data into the Access database, such as the need for other types of data (word, Excel, etc.) and then use the corresponding source code to export data from the Access database.

3.3.2 Results Statistical Analysis Module

Performance statistical analysis module refers to the staff to do the testing and training, the results of their statistics and analysis, including testing and training in two parts. Performance statistics is the staff to do every test and training classification in turn into the Access database, according to a certain order of staff performance [3]. Score analysis function is based on personnel and their performance, through different comparison sort, give a preliminary performance evaluation.

4 Software Implementation Platforms

In the course of design and development, the rapid prototyping method can be used in the design and development. The framework of the evaluation system, data connection, and code debugging and system test are completed by using Delphi, and the corresponding test database is established by Access to ensure the smooth design of the software get on [4].

4.1 Programming Software Delphi

Database application development with Delphi7.0, the focus is to deal with a variety of database components, and database components can be linked to five kinds of objects: Session (database session), Database (database), Dataset (Dataset), DataSource (Data source), Data control (data control components also known as data controls that are data-aware components), four collectively referred to as data access (Data Access) components [5].

4.2 Database Access

Microsoft Office Access is a database management system that combines the graphical user interface of the database engine with the software development tool [6]. The data are stored in its own format on the Access Jet database engine. It can also import or link data directly (the data are stored in other applications and databases).

5 Conclusions

In this paper, the author makes a systematic analysis of human's observation test and training software's requirement, combined with the characteristics of observing power and uses Delphi7 and Access database software platform to realize human's observation test and training software. Personnel through this software, you can observe the scientific test, while training can help to improve attention.

As the ability level can not reach a higher level of demand, in the realization process, there inevitably exist some problems, hoping to get criticism and suggestions.

Compliance with Ethical Standards The study was approved by the Logistics Department for Civilian Ethics Committee of Air Defence Forces Academy.

All subjects who participated in the experiment were provided with and signed an informed consent form.

All relevant ethical safeguards have been met with regard to subject protection.

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Research on the Test of Human Attention

Hongyan Ou, Guopeng Xiao, Zhibing Pang, Hui Gu, Runfeng Hou and Genhua Qi

Abstract Attention is an important psychological index of human; it can affect people's work, life and so on. The present analysis of attention test is mainly in various laboratories, and the testing equipment is so expensive and complex that it cannot be commonly used. Analyzing the attention theory and exploring a simple method can effectively fix this kind of circumstance. This paper was written from the basic concept of attention, analyzed the developing bottleneck of attention testing and combined the methods of digital newspaper reading and finding the little balls. It can scientifically test the attention and also improve the testing measurements. The principles and measurements in this paper have positive meanings of the development of attention testing.

Keywords Attention · Testing · Training · Analysis

1 Introduction to Attention

Attention refers to the person's mental activity on a certain object orientation and concentration and is accompanied by a sense of perception, memory, thinking, imagination and other psychological processes of common psychological characteristics. There are two basic characteristics of attention, one is directed, refers to the psychological activities of a selective reflection of some phenomena and leaves the rest of the object, and the second is the concentration of mental activity, to remain in the selected object on the intensity or tension. Directivity manifests itself as the choice of multiple stimuli that occur at the same time. Concentration manifests itself as suppression of interference stimuli [1]. Usually stability, breadth, distribution, transfers of these four qualities as a measure of a person's attention to good or bad signs.

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1.1 The Stability of Attention

People in a certain period of time, relatively stable, focus on a particular object and the ability of activities. Usually people with good attention are less susceptible to external environmental stimuli.

1.2 The Breadth of Attention

The size of the range of attention to which the person is aware of, or the number of objects perceived by [2], an instant in time. Studies have shown that within a second, the average person can notice four to six letters, five to seven unconnected numbers and three to four unconnected geometries.

1.3 Attentions to the Distribution

The ability of an individual is to distribute his or her attention evenly across activities in a variety of activities. For example, people can work while chatting, while listening to music, while writing and so on. In the case where the type of the target of interest is not very complex, it is possible to do so while paying attention to a plurality of objects.

1.4 The Transfer of Attention

The ability of a person is to be proactive, purposeful and timely adjust attention from one activity or object to another activity or object. For example, students with good attention transfer can quickly adjust from the entertainment state to the learning state. The speed of attention transfer is a flexible expression of thinking and the basic guarantee for the judgment of rapid processing information formation.

2 The Impact of Enhancing Human Attention in the Testing Software

With the development of society and the continuous improvement of the level of productivity, as well as a variety of high-tech content and the introduction of high-precision productivity tools, job skills and career adaptability has now become social workers in the entry into the post began to focus on two aspect. Such as telephone dispatcher, precision instrument operator, simultaneous interpretation, etc., need to focus on the work of a high degree of concentration, therefore, such personnel in the job selection and distribution, only the attention of good or bad included in the selection or Is the selection criteria to reduce unnecessary trouble in the future. However, attention to the selection of this one, whether it is the degree of emphasis or test methods are very lacking, therefore, to strengthen the attention of the software test is very important.

2.1 Solve the Problem of Difficult Scientific Personnel Selection Test

In the past, people in the need for attention to a high degree of concentration of work to choose and allocate, more of their own preferences, first impressions, experience as the basis, very little attention through the test to aid selection and selection, but also due to The limitations of the traditional concept, the test useless and the additional burden of the point of view of the implementation of the attention test, as the early development of psychological tests encountered obstacles. This is the root cause of the inability to test. On the other hand, with the cultural level of managers at all levels to improve, part of the business unit or individual departments of the army has begun to focus and related capabilities into the selection of special post selection process. However, the existing professional test system is bulky, expensive, debugging and maintenance is also very difficult, only suitable for scientific research, for factories and enterprises, as well as military grass-roots units such as job selection is clearly inappropriate. Which has become the main reason why the test selection cannot be carried out? Therefore, the scientific attention to solve the problem of selection is particularly important.

2.2 To Solve the Problem of Attention Training

Attention as a psychological indicator can be improved by the late exercise [3]. Some of the specific positions of staff in the long-term work, the level of their attention will be increased, in their positions due to inattention caused by a corresponding reduction in accidents; in fact, the workload of these personnel in the accumulation process, Attention has also been tempered. However, in the post-exercise, if the error is bound to pay more or less the price, or even a mistake is likely to cause a major accident, this accumulation of experience through mistakes, although effective, but the cost of higher costs. Assuming that we include the attention test in the selection process and then focus on the specific attention of such personnel training, through training so that their attention can be improved, which to some extent, reduce the incidence of their entry just when In addition, for those who have been in such positions, can still be trained to further improve their attention and reduce the incidence of accidents. When we do the attention test, it is an attention exercise. Therefore, while studying the methods and means of the attention test, the training method of attention also comes into being, only need to make some changes in the pattern can be.

2.3 To Solve the Problem of Low Efficiency of Staff Evaluation

In the past a long time, various research team or the need for such attention testing units in the continuous exploration of the creative way to put forward some of the attention of the test method, in the way of carding demonstration process, We found some common problems: First, a considerable part of the lack of test methods of experimental demonstration, more common in some practical application units; Second, the vast majority of tests are written in the face of the measured staff, organizational procedures cumbersome, content information Small amount, high repetition rate, the effect is not obvious; Third, in the final score statistics and standard-setting process, the lack of a complete system and theoretical basis.

To solve these problems, we will simplify the authority of the test means, and then obtained through the demonstration for the public after the test method, through the test sampling to develop more scientific evaluation criteria. Combined with the development of current technology, we design test software. The use of computer software information capacity and functional integration of the characteristics of the test, training, performance statistics and other functions together to effectively avoid too much manpower and material waste, to achieve safe, efficient, economic and scientific testing purposes.

2.4 For the Follow-up Study to Provide Data Support

"Big Data" era, information as a basis for data analysis is extremely important, is a potential, considerable wealth, therefore, everyone, every test is a collection of information, when this amount of information is large enough for the analyst of the attention of the psychological indicators of great significance.

In addition, there are many psychological indicators, including reaction, observation, memory, etc., therefore, attention to the methods and software architecture also applies to other aspects of the study. 3 Attention test method.

After combing and demonstrating the current professional and popular attention methods, we selected two simple methods of attention testing, which are suitable for the needs of the general public, and expanded and innovated on the original basis, which increased the difficulty of testing. The level of testing.

2.5 Digital Enrollment

This method is based on our reference Schulte grid. Schulte grid is the world's most simple, most effective and most scientific attention training method. Is a square card drawn on the 1 cm × 1 cm of the 25 squares, each box has a different number from 1 to 25, training, asked the subjects with their fingers in order of 1–25 in order to point out its Position [4], the number of finished 25 number of the shorter time, the higher the level of attention. The details are shown in Fig. 1.

In order to distinguish between levels, we set three different test difficulties: The first level, by a simple one digit into three digits, increasing the difficulty of this method on the attention of the four qualities is reflected. The specific situation is shown in Fig. 2.

The second level is based on the first level to increase visual interference, by changing the background to increase the interference. Focusing on attention to the stability and distribution. The specific situation is shown in Fig. 3.

The third level is to increase the auditory disturbance, that is, on the basis of the second level through the headset on the number of air intelligence reading, in the final test time and fill out the accuracy of the figures to judge.

In the selection of training mode, the staff can freely choose the difficulty; you can also adjust the number of squares.

2.6 Find the Ball

This method uses three cups of the same shape and a ball; first let the subjects noted that the ball into one cup, and then continue to change the location of paper cups, and finally by the subjects pointed out that the location of the ball. And the judgment was made by five times of accuracy and time. This is a simple but very

Fig. 1 Schulte grid

1	24	3	17	5
10	2	14	25	12
15	9	18	4	16
19	23	6	22	20
11	7	21	8	13

Fig. 2 First level Schulte grid

001	024	003	017	005
010	002	014	025	012
015	009	18	004	016
019	023	006	022	020
011	007	021	008	013

Fig. 3 Second level Schulte grid

001	003	011	012	013
010	018	002	024	008
019	020	017	006	005
014	009	021	007	004
022	015	025	016	023

test of people's attention to the test method; in particular, attention to the stability of the test has a strong effect. The specific situation is shown in Fig. 4:

For this method, we also set up three levels, increased visual interference and auditory interference two kinds of difficulty.

Fig. 4 Find the ball

3 Attention Test Results Analysis

After a series of tests, we need to count the data and then through the organization of a large number of personnel to carry out tests to develop the corresponding criteria for the analysis in order to facilitate the latter and set the necessary training cycle quantification table.

3.1 Data Statistics

The statistical data include the personal information of testers and the data of test and training. The personal information of the subjects includes age, place of origin, length of service; test and training data include time, accuracy, error rate. For the results obtained through system testing or training, use the database for storage, easy to use later.

3.2 Standard-Setting

The development of standards requires some data support. By testing some of the sampled personnel, using the principle of statistics, the original results into a status of magnitude [5], which reflects the measured results of a test staff in the position of all the measured results. The development of standards is conducive to more accurate selection of personnel.

3.3 Quantification of Training Results

Personnel in the training of the results obtained is not useless, by the staff within a cycle of training to quantify the results, and then use the intuitive statistical chart, you can clearly see the effectiveness of personnel training in a certain stage.

4 Conclusions

Our research on people's attention testing aims to solve the scientific and complete set of systems applicable to the needs of the general public. The method is simple and versatile and provides the import and export of data and provides an important data for future research. Source. However, we also have some shortcomings in the research process, such as the standard formulation is not very strict, the function of the software is not very comprehensive, and so in the latter part the research process will continue to strengthen.

Compliance with Ethical Standards The study was approved by the Logistics Department for Civilian Ethics Committee of Air Defence Forces Academy.

All subjects who participated in the experiment were provided with and signed an informed consent form.

All relevant ethical safeguards have been met with regard to subject protection.

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The Analysis on the Application of Psychological Personality Test in Our Army

Chenhui Li, Junyin Zhang, Zhengxiong Hu, Xiaofei Zhai, Hualiang Xu and Zhibing Pang

Abstract As a necessary and important mean of the psychological research, psychological test is valued by more and more people. As one important item in it, psychological personality test also be highly valued. During the modernization of our army, the psychological personality test attracts great attention. Meanwhile, the relative system and institution are being well developed, some part of which even made gratifying achievements. But compared with foreign and civilian, gaps still exist. The thesis illustrates and discusses the application of psychological personality test and some existing problems. Finally the thesis expounds some of my suggestions towards these existing problems. Hope our psychological personality test related construction can be more formal, more orderly, and play a bigger role in raising combat effectiveness.

Keywords Psychological personality test · Military training · Current situation

As a necessary and important means of the psychological research, psychological test is valued by more and more people [1]. Through the psychological science method and means, psychological test focus on the psychological characteristics reflected in the people's activity, giving reference, quantitative analysis and corresponding guidance, which is based on the relative principles. Since the psychological test pioneer, British biologist and psychologists Galton, Psychological test have been in a constant development and progress. Until now, it has played a guiding and objective role in talents selecting, post office and mental health education. The army is a special group because of its high stress in management, urgent time schedule, heavy tasks and great psychological pressure, which make it more urgent for soldiers to take the psychological test [2]. With the development of these years, the psychological test in our army made gratifying achievements under the enormous demand. Personality test is an important content of psychological test,

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and here I will research application status and problems of the psychological personality test in our army, comparing with the foreign study. Then analyze and explore on these questions and put forward my personal points.

1 The Application Overview of Psychological Personality Test in Our Army

Now, psychological problems also has been increasing gradually. Our army advocate putting people first, paying attention to the training and use of people, carrying forward humanistic spirit, and keeping close to the mental health of soldiers, which give rise to the sound development of our psychological test.

1.1 Preliminary Establish the Psychological Selection System of Soldier

To promote our army transform from the mechanization to informatization, the most fundamental and urgent way is to improve the quality of officers and soldiers, including the psychological quality. The good psychological quality is one of the most important aspects of the battle effectiveness, and is the necessary quality to transforming soldier in the new development stage of the new century. Since the 1980s, our leaders have encouraged scientific research institutes to establish a set of military psychological selection standard in order to improve the scientific level of soldier selecting and appointment [3]. Our army have preliminary established psychological selection system of military, which made the re-inspection qualified rate of our recruits jumped to 99%. What's more, it makes psychological quality test results become a part of the comprehensive evaluation, and a factor of talent selection and appointment for the officers and soldiers.

1.2 The General Use of the International Mainstream Inventory

Psychology has been developed for more than a century since the nineteenth century. During these time, there appeared many masters of psychology and the corresponding psychological theory and works, as well as different kinds of the psychological test. Through the practice and the selection, there comes out some psychological test, being the international general inventory.

1.2.1 The Cattell's 16 Personality Factor

16PF, called the Cattell's 16 personality factor, is one of the most perfect psychological test tool in the world. The scale is founded by professor Cattell, based on his 16 kinds of personality theory. Because of its good reliability and validity and result, this scale is admired throughout the world. Now the scale has developed into five versions: A, B, C, D, E. Among them, A and B version are the completed version, including 187 projects; C and D are the parted version, each including 106 projects; E version is adjusted to the starters, who have a low level of culture, including 128 projects. At present, the applicant in this aspect of our country is the Chinese version and the normal model of Liao Ning Province revised in 1981 by S. Li of the Liao Ning Province Training section. As for our army, there are also some regions using the Chinese soldier normal model formulated in 2007 by G. Yang of the Third Military Medical University.

1.2.2 The Evaluation Questionnaire of the Cattell's 16 Personality Factor

The 15FQ+ firstly published by the British PSYTECH international Ltd is similar to the16PF, both of which are based on the theory of professor carter's 16 personality factors. The main difference between 15FQ+ and 16PF is that the latter takes the "intelligent" intelligence factors as one of 16 basic personality traits in questionnaire. The former consider that there should be time limit in the standard intelligence tests, otherwise the result would not be accurate. Contrary, the 16PF test doesn't have time limit, so it is changed to "metacognitive personality variables", namely the individual mastery of their intelligence and trust degree, called "intellectual assessment". In 2015, Z. Yang of the Fourth Military Medical University take it as his master's research, carrying out a deeply upgraded research based on the previous effort.

1.2.3 Eysenck's Personality Questionnaire

The questionnaire is designed by the British psychologist, H.J Eysenck, based on his theory of the personality dimensions and is a self-report questionnaire. Because of its high reliability and validity, it received a high praise in the world from its establishment in 1975, and at present it becomes one of the most widely used questionnaire in the area of judiciary, medicine, education, and counseling. Meanwhile Eysenck professor also constantly improve and upgrade it, and in 1985 complete the adult version of the revised Eysenck's personality questionnaire scale (EPQ-RS).

1.3 The Professional Psychological Workers in the Service of Grassroots Increase Gradually

At present a lot of military colleges and universities have opened the professional courses such as soldier's psychology, soldier's psychological counseling, soldiers psychological services. And many universities, including the Fourth Military Medical University, have a lot of psychology graduated students or even doctoral students. Usually they undertake the responsibility of cultivating psychological service personnel at the grass-roots level. In addition, we also actively communicate with the civilian, and invite the psychological experts and professors to guide, and ask civil professional institutions help to implement psychological test. Besides, our army also organize the backbone to study in civil professional institution. In this way, our army colleges cultivate more professional talents and master more resources to communicate with civil.

2 The Application Problems of Psychological Test in Our Military System

The integrated construction of psychological test system in our army has experienced great changes and has initially formed the relevant institutional mechanisms.

2.1 The System Is not Complete, Lack of Supporting Facilities

Our psychological test and file based system development imbalance, construction is not comprehensive. For pilots, ping jockey, drivers, other special post personnel test and archives management are relatively mature, but for other creatures as well as military officers is still in the exploratory stage, the relevant system construction is not perfect. In U.S. military, for example, in "the classification of the military professional" according to the behavior characteristics of the army divide into 276 jobs [4], every job has set specific psychological requirements. Equipped with advanced psychological evaluation electronic platform, established the perfect soldier psychological archives. Implements the psychological test for the development of the officers and soldiers. And our psychological test results comparing with the post title, post didn't establish correct contact and leaves a psychological test as the skeleton, formalism. Second psychological test related supporting facilities is not complete, no computer unit can only use print, no software unit has a computer, a software unit has no professional operation, even if have a professional operation, psychological files establish dragged on, update slowly. And the test results are on the shelf, as no basis, did not play its proper role.

2.2 Psychological Research is Insufficient, the Inefficiency of Test

At present, psychological test in current research level and scale is relatively lack, the existing number of psychological tests available, the category is not complete, and the lack of originality and aboriginality, more copy and improvement on other countries' scholars research results, the lack of internationally renowned psychology, famous psychologists. On average every 130,000 people in China have a psychology researchers "for imbalances in" is more awkward, for our army situation is more worse, China's five major psychology department no one in our colleges and universities, and even if a unit or organization is studied, the results of the study will not be immediately applied to the troops. As a result, our troops today even with conditions of psychological test forces use test version of questionnaire was at least ten years ago, the fruits of the reform and opening in China shocked the world, the change of the domestic, natural psychological change is huge, and so the test can't meet the requirements of due.

2.3 Aimed at the Lack of Test Characteristics of Soldier

In the case of 16PF including our army in our country now is being used in 1981 revised edition. This version is based on the national people's revised for measuring object, norm is established for Liao Ning province people's sampling [5]. But the truth is, no matter the frontier, island, plateau, south, north, west, our country territory is broad, how can the result of only one province on behalf of the nation, moreover, in addition to the region, and in the same area in different units, different positions, different responsibilities of psychological characteristics is different. Our army for this "a medicine to cure all ills" needs to develop diverse "drug" to "suit the remedy to the case". In addition, our army in psychological research has focused on the civilian, including college students, civil servants, employees, etc., but for a specific group of soldier special research is not enough, so the questionnaire of military feature is not clear, lack of pertinence.

3 Some Suggestions for the Practical Application of Psychological Test of Our Army

3.1 Consummating the Psychological Selection of Military System

According to the current development and the situation of the military psychological selection system now use effect, improve the military psychological selection system plays an important role in the optimization of the combat effectiveness of the armed forces division and enhance of fighting capacity. I think we should do this for improving the psychological selection of military system.

3.1.1 Optimization of Selection Methods to Ensure the Measurement Science

Psychological results on the basis of psychological test is the beginning of the psychological selection of military system and foundation, decided the following implementation process. So must be scientific, careful and accurate. Requires each scientific research unit, institute to study earnestly, careful summary, took out a set of suitable for China's national conditions, the condition of the people, its scientific selection method.

3.1.2 Determine the Selection Standard, Reasonable Sorting

The psychological selection system of U.S. military in the army according to the behavior characteristic has carried on the careful classification for the professional positions, which is divided into 276 jobs, and psychological selection have clear standards in each position. We should learn from American practice, and all the four armed services, including a number of units. Each has different tasks, features, and different psychological characteristics. So we need to have a detailed analysis of each position, and strict classification, and serious conclusion, and lay down appropriate psychological selection criteria for different positions.

3.1.3 Clear the Selection System, Achieves "Follow Law"

Based on the above, the military psychological selection system must be in our army's official rules, and even doctrine regulation. Must let the system to implement in the army to make psychological test work earnestly and be institutionalized.

3.2 Optimization of Cooperation and Exchange System

Our psychological test has two important defects now. First, psychological test scale of old, poor adaptability, and test effect is poor; Second, psychological archives management is" fighting the enemy separately", the lack of sharing, consistency and continuity. To solve these two problems have to strengthen the cooperation and communication [6]. First of all to improve scale, should strengthen the communication among authoritative research unit and research units at the grass-roots level and grassroots units. Authoritative research unit that can improve existent scale is less, but each basic unit is complex, and has different characteristics, for different units need to be improved accordingly, so the scale improved workload is so big that it's not feasible to depend on a handful of authority unit, and we need to communicate actively with grassroots research unit. In addition, it is necessary to strengthen the communication between the basic research units and the grassroots units, especially the communication between professional psychology workers and basic unit of psychological backbone. In this way can help the research unit at the grass-roots level grasp the need and the feature of the grassroots units, and then do concrete operation. Besides we need record the usage of the grassroots units and communicate with authority and form the feedback mechanism of psychological research. So that can we form a closed loop of study.

3.3 Complete Professionals Gap

3.3.1 Widen the Talent Cultivate Path

According to the goal of psychological service talented person troop construction, we must stick to the civil-military integration and open channels, and take many kinds of ways and measures to make full use of various advantageous resources, optimizing cultivation, and strive to build the psychological service personnel training pattern, combined with forces training, military and local introduction of complementary. Military colleges should play a master role in talent training. Also, it must complete task of talent training according to concrete training, teaching, and teachers of different type of military colleges and the different needs of psychological services; each unit should make good use of the unit's psychological service human resources, and also use the professional strength of other units through the way of explaining and giving a lesson by professional psychologist or psychiatrist for satisfactory completion of psychological backbones in basic unit; With the help of social forces, it's a powerful measure to increase the introduction of local professionals for strengthening the construction of military psychological service personnel. Through the civil-military integration mechanism at all levels and social forces to aid, to do a good job of the introduction of local professionals.

3.3.2 To Perfect Management and Use

People is the basis of all activities, but must not only quantity over quality, for personnel management and use must be regular and orderly. First of all, through the personnel qualification, increase the degree of talent specialization; Secondly, by the clear responsibility, ensure all kinds of people do their own job; Finally, take incentive measures to improve the efficient use of talent management. Our psychology talents team will be a normal and orderly, capable team, and play the proper even extraordinary effect.

4 Conclusion

According to the report, the most important factor in the war is the soldiers, which attaches great significance to psychological test. The psychological test system still has many problems, but there is no denying that the construction of psychological system of our country has underwent considerable development, including the medical field, education, business, organization department and the justice department. I am sure that with the quick development of the psychological test, the construction of psychological test of military system will achieve a higher level and benefits the military officers and soldiers as soon as possible.

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Design of Human Reaction Time Testing System

Honglei Li, Yibo Zhang, Hui Gu, Zhibing Pang, Hongyan Ou and Cheng Jin

Abstract To solve the existing reaction time test tools' problems that the test kind and test scheme is single, the stimulus signal is inflexible, and the evaluation method is not reasonable, and meet the reaction time data collection needs of different personnel selection, a general test system for human reaction time is proposed. Considering synthetically the characteristic that the reaction time data collection needs of different personnel selection is different, this test system provides the custom function of the test scheme and the stimulus signal based on modular software design ideas. The human reaction time test system which is proposed in this paper is able to offer the reaction time data collection tool support for different personnel selection and is versatile and universal for different personnel selection.

Keywords Personnel selection · Reaction time · Test system

1 Instruction

Reaction time means the temporal duration between stimulus and response, also called response latency. The traditional reaction time test systems are always the hardware platforms based on the single-chip microcomputer [1, 2]. Because the test equipment is expensive, the process of operating and supporting is complex, and the time of testing is long, so reaction time testing is always used in the kinematics experiment [3] and the elite selection [4]. With the development of computer technology, many reaction time test software gradually appears on the market [5]. Due to the features of reliable method, stable result and good reproducibility, the reaction time test system based on computer technology shows a bright application prospect. The existing reaction time test tools have some problems, such as the test kind and test scheme is single, the stimulus signal is inflexible, and the evaluation

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method is not reasonable, especially the tools could only have a simple reaction time test on auditory reaction time. The existing tools are not convenient for different professional application. Therefore, developing a full-function and easy-using reaction time computer comprehensive test system has practical significance. A reaction time comprehensive test system applying to all kinds of personnel selection for different features of different personnel selection needs is proposed in this paper.

2 Overall Design of System

2.1 System Requirements Analysis

Reaction time includes simple reaction time and complex reaction time, and complex reaction time includes discrimination reaction time and choice reaction time. Simple reaction time is the minimum interval between the presence of a single stimulus and the single responses of a testee. Discrimination reaction time is that there are two or more different stimulus displays, and the testee only gives a response for the appointed stimulus display and without response for the others. Choice reaction time tasks require distinct responses for each possible class of stimulus.

Different professionals have different working environment and operation specification, so they have different needs of reaction time. For example, the simple auditory reaction time of gunshot of an outstanding race athlete must meet a certain standard to ensure he can fast breaking, and the discrimination reaction time and choice reaction time of a driver must meet a certain standard to ensure he can do appropriate reactions when something (man, animal, etc.) suddenly appears.

Therefore, a general human reaction time test system must have following functions: First, it can measure both simple reaction time and complex reaction time and offer the customization function of random combination testing program according to the demand of users. Second, stimulus signals should contain light, sound and pattern, and the test system should offer the edition and customization function of stimulus signals according to the demand of users. Finally, it should have the function of performance statistical analysis.

2.2 Overall Structure of a Human Reaction Time Test System

Test system contains simple reaction time testing, discrimination reaction time testing, choice reaction time testing and management and maintenance module, as shown in Fig. 1.

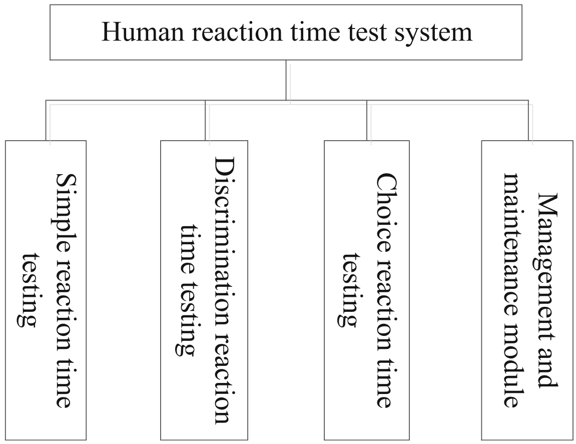


Fig. 1 Main structure of the human's reaction time testing system

3 Design of Function Module

3.1 Simple Reaction Time Test

The testee must hold the mouse by dominant hand, wear headphones and look at the screen horizontally before a test. And the test procedure is as follows:

Step one: Click the start button by left mouse button to start a test. According to the test scheme setting, the system will produce the occurrence time of the first stimulus signal randomly. Turn to Step two.

Step two: The stimulus signal (light, sound and pattern) is showed, and when testee receives it, he clicks the left mouse button immediately to finish one time test. The testee's reaction time will be recorded, and the occurrence time of the next stimulus signal will be produced by the test system. Turn to Step three.

Step three: Repeat Step two, until testee has finished the setting test number of times. Turn to Step four.

Step four: Finish the whole test. The system calculates and shows the testee's score.

3.2 Discrimination Reaction Time Test

The testee must hold the mouse by dominant hand, wear headphones and look at the screen horizontally before a test. And the test procedure is as follows:

Step one: Click the start button by left mouse button to start a test. According to the test scheme setting, the system will produce a group (two or more) stimulus signals and the occurrence time of the first stimulus signal randomly. Turn to Step two.

Step two: The stimulus signal is showed. The testee judges immediately whether it is the signal of response when he receives the stimulus signal. If yes, the testee clicks the left mouse button immediately to finish one time test, otherwise no response. The testee's reaction time will be recorded, and the occurrence time of the next stimulus signal will be produced. Turn to Step three.

Step three: Repeat Step two, until testee has finished the setting test number of times. Turn to Step four.

Step four: Finish the whole test. The system calculates and shows the testee's score.

3.3 Choice Reaction Time Test

The testee must put three fingers (right hand: index finger, middle finger and ring finger. Left hand: ring finger, middle finger and index finger) on the "left," "up" and "right" three direction keys, wear headphones and look at the screen horizontally before a test. And the test procedure is as follows:

Step one: Click the start button by left mouse button to start a test. According to the test scheme setting, the system will produce a group of three stimulus signals and the occurrence time of the first stimulus signal randomly. Turn to Step two.

Step two: The stimulus signal is showed, and when testee receives stimulus signal, he clicks appropriate key (the relationship between keys and stimulation has been explained in the test instruction) to finish one time test. The testee's reaction time will be recorded, and the occurrence time of the next stimulus signal will be produced. Turn to Step three.

Step three: Repeat Step two, until testee has finished the setting test number of times. Turn to Step four.

Step four: Finish the whole test. The system calculates and shows the testee's score.

3.4 Process of Preemptive Response and Wrong Response

Only the correct operation's response time could show the test's true procedures, and the reaction time data can be valid [6]. So, to ensure the correctness of testee's response and avoid preemptive response and other wrong responses, some measures are implemented as follows: First, the stimulus signal's occurrence time of temporal duration is produced randomly to avoid the stimulate signal's occurrence time is predicted by the testee. Second, once testee has preemptive response or wrong response, the whole test must be done again in order to make testee pay more attention.

3.5 Management and Maintenance

3.5.1 Management of Stimulus Signal

The stimulus signal which is saved in the database can be customized and edited by users according to their test needs. The management of stimulus signal has two functions: First, the stimulus signal can be choose freely by users from the database. Second, the stimulus signal can be edited or updated by users according to the users' needs.

3.5.2 Management of Testing Scores

Method of Score Calculation

Jinzhou Yuan [7] had a finding: The best test time for reaction time test is 20–30, and the reaction time's reliability can reach 0.97 which is be calculated by get the average value of the remainder data by removing 5 maximum values and 5 minimum values. It is perfect for athletes and other elites' selection. However, from the perspective of economy, it is deficient if used on the large-scale testing like national physique monitoring, because of too many testing times, too much time consuming and too much resource. Xuemei Sun [8] had a finding: A rather better cost-effectiveness test times is 10 for the large-scale testing, and the reaction time's reliability can reach 0.93 which is calculated by getting the average value of the remainder data by removing 3 maximum values and 3 minimum values.

Therefore, considering generality, the system proposed in this paper adopts the method of self-setting testing times and sampling data to calculate testing scores.

Output Scores

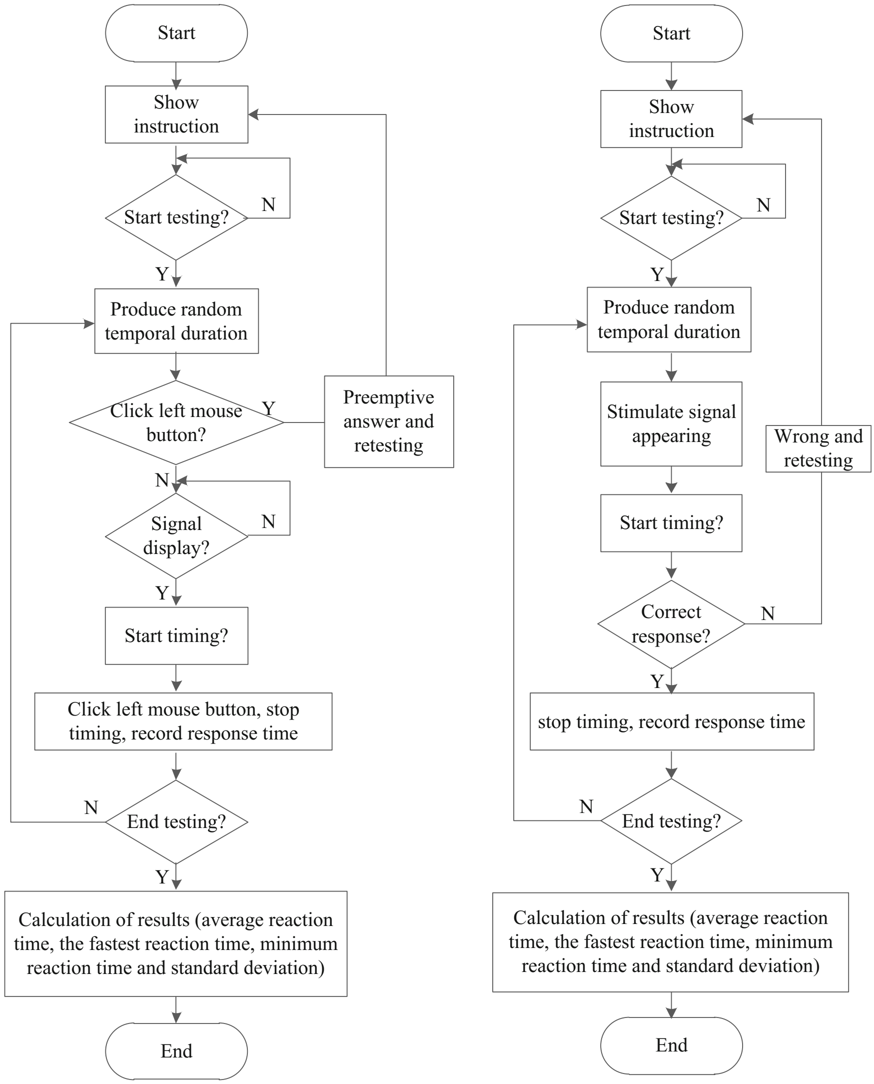
Considering the usability of system, the system which has the scores display function, the scores statistical analysis and the function of scores export to Excel is convenient for different staff types.

3.5.3 Management of Staff Information

The system offers two staff basic information input ways: One is foreground single importing; another is background bulk importing by Excel.

4 Test Procedures

The simple reaction time test procedure is shown in “a” in Fig. 2, and the complex reaction time test procedure is shown in “b” in Fig. 2.



(a) Simple reaction timetesting procedures

(b) Complex reaction time testing procedures

Fig. 2 System testing procedures

5 Conclusion

For the situation of different demands of different professionals' reaction time, designing and developing a general reaction time test system based on the computer technology, this test system has following features except the function of traditional reaction time test equipment: First, stimulus signal, which suits different professionals to have a reaction time test, contains light, sound and pattern and can be customized according to the demand of users, and the testing results are more objective. Second, testing program which can test simple reaction time and also complex reaction time can be customized according to the demand. It solves the problems such as the lack of present reaction time test tools and the lack of no customization of stimulus signal and offers tool support for different professional reaction time test.

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Research on National Defense Students' Frustration Psychology and Its Management in Pre-service Training

Peng Gong, Zhenguo Mei, Yunqiang Xiang, Chang Mei and Guiqi Liu

Abstract During pre-service training period, since the national defense students have heavy learning and training tasks, high management standards, and heavy work and living pressures, they are facing various physical and psychological challenges. Most of them often feel frustrated, which severely influences their working determination and confidence. Therefore, it is of great significance to study the frustration psychology and its management of national defense students in pre-service training period. After carrying out questionnaire survey and symposia for some national defense students who are taking pre-service training, this paper analyzes the concrete manifestation and main causes of their frustration and puts forward basic solutions from aspects such as educational guidance, psychological training, and atmosphere construction. The results provide important foundation for military academies to strengthen the psychological management of national defense students.

Keywords National defense student · Pre-service training · Frustration psychology · Management

With the accelerating of military talent project, more and more national defense students join the army and become the new force [1]. Pre-service training is a critical stage for these students to become qualified officers and plays an important role in the formation and improvement in their ability. During this period, students have heavy learning and training tasks, high management standards, and heavy working and living pressures. They are facing various physical and psychological challenges, which requires them to have strong anti-frustration ability and good psychological quality to adapt to the study and life in military academies.

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According to our survey on national defense students who have graduated in the recent five years, about 82% of them have weak psychological quality and anti-frustration ability. When they face difficulties and challenges in work, they easily become frustrated, which to some extent affects the completion of their tasks and future progress. Therefore, in the pre-service training period, it is important for officers at all levels in military academies to pay great attention on students' psychology, adopt practical measures to help students build good psychological condition and anti-frustration ability, and make students qualified for military jobs.

1 Manifestations of National Defense Students' Frustration Psychology

Frustration psychology refers to the psychological condition of people when they meet obstacles or interference in purposeful activities, and their motivation cannot be met [2]. The frustration psychology of national defense students in pre-service training refers to the state of unhappiness and anguish experienced by students, for they meet obstacles or interference when achieving their motivation [3]. This unpleasant and depressed inner state will directly produce negative emotional experience. Some students will have secondary psychological and behavioral changes, such as retreat, imbalance, or radical behavior, which leads to deviation and lost in the development of students. If this state is brought to work and life, a series of chain reactions will appear, which has a direct impact on quality and efficiency of work and the internal harmony and stability in army.

The manifestations of frustration psychology of national defense students in pre-service training are mainly as follows.

1.1 Antagonistic Psychology for Strict Management

Although national defense students receive paramilitary management in local universities, their management modes are still largely different from the strict and formal management in armies. During pre-service training period, every day students need to have a drill, tide up the dorm, have routine roll call, listen to officer's comments, and ask for permission every time when they leave the barrack. Strict management places many restrictions on these students and deprives them of much personal time, which sets physical and psychological challenges for them. In addition, students cannot use mobile phones and the Internet as they like and have to deal with many interpersonal relationships in the army. A few students cannot bear all these restrictions, and some even have antagonistic psychology instead of their original excitement and pride feelings. They are frustrated, have no spirit and motivation for study and training, and may even feel bewildered with their future life in army.

1.2 Anxiety for Strict Training

National defense students are both college students and reserve military officers. They study in universities like normal students, but they also need to receive special military trainings. Take Guizhou University as an example; national defense students participate in physical fitness training every Monday, Wednesday, and Friday evening. They also have 10 days of training in winter holiday and real army experience in summer holiday, yet these are only practices. The competitive and high-intensity training during pre-service period make students realize the gap between qualified soldiers and themselves. They very much lack military skills, cannot perform standardized tactical actions, and have poor combat skills, and some even fail to follow the basic commands. Students are not clear about the requirements for military positions and tasks and thus may become anxious. They are spiritless and depressed, and some even feel hopeless and act recklessly. Such anxiety appears because students feel that their abilities cannot meet the demands of future positions.

1.3 Escape Psychology for Hard to Achieve Goals

Most students can successfully switch their roles from students to reserve military officers and have clear cognitions about themselves. They can adapt to pre-service training and are eager to exploit their own advantages in the army. But a few students are too optimistic and idealistic about army life. Some want to perform excellent in study, some want to join the party, some want to win more merit and praise, while some want to fully show their abilities and get good positions after graduation. Their expectations are good, yet competition is fierce, and students may not always get what they want. There are always some people that cannot achieve their goals. This makes many students dispirited, and there appears escape psychology.

2 Analysis on the Causes of Frustration Psychology

Analyzing students' psychological condition, we can see that both objective and subjective factors cause their frustration psychology.

2.1 Particular Personal Development Experience

Individual psychological factor has the main influence on a person's psychology. Under the same circumstance and facing the same difficulty, different people have different reactions, for their characteristics directly affect their behaviors [4]. People build their personalities during their long-term development. Most national defense students now are the only child in their families. They are used to the care and love of others and regard themselves as the most important ones. If they can achieve their goals or meet their demands, they feel happy and spirited; if not, they easily become frustrated, blaming the environment or rebelling against the leaders' command. In one word, this self-centered psychology is one of their common characteristics.

2.2 Poor Connection Between Local Universities and Military Academies

After four years of quality education in local universities and since national defense students get special concern of colleges and armies, most students gain certain skills when graduating, such as ball games, art performances, news writing, calligraphy, painting or computer skills. But because they get much attention of others, some students have weak sense of organization. They are self-centered, have poor managing ability, value their own interests too much, and cannot bear losses or criticism. These features are unfavorable for them to become good commanders and officers. After they start to work in military academies, facing the high working demands, strict managements and fierce competition, their simple life experience will affect their psychology. They cannot meet their goals; thus, they become frustrated, self-condemned, and even hopeless. Such a condition will only widen the gap between the army and students.

2.3 Improper Managing Method of Grass-Roots Officers

The improper managing method of officers in military academies is also an important cause for students' frustration. Some officers are used to commanding and criticizing students and fail to create a fair, interactive atmosphere in management. Their managing method is too rigid, strict, and punish-centered. Some officers have little patience on students who do not perform well. They hold the idea that "criticism is the best education," acting too strict on students, which makes students feel frustrated and self-abased, losing the confidence and energy to improve themselves. What is more, some officers have poor knowledge about students' characteristics, thinking that they are not qualified enough comparing with soldiers and officers in the army. Some officers even have prejudice on students who are not well adapted to army life or have contradicted them. Their opinions virtually put heavy pressure on students. Some officers are still not familiar with frustration psychology and the law of students' psychological activities; thus, they cannot scientifically explain students' behaviors led by frustration. They are not able to stimulate students' potential or solve students' psychological problems, so their management is not targeted and efficient.

3 Solutions to Frustration Management

Having analyzed the main manifestations and causes of frustration psychology, military academies need to find solutions from aspects such as educational guidance, psychological training, and atmosphere construction. Academies should adopt comprehensive measures to build students' anti-frustration and psychological endurance abilities. In this way, students can enjoy a harmonious inner environment in their development.

3.1 Strengthening Guidance and Building Good Psychological Quality

National defense students appear to have strong and changeable emotions in pre-service training. They often go to extremes, get into dead ends in work, and tend to be depressed, anxious, and unsociable. In this way, we must strengthen psychological guidance to help students get rid of their negative emotions and maintain a healthy state of mind. First, we should see to it that our psychological counseling work can embrace all the aspects in students' life. We should implement the instructions in Essentials of Basic Military Construction and carry out the "Two Advanced" activity (strive to be an advanced party organization and an advanced party member), guiding students to regulate their moods and keep a balance in mind when participating in competitions. Second, we should establish and improve our psychological counseling rooms, making sure the psychological counseling and testing systems are carried out. When students are facing circumstances such as enrollment, comprehensive exercise, major task conversion, evaluation awards and graduation, we need to test their mental conditions and psychological problems in time, so as to guide them to regulate emotions, overcome psychological barriers, and gradually eliminate frustration.

3.2 Strengthening Psychological Practices and Improving Endurance

Psychological endurance refers to the ability of a person to bravely accept the challenge and be free from behavioral and psychological disorders under pressure

[5]. Therefore, it is important to strengthen students' psychological endurance. First, we should put psychological training into our teaching and training system. We need to have scientific plans and proper arrangements. Students' psychological qualities can be cultivated through a series of urgent, difficult, dangerous and heavy tasks. They can learn to gradually eliminate psychological obstacles and gain courage and confidence to overcome frustration. Second, through the simulation of battlefield environment, we reasonably enhance students' psychological load and help them build good psychological adaptability, endurance, and fighting and regulating abilities. Third, grass-roots officers should learn to set various psychological barriers for students and improve the standards and requirements of their tasks, so as to ensure that all students will face setbacks and difficulties. After that, officers should offer guidance in psychological adjustment according to students' individual responses, efficiently helping them overcome frustration and improve psychological endurance.

3.3 Holding "People-Oriented" Education and Creating Harmonious Atmosphere

"People-oriented" education means not only caring for, understanding, and respecting students, but also cultivating their sound personalities, helping them overcome difficulties, and guaranteeing their development. If our students feel they are respected, they can give full play to their subjective initiatives and work with good mood. This gives them a sense of achievement and helps avoid frustration psychology. In this way, armies and military academies should work together to create a united, harmonious, sound and positive inner atmosphere. Officers should treat each student equally, adhere to lawful and scientific managing methods, respect students' reasonable requirements, enrich their daily life, and try to meet their demands to pursue advanced culture. At the same time, officers need to be fair in rewards and sanctions, stimulating students' working and studying enthusiasm. Only in this way can these students keep good moods, strive for progress in work, face challenges positively, and minimize the bad influences of frustration psychology.

Compliance with Ethical Standards The study was approved by the Logistics Department for Civilian Ethics Committee of Air Defense Forces Academy. All subjects who participated in the experiment were provided with and signed an informed consent form. All relevant ethical safeguards have been met with regard to subject protection.

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Analysis of Learning Behavior of Military Vocational Education on MOOC Platform

Ye Tao, Wenying Xing, Chang Mei, Peng Gong and Leiming Yao

Abstract In recent years, MOOC (Massive Open Online Course) sweeps the world and becomes a booster for military vocational education which effectively enhance the education quality. Following the trend, China has established a MOOC platform called "Dream Course" for military officers and soldiers. Analyzing the characteristics of learning behavior of military vocational education on MOOC platform and giving corresponding suggestions are of great significance to promote our military education. This thesis will first elaborate MOOC characteristics and learning behavior, and then analyze the learning behavior of professional military study on "Dream Course" from three aspects: users, course learning, and communication and interaction. The thesis also gives suggestions on how to create quality online courses, improve encouraging mechanism and utilize the platform innovatively.

Keywords MOOC · Military vocational education · Learning behavior · Management suggestions

Since 2012, with the guidance of Harvard, Stanford and MIT, MOOC (Massive Open Online Course) has developed rapidly and swept the world. After that, many universities in China have introduced MOOC platforms [1]. At the same time, military vocational education, as the continuing education for military officers and soldiers, should follow the world trend of online education and provide practical courses for students [2]. In this way, being a new educational pattern, MOOC will

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become the booster of our military vocational education and effectively enhance our education quality. Analyzing the characteristics of learning behavior of military vocational education on MOOC platform and giving corresponding suggestions are of great significance to promote our military education.

1 MOOC Characteristics and Learning Behavior

MOOC is an online teaching model for the public, including children, the elderly, and people from all walks of life. The core features of MOOC are "mass, online and open". "Mass" is reflected in two aspects: mass learners and mass courses. More than tens of thousands of people can log in and study on a MOOC platform at the same time, and they can choose lots of courses. "Online" means that all the study activities are held entirely online, and people are free from time and place constraints. "Open" means that the course resources are free and open. The public can easily get access to them [3].

MOOC is quite different from traditional online courses. From the aspect of production, online open classes and resource sharing classes are actually "classroom moving" (recording videos of classes), while MOOC is "course moving". For example, if traditional online courses can be compared to dramas, they are like recording the dramas and then play them out. Although certain post-production work is needed, it is quite simple (editing some pictures, adding subtitles, etc.). MOOC is like making movies and TV series. Producers need to shoot from different angles and use different shots to show the teaching contents. From the aspect of learning function, MOOC is not a simple video presentation, but also includes modules of teaching, learning, training, testing and evaluation. Students learn, discuss, do homework, have examinations on the platform and finally get a certificate, thus it is a complete learning process [4].

Through distributed online platforms, MOOC is able to carry out teaching, organization and management in a unified way, which extends learning space, enriches learning resources and promotes knowledge sharing and innovation. It therefore enjoys widespread recognition and praises from both domestic and international educational organizations.

2 Analysis of Learning Behavior of Military Vocational Education on MOOC Platform

The military vocational education can carry out on the basis of domestic, foreign and intra-army MOOC platforms. At present, there are dozens of MOOC platforms in all. Udacity, Coursera and EdX are the three most popular foreign MOOC platforms. "Xuetangx" is the biggest Chinese platform, having 5 military courses, such as "Introduction of China's Surrounding 14 Land Neighboring Countries", "Military Theory" and "High-tech and Modern Local Area War". The only intra-army platform in China is "Dream Course". By February 2017, the platform has more than 120 courses. 32,900 people have registered, and nearly 3100 online examinations have been attended by 36,000 students [5]. Therefore, Dream Course is the main MOOC platform for military vocational education, and we will take it as our research object.

The learning behaviors on Dream Course include login, course learning, and communication and interaction. See Table 1.

2.1 Analysis on the Characteristics of MOOC Users

Viewed from the educational background, 51% users have graduated from "high schools" and "junior vocational academies"; 19% have graduated from "vocational colleges; 30% have received bachelor or higher degrees.

Viewed from ages, "post-80s and 90s" have become the main users, accounting for a total of 84%. Among them, soldiers and noncommissioned officers account for 77%.

Viewed from the analysis of user behavior, students are obviously organized to learn on the platform. We can see the features from the following three aspects: relatively concentrated registration time; quite concentrated active time, and highly concentrated course selecting. Users' active periods often follows their registration time, and decline rapidly after the courses end. What's more, most users learn online from 9:00 to 10:00 am, 3:00 to 4:00 pm, and 7:00 to 8:30 pm. They usually log in from Monday to Friday during their training time, and few will study online during weekends.

2.2 Analysis on the Characteristics of Course Learning

Viewed from course selecting situation, the selections are highly concentrated. By February 2017, the three most selected courses are "Introduction to Multimedia

Table 1 Data of learning behaviors on Dream Course

Login	Course learning	Communication and interaction
Sign up	Watching videos	Asking questions
Login	Quiz	Answering questions
Account settings	Notes	Discussions
Choosing courses	Information retrieval	Cross evaluation
Bulletin	Score management	Sharing experiences
…	…	…

Design and Production", "Basic knowledge of Network Security and Confidentiality" and "Military Physical Fitness". We can see that users have great demand on courses about software using, safety regulations and military training.

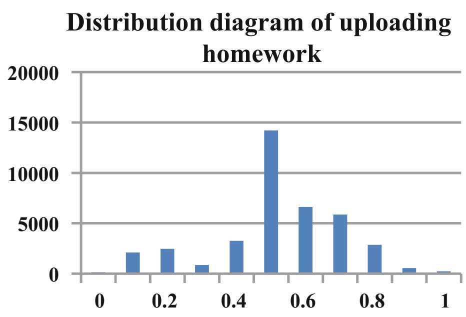
Viewed from learning duration, few students have finished the courses. We divide their studies into four levels by their learning time. If they only finish 10% of the course, they have just "experienced the course"; if they finish 10–50%, they are called "giving up halfway"; if they finish 50–90%, they have experienced "selective study"; only if they finish more than 90% can they be regarded as "finishing the course". According to our statistics, only 14.8% users have "finished the course". This requires our concerns.

Viewed from ways of participation, most users both watch the videos and upload their homework. These are the two basic activities on MOOC platform. The proportion they account for can reflect users' participating situation. We will choose the most popular course "Introduction to Multimedia Design and Production" as an example and carry out statistical analysis. About 39,000 people take this course. We use "α" to represent how many times every user has uploaded his or her homework, and "γ" to represent how many times the user has watched the course videos. In this way "$\alpha/\alpha + \gamma$" stands for the proportion that the activity of uploading homework accounts for. If the value of "$\alpha/\alpha + \gamma$" is 0, it means the user only watches videos; if the value is γ, it means the user only uploads homework. From Fig. 1 we can see that most users' (36.4%) values are 0.5, meaning that they both watch videos and upload homework. The number of users whose values are higher or lower than 0.5 are similar, meaning that their proportions are close.

2.3 *Analysis on the Characteristics of Communication and Interaction*

Mass, timely and efficient interaction is a significant feature and requirement of MOOC. Through our analysis on the big data of Dream Course, after the course questions are released, nearly half of the users will give their first response within 5 min, which fully reflected the learning enthusiasm of users. The teachers' first

Fig. 1 Distribution diagram of uploading homework



reply usually occurs after 3 h. On the one hand, teachers have many teaching and research tasks, thus they do not have enough time to respond online. On the other hand, at present teachers mainly reply by themselves, but many students will ask questions, and there are no professional teams to support teachers. Therefore, it is quite difficult for them to reply in time. In addition, some students chat freely or repeat their questions many times in the Discussion Zone, which affect their learning effect. We need to find some countermeasures to this issue.

3 Suggestions on Improving the Learning Behavior of Military Vocational Education on MOOC Platform

3.1 Creating Quality Online Courses

The core task now for military vocational education is to develop quality online courses. To fulfill this expectation, we need to change traditional teaching methods, give full play to “Military Internet +”, and improve the course creating, releasing, maintenance and upgrading.

First of all, we need to improve our work on course creating and releasing. We should perfect the micro-course production process and strengthen our overall design and layout. We also need to communicate with the production team about the form of teaching and the presentation of micro-course. The whole editing and releasing process should be finished on time, so that the online course can meet the demand of our schedule.

Second, we need to improve course maintenance and upgrades. Teaching staff should communicate regularly with students through the platform to strengthen the learning interaction. Network management staff should check the website and hardware environment. Technical professionals should analyze the learning and operating situation of courses through data accumulation and statistical analysis.

Third, improve the skill training for online courses. We can consult the staff of teaching ability development center in professional normal universities, or invite teachers who have lots of experiences in military vocational teaching to give our teachers some training, or visit famous universities and military academies and learn from them.

3.2 Improving Encouraging System

The encouraging system include encouragement to both course producers and learners.

(1) Encouraging course producers. First, we should to offer material, fund and technical support to the teaching units which set up military vocational courses,

and adopt the learning condition of military vocational courses as one of the requirements in the evaluation of advanced Party branches and teaching units and the rating of training grade in armies. Second, we should recognize and reward teachers' efforts. When Tsinghua University was carrying out MOOC project, they stipulated that the class hour of MOOC equaled to three times of their ordinary courses in teachers' annual evaluation. They also offered special funds to teams that participated in MOOC for the first time and financial support to teams that carried out relevant researches. Once the courses were successfully released, the university provided three assistants for the team and gave assistants working subsidies. Third, we should strengthen the exchanges between teachers and MOOC teams, including seminars, training, teacher's salon, special course exchanges, assistant training, teachers' (assistants') Wechat groups, and MOOC competitions. Fourth, we can evaluate and select the outstanding teachers in military vocational education every year. The candidates should have good management methods, advanced teaching ideas and rich experiences. We set them as models of the whole army, and reward them by promotions and granting higher academic titles.

(2) Encouraging the learners. First, we should ensure the study can be recognized. Now the National University of Defense Technology gives certificates to MOOC learners, but few units give recognition to this certificates, thus we ned to solve this problem in future MOOC projects. Second, we should ensure online discussion is efficient and in time. According to the big data of Tsinghua University's "Xuetangx" platform, the number of assistants needed is inversely proportional to the number of learners, which means fewer assistants are needed when more students select the course. This is because students mainly learn from discussion and interaction, and if they cannot get response after 24 h, their learning initiative will decline. The assistants just help students to continue the discussion. Therefore, on the one hand, we can place communication and interaction as a vital part in learning evaluation, and note down users' interests, concerns and learning habits through big data as the evidence of evaluation. On the other hand, we should build an "honesty management system" to avoid invalid discussion and spams. We can refer to the solutions of foreign platform Coursera, identifying and supervising users' behaviors.

3.3 Using the Platform Creatively

In order to improve the effect of education and quality of talents, we give full play to online platforms by using them innovatively. Through data analysis system, we can investigate a student's every click, every learning time and every interaction, and use big data to analyze students' learning habits, concerns and common problems. Through remote video surveillance system and assessment system, we can build a unified educational system combining military vocational education, examination and military training. Through building distributed platform teaching pattern, we can carry out two-way Q & A discussions, and adopt practices, quizzes, homework and other activities. We will pay attention to the differences in educational background between users, and try to meet every user's individual demand. Through the course releasing platform we divide users into various learning teams, asking each team to build an online discussion group, and let users take turns to upload the discussion result of their team. In this way we can enhance their cooperation and interaction in learning.

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The Influence of Demographic Variables on the Emotional Intelligence and the Mental Elasticity of Undergraduates

Yu Luo, Xin Peng, Kai Wu, Benjun Liu, Peihua Xu and Yunde Sun

Abstract This article is to figure out the relationship between the emotional intelligence and the mental elasticity. *Method* Three ways are applied to this research, that is, an online survey using sojump.com, random sampling survey on undergraduates as well as the SPSS, a software to analyze the relevant figures. *Result* There is an obvious relationship between the emotional intelligence and the mental elasticity. *Conclusion* The higher the emotional intelligence is, the better the mental elasticity is. The nationality, the interpersonal relationship and the participation of the undergraduates are obviously related to their emotional intelligence and mental elasticity. The better of their interpersonal relationship is, the higher their emotional intelligence and the mental elasticity are. The stronger their participation is, the higher their emotional intelligence and the mental elasticity are. Their award-winning experience is related to their optimism. Their tenacity is much better if they have once took major charge of activities ($p = 0.05$). The better they get along well with the opposite sex, the higher their emotional intelligence and the mental elasticity are.

Keywords Undergraduate · Demographic variables · Emotional intelligence · Mental elasticity

At present, the research about the emotional intelligence and the mental elasticity of undergraduates gradually becomes a really hot issue for all walks of life as well as psychology.

One's success depends not only on intelligence but also on the influence of emotion and mental elasticity [1]. Individuality, family as well as society has a clear impact on the contemporary undergraduates.

This article focuses mainly on the influence of every aspect of the demographic variables on the emotional intelligence and the mental elasticity, such as the income of their family, the schooling of their parents, the environment of the university, the

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sum of consumption per month as well as the questions whether they have single parent, whether they are key staff, etc. [2].

1 Research Object and Method

1.1 Research Object

The questionnaire is conducted among the undergraduates randomly. A total of 127 completed questionnaires are collected, cutting out the unqualified ones (for example, the vacancy of questionnaire is over 10%), and there are 92 valid questionnaires remaining. In the valid questionnaires, 44 of the participants are males, while 48 are females; 11 of them are over 25 years old, 74 of them are between 22 and 25 years old, and 7 of them are under 22 years old; 39 of them are single child, while the number of non-single child is 53.

1.2 Research Method

This study applies EIS [3] (the emotional intelligence scale) and CD-RISC [4] (the mental elasticity scale of Schuttle, an American psychologist are applied to this study). The study is conducted in 6 universities of Henan, using sojump.com, an online questionnaire app and random sampling method. The information of the demography variables is the most important part of this study, including their age, gender, politics status, single parent, the schooling of their parents, the income of the family, the sum of consumption per month, the award-winning experience in the university, the relationship with the opposite sex and the question whether they took charge of any important events.

This scale has a very good effect and reliability among the college and secondary school students and the juvenile offenders.

1.3 Statistic Analysis

All the figures are analyzed and disposed by SPSS (a statistical analysis software) and the multiple regression. This study fills the figures that are left out in the emotional intelligence variable. The expectation maximization in the SPSS is used in the results of all the variables including their average, covariance and the correlation index.

Table 1 The statistics of the influence of gender on their emotional intelligence and mental elasticity ($M \pm \text{SD}$)

Gender	Number	Emotional intelligence	Tenacity	Power	Optimism	Mental elasticity
M	44	122.3 ± 2.78	40.1 ± 7.74	28.8 ± 4.69	14.0 ± 3.10	82.91 ± 4.59
F	48	117.9 ± 9.32	37.2 ± 9.29	27.7 ± 5.89	14.4 ± 3.13	79.2 ± 17.74
Total	92	120.1 ± 6.57	38.5 ± 8.66	28.2 ± 5.36	14.2 ± 3.11	80.9 ± 6.33

2 Result

2.1 *The Influence of the Basic Information on Emotional Intelligence and Mental Elasticity*

By disposing the influence of their gender, whether they have single parent and whether they are single child of the family on the emotional intelligence and mental elasticity, the result is shown in Tables 1 and 2.

2.2 *The Influence of the Family Condition on Their Emotional Intelligence and the Mental Elasticity*

By disposing the influence of the schooling of their parents, the income of the family and the sum of consumption per month on their emotional intelligence and the mental elasticity, the results are shown in Table 3.

Table 2 The statistics of the influence of single and non-single child on their emotional intelligence and mental elasticity ($M \pm \text{SD}$)

Single child		Emotional intelligence	Tenacity	Power	Optimism	Mental elasticity
Single child	Average	121.79	38.74	28.13	14.56	81.44
	N	39	39	39	39	39
	Standard deviation	9.948	8.261	5.197	2.954	15.352
	Variance	98.957	68.248	27.009	8.726	235.673
Non-single child	Average	118.74	38.42	28.32	13.96	80.62
	N	53	53	53	53	53
	Standard deviation	20.108	9.022	5.522	3.222	17.147
	Variance	404.313	81.401	30.491	10.383	294.009
Total	Average	120.03	38.55	28.24	14.22	80.97
	N	92	92	92	92	92
	Standard deviation	16.573	8.663	5.358	3.109	16.327
	Variance	274.669	75.041	28.711	9.667	266.581

Table 3 The statistics of the influence of personal factors on their emotional intelligence and the mental elasticity ($M \pm$ SD)

Items	Patterns	Number	Emotional intelligence	Tenacity	Power	Optimism	Mental elasticity
Schooling of their parents	College	17	120.00 ± 16.31	37.88 ± 8.90	29.53 ± 5.01	14.00 ± 2.66	81.41 ± 15.32
	High school	43	118.74 ± 20.37	39.65 ± 9.41	28.60 ± 5.79	14.51 ± 3.38	82.67 ± 18.01
	Primary school	32	121.78 ± 10.06	37.44 ± 7.48	27.06 ± 4.83	13.94 ± 2.99	78.44 ± 2.99
	Total	92	120.03 ± 16.57	38.55 ± 8.66	28.24 ± 5.35	14.22 ± 3.10	80.97 ± 16.33
The family income	>120,000	25	126.16 ± 9.72	40.60 ± 6.79	29.80 ± 4.34	15.08 ± 2.43	85.48 ± 12.64
	60,000	49	118.47 ± 18.92	38.39 ± .15	27.80 ± 5.60	14.35 ± 3.32	80.45 ± 17.37
	<30,000	18	115.78 ± 15.62	36.17 ± 9.37	27.28 ± 5.74	12.67 ± 2.93	76.11 ± 17.11
	Total	92	120.03 ± 16.57	38.55 ± 8.66	28.24 ± 5.35	14.22 ± 3.10	80.97 ± 16.33
The sum of consumption	>3000 RMB	32	124.31 ± 10.12	41.19 ± 7.39	29.13 ± 5.42	15.09 ± 2.95	85.41 ± 14.82
	1500 RMB	48	116.79 ± 20.41	36.54 ± 9.29	27.44 ± 5.64	13.79 ± 3.21	77.69 ± 17.56
	<1000 RMB	12	121.58 ± 10.10	39.58 ± 7.63	29.08 ± 3.52	13.58 ± 2.77	82.25 ± 12.74
	Total	92	120.03 ± 16.57	38.55 ± 8.66	28.24 ± 5.35	14.22 ± 3.11	80.97 ± 16.33

Table 4 The statistics of the influence of personal factors on their emotional intelligence and the mental elasticity ($M \pm SD$)

Items	Patterns	Number	Emotional intelligence	Tenacity	Power	Optimism	Mental elasticity
Key staff	Once	47	122.4 ± 10.16	39.45 ± 8.09	28.8 ± 4.64	14.6 ± 2.86	82.8 ± 14.59
	None	45	117.6 ± 21.16	37.6 ± 9.22	27.7 ± 6.03	13.8 ± 3.34	79.0 ± 17.93
	Total	92	120.0 ± 16.57	38.6 ± 8.66	28.2 ± 5.36	14.2 ± 3.11	80.9 ± 16.33
Interpersonal condition	Widely	54	124.7 ± 8.35	41.6 ± 7.16	29.9 ± 4.23	14.9 ± 2.67	86.6 ± 12.94
	Few	36	114.8 ± 21.99	34.8 ± 8.69	26.0 ± 5.80	13.4 ± 3.29	74.0 ± 17.28
	None	2	89.5 ± 19.09	24.0 ± 2.83	22.5 ± 9.19	8.5 ± 0.71	55.0 ± 12.73
	Total	92	120.0 ± 16.57	38.5 ± 8.66	28.2 ± 5.36	14.2 ± 3.11	80.9 ± 16.33
Award-winning	Many	27	122.9 ± 6.98	42.0 ± 6.99	29.6 ± 4.06	15.3 ± 2.415	86.9 ± 12.22
	Few	49	118.4 ± 20.23	37.5 ± 9.39	27.7 ± 5.99	14.1 ± 3.15	79.1 ± 18.11
	None	16	120.1 ± 15.76	36.1 ± 7.45	27.6 ± 5.06	12.9 ± 3.56	76.5 ± 14.55
	Total	92	120.0 ± 16.57	38.6 ± 8.66	28.2 ± 5.36	14.2 ± 3.11	80.9 ± 16.33
The opposite sex friend	Many	29	124.7 ± 8.12	43.1 ± 6.945	30.3 ± 4.09	15.5 ± 3.02	88.9 ± 13.11
	Few	59	118.8 ± 18.57	36.7 ± 8.53	27.4 ± 5.62	13.8 ± 2.91	77.8 ± 16.33
	None	4	104.0 ± 21.49	32.7 ± 10.31	25.3 ± 6.24	12.0 ± 4.24	70.0 ± 19.09
	Total	92	120.0 ± 16.57	38.6 ± 8.66	28.2 ± 5.36	14.2 ± 3.11	80.9 ± 16.33
Participation	Strong	62	123.0 ± 8.46	40.2 ± 7.93	29.2 ± 4.32	15.1 ± 2.54	84.5 ± 13.69
	Weak	30	113.8 ± 25.54	35.2 ± 9.28	26.2 ± 6.65	12.4 ± 3.42	73.7 ± 18.98
	Total	92	120.0 ± 16.57	38.6 ± 8.66	28.2 ± 5.36	14.2 ± 3.11	80.9 ± 16.33

2.3 The Influence of Personal Factors on the Emotional Intelligence and the Mental Elasticity

By analyzing the personal factors such as whether they are key staffs, the interpersonal condition, the award-winning experiences, whether they took charge of any important events, the relationship with the opposite sex, whether they have a sweetheart friend, whether they have joined the students union or some organizations like that, the results of the influence on the emotional intelligence and mental elasticity are shown in Table 4.

3 Conclusion

According to the survey, there is a correlation and significance between the every aspect of the demographic variables and the emotional intelligence and the mental elasticity. The exact figures are shown in Table 5.

Above 0.001, there is a clear correlation between the emotional intelligence and the mental elasticity [5]. The higher the emotional intelligence is, the better the mental elasticity is. Those who have a higher emotional intelligence are more likely to have the ability to control and adjust their self mood and have a stronger endurance capability and frustration resistance. The two aspects have a mutual impact on one another. Therefore, the conclusion is that the higher they have the emotional intelligence, the better their mental elasticity is.

The nationality, the interpersonal relationship and the extent of participation of undergraduates are obviously related to their emotional intelligence and the mental elasticity. The better their interpersonal relationship is, the higher their emotional intelligence and the mental elasticity are. No one can live without others. Only by communicating with others better can one develop a stronger viability. Those with autism have a bad interpersonal relationship and have a lower frustration resistance. They cannot deal with the external stimulation, so their emotional intelligence and the mental elasticity are lower. On the contrary, those with a better interpersonal relationship have a higher intelligence and mental elasticity.

The more active their participation is, the higher their emotional intelligence and the mental elasticity are [6]. The experience of having once took charge of some important events is clearly related to their tenacity ($p = 0.05$). The better they get along well with the opposite sex, the higher their emotional intelligence and the mental elasticity are. Their award-winning experience is related to their optimism. It is an effective way to develop their ability to adapt to society and to improve themselves by the participation. The more they took part in the activities, the more they got in touch with others, the higher their emotional intelligence and the mental elasticity are.

Table 5 The correlation between the demographic variables and the emotional intelligence and the mental elasticity

Factors		Emotional intelligence	Tenacity	Power	Optimism	Mental elasticity
Nationality	Pearson correlation	−0.498	−0.367	−0.387	−0.310	−0.395
	Significance (bilateral)	0.000	0.000	0.000	0.003	0.000
Family income	Pearson correlation	−0.223	−0.175	−0.169	−0.256	-0.197^{b}
	Significance (bilateral)	0.033	0.096	0.107	0.014	0.059
Interpersonal relationship	Pearson correlation	−0.382	−0.458	−0.393	−0.344	−0.440
	Significance (bilateral)	0.000	0.000	0.000	0.001	0.000
Award-winning experience	Pearson correlation	−0.076	−0.251	−0.147	−0.264	−0.232
	Significance (bilateral)	0.471	0.016	0.163	0.011	0.026
Key staff	Pearson correlation	−0.100	−0.324	−0.219	−0.206	−0.283
	Significance (bilateral)	0.341	0.002	0.036	0.048	0.006
Opposite sex	Pearson correlation	−0.247	−0.367	−0.275	-0.300^{b}	−0.343
	Significance (bilateral)	0.017	0.000	0.008	0.004	0.001
Sweetheart	Pearson correlation	−0.160	−0.236	−0.210	−0.376	−0.269
	Significance (bilateral)	0.126	0.023	0.044	0.000	0.010
Participation	Pearson correlation	−0.262	-0.268^{b}	−0.271	−0.409	−0.313
	Significance (bilateral)	0.012	0.010	0.009	0.000	0.002
Emotional intelligence	Pearson correlation	1	0.699	0.722	0.667^{a}	0.754
	Significance (bilateral)		0.000	0.000	0.000	0.000

Note **a** The every aspect of the demographic variables has a great impact on the emotional intelligence and the mental elasticity **b** The higher the emotional intelligence is, the better the mental elasticity is

Compliance with Ethical Standards The study was approved by the Logistics Department for Civilian Ethics Committee of Air Defense Forces Academy.

All subjects who participated in the experiment were provided with and signed an informed consent form.

All relevant ethical safeguards have been met with regard to subject protection.

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The Effects of the Micro-Expression Training on Empathy in Patients with Schizophrenia

Xueling Zhang, Lei Chen, Zhibing Zhong, Huajie Sui and Xunbing Shen

Abstract *Object* Studies have shown that patients with schizophrenia had impaired in empathy, which is important during social interaction. How to improve the empathy of schizophrenia patients was of practical significance. This study used micro-expression training tool to improve the empathy in patients with schizophrenia. *Methods* Experimental group consisted of 24 patients (10 females), who accepted a completely micro-expression training for 4 times, once a week, each training last for 1–1.5 h, and the control group consisted of 22 patients (10 females), who merely watched the teaching videos about facial expression for 4 times, each time last for half an hour; and the third group, acted as a baseline, consisted of 22 patients (10 females), who were not given any intervention. The scores of empathy at pre-training and post-training were measured by Interpersonal Reactivity Index (IRI). *Results* The empathy of experimental group and control group I had improved, which suggested the training of micro-expression recognition could improve empathy in patients with schizophrenia.

Keywords Micro-expression training tool · Schizophrenia · Empathy

1 Introduction

Empathy is the understanding and sharing of emotions of others, which is important during social interaction and is closely related to social function [1]. Empathy defects can result in impaired interpersonal and social function in patients. Cohen et al. [2] proposed that empathy consisted of two aspects, i.e., cognitive empathy and affective empathy. Accordingly, to improve empathy means to improve the recognition and understanding of emotions of others.

Bora et al. [3] found that patients with schizophrenia have deficits in empathy. Montg et al. [4] also found that the cognitive empathy in schizophrenic patients was

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significantly worse than that of normal subjects, and the emotional empathy, however, was equal to that of normal subjects. Dirndl et al. [5] proposed that the both emotional empathy and cognitive empathy in schizophrenic patients had impaired. Meanwhile, the impaired empathy resulted in the defects in facial expression recognition [6–8].

Ekman et al. [9] discovered the fleeting micro-expression and developed a Micro-expression Training Tool (METT) in 2002. Russell et al. [10] used this tool to investigate the effects of training on the ability of emotion recognition in patients with schizophrenia. The result showed that the ability to recognize micro-expression in both schizophrenic patients and normal control group improved after training.

Based on the aforementioned studies, we hypothesize that the micro-expression training can improve the empathy for schizophrenic patients. The current study aimed to test the effectiveness of METT for improving the empathy of patients with schizophrenia.

2 Materials and Methods

Patients during the recovery period in Jiangxi Mental Hospital participated in the experiment, and the inclusion criteria were: (1) Who met the diagnostic standard of schizophrenia of the Diagnostic and Statistical Manual of Mental Disorders Fifth Edition (DSM-V); (2) who was in the period of recovering, had good comprehension, and could perform related tests; and (3) who volunteered to participate in and signed the informed consent with the family members accompanying. The exclusion criteria were: (1) The patients' condition was not stable and who was in the acute period; (2) those had severe visual or hearing impairment; and (3) who could not complete the experiment. A total of 68 patients were selected.

2.1 Participants

Sixty-eight patients were randomly divided into experimental group 24 (male 14, female 10, age 29.50 ± 11.67 year), who accepted a complete training by using Micro-expression training tool, total 4 times, once a week, each time last for 1–1.5 h; the control group I consisted of 22 patients (male 12, female 10, age 28.09 ± 7.53 year), who merely watched the teaching videos of facial expression recognition, total 4 times, each time last half an hour; and control group II consisted of 22 patients (male 12, female 10, age 27.36 ± 9.53 year), who did not accept any intervention.

2.2 Training Tool

The Chinese version of Micro-expression Training Tool (MEET) was used, which is based on the Ekman's METT. The Chinese version METT is divided into 5 parts: the pretest (used to measure the baseline of ability to recognize facial expressions), training (teaching videos of facial expression recognition), practice (exercise of micro-expression recognition with feedback), review (more detailed teaching videos of facial expression recognition), and posttest (used to measure the micro-expression recognition ability after the training). There were eight labels of options: anger, disgust, fear, surprise, happiness, sadness, neutral, and other (not in the options). There were 3 sub-parts in the pretest: recognizing static facial expression, recognizing artificial micro-expression, and recognizing micro-expression videos. There were 2 sub-parts in the posttest, namely recognizing artificial micro-expression and recognizing micro-expression videos (the pictures of facial expression and videos were totally different from those in pretest). The accuracies were reported by the software at the end of each sub-part.

2.3 Measurement Tool

The Chinese version of Interpersonal Reactivity Index (IRI) was used, which compiled by Davis [11]. IRI had 28 items which included four factors: perspective taking (PT), personal distress (PD), empathy concern (EC), and fantasy (FS). The perspective taking was designed to measure cognitive empathy, and the other three factors were used to measure emotional empathy. The scale had high reliability and validity, the internal consistency of the sub-scales was between 0.71 and 0.77, and the test–retest reliability was between 0.62 and 0.80. The scale also had ideal discriminant and convergent validity. The score of empathy at pre-training and post-training was measured by IRI.

2.4 Procedure

With the permit of the director of the department, the participants had been debriefed by the experimenter. The participants of experimental group independently accomplished METT training on a computer. There was a break of 5 min after each part. IRI was firstly carried out before the training and was re-tested after training for 4 times. The participants of control group I merely watched the teaching videos of expression recognition which were played by the experimenter. Empathy score was measured by IRI at the beginning and end of video watching. The participants of control group II got no intervention, and the IRI carried out at the same time of experimental (only took the IRI test, but did nothing).

3 Result

3.1 Demographic Data

The demographic characteristic was not different among the three groups (see Table 1).

3.2 The In-group Changes of Empathy

The paired sample t test was used to analyze the gain scores of empathy for each group. The results showed that there was no significant difference in the experimental group. There was, however, a significant difference in the control group I and control group II (see Table 2).

3.3 The Inter-group Changes of Empathy

The gains in empathy scores were subjected to a one-way ANOVA. The result showed that there was a significant difference ($F = 4.878$, $p = 0.011$, see Fig. 1). A post hoc analysis of the means of three groups found that there was no significant difference in the paired comparison of experimental group and the control group II, However, there was a significant difference in the paired comparison of experimental group and the control group I ($p = 0.015$).

Table 1 Demographic data of each group ($M \pm$ SD)

Category	Exp. group ($n = 24$)	Cont. group I ($n = 22$)	Cont. group II ($n = 22$)
Age	29.50 ± 11.67	28.09 ± 7.53	27.36 ± 9.53
Duration of illness (M)	64.00 ± 106.48	37.682 ± 42.09	41.46 ± 68.24
Years of education (Y)	10.58 ± 2.81	12.23 ± 3.28	12.05 ± 3.17

Table 2 In-group comparison of empathy in each group ($M \pm$ SD)

Category	Pretest scores	Posttest scores	t	p
Experimental group	22.79 ± 12.84	25.58 ± 11.01	1.32	0.20
Control group I	17.41 ± 11.30	21.46 ± 12.79	2.17	0.04
Control group II	25.05 ± 11.09	21.00 ± 11.89	−2.22	0.03

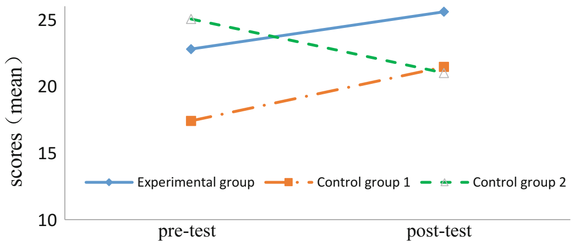

Fig. 1 The interaction of group and test time. Each point represents the mean empathy scores

4 Discussion

In this study, the experimental group accepted complete training of micro-expression recognition, the control group I only watched the expression recognition teaching videos, and there was no intervention for control group II. The results showed there was no difference between pre- and post-training for the experimental group. There was, however, a significant difference in the gain score of pre- and posttest for the control group I. As shown in Fig. 1, the empathy of both experimental group and control group 1 was improved (although the gain score of the experimental group was not significant). The results of inter-group comparison found there was a significant difference in the paired comparison of experimental group and the control group I.

The results suggested that Micro-expression training tool could improve empathy for patients with schizophrenia. The significant difference in the control group 1 implied that simple facial expression recognition training could improve empathy of schizophrenia. The cause of the nonsignificant result in the gain score of the experimental group needed to be explored further. The sample size might play a role in explaining these results.

5 Conclusions

In summary, the current study had used Micro-expression training tool to improve the empathy of schizophrenia patient. The results showed that the micro-expression training could enhance empathy. The research provided insights about how to improve the empathy and social function for patients with schizophrenia.

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Compliance with Ethical Standards The current study was approved by the Institutional Review Board of Jiangxi University of Traditional Chinese Medicine. The methods were carried out in accordance with the approved guidelines.

All subjects who participated in the experiment had given written informed consent before participating and had no problems in understanding consent-related issues.

All relevant ethical safeguards have been met regarding subject protection.

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The Mechanism of Human Error and Defense Strategies of Astronaut Manual Rendezvous and Docking

Jiayi Cai, Weifen Huang, Jie Li, Liping Tian, Yanlei Wang and Zhi Yao

Abstract Astronaut manual rendezvous and docking mission is a complicated systematic project, the astronauts undergo cognitive, decision-making, and implementation stages while on duty. According to the theory of human error, three cognitive stages will be a corresponding error mode. By analyzing the astronaut manual rendezvous and docking mechanism of human error, the current astronaut's errors were classified in manual rendezvous and docking. The barrier levels were analyzed, and multiple human errors' defense strategy of astronaut manual rendezvous and docking was proposed.

Keywords Astronaut · Rendezvous and docking · Human error · Human error classification · Defense strategy

1 Preface

With the development of technology, human needs the help and cooperation from the machine to solve many engineering problems, design problems, and even science problems. Human, machine, and environment form a complicated system. As the behavior subject in the system, human is the key factor deciding mission success. Reported by relevant data, about 85% of the accidents in the industrial enterprises in the present world were directly or indirectly caused by human errors [1]; thus, the subject of human error became one of the key problems researched by people.

Experts gave different definitions from various aspects for the human error. From the psychological view, Jam Reason, the psychologist of University of Manchester

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of UK defined the human error as the phenomena that although a series of planned psychology or body activities were made by people, the anticipated result was not achieved, and the failure was not caused by the interference of some external reasons [2]. From the engineering view, Swain, the cognitive scientist, defined the human error as any human behavior or action exceeding a certain acceptance criterion or the acceptance criterion ruled by normal work or the allowable range [3].

Chinese scholar Li Zhang defined human error as the failure of the planned action carried out by people to complete the mission under the condition that not exceed the design function of the human–machine system, it includes the error of individual, group, and organization [4]. Indicated by the above definitions, the human error composed of the following three factors: human action, it is not carried out as planned during action, and the result of the action exceeded the specified criteria or requirement.

During the process of the astronaut manual rendezvous and docking process, the astronaut was in two airship systems, and it needed the camera installed outside the airship to take photographs to judge the corresponding positions and postures of the two spacecraft, and operate the manual controller for controlling the rendezvous and docking. In this way, the manual rendezvous and docking formed a typical human-in-the-loop complicated control system, as shown in Fig. 1 [5]. During these operating processes, the astronaut's psychological and physical factors and operating strategy, etc., would cause a series of human errors which then failed the mission.

The study showed that the human error could not be completely eliminated; we could only try to minimize it in maximum. To effectively reduce the probability of the human errors during the astronaut manual rendezvous and docking, the human errors must be classified to analyze the different mechanisms and then propose the corresponding prevention measures.

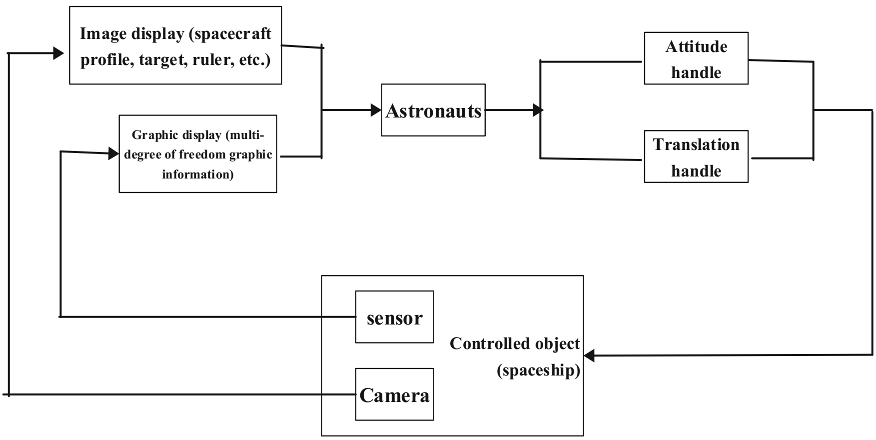

Fig. 1 Diagram of the control loop of manual rendezvous and docking [5]

2 Study and Classification Method of Human Error

According to the viewpoints of the behavioristic psychology, the human behavior patterns could be expressed as S-O-R (stimulation–organism–reaction) [6], which was a continuous circulating process. If the three stages were successfully carried out, the individual could completely perceive the outside information and make a right decision and take reasonable action to complete the mission, or else, if wrongly perceiving the outside information, failing in thinking judgment or the action was blocked, the mission might be caused to fail.

To the three aspects, Whitson boiled the reasons for human error down to overload, wrong decision, and ergonomics. Overload meant the bearing ability of people under a psychological status was not adaptive to the load which included the physical load and psychological load. The human ability meant the body. Physical and psychological bearing abilities (the human's natural quality), the current psychological status, the knowledge and technology level relevant to the current work, and the temporary ability decrease caused by taking medicine or alcohol, pressure, or fatigue. The wrong decision meant under some conditions, the unsafe behavior chosen by the executor was more logical than choosing the safe behavior. The ergonomics mainly comprised of two aspects: The current work condition and his physique were not matched, and the work platform was designed to easily cause people's error [7].

It was a qualitative study method in the human error study by carrying out classification analysis to the human error in the system, and during the analysis, the retrospective classification analysis means were used to get the processing and avoiding measures of human error, which were more specific and targeted. The current classification theory for human error mainly composed of four models, i.e., Swain's classification method [3], Norman's classification method, Rasmussen's classification method, and Reason's classification method [8–12].

The Swain classification method was the early classification method as well as the one proposed for people's execution results. He believed the human error behavior might have the following conditions: incorrectly doing something; failing in completing a mission (failing in execution); or not doing something in time, etc. Based on above, he further divided human error into the error of carrying out (EOC) and the error of omission (EOO). Currently, the classification method was widely applied for the reliability analysis of people in the nuclear industry field, but the key focus point was EOO. The classification method did not study the error mechanism but was only used for the preliminary classification of the error.

The Norman classification method believed the error or the action error might occur at any stage. It tended to study the psychological factor hidden behind the error behavior. Targeting to the human behavior and the psychological factor behind during the human–machine interaction process, Norman divided it into seven stages: (1) establishing the target, (2) form the intention, (3) action description, (4) action execution, (5) understanding of system status, (6) explaining the system status, and (7) assess the system status according to the target and intention. Norman divided specific speech error into three classes according to the psychological factor for generation: (1) formation error of intention, (2) the schema structure was falsely activated, and (3) improper false triggering and confusion was generated to the schema structure in the activation status. Based on the schema psychological model, Norman explained the speech error by the activation trigger schema system (ATS) model and pointed out the classification theory could be applied to the other fields.

The Rasmussen classification method was mainly used for describing the human's cognitive behavior process. According to the cognitive psychology theory, Jens Rasmussen (Risoe-National Laboratory, Denmark) classified human's cognitive behaviors, and with the three information input ways of signal, sign, and symbol, he characterized human's cognitive activities into the skill-based type, the rule-based type, and the knowledge-based type. The skill-based cognitive behavior mode was the one that the operator could react almost without any thinking, and the mode was approximate to human's instinct. The rule-based cognitive behavior was the one that the operator had to choose a certain rule and carry out the mission as required by the rule. The knowledge-based cognitive behavior was the one that the operator needed to analyze, decide, and execute by depending on the operator's knowledge and experience. The human error was influenced by the operator's technology level, experience, and familiarity to the working environment. The classes of human errors generated on every cognitive behavior level were different. Rasmussen deeply discussed the human error and formed the error classification method based on the SRK model.

The error classification method based on psychology mainly considered the relationship between human behavior and intention. Based on Rasmussen's SRK model, Reason proposed a concept classification method which divided human error into slip, lapse, and mistake.

Reason's human error theory divided people's cognition of mission into three stages which mainly comprised of planning, storage, and execution. Planning meant the target was clear and a series of action sequences had been selected for realizing the target. Storage meant the selected plan was stored in the memory until executed at the proper time. Execution meant the plan was executed by executing the behavior process ruled by the plan. There were corresponding error modes in the three cognitive stages. Generally, slip occurred in execution, and was the error in execution of the formed plan. Lapse occurred in storage and was the omission or error occurred in the plan or plan storage. The mistake occurred in the planned process and the designated plan was not proper for completing the target mission [13, 14].

The slip and lapse often occurred in the execution of the skill operation of the SRK model and were mainly caused by people's loss of attention or the high automatic nature of the working environment. The mistake was often hidden and could not be discovered easily or restored within a short time. When encountering the information which was not compatible with the formed judgment or concept, people often would refuse and insist on the former opinion or decision; thus, the restoration way of the mistake was hard, and efforts should be given for prevention.

To further analyze the mechanism of error, based on the SRK model, Reason established the GEMS (Generic Error-Modeling System) model. Same as the SRK model, the GEMS model divided human's cognitive level into the skill-based (SB) type, the rule-based (RB) type, and the knowledge-based (KB) type. The error might occur at any stage, and slip and lapse often occurred in the execution of the skill-based action and were mainly caused by people's loss of attention or the high automatic nature of the working environment. The mistake was often hidden and could not be discovered easily. Selecting improper rule was the main reason causing the mistake of the rule-based cognitive level. The mistake of the knowledge-based cognitive level was mainly caused by inaccurate or uncompleted understanding of the system, deviation confirmation, overconfidence, mental fatigue, etc. [15].

The frequencies of the errors of the three types (SB, RB, and KB) were generally as follows: SB $\gg$ RB > KB. The probability of SB error was about 67% as well as 27 and 11%, respectively, for RB and KB. The statistic result was mainly generated by people executed more SB missions than RB and KB missions, but when individually executing the KB mission, the people's error probability was higher than those of SB and RB [15].

With the comparison of the above four classification methods, we could clearly find out the study on the classification method for human error was gradually developed from the simple execution behavior classification to the classification of the cognitive process analysis and focused on extending to the generation mechanism of human error.

3 Classification and Analysis of Human Errors of Astronaut Manual Rendezvous and Docking

Currently, the astronaut mainly executed the manual rendezvous and docking mission on the near-earth orbit and compared with the ground engineering mission, the requirements for the safety and success of mission completion were higher. Before the astronaut's flight, flight manuals were made for all items to be operated and specified the flow for executing the rendezvous and docking flow, etc., the group and organization error occurred in the astronaut's manual rendezvous and docking were not the key study points of the paper, we mainly analyzed the classification of the human error from the astronaut's individual angle.

The manual rendezvous and docking mission executed by the astronaut was same as the other targeted production activities carried out by human and often needed to experience three stages as follows: (1) perceiving stage, (2) decision stage, and (3) execution stage. The image recognition, human decision, and operation handle work were carried out. Combined with Rasmussen's and Reason's classification methods, the main errors occurred in perceiving, decision, and operation processes of the astronaut's manual rendezvous and docking were analyzed.

During the perceiving process, the astronaut might easily have slip and lapse which were mainly caused the information loss or omission generated by the loss of attention in the image information input process. Most of the astronaut's errors generated in the manual decision process were mistakes. The decision error was mainly caused the astronaut selected wrong rules in image identification and operation decision processes. The decision error mainly comprised of the space direction judgment error and the rule application error. In the process of operating the handle, the main errors generated by the astronaut were slip and lapse. The handle operation error meant the astronaut had made the corrective decision in the manual decision process, however, errors occurred in the process of executing the formed plan, and then, the operation error was caused. The handle operation error mainly comprised of the errors of operating direction, operating amount, and selection of operation handle, etc. The classification diagram of the errors of the astronaut's manual rendezvous and docking is shown in Fig. 2.

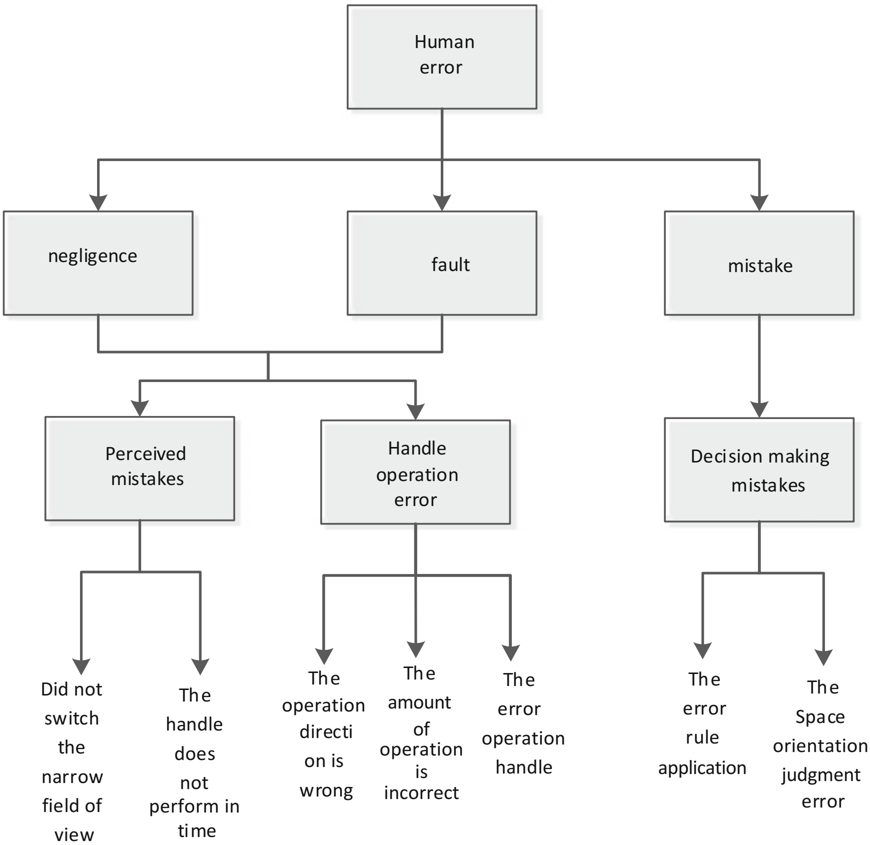

Fig. 2 Classification of the errors of the astronaut's manual rendezvous and docking

Indicated by Fig. 2, it belonged to the error type of the human error when the decision error was caused by rule application error and space and direction judgment error, which was the key point of our study. The decision error was further analyzed.

In the manual rendezvous and docking mission, the astronaut mainly realized the manual rendezvous and docking of the two airships by a plurality of times of handle operation. Every operation included the processes of cognition, decision, and operation, i.e., judgment of the relative space and direction relationship of two airships, decision of handle operation, and implementation of the actual operating action; thus, the mission type was mainly between the RB and KB mission types. The mission firstly perceived the image information, which belonged to the skill mission, and the main errors were slip and lapse. There were two ways for further processing the image information, one could be completed in the rule-based cognitive level, such as the behavior of switching the field of view, when it was judged that the distance between the targeted aerocraft to the airship was smaller than a certain distance, the narrow field of view was switched, and the other one was completed under the knowledge-based cognitive level, it needed the astronaut to judge the space position relationship by images, carry out the decision of the required operation, rapidly form the operation plan in brain, then combine with the operation rules saved in brain by training, and then form the actual handle control operation. Based on Reason's error mechanism model, we analyzed the classification of the human error of the astronaut manual rendezvous and docking was shown as Fig. 3. The analysis and classification of the human error of the manual rendezvous and docking could be the basis for us to make the corresponding barrier and prevention measures.

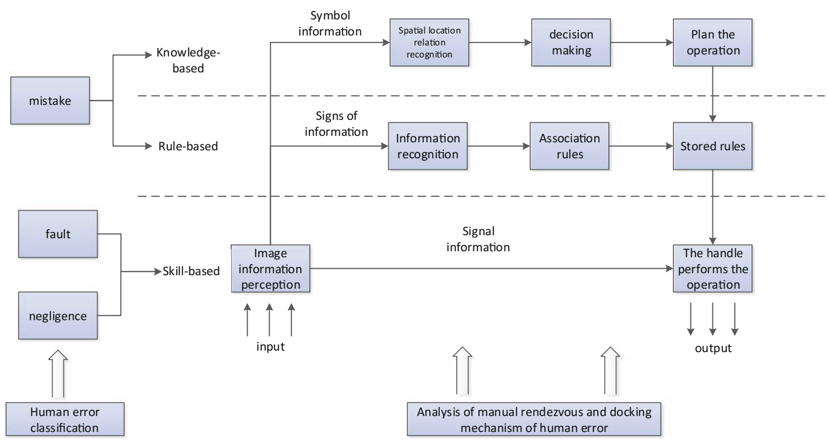

Fig. 3 Diagram for the classification of the astronaut's manual rendezvous and docking error

4 Barrier Analysis and Prevention Measures of Astronaut Manual Rendezvous and Docking [16]

Must disastrous consequence occur once there was human error in the system? No, because there were many barriers set in the modern great system to prevent the harms caused by human error. The barrier was the means for protecting the equipment performance and improving people's safety and could be physical or administrative. The barrier was set to prevent human error or relieving the consequence caused by human error. The barrier analysis was mainly used for us to know how to analyze the barrier and find out which barrier was not useful and why the problem occurred when the human error occurred.

The modern defense technology needed the barrier running experience for feedback so as to provide useful information or suggestion for reinforcing the defense. Not all human errors would cause the disastrous consequence, because multiple barriers were set on the key parts of many systems. The failure of one barrier generally would not cause the severe consequence. The disastrous consequence was often caused by multiple barriers of the accident chain that were invalid. Suppose only one barrier was effective, the barrier would prevent the error or relieve the consequence caused by the error. The defect or bug of the safety barrier could be found out through the barrier analysis so as to provide an effective improvement method, and the system safety performance could be improved by adding a new barrier or modifying the original barrier.

The typical barriers were the physical type and the administrative type, wherein the physical barrier mainly composed of all types of sound or optical alarming signals, safety protection equipment, etc., and the administrative barrier mainly composed of personnel training and education, qualification and personnel appointment, management rules, communication way of working staff, personnel authorization, personnel mutual monitoring, etc.

The astronaut manual rendezvous and docking was an extremely big system behavior and depended on not only the astronaut's personal psychological and physical qualities and personal technology and cognitive level but also the whole astronaut selecting and training system, and the astronaut on-orbit risk and safety assessment system were running. The following was the barrier analysis figure carried out according to the astronaut's actual running mode (Fig. 4).

5 Prevention Strategy for the Human Error During Astronaut Manual Rendezvous and Docking [6]

After the above analysis, to reduce the human error accidents of the astronaut on-orbit manual rendezvous and docking and improve human reliability, the following measures could be taken to reduce the astronaut's unsafe behaviors and decrease the error rate.

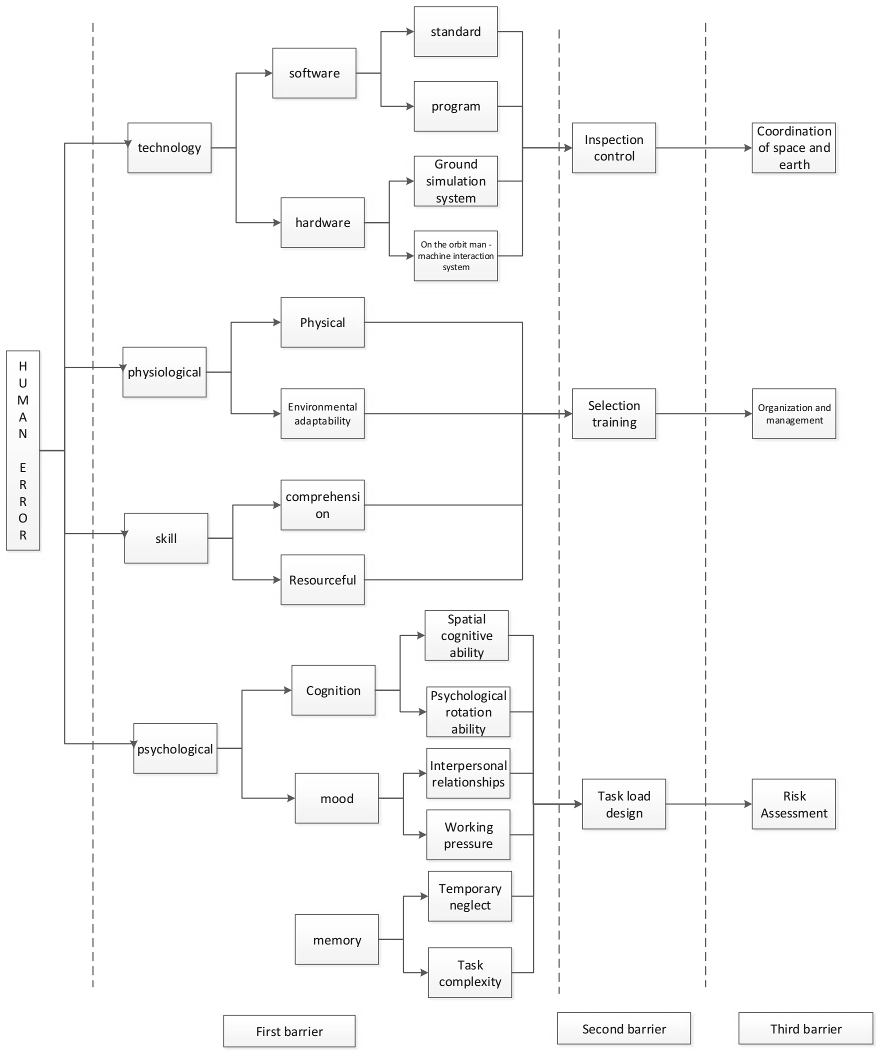

Fig. 4 Step analysis of the barrier of the astronaut manual rendezvous and docking mission

1. Perfect the human–machine interaction system. The human–machine–environment was a completed system, and its whole reliability was very closely relevant to the optimization condition of their mutual intersection. Started by taking people as the center and from the human's physical, psychological, and spiritual characteristics, the safety level and operability of the system were examined from the system height. The docking safety facilities, such as the warning lamps,

safety lock, could be improved and added to improve the human–machine interface status and environmental factor so as to improve the system reliability.

2. Perfect the astronaut's selecting system. Carried out personality test, psychological quality test, cognition test, physical test, etc., to the astronaut to ensure the selected astronaut could meet the requirements on successfully completing the rendezvous and docking mission in the spatial specific environmental factor.
3. Perfect the astronaut's training system. The effect of the training on the astronaut manual rendezvous and docking was directly relevant to the astronaut's ability for executing the mission. The training system of the astronaut ground manual rendezvous and docking and the training method should be studied, and the training efficiency should be increased by the means of teaching, practice, training, etc., so as to relieve the influence of the spatial overload on the astronaut and lower the human error rate. The astronaut's abilities for judging, predicting, and processing in the accident and emergency should be improved so as to essentially reduce the human unsafe behaviors and reduce or avoid human error events and safety accidents.
4. Perfect the astronaut's work load design. Influenced by space weightlessness, radiation, and other factors, the astronaut had high space work load. The astronaut's work mission flow and load condition should be reasonably arranged in every mission period as well as the astronaut's time table so as to ensure the astronaut's work ability for completing the mission.
5. Perfect the space and ground cooperation system. The success ratio on the astronaut for completing the on-orbit rendezvous and docking mission was required to be 100%. When the astronaut was in the ground experiment and on-orbit mission period, the perfected communication and feedback mechanism should be established. Errors should be analyzed and classified, and corrective actions should be taken to prevent the similar events from repeatedly occurring. In addition, the perfect astronaut on-orbit risk and safety assessment system should be established to combine the technology means, organization means, and standard culture means so as to construct the active human error accident defense system in depth from the processes and aspects of management decision, organization, technology, accident analysis and reduction, feedback, etc., actively discover and identify the possible human error accidents, and take effective measures to reduce and prevent. Because of the human complexity and our cognition limit, there were many difficulties to be emergently solved for analyzing the human error reliability, and further study was needed.

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Human-Perceived Quality in Rail Transit Vehicles

Haiyan Ding, Weibing Bao and Xiangfei Yu

Abstract Interior design for rail transit vehicles shall not only focus on the structure of components but also consider the ergonomic performance settling the organic connection of harmonic human–machine–environment system, to make the interior design satisfy the human physical and psychological needs, so that the environment for passengers and crew is safer and more comfortable. Ergonomic design begins with studies on drivers' and passengers' psychology, covering the sense of vision, hearing, smell and touch and combination thereof, which allows passengers to have great ride experience in a tidy, comfortable and wonderful environment inside the car.

Keywords Rail transit vehicle · Human perception · Ergonomics

1 Foreword

With the development of the railway industry in China, a new round of market competition will focus on speed to comfort. The design for rail transit vehicle shall not only be limited to the appearance and decoration of components, but also consider human perception, and the driving and riding environment, and study by focusing on users including passengers and crew members. Of course, studies shall examine people's response and adaptation to the physical factors in the environment, analyze the effects of light, sound, heat, vibration, dust and smell on human physiology, psychology and efficiency, and determine comfort and safety when passengers are staying and crew members are working onboard a vehicle.

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2 Comfort

2.1 Operating Comfort

From the point of people's subjective perception, the design inside the train shall ensure that components are operated in a comfortable manner by considering following:

(1) Whether the components are properly located and easily found;
(2) Whether the components are easily accessible and operating them is restricted or prevented;
(3) Whether markings of components are easily understood and seen clearly, quickly and easily; and
(4) Whether the space for operation is sufficient and the feedback of force is reasonable.

3D prototypes may be used during the design to define the reach of fingers, hands and arms for designers' reference. Some famous companies have established a driver simulation system by using motion capture software for animation design, so that engineers could capture people's motion more accurately and make virtual simulation design before developing more rational and ergonomic vehicles [1].

2.2 Riding Comfort

Components direct or indirect contact with human body, e.g., passengers' seats, driver's seat, driver's console and baggage holder, shall be assessed, including their static and dynamic operation and adjustment. The current analysis methods include some subjectivity assessments, such as CAE analysis (RAMSIS and comfort simulation software), pressure distribution testing and track testing. Based on the parameters from design experience, CAE computer analysis, repeated professional verification and third-party evaluation during development, a rational layout of luggage storage space shall be designed, tested and adjusted according to the seating capacity and the operating zone in order to develop comfortable seats and armrests, driver's control devices that can alleviate driving fatigue, passengers' comfortable zone with privacy being highlighted, and holders that allow luggage to be placed easily and securely.

3 Human Perception System

Ergonomics study means the design is done by considering human physiology, psychology and feeling, including vision, touch, hearing, facility comfortable and subjective perception. In order to distinguish it from the traditional factors, we call it "perceived quality" for the time being, as shown in Table 1.

3.1 Visual Perception

In order to observe, human eyes always sweep objects horizontally first and then vertically. The eyes are not likely fatigue when sweeping horizontally, which is also faster than sweeping vertically. Meanwhile, the dimensional estimate is far more accurate when they sweep horizontally other than vertically. Therefore, the sight window of electric instruments always makes a horizontal rectangle and instrument panels rotate clockwise [2]. All major display instruments are located within 3° from the center of vision, general ones within 20°–40° and minor ones within 40°–60°. Usually, instruments are not located beyond 80°, where human reading is very poor by eye. The color of data and diagrams shown on instruments shall be clear and noticeable with dark background in order to highlight the indication [2].

Human eyes are stimulated to sense different colors. Colors are matched for internal tone, information indication and marking indication by considering color deviation and visibility [3]: highly pure white for wallboard and ceiling, which looks neat and bright; highly saturate colors for fabrics, ornaments and markings, which highlight color layers, light up the in-car atmosphere, ease the longitudinal feeling, and increase the enjoyment.

Table 1 Human perception system in a rail car

Type	Stimulus	External featured identified	Functions
Vision	Outside the scenery, internal lighting, ambient tone	The colors of light and shade, the object shape size, location distance and reversion of motion, etc.	Identification and appreciation
Hearing	Noise, air pressure	Train running noise, atmospheric pressure inside the vehicle	Adjustment
Smell	Carried goods, food, smoking	Nature of volatile matters	Identification
Taste	Food onboard the train	Sour, sweet, bitter, peppery, etc.	Identification
Touch	Fabrics and armrests of seats, etc.	Feeling of materials, stressing, supporting	Identification
Feeling of in-depth balance	Seat cushion materials, luggage sets	Gravity, posture, placement	Adjustment

Fig. 1 Lighting inside Shinkansen trains

Seats are arranged longitudinally under the principle of “laid against the windows.” Decelerating glass is used for windows to avoid the sense of spinning. Hidden curtain is made rolling and pervious to light, which is small in size and resistant to pollution.

Spot, line and area lightings are all used in cars with different meaning: spot lighting guides the flow of passengers; line lighting is the major lighting; and area lighting works to create in-car atmosphere. This is true of Shinkansen, inside which different layers of lighting are created and the melody and order of ceiling patterns are added [4]. See Fig. 1.

3.2 Auditory Perception

Hearing is stimulated by sound waves. The range of frequency that can be heard by human ears is 20 Hz–20 kHz. Any sound more than 30 dB may disturb the sleeping brain wave, thus lowering the sleep quality; that more than 50 dB may affect people’s working efficiency; that more than 70 dB may disturb speech, making people upset and distracted, thus affecting their efficiency and in some cases, which may cause accidents; that more than 90 dB for a long time may affect hearing and even cause illnesses [5]. See Fig. 2.

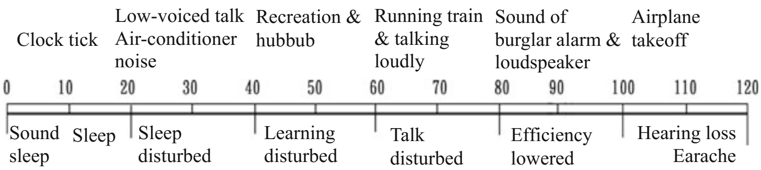

Fig. 2 Effects of noise on people

Unbearable noise is inevitably produced when the vehicle body contacts the air, the wheels contact the rails, and the pantograph contacts the lines during the train travels at a high speed [6]. The following measures are taken to reduce noise:

(1) Noise from the understructure of cars is reduced by employing light-weight body, elastic wheels and shockproof rubber mats;
(2) Noise from the superstructure of the vehicles is reduced by streamlining both front and rear, employing a drum shape, optimizing the shape of car bottom and bogie, improving the structure of pantograph and adding external windshields;
(3) Injecting foaming and loose materials, e.g., polyethylene and asbestos, into the materials of vehicle body to noise-proof, making car body air-tighter and maintaining temperature to reduce noise transmittance [7];
(4) Vibration-damping measures are taken for some components to prevent resonance or reserve some space to prevent noise produced by collision.

Apart from noise, alarming sound may be given when the train is traveling. Audible alarms are usually used together with visual signs, e.g., signal device and warning device [2]. Red spots flash on the display when the speakers give alarming sound to remind the driver.

3.3 Smelling Perception

Human beings have very good sensibility to smell and are able to identify even 2000–4000 different substances by smelling. As a means of public transport, the population density inside rail cars is always on the high side, so cars when in operation are always full of different odors, e.g., sweaty odor of passengers, odor from toilets and smell from food carried by passengers. It constitutes a great challenge for the central ventilation system in cars. Fresh air is drawn into the cars from the outside. As airflow is very weak and transverse diffusion of pollutants is very slow in cars, such pollutants are lifted by up flow into the overhead zone and finally emitted from the outlet on the ceiling, so that the air inside cars may keep clean all the time (as shown in Fig. 3). Airline meal shall be used for long distance trains, where cold food is heated to reduce emission of food smell. Smoking is prohibited in cars. Human perception of ambient air quality is usually measured according to the concentration of CO_2. The higher such concentration is, the more fatigue passengers may feel. See Table 2.

3.4 Touch Perception

The sense of touch is the same as that of vision. It is a main channel from which people have spatial information. The perception of touch in cars involves all

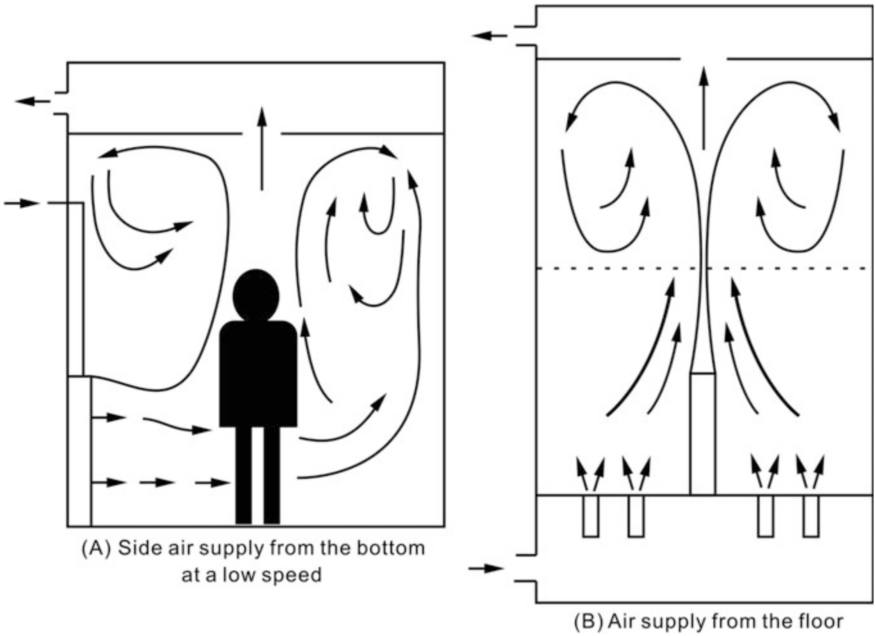

Fig. 3 Airflow inside the car

Table 2 Effect of CO_2 concentration on fatigue

CO_2 concentration (%)	Below 0.07	0.07–0.1	0.1–0.2	0.2–0.4	0.4–0.7
Rating	Good	So-so	Not good	Very bad	Terribly bad

accessible components, e.g., hardness, temperature, viscosity, smoothness and roughness of surface; trimming, parting line and sharp chamfer; response, feedback time, operating force and smoothness of buttons; and response of functional parts. The data for design are acquired by measuring frictional force, roughness, flexibility and temperature of in-car components with touch robot and comparing the measurement with feedback from passengers. Compared with human body, the resolution of a robot's perception is higher, so it can more accurately measure components' surface sense of touch to ensure materials are as expected by people. Comfortable feeling when touching materials can provide favorable psychological suggestion and convey some information of products in use, so they can improve usability and comfort of products to people.

4 Conclusions

With the development of rail transit in China becoming more and more mature, the global market competition becomes more competitive and design plays an increasingly important role. We do not only focus on the structure of components but also consider the ergonomic performance settling the organic connection of harmonic human–machine–environment system, to make the interior design satisfy the human physical and psychological needs, so that the environment for passengers and crew is safer and more comfortable. Ergonomic design begins with studies on drivers' and passengers' psychology, covering the sense of vision, hearing, smell and touch and combination thereof, which allows passengers to have great ride experience in the tidy, comfortable and wonderful environment inside the car.

Compliance with Ethical Standards The study was approved by the Logistics Department for Civilian Ethics Committee of CRRC NANJING PUZHEN CO., LTD.

All participants who participated in the experiment were provided with a signed consent form.

All relevant ethical safeguards have been met with regard to subject protection *k*.

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Predict the Performance of Visual Surveillance by EEG Spectral Band Advantage Activity: Modeling-Based Occipital Alpha Waves Advantage Activity

Deqian Zhang, Wenjiao Cheng and Hezhi Yang

Abstract Monitoring work performance declined has become need solution of important security problem, to prevent operator monitoring performance decline. This research based on simulated monitoring task collected 16 scalp sites EEG signal, by bands filter and wavelet analysis. We found that, in the site of central lobe, parietal lobe, occipital lobe, alpha wave advantage activities (cosine similarity of alpha wave and original waveform) associated with monitoring performance (hit rate). Alpha wave activity increases leading to reduced monitor performance. Alpha wave activity increases as monitor's performance decline. While uses the curve-estimate for the regression analysis we found that quadratic function and cubic function more than the linear function could reflect the relevance of the advantage of alpha wave activity and monitor performance. On the right brain scalp occipital site (O2), the quadratic function model reflects best correlation between the advantage of alpha waves activities and the monitoring performance, and it will fit the helmet acquisition of EEG electrodes placement in actual vigilance work.

Keywords Similarity of alpha waves · Modeling · Monitoring performance · Hit rate · Occipital · Electroencephalogram (EEG)

1 Introduction

[The] Decrease of the monitoring performance [1–3] has become the significant difficulty which needs to be solved by safety monitoring. To prevent the safety monitoring personnel's decrease of monitoring performance, based on the simulation

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monitoring work, the study tries to explore the early warning model of the variation of the brain wave spectrum as vigilance decrease.

The previous study finds the advantageous activities of different frequency ranges of the brain wave reflecting different physical status and different psychological processing states. The advantageous activities of α wave [4] correlates to fatigue, relaxation, rest and conscious activity weakening [5]. The advantageous activities of α wave [4], the study uses the cosine similarity index of α wave [6] and the original waveform [7]. The higher the similarity of α wave is, the stronger the advantage of α wave activity is [8].

2 Methods

2.1 Participants

After undertaking the subject, ten healthy right-handed college students (male 8, female 2) are given the informed consent. Their average age is 19, and their ages range from 18 to 20 years. All participants say their vision is normal or corrected to be normal, and they do not have any problem in the nervous system. They are not trained before, and they sign the informed consent which meets Chinese ethical norms before the experiment.

2.2 Material and Designs

The alertness mission aims to let the participates monitor the movement of the second hand by simulating the ***clock test*** of Mackworth's radar task [9] on the basis of the signal detection theory. The second hand moves clockwise for one space every time. When the second hand moves for two spaces at one time, it is used as a signal. The participator is required to click the left key of the mouse. Then, the software automatically generates a new random sequence signal (between 8 and 52 s). The experiment lasts for 80 min. The participators are required to continue the movement of the second hand. The computer program automatically follows and records the hit reaction, reaction time, detection leakage and false alarm. The experiment software synchronously and automatically records the EEG data.

2.3 EEG Data Extraction

The 16-channel EEG records are from the scalp frontal lobe, parietal lobe, center and occipital lobe (FP1, FP2, F3, F4, C3, C4, P3, P4, O1, O2, F7, F8, T3, T4, T5 和 T6, Fig. 1) areas. All electrodes are connected to the ear electrodes as the ground reference [10]. The 200-Hz sampling rate is used for collecting the data of the frequency range records from 0.03 to 30 Hz. The total value of the recorded electrode impedance is lower than 5 $k\omega$. After the EEG is preprocessed, the Butterworth band-pass filter is used [11], and then, the functional EEG signal which is then extracted and screened is used for postmortem analysis.

2.4 Data Analysis

To the monitoring alertness performance (behavior index), we use the average detection rate of signal detection (the hit rate) and the hit reaction time (RT) for calculation.

The EEG signal for analysis collects a segment of 1.28s (256 points) wave-length of original EEG before 2s of the stimulus appearing to be used as the psychological preparation status of the brain activity of the monitoring work, and the 1.28s wave-length EEG original signal while the stimulus signal appears to be used as the responded status of stimulus. After the band-pass filter is used for filtration, 8 frequency ranges are divided as follows: δ(0.01–4 Hz), θ(4.01-8 Hz), α1(8.01–10 Hz), α2(10.01–13 Hz), β1(13.0.01–20 Hz), β2(20.01–30 Hz), α(8.01–13 Hz), β(13.01–30 Hz). Calculate the **cosine similarity** of the waveform of all frequency ranges (such as α wave) and the original waveform [7].

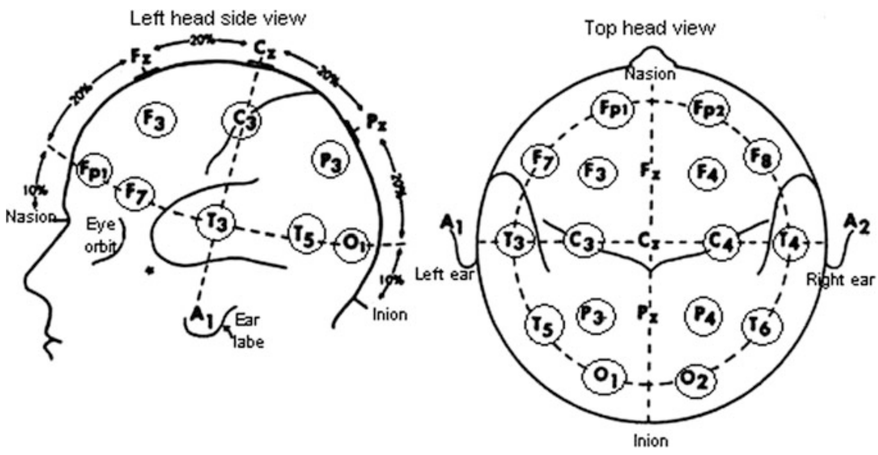

Fig. 1 International 10–20 system of EEG electrodes placement

Set the vector $A = (A1, A2, \ldots, An)$, $B = (B1, B2, \ldots, Bn)$

$$\cos\theta = \frac{\sum_1^n (A_i \times B_i)}{\sqrt{\sum_1^n A_i^2} \times \sqrt{\sum_1^n B_i^2}}$$

wherein, A is used as α wave data of single lead and B is used as the original wave data of single lead

The MATLAB 8.0 software is used for synchronizing the EEG data and the monitoring operation performance data and outputting the text data, and then, the SPSS13.0 software is used for statistic detection and data analysis modeling.

3 Results

3.1 Parameter Estimation Model of Curve Fitting, Curve Estimates of Monitoring Performance Hits Ratio on the Right Brain Occipital (O2) Similarity of Alpha Wave

The two subjects' federated data are used for analysis. Then, it is found the EEG α wave similarity in the occipital visuo-area is most significantly relevant to the monitoring performance, and the EEG α wave similarity in the O2 occipital visuo-area at the right side is more significantly relevant to the monitoring performance than that of the left side.

The SPSS statistic software is used for the parameter estimation of the model curve fitting of polynomial of one indeterminate of the preprocessed data as shown in Table 1. The fitting curve is shown in Fig. 2.

Figure 2 clearly displays the curve relationship between the hitting rate of the monitoring performance and α wave similarity of the occipital region at the right side. The implemented curve fitting shows that the relationship of the linear function is not significant, and the quadratic function and the cubic function have significant fitting effect as shown in Table 1.

Table 1 Model summary and parameter estimates[a] (brain right occipital areas, O2)

Equation	Model summary					Parameter estimates			
	R Square	F	$df1$	$df2$	Sig.	Constant	$b1$	$b2$	$b3$
Linear	0.000	0.052	1	265	0.819	0.810	−0.060		
Quadratic	0.036	4.880	2	264	0.008	0.851	0.127	−5.005	
Cubic	0.036	3.315	3	263	0.021	0.848	0.270	−4.820	−4.221

[a]Dependent variable: Hits. The independent variable is alpha bands similarity (right occipital sites, O2)

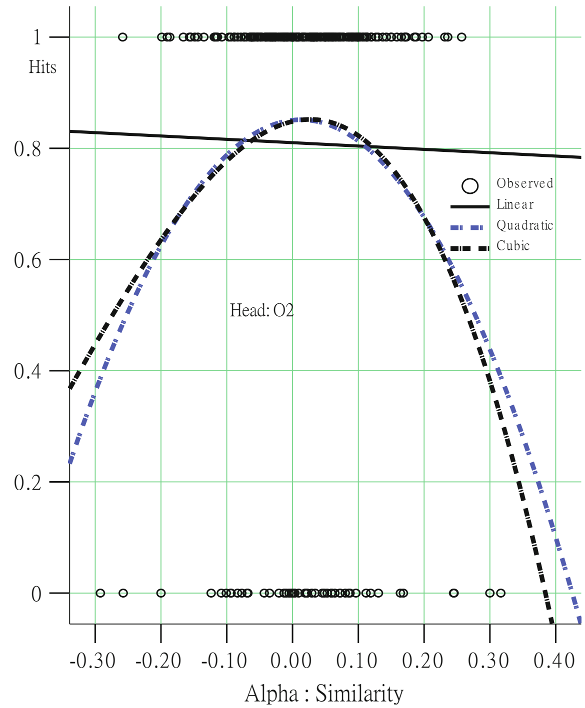

Fig. 2 Curve estimates of monitoring performance hits ratio on the right brain occipital (O2) similarity of alpha wave

The curve fitting analysis is carried out [12], as shown in Table 1. It is indicated that in the curve model of the quadratic function, $R^2 = 0.036$, $F_{(2,264)} = 4.880$, $p = 0.008 < 0.01$). The fitting superiority of the curve model of the quadratic function is the best fitting model. The implemented curve fitting shows the relationship of the linear function is not significant, and the quadratic function and the cubic function have significant fitting effects. Shown in Table 1.

$$\mathbf{Y} = \mathbf{0.851} + \mathbf{0.127} * \mathbf{X} - \mathbf{5.005} * \mathbf{X}^{\wedge 2}$$

$$\mathbf{X} = \mathbf{0.0136873} \pm [(\mathbf{0.8518056} - \mathbf{Y})/\mathbf{5.005}]^{\wedge \mathbf{2}}$$

$$Y_{\mathrm{Max}} = 0.8518056 = Y_0$$

Then, $X_0 = 0.0136873$

Then, vertexes of the curve model of the quadratic function are calculated as (0.0136873, 0.8518056).

wherein X is α wave similarity and Y is the concentration ratio of the monitoring performance.

Table 2 Brain right occipital areas (O2) similarity of alpha waves in absolute terms $|X| = 0.16$ (threshold), two layers of performance variance T test

$\|X\|$	N	M Hits	SD	SE	F	Sig.	t	df	Sig.
≥ 0.16	26	0.654	0.485	0.095	11.065	0.001	−2.128	265	0.034
<0.16	241	0.826	0.380	0.024					

3.2 Check of Parameter Estimation Model of Curve Fitting

To check the application effectiveness of the model, the absolute value of α **wave similarity** is used for the extensive estimation. The gradual check from the vertex of the origin curve is carried out. When $|X|$ is amplified to 0.16, the double-layer performance Y is significantly differed which is shown in Table 2.

When the absolute value $|\mathbf{X}|$ of α wave similarity of the occipital region (O2) at the right brain side is 0.16 (threshold value), the double-layer performance significantly differed, $F = 11.065$, $p < 0.01$, $t = -2.128$, $p < 0.01$. When the absolute value $|\mathbf{X}|$ of α wave similarity is ≥ 0.16 (threshold value), the performance of the hitting rate of the monitoring work significantly decreased.

Thus, the absolute value 0.16 of α wave similarity can be used as the early warning threshold.

4 Discussion and Conclusions

In the study, α wave similarity (the cosine similarity of α wave and the original waveform) can reflect the advantageous activity of α wave. The absolute value of α wave similarity and the monitoring performance are in a negative direction relevance. With the increase in the advantageous activity of α wave, the monitoring performance tends to decrease. The phenomenon is clear in the brain center region, parietal region and occipital region, and it is the clearest in the occipital region (visuo-area) at the right side. To consider the real situation, combining with the monitoring of the actual central or double-layer monitoring on the monitoring operator, using the scalp occipital regions are more convenient for placing the helmet-type electrodes which is used for collecting EEG signals, and can be practically applied. Thus, selecting the O2 area of the occipital region for modeling has practical application value.

The parameter model of the quadratic function established by the study result has the reference value for actual application.

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Compliance with Ethical Standards

The study was approved by the Logistics Department for Civilian Ethics Committee of the Jinggangshan University.

All subjects who participated in the experiment provided signed informed consent form.

All relevant ethical safeguards have been met with regard to subject protection.

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Military Relations with Physical Combat Power Generation of the Somatotype Standards

Zecheng Guo and Weiming Deng

Abstract This paper is based on the data in the literature for research. Use the document studies, statistical analysis, logical analysis, literature retrieve to the officers and soldiers physical fitness, somatotype data carried on the thorough analysis and discussion, somatotype is one of the important factors that affects the Soldiers' physical strength. According to the age and BMI index as partition size standards, respectively, the power quality, endurance quality, sensitivity and coordinating the quality aspect of somatotype are analyzed. Without qualified somatotype, there is no strong physical fitness, and there would be no physical combat fitness power generated by the way; I hope this article can reform the military academy of military sports training and teaching and provides some reference for the fighting capacity of ascension.

Keywords Somatotype · Physical fitness training · Combat power

Since New China was founded, physical training is listed into the training outline of our army, and the *Physical Teaching Norms* is issued, in which the physical training is listed as the formal training subject and examination assessment item. It reinforces the officers and soldiers' physique, trains their brave and tough spirits, improves the army's combat effectiveness and promotes our army's revolutionized, modern and regularized construction. The military sports is the basic training for improving the soldier's physique. The strong body is the excellent foundation for military training as well as one of the important factors forming the combat effectiveness. During the combat, the best weapon and the soldier's tenacious spirit are the important factors for winning. Sufficiently displaying the combat effectiveness is based on the strong physical fitness in a certain degree. Under the modern war condition, no matter how advanced the weapon is, people still decide

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the result of the war and is the key element for military occupation. Thus, the people factor is the most important factor for winning the war, and to the people factor, the strong physical fitness is the important material basis for the combat effectiveness. The consolidation, improvement and displaying of the military skill and tactical level depend on the base of the strong physical fitness reserve; thus, the military sports training has a close connection with the military skill training, tactical training and application. Without the strong body and vigorous energy, people cannot be adapted to the military work demand which is intensive and difficult.

Generally, there are two types of physical fitness examinations in the US army, in which it is ruled the soldier passing the assessment gets the certificate of military physical training and the one who is graded A for physical fitness will be rewarded spiritually and materially. The one who fails the examination will also be strictly punished. Rule by the US land army is that the one who fails in body weight standard and physical fitness examination cannot be promoted, and the one whose body weight cannot meet the standard within 2 moths will be dismissed. Rule by the US navy [1] is that the officer or soldier who fails in the physical fitness examination will not be promoted and the one who fails for three times in the last four years will be dismissed. In 2003, there were more than 3000 personnel dismissed from US army because of the body weight issue. Arthur who is the former vice chief of naval operations as well as the four-star general ever nominated as the commander of the Pacific Ocean headquarter of US army, but he failed because of he is too fat and also he was commanded for early retirement.

The soldier's somatotype is one of the important parts forming the soldier's physical fitness. The change in the soldier's height and somatotype also reflects the significant change in our army construction idea and the officers and soldiers' concepts. The most prominent characteristic of the *Soldier Military Physical Fitness Standard* (issued in 2006) which is being implemented by us is that the somatotype standard is listed into the soldier examination. After the development about ten years, how does the soldier's somatotype assessment influence the generation of the army combat effectiveness is the purpose and significance of the paper.

1 Study Object and Method

The paper studies on the basis of the data from documents. For the Outline proposes, the soldier's body weight standard is forced to be satisfied, using the international general indicator—BMI index (body mass index) can better accurately reflect if the somatotype meets the standard and also it is the index adopted by Chinese National Health Standards for Students. With CNKI, the paper named as Investigation and Study of the Conditions of Somatotype and Physical Fitness of the Officers of the Armed Police College, which is published by Hongjun [2] on the *Journal of Chinese people's Liberation Army Special Warfare School* (volume 31, fourth issue, October, 2012) is found.

The somatotype and physical fitness qualities of the officers from four armed police colleges are tested and analyzed, and the conclusion is the somatotype conditions of the college officers are worrying, and the cardio-pulmonary function and waist and abdomen strength are their main weakness, and the somatotype has a close relationship with the body quality. We think the study result analysis is not deep enough; thus, it is necessary to deeply analyze these data, but we only take male soldiers as the study subject for analysis.

2 Study Result and Discussion

As required by the *Soldier Military Physical Fitness Standard* [3], the basic physical fitness items are tested, which include somatotype, push-up, sit-up, 10 m $\times$ 5 shuttle run and 3000-m run. BMI is the derivative index.

BMI (body mass index) is the index which is closely relevant to the in vivo fat total amount and is the current international common standard for measuring the somatotype and health condition. According to the Judgment Standards for Adult Body Weight (WS/T 428-2013) issued by National Health and Family Planning Commission of PRC in April, 2013, the BMI standard is [4]:

BMI $\leq$ 18.5 kg/m^2 underweight

18.5 kg/m^2 < BMI $\leq$ 24.0 kg/m^2 normal

24.0 kg/m^2 < BMI $\leq$ 28.0 kg/m^2 too fat

BMI > 28.0 kg/m^2 obesity

The BMI assessment standard of the study is classified according to the classification standard. The test results of the items of the somatotype and basic physical fitness items of the male soldiers of the four age sections are shown in Table 1. For direct expression, we also make the series statistic chart for expression.

Shown by the analysis of the test data of the physical fitness of different BMI groups of different ages, there is a close relationship between the somatotype and physical fitness quality of the male officers of the armed police colleges (shown in Table 1).

2.1 *Analysis of Soldier's Strength Quality*

The strength quality is mainly represented by the push-up and sit-up items of the basic physical fitness. In a direct comparison of the test data for analysis, the average times of the push-up ranked from more to less are, respectively: underweight group > normal group > too fat group > obesity group, and the average times of the sit-ups ranked from more to less are, respectively: normal group > too fat group > obesity group > underweight group. It is apparently not

Table 1 Results of physical fitness and somatotype in different age groups for soldiers [1]

Age group	BMI	*N*	Push-up (n)	Sit-up (n)	Shuttle-run (s)	3000 m(s)
Under 25 years old	Normal	14	49.21 ± 9.6	51.86 ± 7.8	25.78 ± 1.8	872.3 ± 82.4
	Too fat	1	50	45	28	910
	Mean	15	49.36 ± 9.4	50.14 ± 6.2	26.13 ± 1.7	886.07 ± 75.2
25–34 years old	Normal	144	40.51 ± 8.8	42.8 ± 8.5	26.87 ± 1.4	904.7 ± 82.9
	Too fat	118	38.16 ± 9.4*	40.27 ± 9.2*	27.07 ± 1.3	950.63 ± 91.7*
	Obesity	8	35.88 ± 7.0**	34.62 ± 6.1*	27.99 ± 2.0*	1146.50 ± 139.2**
	Mean	270	39.38 ± 9.1	41.48 ± 8.9	26.99 ± 1.4	907.02 ± 157.4
35–44 years old	Tin	1	26	46	28	840
	Normal	77	29.92 ± 6.5	32.55 ± 6.3	28.53 ± 1.6	924.29 ± 75.9
	Too fat	142	29.08 ± 8.2	32.29 ± 7.5	28.59 ± 1.5	959.30 ± 86.6
	Obesity	7	27.71 ± 5.1	33.57 ± 8.0	29.33 ± 1.4	998.00 ± 108.9*
	Mean	227	29.22 ± 7.5	32.44 ± 7.1	28.59 ± 1.5	947.64 ± 85.6
Over the age of 45	Normal	28	18.57 ± 7.9	22.75 ± 2.6	29.88 ± 2.2	1063.68 ± 128.6
	Too fat	29	17.14 ± 5.9	20.07 ± 4.8*	31.46 ± 3.0*	1096.66 ± 103.5
	Obesity	4	18.25 ± 3.3	19.32 ± 7.4	32.29 ± 3.7*	1133.25 ± 101.5
	Mean	61	17.86 ± 6.8	20.55 ± 5.9	31.77 ± 3.4	1082.24 ± 117.1

*Indicates the hypothesis test of $p < 0.05$ and normal group
**Hypothesis test $p < 0.01$ and normal group

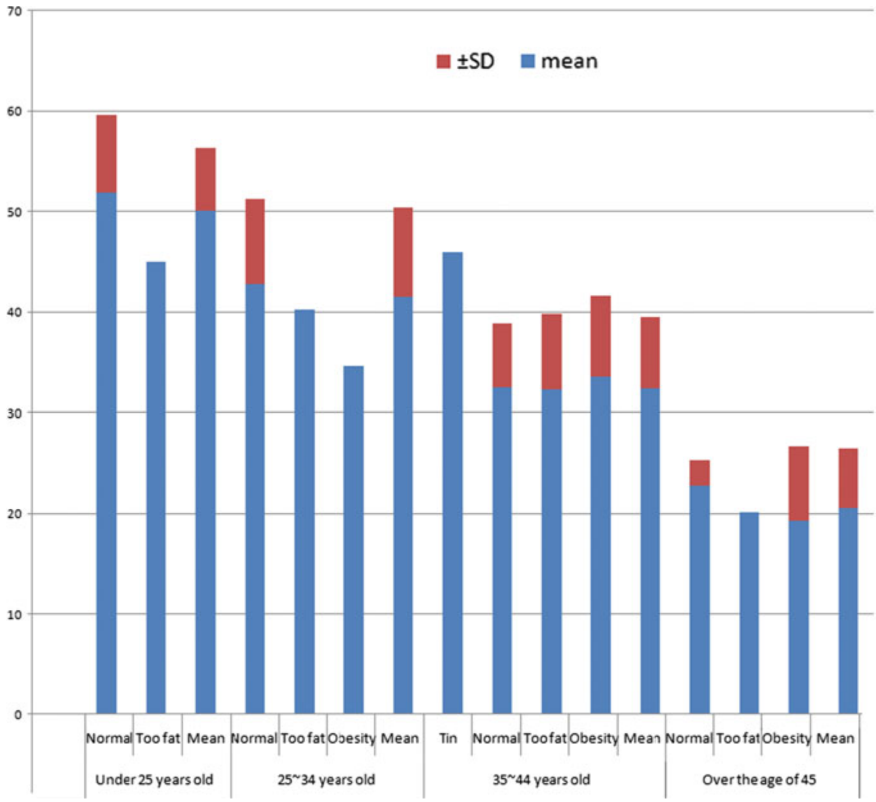

Fig. 1 Statistical chart in push-up

comprehensive, and we shall also consider it according to ages and, respectively, make the assumption tests for the reasonable judgment. Take the push-up as the example, there is only one person in the too fat group lower than 25 years old as well as only one people in the one from 35 to 44 years old; thus, it can be, respectively, merged into the normal group but not for comparison. To the other groups of all ages, the independent mean value *t*-check of two samples is, respectively, carried out with the normal group.

The results show that there is no significant meaning in the push-up and sit-up of people of age older than 35 years, who are the officers of the command organizations, and the people of the age from 25 to 34 years who are just the main force of the officers for the battalion, company and platoon units; the deviations of the too fat group and the obesity group from the normal group both have the significant meaning, which proves the somatotype is one of the important factors influencing the strength quality (Refer to Fig. 1).

2.2 Analysis of Soldier's Agility and Harmony Qualities

The agility and harmony qualities are mainly represented by the 10*5 shuttle run of the basic physical fitness. If directly compared the test data for analysis, the average time consumption of the 10*5 shuttle run ranked from short to long is, respectively: underweight group < normal group < too fat group < obesity group. It is apparently not comprehensive, and we shall also consider it according to ages and, respectively, make the assumption tests for the reasonable judgment. There is only one person in the too fat group lower than 25 years old as well as only one person in the one from 35 to 44 years old; thus, it can be, respectively, merged into the normal group but not for comparison. To the other groups of all ages, the independent mean value *t*-check of two samples is, respectively, carried out with the normal group.

The results show that there is no significant meaning in the 10*5 shuttle run of the age range from 35 to 44 years old, who are the officers of the command organizations. The deviation of the too fat group and the obesity group and the

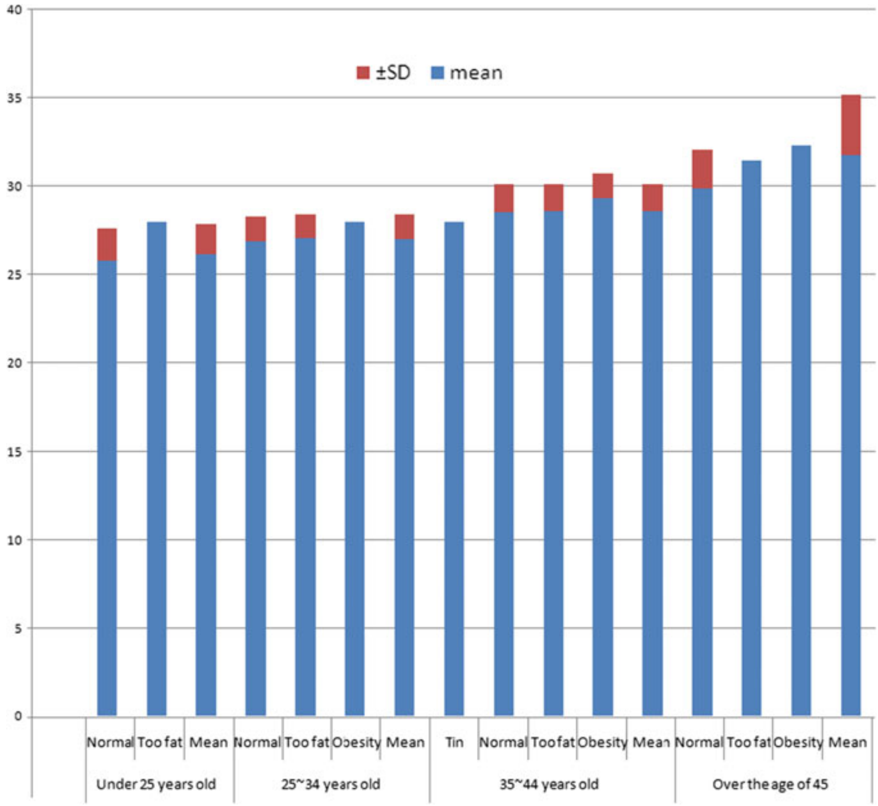

Fig. 2 Statistical chart in shuttle run

normal group from 25 to 44 years old and the age higher than 45 years old has the significant meaning, which proves the somatotype is one of the important factors influencing the agility and harmony qualities. Particularly to the command officers who are older than 45 years, their body weights continuously increase but the time for and the strength of physical fitness training are continuously decreased, and the influence from the somatotype is more (Refer to Fig. 2).

2.3 Analysis of Soldier's Endurance Quality

The endurance quality is mainly represented by the 3000-m running of the basic physical fitness. In a direct comparison of the test data for analysis, the average time consumption of the 3000-m running is, respectively, ranked from short to long as normal group < too fat group < obesity group. It is apparently not comprehensive, and we shall also consider it according to ages and, respectively, make the assumption tests for the reasonable judgment. There is only one person in the too fat

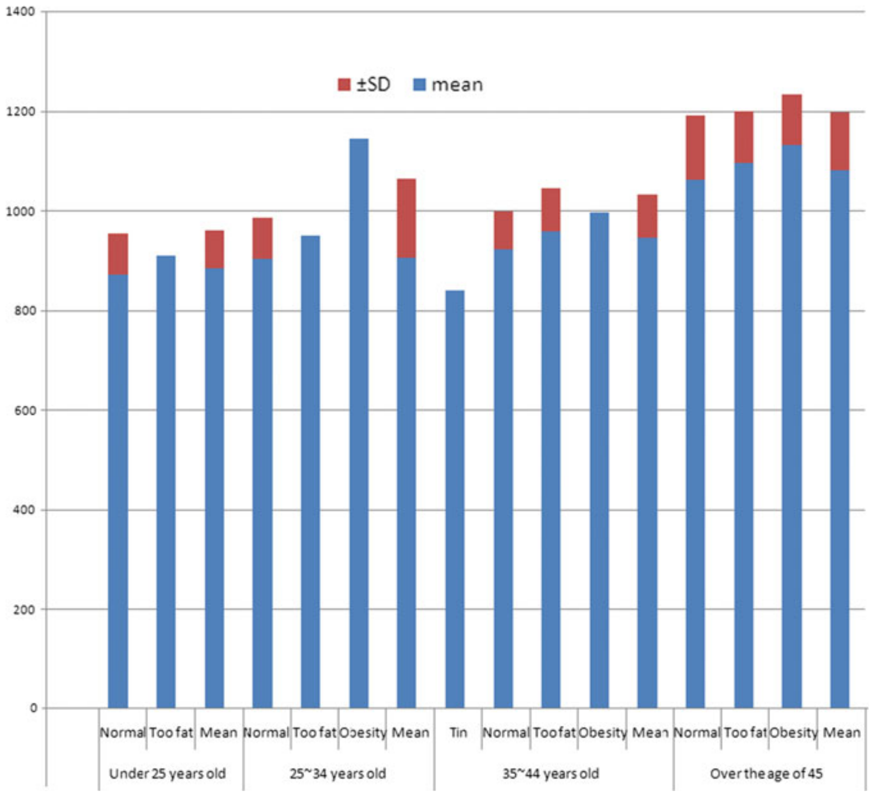

Fig. 3 Statistical chart in 3000-m run

group lower than 25 years old as well as only one people in the one from 35 to 44 years old; thus, it can be, respectively, merged into the normal group but not for comparison. To the other groups of all ages, the independent mean value t-check of two samples is, respectively, carried out with the normal group. The results show that there is no significant meaning in the 3000-m running of the ages older than 45 years, who are the officers of the command organizations, and it proves although the body weights of the command officers who are older than 45 years increase continuously, their endurance quality is kept well in general. The deviation of the obesity group and the normal group from 35 to 44 years old has the significant meaning. The deviation of the too fat group and the obesity group and the normal group from 25 to 34 years old has the significant meaning, which proves the somatotype is one of the important factors influencing the endurance quality (Refer to Fig. 3).

3 Conclusion and Recommendations

3.1 The study results indicate the male soldier's somatotype is one of the important factors influencing the physical fitness and has a close relationship with the physical fitness. The physical fitness of the officers who are 35–44 years old and whose somatotype is in the normal range is clearly better than the one whose somatotype is not standard.

3.2 All ages have a certain advantage for the push-up ability which reflects the upper limb strength, and their overall level difference is little. All ages under 44 years old show high levels for the sit-up ability which reflects the waist and abdomen strength, but the ages after 45 years old show clear decrease in the waist and abdomen strength.

3.3 Keeping the qualified somatotype is one of the methods for improving the combat effectiveness. On February 13, 2015, report by PLA Daily [5], the four headquarters together issued *Outline of Reform and Development of Military Physical Training* (from 2015 to 2020) (hereinafter refer to as the outline), which requires the soldier's body weight to be forced to be standard and links up with promotion.

3.4 The footstone for reinforcing military can only be firmed by controlling the solder's body weight. For more than one year, the few fat men in the barracks start their plans for losing weight. To the whole Chinese army, it is the battle in which the combat effectiveness is asked from the physical fitness—scientific plan for losing weight. To completely implement the outline, all departments shall cooperate. It shall rule that the people whose body weight is not standard cannot be promoted or undertake the relevant duty so as to promote the soldier to meet all items of physical fitness.

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Discussion on Approaches and Method of Cultivation of Talents in Military Big Data

Weiming Deng

Abstract Military postgraduate education is an important propeller of the transformation of combat power generation model. It is the cornerstone of the army's innovation system and innovation ability. It is the main basis for the construction of the high-level military talent. It plays a basic and leading role during constructing an information-based army and wining the information war. Facing the challenges of the big data time and the lack of talent in the military data, the paper proposes adding new data-related majors and courses in the military postgraduate education. From the basic level of big data management, the level of joint operational data security and the level of military decision-making command, the author makes demonstration to explore the approaches and methods to cultivate the talents in the military big data.

Keywords Big data · Military master degree · Talent cultivation

Military postgraduate education is an important part of the military academy education, with both academic and professional dual attributes. It faces not only the military teaching and research positions, to cultivate and explore scientific laws and pay attention to knowledge innovation of high-level academic talents, but also special positions in the army to cultivate high-level applicable talents adaptable to the actual needs of the work, with strong practical ability and the ability to find and solve the problems.

Postgraduate students as a force of the military research team will not only undertake the task of innovation and development of military theory and military science and technology, but also have the mission to settle the key and difficult issues in building and combat training and directly improve the combat effectiveness. Military postgraduate education is an important propeller of the transformation of combat power generation model. It is the cornerstone of the army's

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innovation system and innovation ability. It is the main basis for the construction of the high-level military talent. It plays a basic and leading role during constructing an information-based army and wining the information war.

On March 29, 2012, US President Barack Obama announced the launch of the Big Data Research and Development Program to improve the ability to acquire knowledge and ideas from massive digital data, thereby accelerating the science and engineering discovery, strengthening US national security and achieving education and learning change. In order to fill in the gap between big data-related talent and the lack of relevant skills, IBM is cooperating with more than a thousand universities in the world in big data and analysis. According to incomplete statistics, there are nearly 170 universities around the world which have set up big data-related specialties, of which about 150 universities have opened courses for master or higher degree.

The Standing Committee of the State Council, held on August 19, 2015, adopted the “Outlines for Action of Promoting the Development of Big Data.” In China’s big data development, we finally had a guide to promote the government information system and public data sharing and eliminate the information island. The adoption of the outlines means that top design is available for China’s big data development. From the data sovereignty, industrial chain covering the industry and other key elements, the government will assess the revolutionary influence of the big data on the government, economic and social operation. The scale of the local data center construction should be oriented by industrial demand so as to realize fine design and promote the formation of a good and sustainable ecological environment for development of the big data. Therefore, the release of the outlines will certainly have a significant influence on national defense and army building.

1 Requirements of the Time of the Big Data on Cultivation of Military Talents

Big data age has come and talent demand is more vigorous. The use of data to make decisions has become a consensus among managers. The surveys of SAS and Harvard Business Review show that 75% of the 700 senior managers surveyed believe that their management decisions are actually dependent on data analysis, and 40% of have noticed that they make decisions using the results of data analysis to enhance the importance of their work and the status of the enterprise [1].

Similarly, big data changes the mode of future warfare and also alters the basic outlook of world military change. Big data is also changing the form and model of information warfare with deep influence on the contrast and balance of the world’s strategic forces.

The military big data has changed the command process of future operations. The operational command information system has become an important decision-making tool for all levels of commanders. Through the application of military big data and the R&D of data visualization, it will greatly improve the ability to dig out useful intelligence information, visualize the display from massive intelligence data, realize real-time awareness and sharing of the battlefield situations of the joint combat, shorten the link cycle of the "sensor–command post–weapon platform" link and then conduct seamless connection with the real-time perceptive, cognitive and decision support system so as to establish a real automated information system which can complete control independently and make decision, greatly shorten the cycle from decision and command to the implementation of the fighting action, improve the rapid response to combat and achieve the integration of investigation and operation.

Military data security will be the core of future military decision-making operations. From the recent large-scale exercises on the battlefield home and abroad, we can see that the information collected from real-time information exchange and various reconnaissance platforms (such as aerospace reconnaissance, unmanned aerial vehicle reconnaissance, radar reconnaissance and photoelectric equipment reconnaissance) and the decisions and instructions of the command center exist and play the role in the form of data. If we grasp these ever-changing, structural and non-structural massive data, we grasp the most comprehensive, the core of the battlefield situation and offensive and defensive focus, and further take the initiatives.

Military big data speeds up the course of information development of weapons and equipment. We always stressed that our army was still in the transition period of mechanization and information, and now we find that we have no time to wait, that future battlefield environment is complex far beyond our imagination, and that intelligent weapons and equipment have become the mainstream of the development trend of equipment. Big data is committed to innovative use of massive data by using artificial intelligence to deal with a variety of unstructured data to replace the traditional information processing method relying on experts and technical staff. So, with the application of big data technology, weapon and equipment information system will be upgraded to a highly intelligent and autonomous system from information user on the battlefield.

Therefore, the requirements of the time of big data on military talents should be analyzed from the following three levels.

1.1 Basic Level Big Data Management

The professionals of big data theory are called data analysis engineer sometime. Internationally, it is generally believed that [2] big data talent is scientist and engineer with a big data processing capacity. At present, overseas universities or research institutions have set up a large number of theoretical courses on data science, set the degree of data science and held a variety of short-term training in data science. From the setting of talent training program, big data talent should systematically master the skills related to data analysis, including machine learning, probability theory, statistics, artificial neural network, data mining business analysis and natural language processing among extensive knowledge, able to independently access to knowledge and make applications, with team spirit.

1.2 Joint Operation Data Security Level

It is reported that [3] the day of the outbreak of the Iraq War, the US military headquarters in Qatar and Kuwait were forced to shut down the system due to the failure to deal with massive comprehensive protection data, resulting in loss of contact with some of the front-line combat units. It can be seen that the time of big data has higher requirement on data processing capability. Joint operations focus on data, and the data are the key to the result. Without data, information warfare is also out of the question. Data are the core basis of a variety of command information systems and equipment, a main form constituting information flow of the joint battlefield and a link connecting all arms of service and all battlefield spaces. So we must establish a sense of joint operations and stress big data security work. We will have no data of joint operations without sense of joint operations. As a data staff, we shall master the data technology, take the initiative to bring data demand in the joint operations, identify the key issues of joint operational data security and provide effective security for the decisions made by the commander.

1.3 Military Decision Making and Command Level

We should vigorously cultivate professionals in other fields that are good at applying the results of big data, such as talents in intelligence security and military decision making and command of joint operations. In the past, military decision making had being mainly based on the experience, intuition, military intelligence and thinking strategy and data had been deemed as a auxiliary tool for decision making, while in the time of big data, the data have been updated to support the decision making. Military decision making must be made based on data analysis. Relying on big data and cloud computing platform, pre-war simulation, from the use of weapons to command and control means, can be clearly seen, as the basis for military decision making. Once the operation plan is found to have problems or there are unexpected situations, the deployment of operations can be adjusted to ensure the actual victory and minimize casualties.

2 Approaches and Methods of Cultivating Military Talents in Big Data

Headquarters' "Opinions on In-depth Facilitation of Scientific Development of Military Postgraduate Education" [4] points out that the mission of military postgraduate education is both academic and professional. The main problems include the imbalance between the academic degree and professional degree, lag of high-level application-oriented training and the failure of the military postgraduate education to meet the demand of the construction of the command officer team. "Opinions" points out that the main objective of the cultivation of the military postgraduate students is special degree. By 2020, the varieties of military postgraduate students will increase from the current XXX varieties to XXX varieties. According to this, combined with the above analysis of the needs of military talents in big data, the author puts forward some approaches or methods of cultivating high-level application-oriented military talents in big data to meet the needs of future wars.

2.1 Basic Level of Big Data Management—Set Authorization Point for the Degree Related to Data Science

This means cultivation of professionals mastering theory of the big data. According to the "Opinions" [4], in some military academies or research institutes, we may set more data science degree granting points under overall management and classified deployment within the entire PLA. The objectives of the military talents in big data should be making such talents systematically mastering the skills related to the military data analysis, such as distributed file system (HDFS), redundant and efficient low-cost big data storage technology, new database technology (key database, column database, diagram database and file database, etc.), heterogeneous data fusion technology, distribution non-relational big data theory and processing technology, big data indexing technology and big data movement, backup, copy and other technologies. The talents should be big data management engineer able to complete the big data management of the platforms from the civil database to the military database, from the data collected individually to space data. Big data analysis techniques include data mining, machine learning and other artificial intelligence technologies, including association rule mining, neural network, genetic algorithm, pattern recognition, regression prediction model, time series analysis and cluster analysis.

2.2 Joint Operational Data Security Level—Set a Joint Operation Data Crew

Joint operations focus on data, while operational data are the basis of operations and decision making and the blood of the system. The joint operations depend on data. Without data, information-based operations are empty talks only. Data are "blood" of a variety of command information systems and equipment, a main form constituting information flow of the joint battlefield and a "bond" for all arms and battlefield spaces. So, the importance of the data is self-evident. The President Xi has issued a data engineering construction plan to make clear the overall planning and development thinking in the next step. The combat data project has been developed for over 20 years with certain degree of basic data scale, but with the in-depth understanding on joint operations, current combat data are far from meeting the needs of joint operations and there is a long way to go for cultivating operational data staff.

2.3 Military Decision Making and Command Level—Set Big Data Application Courses for Postgraduate Students for Special Degree

The future war will be the global multi-dimensional joint operations featuring a system against another system, and the entire army will face the problem of transformation and upgrading. The degree of the master in the information of the battlefield environment, enemy, friend and our army decides the result of a war. The data come from the army, and the army uses the data, so the army needs data more urgently. Today, in the peacetime, the PLA produces massive data everyday and the volume of the data will become larger in the future wars. How to grasp these massive data and how to analyze, extract and understand the valuable information are the cores to win an information war. In order to quickly cultivate high-level, compound military command talent and keep up with the trend of the times, it is recommended that the big data theory and application courses should be set for military postgraduate education (covering four respects: military command, military political work, military logistics and military equipment).

In the talent cultivation program, big data application courses can be set as public basic courses or elective courses with 2–3 credits in 30–50 h each. The course content is divided into two parts: theoretical part and practice part.

2.3.1 Contents of Theory

(1) Concept of big data: the concept of the big data is inevitable historically, 4-V characteristics of big data, relationship between big data and cloud computing/ internet of things and difference between big data and large-scale/massive data.
(2) Applications of big data: Baidu search, real-time hot spots of navigation, “November 11” shopping festival of Taobao, full-process interpretation of killing Osama bin Laden, etc.
(3) Big data analysis technology: a technology of finding rules from the big data, usually composed of three links: data preparation, regular exploration and visual representation [5]. The core of the rule is data mining technology, including clustering analysis, correlation analysis, prediction model, timing model and abnormal trend discovery, which may be analyzed with a variety of statistical analysis software such as SAS, SPSS and Statistica.

2.3.2 Contents of Practice

(1) Determine the topic: clear demand and write the task book.
(2) Data collection and preprocessing: according to the topic, collect high-quality data and conduct data processing and sorting.
(3) Exploratory data analysis: big data analysis of the data usually reaches PB level or above, so it is hard to reach the goal and find the role of the data by a selected model. Generally, we can find the possible rule only if we use the amount of features and other methods through description statistics, statistical graphics rendering, a variety of forms of fitting and a variety of pattern associations and some other means.
(4) Verification of model: make verification and analysis on the selected model and the results; generally statistical inference is made for reliability and accuracy of the selected model through the mathematical statistics on the basis of the specific knowledge to test whether the decision information from the model is sufficient and credible.

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Research on the Status Quo of Archives Management of Ex-serviceman in China

Chan Zhang

Abstract Because of the special life experience, the ex-servicemen are important human resources. The perfect archives management of the ex-serviceman archives is essential to the use of talents and the protection of rights and interests. Combined with the survey of ex-servicemen archives management in some region, to analyze the status of ex-serviceman at the present stage of China's archives management, put forward to establish and perfect the ex-servicemen archives management regulations, management system will be included in the National Archives of ex-servicemen archives management according to law and legal system and the use of the channel, a clear management subject, clear responsibilities and other related rights the strategy, in order to provide reference for the improvement in China's demobilized military personnel archives management.

Keywords Ex-serviceman · Archives management · Archives docking

1 Introduction

In any country with military force in the world, there are a large number of ex-servicemen. Because they have been exercising, studying, working and living in the army for many years with special experience, their personal qualities in all aspects are at a higher level and they are rare important human resources and an important force in national construction. The archives of the ex-servicemen are the historical records that reflect the thoughts, work and abilities of the ex-servicemen in the service of the army. It is the important basis for the local government and relevant authorities to examine, understand, resettle and manage the ex-servicemen. It is the basic certificate of the vital interests of the ex-servicemen and an important part of the national archives. The quality of the management and use is an important factor for social harmony and stability. Therefore, the ex-serviceman archives with

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complete management and use mechanism in line with social demands are undoubtedly a valuable asset of our country.

With the development of the national economy the need for national defense construction in the time of the information, Chinese government still implements compulsory military service system, but the source structure, job requirements and some other conditions have undergone great changes and the situation of ex-servicemen becomes more complicated and diverse than ever. These persons contribute their own youth and strength to national defense, while the army also provides them with the opportunity to exercise, learn and improve, and takes high cost for cultivating talents for some technical positions or special jobs. After retirement, the ex-serviceman archives are important basic references and certificates for them to find the right positions, enjoy the benefits, maximize their potential and enhance their ability to continue contributing to the country. Therefore, a perfect ex-serviceman archives management mechanism is essential.

2 Status Quo of Archives Management of Ex-servicemen in China

China's ex-serviceman archives management should be an important part of our archives works. However, in the CNKI database, if we search the keywords "ex-servicemen" and "archives management," we cannot find relevant theoretic studies from 1994 until 2016 and most of the contents we find will be limited to the issues when using the archives of ex-servicemen, such as how to find archives to help solve the requirements of ex-servicemen with the archives; there is no relevant published special work in this field, and there is no clear regulation on the China's ex-serviceman archives management in China. From the conditions in different cities, in most of the cities, the ex-serviceman archives are basically scattered in a variety of management units or authorities at all levels and managed with traditional manual physical methods so as to cause extreme inconvenience in the use of ex-serviceman archives.

2.1 Incomplete Regulations and System

The regulations and system for ex-serviceman archives management need to be further improved. That is the major reason for unclear duty division of archives management of a large number of ex-servicemen.

Article 14 of the "Regulations on the Arrangement of Retired Soldiers" promulgated in China in 2011 stipulates that "the troops of the ex-serviceman shall transfer their archives to the resettling place's government at the county level or above at the time of retiring in accordance with the relevant national provisions of the archives management.” Article 15 also points out that, “the archives of the officers self-employed and those arranged shall b handled by the ex-serviceman authority at the resettling place g in accordance with the relevant national provisions of the archives management, and the archives of the retired and supported soldiers shall be handed over to the service management unit from the ex-serviceman settlement authority at resettling place.” There is also a clause in current regulations of management of archives of officers of the PLA: “Once an officer is decided to be retired, his archives will be transferred to the ex-serviceman officer work office of provincial military region (garrison area) at the resettling place” and then to employer or talent communication center for keeping and other matters. This is a root cause for the diversification and uncertainty of management authority of ex-serviceman archives! This means that the ex-serviceman archives will go through two transfers and be handled by two units at least. Let alone rare ex-servicemen arranged by the government, the years of experience has proved that the loss or damage of archives always appears in the transfer link and most of the ex-servicemen cannot meet conduits for work arrangement, especially for those from rural areas whose archives will be distributed to street offices and township governments mostly and rarely managed according to regulations strictly.

Due to the imperfect laws and regulations, the uncertainty of management authority, there is no principle to implement or track to follow for ex-serviceman archives management. First, due to the lack of legal support for the security of archival entities, the authenticity, reliability and uniqueness of the contents of the archives cannot be effectively guaranteed. Secondly, there are no institutional regulations and constraints for the collection, custody, protection, use, transfer and other archives management behaviors. According to the research, if the leaders of the local authority attach importance to this matter and are willing to spend money, the ex-serviceman archives are managed well and valuable here; otherwise, the ex-serviceman archives may be cannot be searched. As to the official document released to third party, there are different understandings and practices. Some documents are released in the name of People’s Armed Force Department, some in the name of Military Department, some in the name of Confidentiality Room and some in the name of Archives Room; some is confirmed by seal and some by signature of relevant leader [1].

2.2 *Prominent Conflict Between Distributive Management Model and the Service for Utilization*

At present, China’s ex-serviceman archives generally are transferred and filed with the ex-servicemen. In most of the districts/counties, the ex-serviceman archives are reviewed by the ex-serviceman resettlement office of Civil Affairs Bureau. If the conditions for resettlement are met, the ex-serviceman archives are transferred to the receiving unit; if the ex-servicemen choose self-employment, the ex-serviceman archives are handed over to Human Resources and Social Security Bureau; if the ex-servicemen came from rural areas, the ex-serviceman archives will be handed to the People's Armed Force Department of different levels after kept by the Civil Affairs Bureau for one year; after the ex-serviceman officer archives have been transferred to local ex-serviceman officer work office, the ex-serviceman archives for these officers arranged by the government will flow the employers and the ex-serviceman archives of those self-employed will be managed by the third party or local talent exchange and service center [2]. This decentralized management is easy to cause the prevarication at the time of search for unspecified management authority and diverse management authorities and links. As a consequence, many ex-servicemen cannot find their archives and the authorities in charge when needing the archives.

With the national economic development, the gradual enhancement of national defense construction, the environment and conditions of resettlement and employment of ex-servicemen have been improved gradually and the preferential policies and measures have been perfected step by step. The volume of query, consultation and transfer of ex-serviceman archives increases by years; there are many changes of local administrative zoning and the management authorities of the ex-serviceman archives; the ex-serviceman archives managed by relevant authorities of all levels involve a large time span, the number of ex-serviceman archives are increasing year by year and the search and use of ex-serviceman archives become more frequent than before. All these will affect the success rate of archives search, and the pressure on the archives managers of authorities of different levels is also obvious.

2.3 Big Gap of Management Levels

There is not an express regulation for management and the management authority is not clear, there is special sustainable fund or capital, the construction of archives management team is absent and lagging behind other fields, and more conditions like professional management personnel and technical standards need to be met. For instance, at the keeping place, there is no clear construction standard; there is no a unified standard format for archives boxes and bags; the repair of damaged archives needs a technical reference; the archives protection measures are not uniform; archives storage period is not clear and so on. Disordered management and non-standard and nonmatching software and hardware cause the complicated and slow search and even result in the damage, missing or loss of ex-serviceman archives sometimes. For example, some policies granted by the government cannot be implemented for the absence of evidence of archives sometimes. This not only brings extreme negative impact on the harmony and stability of the society, but also affects the social contribution and social status (such as reliability and authentication) of ex-serviceman archives.

2.4 High Risk of Archival Information Security

The contents of the archives of the ex-servicemen involve a lot of respects, related to the confidential matters of the country and the army sometimes. The regulations on the military archives management have expressly stipulated that the relevant materials involved in military secrecy cannot be included into personal archives, but the retired soldiers came from different positions in different services in different periods; there are still some confidential matters related to the country and the army. Therefore, the problems like decentralized and disorderly management of physical ex-serviceman archives may cause leak of the information contained in ex-serviceman archives and increase the risk of information security.

3 Strategy for Development of Ex-serviceman Archive Management in the New Period

Currently, Chinese government is comprehensively promoting the construction of urbanization, facilitation of overall urban and rural planning and implementation of various livelihood policies so as to cause the surge in the demand for ex-serviceman archives. Satisfaction of growing needs of using different archives is not only the requirements of national economic construction and an important content of people's livelihood construction, but also a way to solve social contradictions and safeguard the social stability.

3.1 Establish and Improve the Regulations on the Ex-servicemen Archives Management

To establish and improve the regulations on the ex-servicemen archives management are a basic condition for ex-servicemen archives management.

We should actively make centralized management of ex-serviceman archives in accordance with the regulations of "Archives Law of the People's Republic of China" on centralized management of national archives.

The relevant work cannot be facilitated without specific management authority and fund provider (or duty and interest). We can find in the practices in many areas; the unified handover of ex-serviceman archives for centralized management shows a well effect [3] which not only makes the ex-serviceman archives resorted, kept and used at professional level, but also enhances the authentication of the ex-serviceman archives use. The ex-serviceman archives must be handed by Civil Affairs Bureau of the city/county to local archives office with relevant handover procedure; the archives office will not accept any ex-serviceman archives submitted by the ex-serviceman himself or in other circumstances. Once the ex-serviceman archives have been handed over to the archives office, the use may be according to relevant provisions of “Archives Law” and the “Regulations on the Implementation of the Archives Law.”

In contrast, you can also refer to some other countries on the ex-servicemen archives management approaches. In the USA, the ex-serviceman archives are permanently preserved in the national archives, free of charge for the involved persons and their families [4]; on the one hand, the archives are not easy to lose and confidential contents are safe and easy to find when the government needs to use (especially for the reserve of some special talents); the Ministry of Defense Civil Affairs Department, through the establishment of an automatic archives system with the National Personnel Management Office, introduces the personal situations of the ex-servicemen to national government departments or private companies. This is conducive to the use of talent [5].

3.2 Establish and Improve the Standard System of Ex-serviceman Archives Management

The ex-serviceman archives are the predecessor of the ex-serviceman archives, which are formed based on the recruits’ materials submitted at the time of joining the army. Therefore, we may complete the ex-serviceman archives management by taking the reference of method of service archives management.

According to China’s “Military Service Law,” the annual conscription is one of the important tasks of local governments. For the selection of recruits, the establishment of strict, high standards of recruit archives is one of the important and necessary links. Local governments may establish a corresponding recruits archives system, strictly according to the requirements of standardization and digitalization for future reference and conscription work performance evaluation; most of the soldiers will return to the original places when they leave the army, so the ex-serviceman archives taken over maybe match the recruit archives.

With the help of information technology, we should establish a sound electronic archives team, to achieve a seamless delivery and operation system of physical archives and electronic archives: recruit’s materials → serviceman archives → ex-serviceman archives.

4 Conclusion

In China, the ex-servicemen are a large group with high comprehensive quality as a whole. In particular, those people who just left the army are in the prime of life as the backbone in the national construction. Inclusion of ex-serviceman archives in the legal management and legal use channel, clear management authority and positive push for ex-serviceman archives management help standardized professional management of ex-serviceman archives, ensure the security of the physical archives and information contained therein, make search and use easy and reflect the value of archives. All these are significant for effective protection of legal interest of ex-servicemen, well grasp of national defense potential, pertinent social defense mobilization and educational activities, enhancement of social recognition of archival work, etc.

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The Research on Task Unit Workload of Civil Aircraft Flight Operation

Xueli He, Lin Ding, Chongchong Miao and Lijing Wang

Abstract The paper aimed at studying the unit workload of civil aircraft flight operation task, and studying and analyzing the influence of the flight experience and flight stage on the single-task workload. Firstly, the less experienced and experienced pilots were chosen as the assessment objects to get the single-task workload so as to analyze the influence of the flight experience on the task workload. Then, the pilots were used as the assessment objects, and the objective assessment method was used for assessing the operation single-task workloads under different flight phases so as to analyze the influence of the flight phase on the operation single task. The results indicated the flight experience didn't influence the task workload, and the task workload values under different flight phases were greatly differed, and the workload values were ranked from high to low as follows: approach stage, takeoff stage, climb stage and cruise stage. The analysis results of the influences of the operation task unit workload, flight experience and flight stage on the task unit load value could provide basis for studying the pilot's workload.

Keywords Subjective assessment · Task load · Task unit · Pilot · Flight operation

1 Introduction

The workload is defined as the work amount undertaken in a unit time. The heavier the work amount is, the higher the workload will be. Lysaght et al. [1] proposed in 1989 that the workload comprises of three aspects, i.e., work amount, time consumption and operator's subjective psychological experience. Hart [2] proposed in 1991 that the workload comprises of the combination of some specific operators

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and different designed missions. Differed by work natures, the workload can be classified as the physical workload and the mental workload [3]. The task demand (task load) is determined by the task quantity to be executed, the necessary attention and the time for use [4]. Hilburn and Jorna [5] described the relationship between the task load and the mental load as follows: The task load is the requirement on the operator proposed by the task itself, and the mental load is the operator's objective experience to the task requirement.

Because the periods and application fields studied by the work prediction model are different, a plurality of workload prediction models based on task are proposed. To carry out the workload prediction model based on task, the task unit attributes (task load value and operation time) have to be confirmed at first.

The methods for confirming the task unit load values are also differed in different prediction models. In the task analysis/work load model [6], the expert assessment method is used and the assessment of the task unit load value is carried out by using the objective assessment tables from 1 to 7, but indicated by the load value data, the objective assessment value is secondarily processed, and the load value is relative. In the calculation model for the multi-source task load [7], to the single-task demanding unit, the load of each task is evaluated as automatic ($D = 0$), simple ($D = 1$) and difficult ($D = 2$). In the task load model of the human–machine interactive design and analysis system [8], the demand value of every attribute under the task unit is evaluated as 0 or 1 to represent the task unit demand. The load values of the CMRM and TLM (the task loading model) are obtained by the direct evaluation method and are also relative. The comparison analysis of the absolute values cannot be carried out between the relative value and the actual value, but only the relativity analysis can be carried out. The paper aims at getting the absolute value of the task unit workload. Thus, the operation task unit load value of the paper uses the expert assessment method proposed by TAWL (Task Analysis/Workload methodology) and assesses the task unit load with the objective assessment table of 0–10 marks. No secondary processing is given to the assessment results which are directly used as the database of the task unit load values.

With the objective assessment method, the paper gets the task unit workload value of the civil aircraft flight operation and studies and analyzes the influences of the flight experience and flight stage on the single-task load.

2 Task Unit Load Value

2.1 Assessment Method

The classification of the flight operation task units is obtained by combining with the human attributes and task attributes. The objective assessment method is used for the task load assessment to the task unit (Table 1) obtained by classification. The mark from 1 to 10 of the task load is given according to the task difficulty [9]. 1 mark means the task load is very low, and 10 mark means the task load is very high.

Table 1 Task unit classification of flight operations of civil aircraft

Human attribute			Task attribute			Tab num.
Perception	Visual sense	Scan	Far			V1
			Near	Location status information		V2
				Color status information		V3
		Monitor	Character			V4
			Picture			V5
		Achieve information	Character	Static state		V6
				Dynamic state	Unit information	V7
					Synthetical information	V8
			Picture	Static state		V9
				Dynamic state	Unit information	V10
					Synthetical information	V11
	Auditory sense	Signal	Attention tone			A1
			Warning tone			A2
			Computer speech			A3
		Communication	Conversation			A4
			Command			A5
			Report			A6
Cognition	Simple related					C1
	Selection					C2
	Signal distinguish					C3
	Estimate judgment					C4
	Prediction					C5
	Calculation					C6
Respond	Language	Conversation				S1
		Command/report				S2
	Operation	Simple operation	Button/knob/switch knob			K1
			Pedal			K2
		Precise operation	Continuation	Adjust		K3
				Manipulate throttle		K4
				Manipulate (control stick/handwheel)		K5
			Keyboard	Solo import		K6
				Continuation import		K7

Where V represents visual sense task, A represents auditory sense task, C represents cognition task, S represents language respond task, and K represents operation respond task.

2.2 Subject

The subjects for the experiment are divided into two groups: One group comprises of 18 students who are just graduated from the flight colleges, and the plane for the flight training is Cessna 172, and their average flight time is about 250 h, and the other group comprises of 15 experienced pilots, and their planes are A320 and B737, and their average flight time is about 12,000 h.

2.3 Data Processing

At first, the results of the objective assessment of the operation single-task workload values obtained by the objective assessment of the pilots of different experience are averaged, and also the operation single-task load values under different flight stages are also averaged, and then, the Pearson relativity is used for carrying out the relativity analysis to the single-task load under different flight experience, and at last, the linear regression analysis method is used for the regression analysis of the two sets of data, and then, the coefficient relationship between different flight experience is obtained.

2.4 Result Analysis

The averaged operation single-task load values obtained by the objective assessment of the 18 less experienced pilots and the 15 experienced pilots are used as the database of the single-task load values of the study, which is shown in Table 2, and then, the Pearson relativity is used for analyzing the relativity of the two sets of data, and the analysis results show the relativity of the flight task load obtained by the assessment of different flight experience is not high, and the relevant coefficient is 0.942 ($p < 0.05$). Indicated by the regression coefficient table shown in Table 3, because the constant is 0.264, thus, it can be believed that their coefficient relationship directly is 1.002, i.e., there is no deviation in value; thus, the influence of the flight experience on the flight task load is little.

Table 2 Value of single-task workload in different flight experiment

Task classification		Tab num.	Result from pilots with less experience	Result from pilots with rich experience
Perception	Visual sense	V1	3.46	3.27
		V2	2.97	2.85
		V3	2.37	2.97
		V4	4.00	4.00
		V5	3.54	3.55
		V6	2.47	3.03
		V7	3.16	3.64
		V8	4.86	5.3
		V9	2.39	2.88
		V10	3.25	3.63
		V11	4.9	5.05
	Auditory sense	A1	2.62	2.88
		A2	3.08	3.69
		A3	3.31	3.89
		A4	3.31	3.45
		A5	5.08	4.41
		A6	4.69	4.45
Cognition		C1	2.10	2.55
		C2	3.74	4.08
		C3	3.3	3.95
		C4	4.88	5.63
		C5	4.72	5.41
		C6	5.84	5.85
Respond	Language	S1	2.96	3.14
		S2	4.02	4.42
	Operation	K1	3.15	3.27
		K2	3.92	3.29
		K3	4.15	4.59
		K4	4.28	4.35
		K5	4.45	4.61
		K6	2.99	3.09
		K7	4.88	4.81
Coefficient			0.94	

Table 3 Coefficient of linear regression analysis

Model		Non-standardization coefficient		Standard coefficien*t*	*t*	Sig.
		B	Standard error			
Result from Pilots with less experience	constant	−0.264	0.263		−1.004	0.324
	Result from Pilots with rich experience	1.002	0.065	0.942	15.390	0.000

3 Study of the Influence of the Flight Stage on the Task Load

3.1 Assessment Method

The objective assessment method is used for the task load assessment of the task unit (Table 1) obtained by classification. The task load is marked according to the task difficulty, 1–10 marks: 1 mark means the task load is very low, and 10 marks means the task load is very high.

3.2 Subject

The plane for flight training is Cessna 172, and 18 pilots are tested, and their average flight time is about 250 h.

3.3 Data Processing

At first, the pilots of same experience level are chosen, and then, the objective assessment of the operation single-task load under different flight stages is carried out, and then, the obtained results are averaged; then, the Pearson relativity is used for the relativity analysis to the single-task load under different flight stages, and then, the linear regression analysis method is used for the regression analysis to the obtained data, and the coefficient relationship under different flight stages is obtained.

3.4 Result Analysis

The single-task load values of the operation under different flight stages obtained by the pilots' objective assessment are shown in Table 4.

The relativity analysis results of the single-task load of unit under different flight stages and the comprehensive objective assessment are shown in Table 5. The relativity results show there are the high relativity ($P < 0.05$) of the single-task load of operation and the comprehensive objective assessment under the flight stages. Indicated by the regression analysis results in Table 6, the single-task loads under different flight stages and the constants under the single-task load regression are all lower than 0.5; thus, it is believed that the factors of the influences of the flight stages on the single-task load of flight are as follows: takeoff coefficient 0.834,

Table 4 Value of task workload in different flight phases

Task classification		Tab Num.	Takeoff	Climb	Cruise	Descend	Approach	Land	Average
Perception	Visual sense	V1	4.63	3.00	1.84	2.95	4.80	5.53	3.79
		V2	3.50	2.95	1.68	2.74	4.00	4.44	3.22
		V3	3.37	2.74	1.37	2.53	3.60	4.28	2.98
		V4	4.84	3.58	1.84	3.16	6.00	5.84	4.21
		V5	4.26	3.26	1.89	2.79	5.00	5.17	3.73
		V6	3.71	2.68	1.68	2.63	4.60	4.76	3.35
		V7	4.00	3.33	1.79	3.37	5.40	5.42	3.89
		V8	4.12	3.56	1.95	3.76	6.00	5.24	4.10
		V9	3.31	3.22	1.44	3.17	5.80	5.19	3.69
		V10	3.89	3.53	2.05	3.16	5.00	4.67	3.72
		V11	4.18	3.72	2.32	3.21	6.40	5.24	4.18
	Auditory sense	A1	3.79	2.58	1.53	2.37	4.40	4.79	3.24
		A2	4.00	3.26	2.37	3.21	4.20	4.72	3.63
		A3	3.94	2.89	1.89	3.00	5.50	4.71	3.65
		A4	4.17	3.11	1.79	2.84	4.80	5.24	3.66
		A5	4.58	3.63	2.45	3.51	6.00	5.89	4.34
		A6	4.53	3.47	1.95	3.21	6.00	5.56	4.12
Cognition		C1	2.53	2.11	1.42	2.16	3.40	3.44	2.51
		C2	3.47	2.63	1.79	2.63	4.40	4.95	3.31
		C3	3.28	2.74	1.74	2.58	5.20	4.78	3.38
		C4	4.56	3.37	2.53	3.37	5.80	5.78	4.23
		C5	4.56	3.53	2.26	3.37	5.80	5.50	4.17
		C6	5.11	4.53	3.50	4.11	7.00	6.50	5.12
Respond	Language	S1	2.82	3.47	1.63	3.16	5.60	5.00	3.61
		S2	4.53	4.05	2.11	3.84	6.40	5.89	4.47
	Operation	K1	4.00	2.84	1.68	3.05	5.60	5.11	3.72
		K2	3.42	2.63	1.58	2.26	3.20	4.68	2.96
		K3	3.67	3.13	2.11	3.42	6.40	6.47	4.20
		K4	3.26	2.58	1.84	2.68	3.80	5.21	3.23
		K5	3.74	2.79	1.98	2.68	4.20	5.26	3.44
		K6	3.83	3.13	1.74	3.16	4.40	5.76	3.67
		K7	5.44	4.42	2.53	4.11	7.00	6.94	5.07

Table 5 Correlation analysis of signal task workload in different flight phases

		Takeoff	Climb	Cruise	Descend	Approach	Land	Average
Subjective evaluation value	Pearson correlation	0.697*	0.684*	0.825*	0.690*	0.667*	0.723*	0.788*
	Sig.	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 6 Analysis of the regression coefficients

		Non-standardization coefficient		Beta	*t*	Sig.
		B	Standard error			
Takeoff	Constant	0.265	0.480	–	2.637	0.013
	Subjective evaluation	0.834	0.128	1.087	5.748	0.000
Climb	Constant	0.239	0.435	–	1.700	0.099
	Subjective evaluation	0.769	0.116	1.182	5.774	0.000
Cruise	Constant	0.274	0.231	–	1.187	0.245
	Subjective evaluation	0.454	0.062	1.024	7.372	0.000
Descend	Constant	0.421	0.392	–	2.093	0.045
	Subjective evaluation	0.650	0.104	1.191	5.840	0.000
Approach	Constant	0.550	0.842	–	0.653	0.519
	Subjective evaluation	1.257	0.224	1.162	5.606	0.000
Land	Constant	0.513	0.509		4.352	0.000
	Subjective evaluation	1.024	0.135	1.133	6.088	0.000

climb coefficient 0.769, cruise coefficient 0.454, descend coefficient 0.650, approach coefficient 1.257 and landing coefficient 1.024.

4 Discussion

All of the prediction models are required and introduced in the study of the task unit attributes. Because the task unit attributes include the task load value and the task operation time, not all models study the two aspects, such as SPOM (simulation to predict operator workload in a command system) which only analyzes the operation time of the task unit, because the method only predicts the workload by time relationship. The confirmation methods of the task unit load values are also differed in different prediction models, e.g., the load values of CMRM and TLM are only relative values and cannot carry out the comparison analysis of absolute values with the actual value; thus, the paper aims at getting the absolute value of the task unit load value, and the task unit load value of the operation of the paper uses the expert assessment method proposed by TAWL and doesn't secondarily process the assessment results which are directly used as the database of the task unit load values. Indicated by data in Table 2, the load values of the pilots of different experience are basically same, and the load deviation generated by experience under the normal flight status can be neglected. Indicated by the results in Table 4, the obtained loads are not high in general, and the pilots' load in the normal flight status is proper, but the loads are high in the takeoff stage and the approach and landing stages; thus, particular attention shall be paid when driving in the takeoff stage and the approach and landing stage.

5 Conclusion

Targeting to the A320 operation program and combining with the human's information processing channel analysis and operator's human–machine interface analysis, the paper gets the classification of the operation task units applicable for the civil aircraft under sensing, cognition and response. Based on the obtained results of task classification, and according to the 33 pilots' objective assessment, the paper analyzes the influence of the flight experience on the single-task load, and on the other hand, combining with the 18 pilots' assessment results, the paper analyzes and studies the influences of different flight stages on the single-task load. Results indicate the influence of the flight experience on the flight load is little, and the influences of different flight stages on the single-task load of operation are high and the high relativity exists. Also the paper gives out the coefficients of the influences of different flight stages on the single-task load of flight.

The results obtained by the paper can provide basis for further studying the pilots' workload; however, the objective assessment of the paper depends on the pilots' objective experience and knowledge; thus, it is influenced by the pilots' personal factor. To solve the problem, the quantity of the pilots is increased in the paper to ensure the accuracy of the result in a certain degree, but how to further improve the model accuracy is still to be deeply studied.

Compliance with Ethical Standards The study was approved by the Logistics Department for Civilian Ethics Committee of the AVIC China Aero-polytechnology Establishment.

All subjects who participated in the experiment were provided with and signed an informed consent form.

All relevant individual information of subjects has been met with regard to subject protection.

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Classification and Cause Analysis of Human Errors in the Flight Accidents of International Modern Fighter Planes

Yan Lyu, Yi Xiao and Qianxiang Zhou

Abstract Most of the current aviation accidents are caused by human errors. Analyzing the types of human errors, causes, etc. is the important basis for finding out the defects in the system and making the prevention measures. The prior classification generally classifies the human errors or analyzes the causes from the engineering or human ability and status, and has big defect and difficulty for the active identification of the errors in human's cognition process stage. Based on the HFACS error analysis model and CREAM reliability analysis method and combining with a great amount of flight accident data of the international modern fighter planes, the paper analyzes the human error causes in the flight accidents of the fighter planes and proposes the relevant measures for reducing human errors according to the analysis results. The method can be used for directing the monitoring and analysis of the human error events in the daily flight of the air force and improving the safety level of the flight stage.

Keywords Human error · HFACS model · CREAM

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1 Introduction

The statistic data prove that 70–80% aviation accidents are related to human errors. Most of the researchers analyze according to the human errors in the flight accidents or accident symptoms and cannot ensure the results to be comprehensive and consistent. The analysis method for the pilot's human errors is still in the development stage at present. Based on the statistic data of the flight accidents caused by human errors in the flight activities of the international modern fighter planes [1], the paper carries out the classification of human error types, analysis of human errors, and cause sourcing so as to provide reference for preventing flight accidents and improving flight safety as well as the basis for making the prevention measures. It hopes that the paper can be used for directing the monitoring and analysis of the human error events in daily flight, and improving the safety level of the flight activity.

2 Classification Method for Human Errors of Aviation

The study of the aviation industry for human errors is started from the 1940s. With the development of the study of human error reliability, the researchers make a series of mature theory models from the aviation physiology and psychology, system engineering, etc., and by combining with human's cognition psychological process and accident causation theory. The paper introduces the following two classification methods which, respectively, are the Cognitive Reliability and Error Analysis Method (CREAM) [2] and the Human Factors Analysis and Classification System (HFACS) [3].

The CREAM [2] divides the human's cognition process into the four stages of observation, explanation, plan, and execution so as to analyze the possible corresponding human errors of different cognition stages; however, the human error mode given by the method in every stage totally depends on the designer's personal experience and knowledge level. The detailed causes are insufficient; thus, the error mode cannot be said to be comprehensive.

HFACS model [3] encodes the human errors of the flight activity in detail and is widely applied in the aviation accident analysis, but when the HFACS model is used for analysis, only the ratios of all types of errors can be counted, but the deep causes cannot be explored, which is not very meaningful for error prevention.

Thus, on the basis of considering the HFACS model and combing with the opinions of the cognition psychology, the identification of human errors in the flight accidents of the fighter planes is carried out. In addition, combining with the CREAM tracing analysis method, the tracing analysis is carried out to the root causes of the flight human error events of the international fighter planes.

3 Human Error Cause Analysis and Root Cause Tracing Method Based on Cognition Opinions

3.1 Classification of Cognition Process

Based on the encoding of the HAFCS model to the flight human errors, combining with the four function stages of the cognition process in the CREAM and integrating with the actual condition in the flight activity of the fighter planes, the paper deeply analyzes the generation mechanism and psychological causes for the human error events in the flight activity of the fighter planes, the results are in Table 1.

3.2 CREAM Tracing Analysis Method

Firstly, the method decomposes the events and establishes the event sequence; secondly, according to the CREAM expansion analysis method [4], the paper identifies and analyzes the human's cognition function sections and corresponding invalid modes involved in each sub-event; and at last, the CREAM tracing method [5] is used for the tracing analysis of the root cause of each sub-event to determine the error mode of each sub-event. The tracing analysis is carried out according to the error mode and the corresponding former cause tracing table until the root cause of the event is found.

According to the current flight human error code table and combining with accident statistics, Huang et al. [6] refined the former cause class of human errors in the takeoff stage of the aviation flight and concluded the basic factors of the accidents into the 6 aspects including hardware information, software information, environment, organization management, crew management, and personal status. The former causes of the flight human error event can also be correspondingly divided into six types which become the classification groups and are represented by letters. Each group is further refined into a plurality of former causes and differed by numbers. The names and codes of the former types are shown in Table 2.

Every human error event can be corresponded to a stage of cognition. The error cause corresponding to the stage is looked up according to Table 1. If the cause is the root cause already, continuous tracing is not required; if not, the other former causes can be continuously looked up from Table 2.

Table 1 Cognitive process classification table

Human error	Cause
Observation	Monitor invalid; expect deviation; information chaos; overload; dizziness
Explanation	Information similar; memory overload; distract; lack of knowledge
Decision	Knowledge incorrect; paranoid; risk assessment invalid; priority disorder
Execution	Operation incorrect; environment mutate; misuse; space disturbed

Table 2 Classification of pre-cause (pre-cause and result retrofit method in CREAM)

Code	Pre-cause
H1	Design defects in control and equipment devices
H2	Design defects in display interface
H3	Design defects in automation device
I1	Arrangement disorder in checklist, chart, and user manual
I2	Design defects in standard operation procedures
E1	Poor physical environment
E2	Poor working environment
O1	Organization influence
O2	Unsafe supervision
C1	Internal cooperation in aircrew
C2	Cooperation with ATC
P1	Poor personal mental state
P2	Poor personal physical state
P3	Poor personal preparedness state
P4	Poor knowledge and skills in personal

4 Analysis of Human Errors and Root Causes in the Flight Accidents of International Fighter Planes

4.1 Description and Classification of Flight Accidents of International Modern Fighter Planes

Table 3 is based on the behaviors which directly cause the accident, and carries out sub-event activity decomposition to the accidents relevant to human errors in the book named as the Flight Accidents of I*nternational Modern Fighter Planes* [1]. The error section (Table 1) of each event is analyzed on the basis of the cognition reason, and the CREAM consequence former cause tracing table (Table 2) is used for the tracing analysis of the accidents and exploring the root cause of the accident (Table 3 selects some events for exhibition).

Table 3 Activity disintegration of international modern fighter (partial)

Type	Description	Cause	Human error	Pre-cause
Harrier fighter	Two fighters collided during training	Failed to perform flight plan	Explanation	I1
Wind fighter	Re-flight failure at low attitude	Due to bad weather, pilot performs wrong Operation	Execution	E1

4.2 Analysis of Human Error Types

Based on the 138 human-error-relevant accidents of 13 models of fighter planes, which are provided by *Flight accidents of international Modern Fighter Planes*, the statistic data indicate that there are 60 observation errors, which is 43.4%; 10 explanation errors, which is 7.2%; 41 plan errors, which is 29.7%; and 27 execution errors, which is 19.6%.

Indicated by above, the observation stage owns the most cognition sections corresponding to the human error accidents. The observation error not only relates to the perception ability but is also influenced by environment and task. When all factors are integrated together, the attention load is increased, and then, the error probability increases. The pilot has sufficiently understood and been trained for the task, and the errors caused by memory are few. The plan errors are mainly caused by overload information. Most of the accidents caused by execution errors are emergent accidents, and the causes comprise of unreasonable design, mistakes of the ground service personnel or air management personnel, etc.

4.3 CREAM Tracing Analysis

To find out the essential cause of the accident, the CREAM former cause-type table (Table 2) is used for the root cause tracing analysis of 138 accidents, and some results are exhibited in Table 3. Then, the accident root cause types are counted, and the results are in Table 4.

Table 4 Root cause statistical table

Code	Root cause	Accident QTY
H1	Design defects in control and equipment devices	5
H3	Design defects in automation device	3
I1	Arrangement disorder in checklist, chart, and user manual	3
I2	Design defects in standard operation procedures	1
E1	Poor physical environment	9
E2	Poor working environment	7
O1	Organization influence	9
O2	Unsafe supervision	11
C1	Internal cooperation in aircrew	15
C2	Cooperation with ATC	7
P1	Poor personal mental state	16
P2	Poor personal physical state	18
P3	Poor personal preparedness state	1
P4	Poor knowledge and skills in personal	55

Indicated by the statistics of the above table, the errors caused by personal status is 65.2%; the errors caused by the crew resource management is 15.9%; the errors caused by organization management is 14.5%; the errors caused by environment is 11.5%; the errors caused by hardware is 5.6%; and the errors caused by software/information is 2.9%.

The statistic results indicate the errors caused by the software/hardware facilities are few, which means the human errors purely caused by the mechanical failure are gradually decreased with the development of the industrial technology, and the errors caused by personal status are the most, wherein the pilot's personal quality and professional quality are the top factors, and also being influenced by the environment, the pilot may have vertigo, blackout, spatial disorientation, etc., and then, the human error operation is caused.

4.4 Root Cause Analysis Based on the Cognition Stage

Based on the former CREAM consequence and cause tracing table (Table 2), the root causes causing the accidents are, respectively, counted and analyzed according to the four stages of cognition, and the results are shown in Table 5.

Combining with the analysis of Tables 1, 2, and 5, the human errors of the cognition section are induced together by a plurality of root causes. To the four stages of cognition, the pilot's personal knowledge and insufficient skill are both the primary causes for human errors. Accurate perception to the visual information is the precondition for the pilot to execute the task. The over-high cognition load, insufficient spatial ability, unfamiliar utilization of regulations, and insufficient task training can all cause the human errors of the explanation and plan stages, and in the execution stage, besides the heavy task information, the pilot's overconfidence inexperienced cooperation with the crew, insufficient experience for emergencies, etc. also cause the human error.

To the observation stage, the crew resource management is the secondary reason causing the human error, e.g., the navigator does not report the radar position to the pilot, and then, two planes are collided, etc.; thus, in the daily training, the cross-check in the crew, team atmosphere, crew communication, etc. shall be reinforced.

To the explanation stage, the ratios of the human errors caused by the pilot himself/herself, the personal ability of the flight crew and team cooperation are basically the same; thus, the organization management errors cannot be neglected,

Table 5 Root cause statistical table in different cognitive staircase

Human error	Root cause code(number)
Observation	H1(2)/H3(2)/E1(5)/O1(3)/O2(3)/C1(8)/C2(1)/P1(10)/P2(17)/P3(1)/P4(22)
Explanation	I1(1)/E2(2)/O1(1)/C1(1)/P4(6)
Decision	H1(1)/I1(2)/I2(1)/E1(2)/E2(4)/O1(4)/O2(6)/C1(2)/C2(6)/P1(6)/P4(14)
Execution	H1(2)/H3(1)/E1(2)/E2(1)/O1(1)/O2(2)/C1(4)/P2(1)/P4(14)

and during the flight task, the task content shall be clearly specified, the excellent communication between aviation management systems shall be ensured, the ground service and maintenance personnel shall perfect the check regulations, etc.

To the plan stage, the crew resource management is the secondary factor causing the human error. Besides making the right decision, the crew shall also reinforce the cooperation with ATC, e.g., the fighter planes lacking of the air anti-collision warning system shall keep well communication with ATC to make the right decision in time.

To the execution stage, the bad physical environment or work environment can easily cause human errors. To the influence of the environmental emergency, besides the task regulations of the pilot training, the pilot shall also be trained for skills and emotion control by combining with the environmental factors, and the measures for all possible emergent conditions shall be made.

5 Conclusion

The paper refers to the research theory of aviation human errors, combines with the task classification and root cause tracing analysis method based on the cognition to analyze the 138 flight accidents caused by human errors, and the gets the following conclusions:

(1) The paper combines with the flight activity environment and refines the former cause classification table of human errors of the flight accidents of the fighter planes to construct the perfected analysis system of aviation human error reliability.
(2) The analysis results indicate that the observation and plan stages are the main sections causing human errors, and the main causes for the errors are insufficient personal knowledge and skills; indicated by the statistic results of the root causes, the crew inside cooperation, organization management, environmental factors, etc. are the essential causes of the accidents.
(3) Combining with the accident statistics, the corresponding methods in daily training are proposed. The paper can be used for directing the monitoring and analysis works of the daily human errors of the fighter planes and improving the flight safety.

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Experiment Study of Weight-Bearing Walking Fatigue of Human Body Based on ECG Signal Characteristics

Xiuyun Hao, Qianxiang Zhou and Zhongqi Liu

Abstract To discuss the judgment for the variation of the human body fatigue under the weight-bearing walking condition and based on the characteristics of the indexes of heart rate, heart rate variability, etc., the paper uses the LabVIEW software to realize the preprocessing of ECG signals, detection of R wave, and HRV analysis, which is based on confirming the relativity of the ECG signal index and human body weight-bearing fatigue. Results indicate through the analysis of ECG characteristic indexes, with the increase of the weight-bearing walking time and the increase of the human body fatigue, HRmean, RMSSD, HFnorm, LF/HF, and sample entropies clearly change, wherein HRmean, HFnorm, LF/HF, and sample entropies are sensitive to the fatigue variation, and then does the RMSSD. The principal component analysis (PCA) method is used for establishing the ECG comprehensive index which is the basis for judging that under the condition of the weight-bearing walking experiment of the paper, the volunteers are clearly fatigue in stage 3, and the fatigue is significantly increased in stage 5.

Keywords Weight-bearing walking · ECG · LabVIEW · HRV

1 Introduction

The human body weight-bearing walking is closely relevant to people's life, such as military march, worker's weight-bearing labor work, wild survival, labor transportation. People often feel fatigue because of the big load, long walking time, etc.

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As the way causing human body fatigue, the weight-bearing walking can be studied from the aspect of fatigue. There is a close relationship between the human body's physical fatigue and the electro-physical signals (EEG, ECG, EMG, etc.). To walling fatigue, the ECG variation is direct; particularly, the heart rate variability (HRV) can reflect the activity of the autonomic nervous system and quantitatively assess the tension and the balance of the cardiac sympathetic nerve and pneumogastric nerve. Thus, it can reflect the influences of the physical fatigue and mental fatigue on the human body at the same time, and in general, the study analysis methods are divided into four types, i.e., the time domain analysis method, the frequency domain analysis method, the time and frequency domain analysis, and the nonlinear analysis method, wherein the time domain analysis method and the frequency domain analysis method are often used, and their analysis theory systems are relatively mature.

Thus, based on the heart rate and heart rate variability, the paper discusses the generation and variation mechanisms of the fatigue in the weight-bearing walking process as well as the relationship between the indexes of heart rate and heart rate variability and the fatigue of the weight-bearing walking movement through the method of combining objective and subjective ways so as to establish the objective judgment method for the weight-bearing walking fatigue and provide reference for further studying the weight-bearing walking fatigue.

2 Method

(1) Subject

The volunteers comprise of 15 young healthy males who are 20–26 years old and do not have any anamnesis. Their physical parameters such as the resting heart rate are not significantly differed, and they have high understanding and cooperation abilities for the experiment and can accurately express their fatigue feeling.

(2) Experiment equipment

One treadmill, one MP150 multi-conductive physical recorder, one laptop, one bag, a plurality of weights, and a plurality of wires are used for the experiment.

(3) Setting of walking conditions

The group slope is 0^{o}, the weight is 30% of the body weight, and the walking speed is 7 km/h.

(4) Weight-bearing way

Backpack weight bearing.

(5) Procedures

a. The experiment purpose, flow, and relevant notices of the experiment are told to the volunteers by the work staff before the experiment. The objective fatigue assessment table, i.e., the improved Borg measurement table (Table 1), is distributed, and the volunteers understand and are familiar with the content of the assessment table and then fill the personal information.
b. When the experiment starts, the volunteers hand their objective fatigue assessment table to the work staff. The experiment is divided into seven stages of which the time durations are, respectively, 0–1, 4–5, 8–9, 12–13, 16–17, 20–21, and 24–25 min. Before the weight-bearing walking, the volunteers rest for 1 min, and the work staff ask the volunteers for their objective fatigue marks at this time and record, and then collect and save 1 min of ECG data at every 3 min, and the work staff also ask the volunteers for their objective fatigue marks at this time and record. During the whole experiment, the ECG data of 7 sections of each volunteer are collected and recorded.

(6) Data analysis method

The paper is mainly based on LabVIEW for processing and analyzing the collected ECG data, including ECG signal processing, R wave detection [1, 2], and HRV analysis [3, 4].

a. Data collection

The MP150 multi-conductive physical recorder of USA Biopac Company is used for sampling the ECG signals at the speed of 1000 Hz. The collection time is 1 min, the collection time interval is 3 min, 7 sections of data are collected, and the collected ECG signals are stored in the computer.

b. Signal preprocessing

The work frequency interference and the baseline drift are the most common external interference of the ECG signals. The paper uses the method of small wave change to filter out the baseline drift [5, 6], and the filter with resistance is designed to filter out the 50 Hz work frequency interference [7, 8].

c. R wave detection

HRV is the little fluctuation of the R wave intervals between successive beats; thus, accurately detecting the R wave and measuring the time when the R wave peak occurs are the key points for collecting the HRV signals. The paper uses the method of combining the threshold and inclination rate to detect the R wave.

Table 1 Measurement table of fatigue degree

Subjective feeling			
No effect	A little pain	Painful	A strong pain
0–3	4–5	6–8	9–10

d. HRV analysis

The paper mainly carries out the HRV analysis from time domain, frequency domain, and nonlinearity and extracts the indexes of RMSSD, HFnorm, LF/HF, and sample entropies.

3 Result and Analysis

3.1 Objective Assessment of Fatigue of Weight-Bearing Motion

The Borg measurement table is a method for speculating the motion strength and has been widely applied in foreign countries for many years. The experiment uses the modified Borg measurement table and makes detailed explanation for the volunteers before the experiment is carried out. Figure 1 shows the objective fatigue average evaluation condition of the volunteers in the seven experiment stages. Indicated by Fig. 1, with the increase of time, the objective fatigue gradually increases in the tendency of fast first and slow second. The curve increases rapidly from 0 to 12 in., which means the fatigue accumulation is fast, and then, the fatigue accumulation is slow. Indicated by questionnaires, most volunteers feel breathing quickly in the third stage (8–9 min) and feel a little fatigue; in the fifth stage, most volunteers feel very fatigue and run with sweat, and some volunteers' electrode plates even disconnect because of the sweat. After the end of the experiment, most volunteers feel very fatigue.

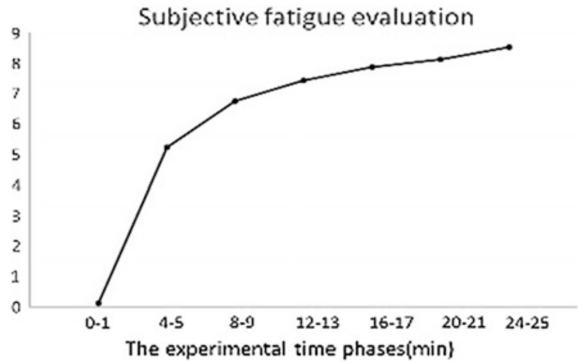


Fig. 1 Result of objective fatigue investigation

3.2 Analysis of Heart Rate and Heart Rate Variability

The results of the time domain, frequency domain, and nonlinear index of the heart rate and the heart rate variability are as follows (as in Figs. 2, 3, 4, 5, and 6).

Indicated by the above figures, with the increase of fatigue, the indexes of HRmean and LF/HF tend to increase, and the indexes of RMSSD, HFnorm, and sample entropies tend to decrease. The variation in amplitudes of the indexes of HFmean, RMSSD, and sample entropy curves are big in the early stage of the weight-bearing motion, which is caused because the volunteers' bodies are in the stage of being adaptive to the whole experiment weight-bearing condition and motion rates and rhymes in the early stage; thus, the variations of all indexes are high (indicated by the volunteers' objective fatigue scoring condition), and then with the weight-bearing motion time goes by, the motion condition is gradually adapted, and the curve fluctuation is decreased.

The relativity analysis is carried out to all indexes and the objective fatigue degrees of the HRV experiment stage. The SPSS19 software is used for calculating the Spearman correlation coefficients, and then, the Spearman correlation coefficients and significance levels of all indexes and the objective fatigue are obtained. The results are given in Table 2.

Indicated by Table 2, the significance levels of all indexes and the objective fatigue are all lower than 0.05, which means there is a significant linear relationship among all indexes and the objective fatigue; thus, in the process of the weight-bearing walking motion, the indexes of HRmean, RMSSD, HFnorm, LF/HF, and sample entropies of the HRV sequence can all reflect the volunteers' fatigue degree, wherein the significance levels of the HRmean, HFnorm, LF/HF, and sample entropies are all lower than 0.01, and the significance levels of RMSSD and the objective fatigue are between 0.01 and 0.03.

Thus, it can be indicated that in the processing of weight-bearing walking, the HRmean, HFnorm, LF/HF, sample entropies, and the objective fatigue have high relativity and are more sensitive to fatigue, and then is the sensitivity of RMSSD to fatigue.

Fig. 2 HRmean

Fig. 3 RMSSD

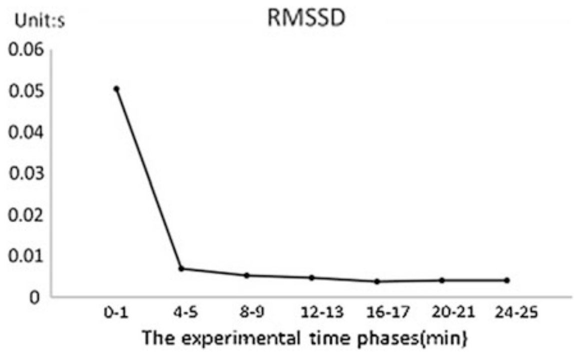


Fig. 4 HFnorm

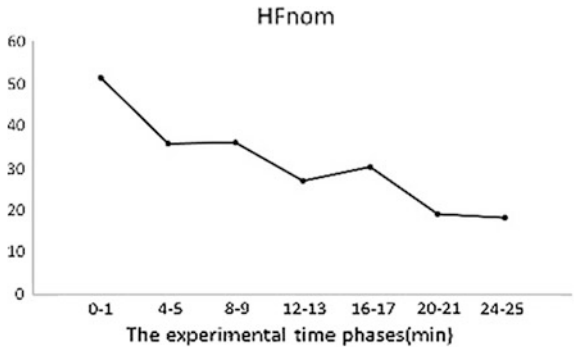
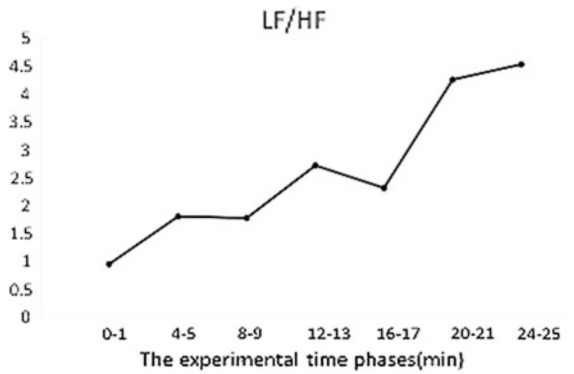


Fig. 5 LF/HF



Because the HRmean, RMSSD, HFnorm, LF/HF, and sample entropy indexes clearly change with the prolongation of the weight-bearing walking, based on the five indexes, the principal component analysis method is used for establishing the comprehensive assessment indexes.

The SPSS19 software is used for principal component analysis of the ECG signals, and after being analyzed by the main ingredient analysis method, the

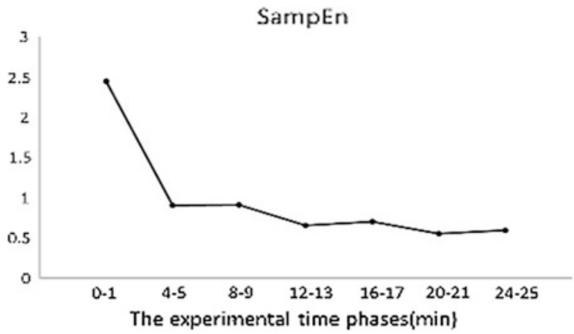


Fig. 6 Sample entropies

Table 2 Analysis results of relativity of all indexes and the objective fatigue degree

HRV indexes	The correlation coefficient	Sig.
HRmean	0.9643	0.0005
RMSSD	−0.8571	0.0137
HFnorm	−0.9285	0.0025
LF/HF	0.9286	0.0025
Sample entropies	−0.8928	0.0068

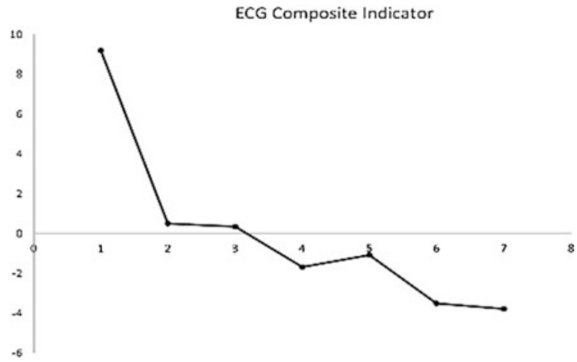


Fig. 7 ECG comprehensive index

accumulated contribution rate of the first main ingredient reaches 87.87%; thus, the first main ingredient is taken as the target index of characteristic extraction. The comprehensive index is:

$$\begin{aligned} Y = & -0.97367\,\mathrm{HRmean} + 0.939548\,\mathrm{RMSSD} + 0.959978\,\mathrm{HFnorm} \\ & - 0.825\,\mathrm{LF/HF} + 0.980062\,\mathrm{SampEn} \end{aligned} \quad (1)$$

The values of HRmean, RMSSD, HFnorm, LF/HF, and sample entropies are substituted into formula (1), and then, the physical comprehensive index curve of the weight-bearing walking shown in Fig. 7 is obtained. Indicated by the figure, the change of the initial ECG comprehensive index value is big, which is caused by the volunteers' bodies that are in the stage of being adaptive to the whole experiment weight-bearing condition and motion rate and rhyme in the early stage; thus, the change is big. From the third time section, the value of the ECG comprehensive index is significantly changed, and from the third time section, the values of the ECG comprehensive index are lower, which reflects that the volunteers begin to feel fatigue. Since the fifth time section, the value of the ECG comprehensive index is significantly changed again, which reflects that the volunteers' fatigue is increased.

4 Conclusions

(1) After the analysis based on the heart rate and heart rate variability, when the volunteers are in the weight-bearing walking motion, the indexes of HRmean and LF/HF tend to increase and the indexes of RMSSD, HFnorm, and sample entropies tend to decrease.
(2) The indexes of HRmean, RMSSD, HFnorm, LF/HF, sample entropies, and the objective fatigue are in linear relativity, which reflects the weight-bearing motion fatigue; in the weight-bearing walking process, the indexes of HRmean, HFnorm, LF/HF, and sample entropies are relatively sensitive to fatigue, and then is the sensitivity of RMSSD to fatigue. Thus, the paper provides index reference basis for further studying the weight-bearing walking fatigue.
(3) The method of principal component analysis is used for establishing the ECG comprehensive index which is used for judging that in the weight-bearing walking experiment condition of the paper, the volunteers are clearly fatigue in the third stage (8–9 min), and their fatigue is increased in the fifth stage (16–17 min).

In summary, under the weight-bearing environment, the paper discusses the variation in tendencies of the time domain, frequency domain, and nonlinear indexes of the ECG signals during the weight-bearing walking process. The experiment results indicate when people walk in the weight-bearing way, with the increase of the fatigue, sometime, frequency and nonlinear indexes show the clear variation tendencies. Through the significance analysis to all indexes and the objective fatigue, the study preliminarily confirms the ECG signal index which can effectively characterize the fatigue process and degree. Combined with the method of principal component analysis, the paper establishes the ECG comprehensive index and judges the fatigue variation with the ECG comprehensive index, which more subjectively reflects the generation and deepening time sections of the weight-bearing walking fatigue and more effectively analyzes and assesses the variation rule of the weight-bearing walking fatigue; thus, the paper provides relevant basis for the work efficiency design of the weight-bearing walking system.

Compliance with Ethical Standards The study was approved by the Logistics Department for Civilian Ethics Committee of School of Biological Science and Medical Engineering of Beihang University.

All subjects who participated in the experiment were provided with and signed an informed consent form.

All relevant ethical safeguards have been met with regard to subject protection.

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Evaluation of Operator's Workload Based on EEG Signal

Haiyan Niu, Shunwang Xiao, Qianxiang Zhou and Yaofeng He

Abstract The degree of special vehicle's automation and intelligent is getting higher and higher. The efficient integration of operator and vehicle will become the fundamental guarantee of full efficiency. The operator's ability is the core element of the special vehicle capacity, but the operator's ability is limited. The subjective evaluation and objective physiological evaluation are combined in this paper. The operator gives the degree of mental fatigue through the narration after completing the task; at the same time, the operator's EEG signal is got. The mapping relation of EEG signal and mental fatigue degree is set up, and then the evaluation mathematical model of operator's workload based on EEG is built. This evaluation model can provide technical support for the new style special vehicles' design and development.

Keywords EEG · Mental fatigue · Evaluation

With the higher degree of vehicle automation and intelligent, the efficient integration of people and vehicle becomes the fundamental guarantee of playing a full role in efficiency. People are regarded as the core elements of playing the ability of special vehicles, and information perception and control ability are limited, and are the fundamental basis of design. Mental load of personnel is forecasted and evaluated. On the one hand, the constraintswere put forward on the usability from the angle of personnel ability. On the other hand, in the design process, the implicit major defects in man-machine engineering is timely discoveried.

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1 The Evaluation Method of Mental Load

The mental load refers to the workload of mental activity that is borne by personnel in unit time and is mainly shown as information acquisition, tracking, decision, memory, and other workloads without the obvious physical power. Evaluate the personnel mental load of special vehicles, make their mental load in a better state in operation process in order to provide the basis for design of intelligent manipulation interface of special vehicle. The mental load evaluation is not general method of direct measurement, and only adopts the indirect method. According to the workload, evaluate the internal characteristics and applicable range, and generally divide into four categories: subjective evaluation method, elevation method of main task, evaluation method of auxiliary task, and evaluation method of physiological index. The subjective evaluation method refers to the subjective statement mode after the operating experience of personnel, including Cooper-Harper evaluation method, NASA-TLX subjective evaluation method; the elevation method of main task refers to calculate in turn the mental load through evaluating the performance indexes of personnel operation, including the single indicator evaluation method and the multi-criterion evaluation method. The evaluation method of auxiliary task means that personnel uses the remaining resources to complete the auxiliary task and to express the main task mental load, and the design of auxiliary task is based on the characteristics of main task. The evaluation method of physiological index mainly includes the heart rate variation, electroencephalogram, breath, blood pressure, human body temperature [1, 2].

For electroencephalogram (event-related potential), the change of electroencephalogram is sensitive to the mental load. It means that a series of transient brain potential change can be recorded in scalp when a brain conducts the information processing for a discrete event. For example, P300 is regarded as the sensitive and meaningful index that can reflect the information processing activities and refers to a positive potential that is recorded in about 300 ms after a stimulus event. This can reflect the utilization degree of information processing resources. According to its change, quantitatively evaluate the workload of main operation [3].

This paper adopts the combination of subjective evaluation and evaluation method of objective physiological index, provides the mental fatigue degree through a topic comment after the personnel completes the operation task, extracts the personnel electroencephalogram, and establishes the model of the mapping relationship between electroencephalogram change features and mental fatigue degree. Its purpose is to express the people's subjective fatigue feelings in an objective way, to further establish the evaluation model of mental load based on electroencephalogram, and to provide the technical support for mental load evaluation in the design and development course of a new generation of special vehicles.

Overall plan: Test the person's electrooculogram in the course of a person observation and targeting, record the people's fatigue degree of attention, according to the score value of subjective evaluation scale on the fatigue degree and to the theory of physiological signal processing, establish a scatter-fatigue scores drawing of continuous signal, adopt the data fitting and other modeling approach, establish the model of the mapping relationship between electroencephalogram change features and mental fatigue degree, and put forward the threshold value of brain wave fatigue.

2 Test Schematic Design

The selection of tested people: Select 40 operators of a special vehicle, with good eyesight, without fatigue in body and mind.

The selection of test task: Rely on a certain type of training simulation equipment, and set 4 items of people's daily training tasks as the test task.

The selection of test equipment: Adopt Neuroscan electroencephalogram record equipment, with the sampling frequency of 256 Hz, conduct 32-lead record, and adopt the standard record of 10–20 electrode lead positioning that is calibrated by the International Electroencephalogram Society.

The design of test steps: ① Test training, through pre-experiment adaption and familiar with testing procedures; ② Conduct the resting evaluation of tested people, record 5 min electroencephalogram as a state before mental load producing; ③ The tested people complete the specified operation tasks are subject to a subjective fatigue inquiry every 2 min; the test task is over in 30 min, and electroencephalogram is recorded in the meanwhile.

Test data record: When people's mental state changes, the recorded electroencephalogram mode will change accordingly, so people's fatigue degree can be estimated through recording and analyzing the electroencephalogram in the course of performing a task. In general, in the course of change from the normal state to the fatigue state, the slow wave increases, and the fast wave reduces. Four frequency bands that are the most commonly used are recorded in test, namely, δ(0.5–4 Hz), θ(4–8 Hz), α(8–13 Hz), β(13–25 Hz) [4].

Four kinds of waveforms are recorded in the test:

(1) α-wave frequency 8–13 Hz, wave amplitude 20–100 μV. It is formed because the excitement and inhibition of nonspecific subthalamic nucleus under the cerebral cortex start the synchronism of electric activity of a large number of nerve cells in cortex. α-wave is more in the condition of closing eyes in quiet, and is the most in occipital region, but it disappears in the condition of emotional tension, thinking about a problem, or opening eyes.
(2) β-wave frequency 14–30 Hz, wave amplitude 5–20 μV. Its frequency is more than the frequency of α-wave, so it is called the fast wave. It is significant at frontal lobe and parietal lobe. When the emotional tension β-wave increases, wave amplitude rises. β-wave amplitude is higher than a normal value, which is an expression of cortical excitability rising.

(3) θ-wave frequency 4–7 Hz, wave amplitude 100–150 μV. This is an expression of inhibition state of central nervous system. When an adult is sleepy, θ-wave is visible generally.
(4) δ-wave frequency is less than 4 Hz, and wave amplitude is more than 200 μV. The frequency of θ-wave and δ-wave is lower than the frequency of α-wave, so they are called the slow wave.

According to the characteristics of four kinds of waveforms, it can be found that β-wave mainly participates in people's thinking activity and is closely relevant with people's cognition, memory, and attention. In this article, the brain fatigue and mental load are researched through the change of β-wave.

3 Data Processing and Analysis

(1) Test data preprocessing: Electroencephalogram preprocessing mainly refers to artifact processing. Directly delete the signal spectrum with a great fluctuation, remove the power frequency interference, etc., through band-pass filtering, keep the useful signal spectrum, and use the independent component analysis to remove the vertical electrooculogram and the horizontal electrooculogram.
(2) Fatigue energy calculation: Intercept the β-wave signal before fatigue (resting) and in the course of fatigue, as shown in Fig. 1. According to the method of signal processing, calculate its energy. After normalization processing on energy, gain the fatigue energy points. According to the fatigue evaluation results, gain the evaluation results of mental load. Calculation process is as follows:

    ① According to 1/3 frequency octave method, calculate the octave spectrum. According to the frequency domain characteristics of β-wave signal, select the octave analytical method as the processing method of β-wave frequency domain analysis. According to the formula (1), calculate β-wave energy spectrum after preprocessing and Fourier transform, namely, octave spectrum.

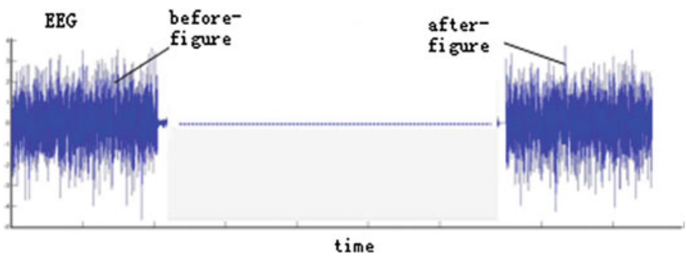

Fig. 1 β signal of before fatigue and after fatigue

$$F(f_i) = \int_{\text{Lower limit}}^{\text{Upper limit}} F(f)\mathrm{d}f. \tag{1}$$

In the formula: f_i as each center frequency, f as the frequency of sEMG signal after Fourier transform, $F(f)$ as the fatigue energy value of δ-wave after Fourier transform. The octave spectrum of energy is shown in Fig. 2.

② Regard the maximum value of before-figure octave spectrum as a reference value, divide the frequency interval spectrum by it and conduct the normalization processing to get the relative 1/3 octave spectrum $F'(f_i)$.

③ According to the following formula and the relative octave spectrum of fatigue process, calculate the fatigue energy p that is corresponding to β-wave signal.

$$p = \sum_i g(f_i)F'(f_i). \tag{2}$$

In the formula, $F'(f_i)$ as its relative 1/3 octave spectrum, f_i as center frequency, $g(f_i)$ as the spectral band coefficient. According to Black Man window, calculate its value.

$$g(f_i) = \begin{cases} 0.42 + 0.5\cos(\pi f_i/f_0) + 0.08\cos(2\pi f_i/f_0), & 0 < f_i \le f_0 \\ 0, & f_i \ge f_0 \end{cases}. \tag{3}$$

In the formula (3), f_0 in the frequency band coefficient $g(f_i)$ is a effective cut-off frequency. Due to the β-wave signal frequency 14–30 Hz, generally select f_0 = 30 Hz.

④ Record and sort out the questionnaire results of subjective fatigue feeling, and record the Borg scale value of the subjective fatigue evaluation index of each tested people in the course of test.

Fig. 2 1/3 octave result of before fatigue and during fatigue

(3) Eliminating the invalid data: Calculate the fatigue energy of each testee in a resting state and in the course of performing a task, normalize it (energy in the course of performing a task/energy in resting state), at the same time get the energy values of different frequency bands to obtain the ratio, and inspect and eliminate the data, mainly including the following methods:

① Electrooculogram data with the bigger span of subjective score value should be eliminated directly. It is the result of testees' not serious attitude and lying about the fatigue score value in the course of test,

② Use the Pauta criterion method to eliminate too big or too small energy values that are obtained after calculating.

4 The Establishment for Evaluation Model

Eliminate the abnormal data and retain the effective data, combine with Borg value to obtain a average normalized energy values E that are corresponding to 1–10 scores, respectively, conduct the curve fitting of fatigue energy and subjective feeling result, and select the optimal fatigue evaluation model according to the related coefficient. Researches show that the energy contrast between different rhythms of electrooculogram before the mental fatigue and after the mental fatigue, the energy percentage of low-frequency stage ($\theta + \alpha$) increases, and the energy percentage of high-frequency stage reduces. The combination of these characteristics can be used in the monitoring of mental fatigue. The energy ratio of two frequency bands of 4–13 Hz ($\theta + \alpha$) and 13–25 Hz (β) in each unit time is regarded as an index of fatigue evaluation. The above data results are shown in Table 1.

Fit the curve of E and borg fatigue scale, and then establish the mathematical model. respectively conduct the data linear fitting, power function fitting and S-function fitting, select S-function fitting as the evaluation model of mental load according to relevant coefficient. Curve is shown in Fig. 3, and fitting function is shown in the following formula (4), with the corresponding correlation coefficient $R2 = 0.808$ [5] :

$$\ln y = 4.144 - 3.524/x \tag{4}$$

With the increase of fatigue degree score, R value should also increase in theory. According to Table 1, make E, R, and Borg scatter diagram, and add the corresponding trend line, as shown in Fig. 4. It can be seen from the figure that E and

Table 1 Relation of Borg and the E/R

	1	2	3	4	5	6	7	8	9	10
E	0.89	1.09	1.36	1.07	1.56	1.54	1.38	1.84	1.55	1.79
R	3.70	3.92	4.12	4.14	4.07	4.30	4.06	4.18	3.92	4.32

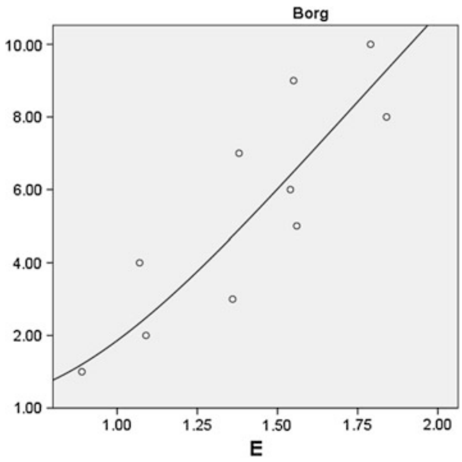

Fig. 3 Fitting curve model of S-function

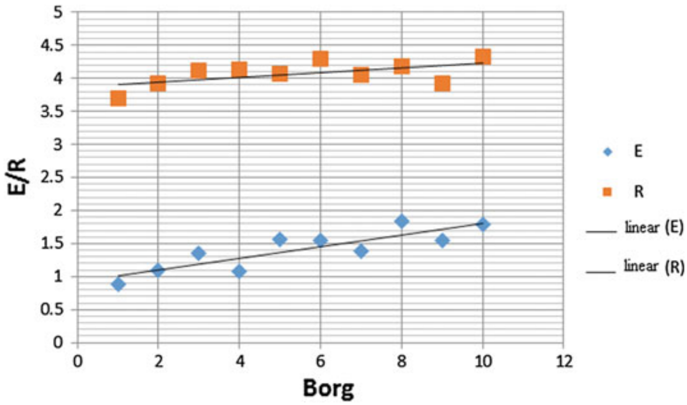

Fig. 4 Borg-*E*/*R* scatter diagram

R are on the rise with the increase of Borg, and there is a positive correlation between the fatigue energy *E* and the energy ratio *R* of different rhythms. This shows that the electrooculogram energy as an index for evaluating the mental fatigue is feasible.

5 Evaluation Model Validation

Select five testees for model validation. Substitute the average normalized fatigue energy value into a fitting model to forecast Borg value expresses the distribution conditions of difference values corresponding to each Borg value with a scatter diagram. It can be seen from the diagram that the difference value is distributed at ± 1. At the same time, according to $\alpha = 0.05$, pass through t-test. This shows that the modeling effect is better and can be used to evaluate the mental fatigue.

Compliance with Ethical Standards The study was approved by the Logistics Department for Civilian Ethics Committee of the Beijing Special Vehicle Institute.

All subjects who participated in the experiment were provided with and signed an informed consent form.

All relevant ethical safeguards have been met with regard to subject protection.

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Part II
Research on the Machine Character

An Improved Clone Selection Algorithm for Set Optimization

Liguan Pei, Kehai Dong, Yanhui Tang, Bo Zhang and Chang Yu

Abstract An improved CSA is put forward based on the shortcomings of traditional CSA which cannot meliorate set well. First, antibody cleaning is added, and antibody selection is improved. This step is very important for the process of set optimization, and antibody cleaning's aim is to delete the similar antibody. Antibody selection is to perform the local search to cleaned antibody set, and the process of total optimal solution searching is deleted. Then, the objective function of the antibody set is made to judge set's quality which does not exist in the traditional method. Each time the local search is completed, the affinity of antibody set needs to be calculated, and the several times iterative calculations need to be compared. In addition, the process of best individual selection is cut out, and the quality of analysis is increased. At last, the experiment and simulation prove that the improved CSA is effective.

Keywords The optimal set · Antibody cleaning · Objective function

1 Introduction

The optimization problems can be classified as the optimal solution and the optimal set from the aspect of analysis result. Many optimization methods have been proposed, such as the simulated annealing algorithm, the particle swarm optimization, and the clone selection algorithm (CSA). CSA which can do a good full-scale search, keeps population diversity, and has great interaction between antibodies, has been developing rapidly [1, 2]. Thus, CSA is necessary to be analyzed to exploit more of its performance.

CSA which flourishes on the basis of the clonal selection theory which is put forward by Burnet in 1959 is analyzed from two aspects by scholars [3]. On the one

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hand, CSA is combined with other theories or systems to better solve problems. For example, Niu [4] proposed land use zoning system on the basis of GIS and CSA, and Zhang [5] did an association between Gaussian mixture model and CSA. On the other hand, some detailed procedures of CSA have been improved to realize more satisfying performance. For example, Gao [6] adopted differential evolution algorithm to avoid prematurity phenomenon of CSA, Yet the past researches are focused on the optimal solution, and there are few researches which are aimed to seek the optimal set [7].

Thus, an improved CSA is put forward by adding antibody cleaning, the objective function of the antibody set in the paper. The process of best individual selection is cut out, and the quality of analysis is increased.

2 Traditional Clone Selection Algorithm

2.1 Analysis Process of Traditional CSA

The traditional CSA is the simulation of immune responses. The cells which could detect more antigen would be cloned the greater the number, and they will produce antibodies and memory cells through mutation operation. The objective function is regarded as antigen, and the candidate solution is considered as antibody in the analysis of practical engineering problems. The antibody population fosters competition through the calculation of affinity of antibody, and the cutthroat competition is avoided by clone and mutation. The algorithm convergence is ensured by the process of antibody memory.

2.2 Problem Analysis of Traditional CSA

There are some inappropriate processes in the traditional CSA while calculating the optimal set, because the initial goal of this algorithm is seeking optimal solution. The major problems are included as follows:

(1) The existence of redundant steps. The competition systems of initial population and muted antibody are a critical process of seeking optimal solution. The systems will delete some local optimal solution when looking for the optimal set, because its main aim is to seek antibody population with whole performance. It will reduce the total antibody population's quality.
(2) The potential repeatability of antibody. The antibody population may have some repeatability, because the initial antibody population is generated randomly and there is mutation. The potential repeatability will not affect the process of seeking optimal solution, but will affect the optimal set's seeking.

(3) The lack of judgment standard. The affinity of single antibody is the judgment of optimal solution in the traditional CSA. Yet there are no criteria for the seeking of optimal set.

3 Modeling of the Improved CSA

An improved CSA is put forward based on the shortcomings of traditional CSA. First, antibody cleaning is added, and antibody selection is improved, which are to eliminate duplicate individuals in the set. Then, the objective function of the antibody set is made to judge set's quality which is non-existing in the traditional method. In addition, the process of best individual selection is cut out, and the quality of analysis is increased.

(1) The initialization of antibody population. Define the number of iteration times as 0, i.e., $i = 0$. The number of antibody population (recording A) which is produced randomly is N.

$$A = \begin{bmatrix} A_1 & A_2 & \ldots & A_{N-1} & A_N \end{bmatrix}^{\mathrm{T}} \tag{1}$$

$$A_j = \begin{bmatrix} a_1(j) & a_2(j) & \ldots & a_{M-1}(j) & a_M(j) \end{bmatrix} \tag{2}$$

As shown in the formula above, A_j presents the jth antibody of the antibody set, $j = 1, 2, \ldots, N-1, N$. $a_l(j)$ presents the lth coding of jth antibody, $l = 1, 2, \ldots, M-1, M$.

(2) Antibody cleaning and mutation. When the antibody set's affinity is greater, the number of antibody cloning becomes more according to clone selection theory. Thus, the objective function, defined $f\left(A_j\right)$, which could represent the antibody set's performance, is needed to be established, and the concrete cloning's process is in accordance with the function (Formula 3) of antibody cloning's number.

$$Q_s = \frac{\beta f(A_s)}{\sum_{j=1}^{N} f\left(A_j\right)} \quad (s = 1, 2, \ldots N-1, N) \tag{3}$$

As shown in the formula, $f(A_s)$, Q_s, and β, respectively, represent the antibody's affinity, the cloning's number, and the amplification coefficient.

Every initial antibody A_j is expanded to Q_j antibody sets: $\left(h = 1, 2, \ldots Q_j - 1, Q_j\right)$, which could provide the basis for mutation. The antibody mutation of traditional CSA occurs in the antibody set, which could conserve effective information of initial antibody set.

(3) Antibody cleaning and selection. This step is very important for the process of set optimization, and antibody cleaning's aim is to delete the similar antibody in the $j-1$ local optimal antibodies. Antibody selection is to perform the local search to clean antibody set A_j, and the process of total optimal solution searching is deleted, as shown in Table 1.

(4) Calculating affinity of antibody set and judging. Each time the local search is completed, the affinity of antibody set needs to be calculated, and the several times iterative calculations need to be compared. The optimal set is the antibody set which corresponds to the largest value of function.

Table 1 Antibody cleaning and selection process

Step1：Calculation of extended antibody set's affinity
Step2：Searching the optimal solution in the A_1 affinity set, denoted by B(1)
Step3：Searching the optimal solution in the every affinity set. Loop condition: $2 \leqslant j \leqslant N$. Yes, continue; Not, end.
Step3.1：initialize j=1
Step3.2：A_j antibody set cleaning. Loop condition: $1 \leqslant l \leqslant Q_j$。 Yes, continue; Not, jump to Step3.4.
Step3.2.1：initialize m=1
Step3.2.2：Judging A^h_j's repeatability. Loop condition: $1 \leqslant m \leqslant j-1$。 Yes, continue; Not, jump to Step3.3.
Step3.2.2.1：Judging whether Ahj is equal to B(m). Equal, f(Ahj)=0，jump to Step3.3. Otherwise, m=m+1,jump to Step3.2.2
Step3.3：l=l+1, jump to Step3.2.
Step3.4：Searching A_j antibody set's optimal one, defined B(m)
Step4：j=j+1，jump to Step3

Note $B(m)$ represents the optimal antibody when j is equal to m

$$F_i = \sum_{j=1}^{N} f[B(j)] \tag{4}$$

As shown in the formula, F_i represents antibody set's affinity when ith iteration is completed.

4 Experiment and Simulation

In order to test the effectiveness of the improved CSA, this article optimizes the rule sets in the FCREAM by the simplified CSA (denoted Method 1), which is proposed by Wang An-si, and the improved CSA (denoted Method 2), and the solutions are compared and analyzed. FCREAM is an improved CREAM basic method which belongs to the second-generation human reliability analysis method and could make human cognitive reliability quantitative prediction through the method combining quantitative and qualitative analysis.

4.1 Standard Setting

In order to enhance the credibility of the comparison of results, do the following:

(1) The initial population used by Method 1 and Method 2 should be similar.
(2) The basic coefficients setting: the number of initial population is 20,000, denoted $N = 20{,}000$; the time of iteration is 50, denoted as $n = 50$. $\beta = 10 \times N = 200{,}000$; The mutation rate is 0.5, denoted as $pm = 0.5$.
(3) The basic formula setting:

① The cloning number of mth antibody:

$$q(A_m) = \mathrm{ceil}\left(\beta f(A_m) \middle/ \sum_{i=1}^{N} f(A_i)\right) \tag{5}$$

② The total number of cloning antibody set C:

$$Q = \sum_{m=1}^{N} q(A_m) \tag{6}$$

③ In the cloning antibody C, if jth coding of hth antibody matches mutation condition, then the concrete mutation method is

$$\begin{cases} C(h,j) = \mathrm{round}(1 + 3\,\mathrm{rand}), \mathrm{if}\ j = 1, 3, 9, \mathrm{else} \\ C(h,j) = \mathrm{round}(1 + 2\,\mathrm{rand}) \end{cases}, h \in [1, Q] \tag{7}$$

④ The function of set's affinity in the process of ith iteration

$$F_{\mathrm{i}} = \sum_{m=1}^{N} f[A_m] \tag{8}$$

As shown in the formula, $C(h,j)$ represents the mutation solution of jth coding of hth antibody.

4.2 Case Analysis

Optimize the rule sets in the FCREAM by Method 1 and Method 2 through MATLAB algorithm. Set 4 conditions, which are analyzed by FCREAM, Method 1, Method 2, and their solutions are defined as HEP0, HEP1, HEP2. HEP3 represents the solution which is obtained by CREAM basic method. The solutions are shown in Table 2.

4.3 Effective Analysis of Methods

As shown in Table 2, the result obtained by FCREAN cannot correspond to the result obtained by the basic method, and it is not effective because HEP is 0.265 in the condition 4. When using Method 2, the higher the level of the condition, the smaller the HEP2. Comparing HEP2 with HEP3, HEP2 is within limits of HEP3 no matter what the condition is, which proves Method 2 is effective. Thus the improved CSA is effective.

4.4 Analysis of Method's Characteristic

As shown in Fig. 1, the continuity of the rule surf obtained by the improved CSA is great, and it proves the method preserve set's diversity. When observing the changes of the optimal set's affinities, Method 2 can obtain the optimal result faster

Table 2 Human reliability prediction

Common performance condition (CPC)	Condition 1	Condition 2	Condition 3	Condition 4
CPC1	30	69	81	93
CPC2	35	63	79	95
CPC3	29	62	91	94
CPC4	32	66	89	87
CPC5	34	71	91	95
CPC6	33	73	90	90
CPC7	3	22	12	12
CPC8	34	67	92	92
CPC9	36	69	94	94
HEP_0	0.723	0.385	0.321	0.265
HEP_1	0.583	0.0497	0.00513	2.98e−3
HEP_2	0.567	0.0474	0.00442	2.06e−3
HEP_3	[0.1, 1]	[0.01, 0.5]	[0.001, 0.1]	[5e−6, 0.01]

Note The meaning of CPC1–CPC9 is adequacy of organization, working condition, adequacy of MMI and operational support, availability of procedures/plans, number of simultaneous goals, available time, time of day, adequacy of training and preparation, and crew collaboration quality

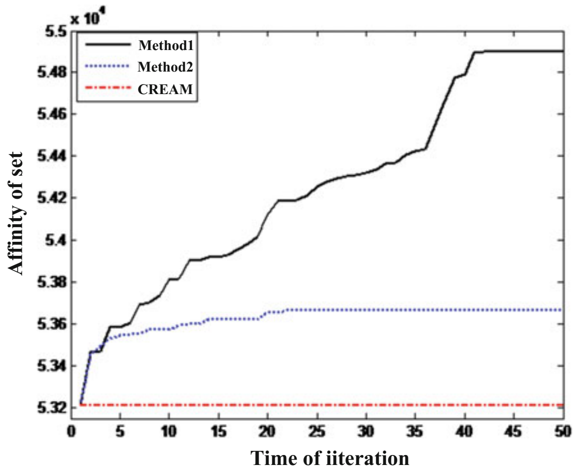

Fig. 1 Affinity curve of the optimal set

than Method 1 if two methods use the same initial population, and they both have good stability. But the affinities obtained by Method 2 are more small in the process. There is a difference of 1237 at last, and it proves the repeatability of Method 1 has great effectiveness to result, and Method 2 avoids this problem well.

5 Conclusion

This article proposes an improved CSA on base of the shortcomings which traditional CSA has when searching optimal set. Experimental results show that the improved CSA has good reliability, stability, optimization speed, ability to keep population diversity, and optimization speed, and it can avoid repeatability effectively.

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The Method Studied in this Paper is One of Many Decision-Making Methods

Kun Yu, Ying Zhang, Wanyuan Nie and Jun Zeng

Abstract The decision-making methods were widely used in complex system involving human subjective factors. In this research, a group feedback mechanism was constructed based on grey similarity degree, and the divergence degree indicator was established based on grey similarity degree to determine divergence degree between individual decision-making vectors and mean vector. In group feedback mechanism, an improved scale model was constructed based on Weber-Fechner law to increase closeness between scale model and subjective judgments for analytic hierarchy process method. And the validation method for scale model was proposed to verify the advantage of the scale model. The proposed method can more truly reflect the decision makers' decision-making intention and improve the accuracy of decision-making results for complex system.

Keywords Group feedback mechanism · Grey similarity degree · Analytic hierarchy process · Scale model

1 Introduction

The decision-making methods were widely used in complex system engineering involving human subjective factors, such as the system value assessment, multi-indexes comprehensive sorting, multi-programs selection, weights calculation. The basic process of subjective decision-making for complex system engineering usually included three steps: firstly, simulated human subjective decision-making process to construct the hierarchy structure model; and then, established comparison judgment matrix using the comparison method; lastly, calculated the judgment vectors for decision-making. The traditional analytic hierarchy process (AHP) method was usually used in decision-making. The scale models were used to construct the comparison judgment matrix, which had a direct

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impact on the results for system decision-making. But researches showed that the traditional decision-making methods with using AHP method cannot accurately determine the final decision-making results. The individual decision-making opinions were used to construct the comparison judgment matrices, but the individual subjective opinions couldn't give accurate comparison value in decision-making. The (1/9, 9) scale model was widely used to construct the comparison judgment matrices in AHP method [1]. Zhang [2] indicated that scale values of (1/9, 9) scale model were different from cognitive value of subjective judgment group. For this problem, (9/9–9/1) scale model and ($9^{(0/9)}$–$9^{(9/9)}$) scale model were developed to solve the reasonable matching problem between physical stimuli decision-making objects and psychological feelings of decision makers. The results showed that the newly proposed scale models had been optimized to ensure the thinking consistency of judgment. But the scale system uniformity and perceivability of scale models were significantly lower than (1/9, 9) scale model.

In this research, an improved decision-making method based on group feedback mechanism and scaling method were proposed, in order to ensure the accuracy of final judgment vector for decision-making.

2 Decision-Making Method Based on Group Feedback Mechanism

The process of the group feedback mechanism in decision-making was shown in Fig. 1. In which, comparison judgment matrices based on (1/9, 9) scale model were transferred to be judgment matrices by an improved scale model. The decision-making method based on group feedback mechanism could improve the diversity, extensiveness and representation of decision-making opinions by increasing the number of independent samples. The method could effectively coordinate the contradiction between the individuals' subject opinions. The advantage of this method was the feedback and correction for decision-making opinions in group.

3 Improved Scale Model for Comparison Judgment Matrix

The principle of Weber-Fechner law expounded the different threshold of human perception with a change in the original stimulation, as $\Delta\Phi/\Phi = X$. In which, Φ was original stimulate variable; $\Delta\Phi$ was difference threshold; C was a constant, as Weber ratio [3]. According to Weber-Fechner law, the human subjective judgment variable could be determined through measuring the amount changing of external stimulation intensity. The amount of external stimulation intensity usually increased

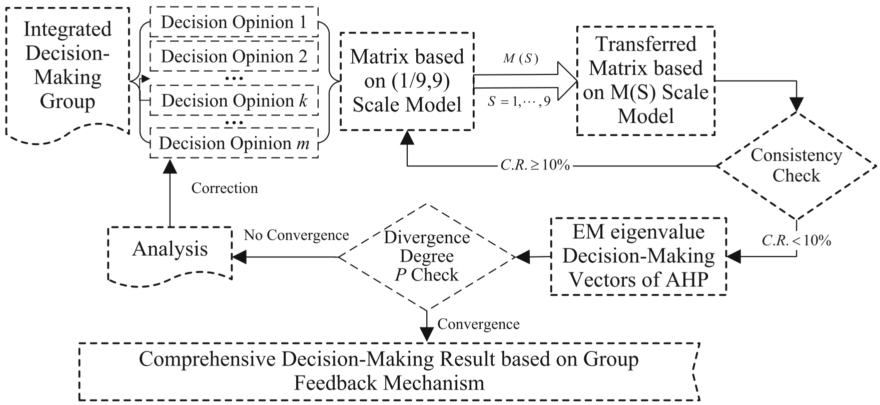

Fig. 1 Process of improved decision-making method based on group feedback mechanism

geometrically, while the amount of human subjective feeling increased linearly. The relationship between human psychological variable and external physical variable strictly followed Weber-Fechner law as in (1).

$$S = K\,\log R \tag{1}$$

In which, S was the variable of human subjective feeling; R was variable of objective stimulation; K was a constant. Weber-Fechner law was the relationship between psychological variable and physical variable [4]. The scale value of scale model should have actual physical meaning to ensure that the difference between scale values can reflect the quantitative concept of human subjective feeling. The new scale model $M(S)$ of paired comparison judgment was constructed based on Weber-Fechner law, as in (2).

$$M(S) = x^{S/K} \tag{2}$$

In which, S was the subjective scale levels of scale model; K was the smallest discernible difference number, $K = 5$ [5]; $M(S)$ was the variables of objective stimulation. The scale model $M(S)$ for AHP method was shown in (3).

$$M(S) = \begin{cases} 1, & S = 1 \\ x^{S/5}, & S = 2, 3, \ldots, 8 \\ 9, & S = 9 \end{cases} \tag{3}$$

The expectations of five grades of natural judgment linguistic were $D(S)$ = [1, 1.30, 1.77, 2.40, 3.63] [6]. Construct the minimum fitting function model between $M(S)$ and $D(S)$, as shown in (4).

$$\min : \left[\sum_{S=1}^{5} (M(S) - D(S))^2 \right]^{1/2} \tag{4}$$

Through the quadratic interpolation fitting calculation, when $x = 3.326$, $M(S)$ and $D(S)$ could get a excellent fitting degree, and the fitting function value was 0.6288. Therefore, $x = 3.3263$ was used in $M(S)$ model. Then, the meaning of improved degree number and the detailed data for comparison judgment matrix for AHP method based on $M(S)$ was shown in Fig. 2.

The ranking preservation indicator, consistency indicator, uniformity indicator, scale uniformity indicator [7], perceivability indicator could be used as the availability criteria to verify effectiveness of the $M(S)$ scale model. The ranking preservation indicator meant the performance of scale model to ensure the proper ranking among different attributes in AHP method. The consistency indicator of the random consistency rate was $\mathrm{CR} = \mathrm{CI}/\mathrm{RI}$. If $\mathrm{CR} < 0.10$, the judgment matrix satisfied the consistency requirement. The scale uniformity indicator was the uniform degree of numerical changing of the adjacent scale values. The uniformity indicator was used to describe the uniformity between vector elements of judgment result [8]. These validation indicators were used to verify the advantages of $M(S)$ scale model in the typical 9 order uniform matrix. Establishing the typical 9 order uniform matrix A. First, (1/9,9) scale model is used to construct the paired comparison judgment matrix; constructed the specific new $M(S)$ scale model; lastly,

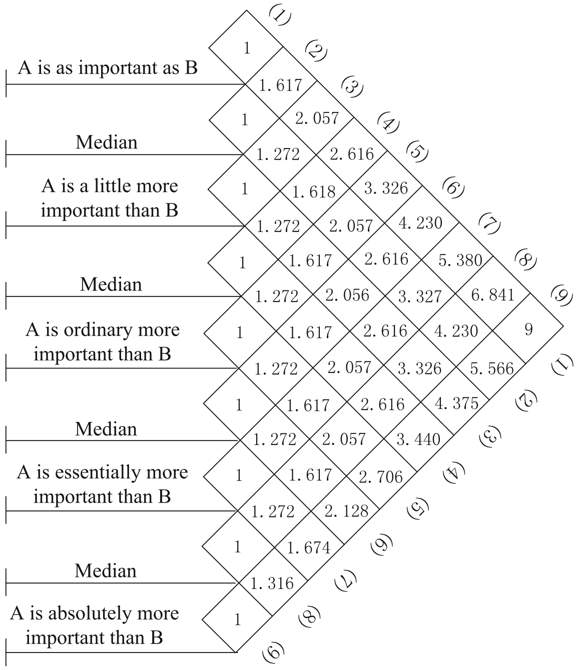

Fig. 2 Paired comparison data for judgment matrix based on $M(S)$ in decision-making

Table 1 Results comparison of validation indicators for different scale models

Items	$M(S)$ scale model (a)	(1/9, 9) scale model (b)	(9/9–9/1) scale model (c)	($9^{(0/9)}$–$9^{(9/9)}$) scale model (d)
CR	0.007	0.050	0.0017	0.0046
D_w	0.013	0.163	0.267	0.007
d_{ij}	1.719	1.00	36	6.0
D_{ij}	1.272	1.778	1.778	1.0
b	1.352	1.778	20.25	6.0

used the $M(S)$ scale model to transform the constructed comparison judgment matrix. Then, *EM* vector Eigen value method is used to calculate judgment vector of matrix A, $W = [0.0260, 0.0350, 0.0470, 0.0630, 0.0845, 0.1134, 0.1521, 0.2041, 0.2748]$. The consistency indicator CR = 0.007. Calculated the D_w, d_{ij}, D_{ij},b of the $M(S)$ scale model, and compared the results of the (1/9, 9) scale model, (9/9–9/1) scale model, and ($9^{(0/9)}$–$9^{(9/9)}$) scale model. The results comparison of validation indicators for different scale models were shown in Table 1.

The detail scale value of $M(S)$ scale model, (1/9, 9) scale model, (9/9–9/1) scale model and ($9^{(0/9)}$–$9^{(9/9)}$) scale model was shown in Fig. 3.

The ranking result of validation indicators for $M(S)$ scale model, (1/9, 9) scale model, (9/9–9/1) scale model and ($9^{(0/9)}$–$9^{(9/9)}$) scale model were shown in Fig. 4

(1) The ranking of the typical 9 order uniform matrix was pre-determined in this validation instance. The vector result which uses *EM* vector Eigen value method to calculate the judgment vector of matrix A was correct. It proved that the $M(S)$ scale model had the function of ranking preservation.
(2) Consistency indicator of $M(S)$ scale model was $\text{CR} = 0.007 < 0.10$, and it was better than the consistency indicator of (1/9, 9) scale model. It proved that the $M(S)$ scale model could satisfy the consistency requirements of comparison judgment matrix construction.

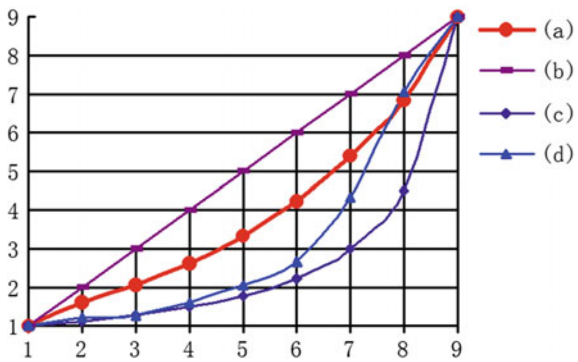

Fig. 3 Scale value for judgment matrix of different scale models in decision-making

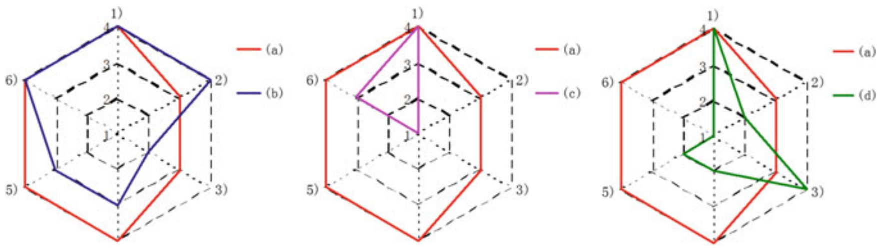

Fig. 4 Ranking of validation indicators for scale models: $M(S)$ scale model (**a**) and (1/9, 9) scale model (**b**), (9/9–9/1) scale model (**c**), ($9^{(0/9)}$–$9^{(9/9)}$) scale model (**d**)

(3) Uniformity indicator of $M(S)$ scale model was $D_w = 0.013$. It was better than the uniformity indicator of (1/9, 9) scale model, (9/9–9/1) scale model.

(4) Scale uniformity indicator and equilibrium indicator of the scale distance of $M(S)$ scale model were $[d, D, b] = [1.719,\ 1.272,\ 1.352]$. The equilibrium indicator of the scale distance b was best among these scale models; the distance of commercial value D was only more than (1/9, 9) scale model. It proves that the $M(S)$ scale model has a good performance on scale uniformity.

4 Group Feedback Mechanism Based on Grey Similarity Degree

The divergence degree was defined to control the group feedback mechanism. The mean vector $\bar{W}$ of k group decision vectors in the group was shown as (5).

$$\bar{W} = \sum_{k=1}^{m} \omega_k W^k \tag{5}$$

In which, ω_k was the weight of the kth decision-making individual. The divergence degree validation indicator of group feedback mechanism was constructed based on grey similarity degree [9].

Set system ranking X_i, $X_j X_i = (x_i(1), x_i(2), \ldots, x_i(n))$, $X_j = (x_j(1), x_j(2), \ldots, x_j(n))$. The initial zero operator $x_i^0(k) = x_i(k) - x_i(1)$, $x_j^0(k) = x_j(k) - x_j(1)$ is used to deal with X_i, X_j, the corresponding initial zero operated vector X_i^0, X_j^0 was

$X_i^0 = (x_i^0(1), x_i^0(2), \ldots, x_i^0(n))$, $X_j^0 = (x_j^0(1), x_j^0(2), \ldots, x_j^0(n))$. The corresponding polyline of X_i^0, X_j^0 was set as X_i^0, X_j^0.

$$s_i - s_j = \int_1^n (X_i^0 - X_j^0)\mathrm{d}t \tag{6}$$

If the length was same between ranking X_i and X_j, ε_{ij} was grey similarity degree between ranking X_i and X_j. The ε_{ij} was used to test the similarity degree of polyline geometry between ranking X_i and $X_j, 0 < \varepsilon_{ij} \leq 1$, $\varepsilon_{ij} = \varepsilon_{ji}$.

$$\begin{gathered} \varepsilon_{ij} = 1 \big/ \left(1 + \left|s_i - s_j\right|\right) \\ \left|s_i - s_j\right| = \left|\sum_{k=2}^{n-1} \left(x_i^0(k) - x_j^0(k)\right) + \tfrac{1}{2}\left(x_i^0(n) - x_j^0(n)\right)\right| \end{gathered} \tag{7}$$

The individual decision-making vector W^k and mean vector $\bar{W}$ had the same dimensional number, and $\sum w_k(i) = 1$, $\sum \bar{w}(i) = 1$. When W^k and $\bar{W}$ had same length, it ensured the uniqueness of polyline shape. And when $W^k = \bar{W}$, grey similarity degree $\varepsilon_{ij} = 1$. Constructed the divergence degree indicator ρ_k based on grey similarity degree to divergence degree between the individual decision-making vector W^k and mean vector $\bar{W}$.

$$\begin{gathered} \rho_k = \left|s\left(W^k\right) - s(\bar{W})\right| \big/ \left(1 + \left|s\left(W^k\right) - s(\bar{W})\right|\right) \\ \left|s\left(W^k\right) - s(\bar{W})\right| = \left|\sum_{i=2}^{n-1} \left(w_k^0(i) - \bar{w}^0(i)\right) + \tfrac{1}{2}\left(w_k^0(n) - \bar{w}^0(n)\right)\right| \end{gathered} \tag{8}$$

The comprehensive decision-making divergence degree P was shown as (9).

$$P = \sum_{k=1}^{m} \left[\omega_k \left|s(W^k) - s(\overline{W})\right| \big/ \left(1 + \left|s(W^k) - s(\overline{W})\right|\right)\right] \tag{9}$$

Set the threshold of divergence degree ξ, which was the divergence degree threshold of decision-making. When $P \geq \xi$, the decision-making process needed feedback and correction. And when $\rho_k \geq \xi$, the comparison judgment matrices of W^k needed correction.

Used 12 indexes ranking decision-making as an instance, six individuals in a group, and the group weight vector was $[0.119, 0.215, 0.226, 0.180, 0.130, 0.130]$. The individual constructed the comparison judgment matrix, and the matrix was transferred by $M(S)$ model. EM Eigen value method is used to calculate decision-making vector C^1–C^6 and the corresponding consistency indicator.

$$W^1 = [0.1487, 0.1611, 0.0957, 0.1080, 0.0784, 0.0592, 0.0938, 0.0504, 0.0504, 0.0359, 0.0709, 0.0435]$$
$$W^2 = [0.1522, 0.1975, 0.1061, 0.1061, 0.0740, 0.0582, 0.1000, 0.0496, 0.0390, 0.0236, 0.0618, 0.0319]$$
$$W^3 = [0.1454, 0.3077, 0.0917, 0.0736, 0.0653, 0.0387, 0.0847, 0.0556, 0.0412, 0.0388, 0.0304, 0.0269]$$
$$W^4 = [0.1466, 0.1791, 0.1043, 0.0963, 0.0837, 0.0583, 0.0982, 0.0497, 0.0459, 0.0284, 0.0727, 0.0368]$$
$$W^5 = [0.1591, 0.1984, 0.1088, 0.0984, 0.0822, 0.0609, 0.0855, 0.0479, 0.0408, 0.0252, 0.0609, 0.0319]$$
$$W^6 = [0.1708, 0.1641, 0.0956, 0.1015, 0.0736, 0.0591, 0.0956, 0.0474, 0.0474, 0.0337, 0.0666, 0.0446]$$

$\text{C.R.}^1 = 0.012 < 10\%$, $\text{C.R.}^2 = 0.060 < 10\%$, $\text{C.R.}^3 = 0.012 < 10\%$, $\text{C.R.}^4 = 0.031 < 10\%$, $\text{C.R.}^5 = 0.054 < 10\%$, $\text{C.R.}^6 = 0.026 < 10\%$.

The mean vector $\bar{W}$ of group:

$$\bar{W} = [0.1526, 0.2105, 0.1003, 0.0956, 0.0753, 0.0544, 0.0930, 0.0506, 0.0434, 0.0309, 0.0583, 0.0352]$$

The initial zero operated vectors of individual decision-making vector W^1–W^6 and mean vector were:

$$\bar{W}^0 = [0,\ 0.0579,\ -0.0523,\ -0.0570,\ -0.0773,\ -0.0982,\ -0.0596,\ -0.1020,\ -0.1092,\ -0.1217,\ -0.0943,\ -0.1174]$$

$$W^{1^0} = [0,\ 0.0124,\ -0.053,\ -0.0407,\ -0.0703,\ -0.0895,\ -0.0549,\ -0.0983,\ -0.0983,\ -0.1128,\ -0.0778,\ -0.1012]$$

$$W^{2^0} = [0,\ 0.0453,\ -0.0461,\ -0.0461,\ -0.0782,\ -0.094,\ -0.0522,\ -0.1026,\ -0.1132,\ -0.1286,\ -0.0904,\ -0.1203]$$

$$W^{3^0} = [0,\ 0.1623,\ -0.0537,\ -0.0718,\ -0.0801,\ -0.1067,\ -0.0607,\ -0.0898,\ -0.1042,\ -0.1066,\ -0.115,\ -0.1185]$$

$$W^{4^0} = [0,\ 0.0325,\ -0.0423,\ -0.0503,\ -0.0629,\ -0.0883,\ -0.0484,\ -0.0969,\ -0.1007,\ -0.1182,\ -0.0739,\ -0.1098]$$

$$W^{5^0} = [0,\ 0.0393,\ -0.0503,\ -0.0607,\ -0.0769,\ -0.0982,\ -0.0736,\ -0.1112,\ -0.1183,\ -0.1339,\ -0.0982,\ -0.1272]$$

$$W^{6^0} = [0,\ -0.0067,\ -0.0752,\ -0.0693,\ -0.0972,\ -0.1117,\ -0.0752,\ -0.1234,\ -0.1234,\ -0.1371,\ -0.1042,\ -0.1262]$$

$$\left|s(W^1) - s(\bar{W})\right| = 0.0386,\ \left|s(W^2) - s(\bar{W})\right| = 0.0062,\ \left|s(W^3) - s(\bar{W})\right| = 0.0869,$$
$$\left|s(W^4) - s(\bar{W})\right| = 0.0681,\ \left|s(W^5) - s(\bar{W})\right| = 0.0732,\ \left|s(W^6) - s(\bar{W})\right| = 0.2141$$

The divergence degree between individual decision-making vector W^1–W^6 and $\bar{W}$:$\rho_1 = 0.0372$, $\rho_2 = 0.0061$, $\rho_3 = 0.0799$, $\rho_4 = 0.0638$, $\rho_5 = 0.0682$, $\rho_6 = 0.1763$. Set the divergence degree threshold $\xi = 1 - 1/(1 + 0.5) = 0.3333$, the final group comprehensive divergence degree $P = 0.0738 < 0.3333$. It had a good performance on convergence opinions in group decision-making.

5 Conclusion

The decision-making method based on group feedback mechanism can improve the diversity, extensiveness and representation of decision-making opinions by increasing the number of independent samples. The method can effectively coordinate the contradiction between the individuals' subject opinions. The improved scale model based on Weber-Fechner law can more truly map the relationship between human psychological variable and external physical variable in subjective decision-making. The improved scale model can ensure the accuracy of judgment vectors for subjective decision-making. The improved method can be used in subjective decision-making for complex system engineering. And more practical applications will be carried out in further research.

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Simulation and Evaluation Prototype of Intelligent Lower Limb Prosthesis Based on Function Requirements of Human–Machine System

Wujing Cao, Hongliu Yu, Weiliang Zhao, Qiaoling Meng and Xiaodong Wei

Abstract Robotic testing can facilitate the development of new concepts, designs and control systems for prosthetic limbs. Human subject test clearances, safety and the lack of repeatability associated with human trials can be reduced or eliminated with automated testing, and test modalities are possible which are dangerous or inconvenient to attempt with patients. In order to make evaluation of the function of the intelligent lower limb prosthesis, according to the requirements of main function of the human–machine system of prosthetic leg, the simulation and evaluation system of above-knee prosthesis function was designed. The control system was designed on the basis of overall design. A set of evaluation method was proposed, and the gait symmetry was measured by the designed evaluation system. The experimental results showed that the symmetry of the swing gait velocity was 96.5% and gait tracking effect was good. Therefore, the system had a good effect on the function simulation and evaluation of the prosthesis.

Keywords Prosthesis · Function simulation · Evaluation · Human–machine system

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1 Introduction

According to the data calculation of the second national handicapped person sampling survey, the sum of disabled people in China was 82.96 million, 6.34% of the total population, including 24.12 million physical disabilities and 2.26 million amputees. The amputee number was far more than that in the last few years [1]. The residual limb regeneration cannot be reached in the current medical treatment level. The recovery of motor function of patients with amputation can only give priority to install artificial limb. Lower limb prosthesis for amputees plays an important role to restore self-care ability in a degree. In order to test the performance of the prosthesis, function simulation and evaluation system of the lower limb prosthesis is particularly important [2].

At present, there is not a set of mature evaluation standard or system of the performance evaluation of the lower limb prosthesis. International standard or national standard only rules the structure strength and fatigue strength of the prosthesis joint [3]. However, the main evaluation indexes stability, gait symmetry, function compensation and energy consumption which influence the performance of the lower limb prosthesis are not established [4–7]. This field of research is mainly to characterize the lower limb prosthesis; then, the prosthesis can be evaluated with the gait. For example, the Dingwell et al. [8] have set up a system for real-time evaluation and providing gait symmetry information which can show symmetry conditions in the process of walking of two feet; Richter et al. [9] describe the development, modeling, parameter estimation and control of a robot capable of reproducing two degree-of-freedom hip motion in the sagittal plane. Hip vertical displacement and thigh angle motion profiles are applied to a transfemoral prosthesis attached to the robot. A treadmill is used as walking surface. Aside from tracking hip motion trajectories, the control system can be used to regulate the contact force between the treadmill and the prosthesis. With the use of gait analysis data of healthy people and patients, Wang and Zhang [10] calculated the phase symmetry index, symmetry and asymmetry indicators based on Fitts law and comparative analysis, finding that the score of different evaluation index was varied; Pitkin [11] designed a cycloid to fake ankle joint institution, its purpose is to provide a more natural damping torque of ankle with dorsiflexion movement.

For the function simulation and evaluation of the lower limb prosthesis, according to the requirements of main function of the man-machine system of the lower limb prosthesis, the designed system used synchronous belt to simulate level walking of the prosthesis and lift air cylinder to simulate the human body's gravity shift. Intelligent lower limb prosthesis connected with the simulator by a special joint and realized the function simulation. Applying microcomputer control structure to simulate the damper control of the lower limb prosthesis, gait symmetry performance of the lower limb prosthesis was evaluated.

2 The Main Function Requirements of the Man–Machine System

According to ergonomics and mechanism of leg prosthesis bionics design, the main function requirements of the prosthetic leg include the comfort of swing phase, the stability of supporting phase, the self-adaptability of working modes and the verisimilitude of shape [12]. The core of these requirements constitutes the targets of the availability of prosthetic leg product through different forms.

The comfort of swing phase is concerned with gait symmetry and rangeability of the center of gravity. Gait symmetry of swing phase refers to two legs of the normal body have the phase symmetry in a gait cycle. A large study showed that gait phase symmetry is the core requirement of the prosthetic leg [13–15]. If the human body is regarded as the multi-rigid-body system by muscle involvement and innervation, adjusting their gait parameters to achieve the best condition in order to save energy consumption [16]. The research results of Liu et al. [17] showed that each lower limb can appear abnormal gait when different degree damage of movement symmetry happened in the process of walking, thus putting forward the concept bilateral symmetry as an evaluation index of walking function to measure amputation patients after wearing leg prosthesis. Gait symmetry index can be calculated by the following formula:

$$S_r = \left(\frac{T_z}{T}\right)^{0.5} \times (Z_r * 0.62 + M_r * 0.38)$$

Among them, S_r is the gait symmetry index, T_z is a normal gait cycle, T is the gait cycle, Z_r is the support phase ratio (small/large), M_r is the step phase ratio (small/large).

In the process of walking forward of normal people, hip moves up and down with rhythm, its trajectory is very smooth and has no sudden change in the direction, its amplitude is about 6 cm. In order to make the prosthesis not touch the ground in the middle of the swing phase, the center of gravity of leg prosthesis wearer moves larger than normal people, the total displacement is nearly 8 cm which increases energy consumption [18]. Therefore, knee prosthesis should be designed to simulate the variable rotation instantaneous center of normal people, reducing variations in the center of gravity of human walking [19].

3 Design of Function Simulation and Evaluation System

In order to simulate and evaluate the gait following performance of the microcomputer controlled knee prosthesis, the design objective of the experimental apparatus is for the realization of the three main functions: (1) simulation of velocity changes of normal knee joint and the real-time detection of angular

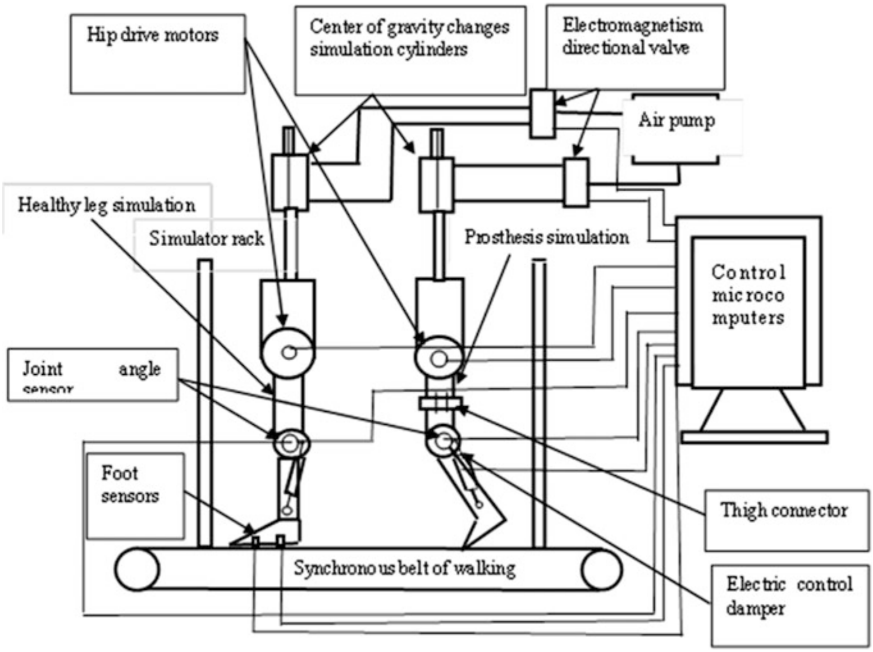

Fig. 1 Schematic diagram of function simulation and test system

velocity; (2) simulate the hip drive of the prosthetic leg and drive the prosthetic knee joint to swing to evaluate the gait following performance and security; and (3) control the damping of the prosthetic knee joint by program and assessment tracking results of step speeds by changing the prosthetic foot or other counterweight.

To achieve this target, the article designed the performance evaluation system. The composition and working principle of the device is shown in Fig. 1. The whole control circuit included four control modules:

1. Cylinder control module of the prosthetic leg height adjustment. Height adjustment cylinder was controlled by a logic circuit board. Self-locking cylinder which was controlled by integrated circuit 4013 CMOS was also used to prevent the prosthetic leg to fall into the ground and improve the location accuracy.
2. Control transformation module of manual automatic switch. Manual button buffers the switch signal by a piece of integrated circuit ULN2803 and sent it to the step motor driver.
3. Starting module of step motor driver and brushless electric machine driver. The circuit board module adopted the AD654 integrated circuit to produce the drive signal of step motor in the case of manual control.

4. Automatic control module. This module used the microprocessor AT89S52 to signal detection and automatic control. Simulators communicated with desktop computer, microcomputer control and detection were achieved directly.

4 Test Evaluation of Gait Symmetry of the Intelligent Lower Limb Prosthesis

A set of function simulation and performance evaluation system of intelligent lower limb prosthesis was made (see Fig. 2). In the simulation and measurement system, testing data of the healthy leg and values of the needle valve opening obtained through computer simulation to conduct swing speed test of the intelligent lower limb prosthesis. Experimental procedures were as follows:

1. The intelligent lower limb prosthesis was installed on the simulation hip joint.
2. Angle sensors of the healthy leg and false leg were connected with computer through data collector.
3. Manual mode drives the motors of the hip joints swing. The largest drive pulse frequency was 500 Hz, the step angle was 1.8°, so the drive speed of the hip joint was 225°/s.

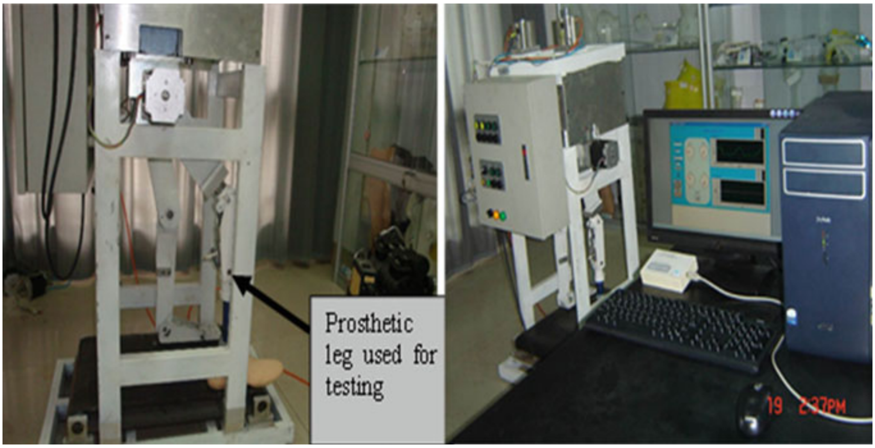

Fig. 2 Intelligent lower limb prosthesis function test

4. The knee joint completed one swing cycle was about 12 sampling interval, so the oscillation cycle was: Th = 12.0 × 50 = 600 (ms) = 0.6 (s). The peak of swing angle was about 1.50 v. As the range of the precision potentiometer was ±5.0 v, the max swinging angle could be calculated.

$$\theta h_{\max} = \frac{1.50}{5.0} \times 180^\circ = 54.0^\circ$$

Average angular velocity of the healthy leg in a swing period could be calculated.

$$\dot{\theta} h_{\text{ave}} = \frac{2 \times \theta h_{\max}}{T} = 180.0(^\circ/\text{s}) = 3.14(\text{rad/s})$$

5. Set the needle valve opening X to be 0.42 mm. It showed that swing cycle of the intelligent lower limb prosthesis was also approximately 12 sampling interval. The oscillation cycle was: Tp = 12.0 × 50 = 600 (ms) = 0.6 (s). Swing angle peak of the prosthetic leg knee joint was 1.55 v; the max swinging angle could be calculated.

$$\theta p_{\max} = \frac{1.55}{5.0} \times 180^\circ = 55.8^\circ$$

Average angular velocity of the intelligent lower limb prosthesis was $\dot{\theta} p_{\text{ave}} = 3.25\,(\text{rad/s})$.

Therefore, the swing speed error which intelligent lower limb prosthesis tracked the motion of the healthy leg gait could be calculated:

$E = \frac{\left|\dot{\theta} p_{\text{ave}} - \dot{\theta} h_{\text{ave}}\right|}{\dot{\theta} h_{\text{ave}}} \times 100\% = 3.50\%$. The symmetry of the swing gait velocity was 96.5%.

5 Conclusion

The designed function simulation and evaluation system could not only simulate the microcomputer control of the damper, but also realize the measurement and evaluation of gait following symmetry. Test results showed that the needle valve opening was set according to the theoretical analysis value; the intelligent lower limb prosthesis tracked the swing speed of healthy leg commendably. The experimental results were well consistent with theoretical analysis results. The symmetry of swing speed was as high as 96.5%. Gait tracking effect was good. This measurement system can also make test and evaluation of real-time gait tracking control, automatic safety lock in support phase after further improving the software system.

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The Design of Wearable Integrated Physiological Monitoring System

Yuhong Shen, Chenming Li, Yichao Du and Guangda Liu

Abstract *Objective* To realize the continuous, dynamic and long-term acquisition of human physiological signals, the wearable integrated physiological monitoring system is designed. *Methods* The technology of physiological parameters acquisition and wearable technology are combined. The ECG sensor is designed by collecting the fabric electrode, and the ECG signal is extracted with a non-stick way. Based on the fabric sensor, the respiratory signal detection circuit is designed according to the impedance characteristics of biological tissue, and the peak threshold method is used to calculate the respiration rate. Based on MPU6050 six-axis motion detection integrated chip, the body movements monitoring circuit is designed. *Results* The system is designed to achieve the wearable integrated monitoring of ECG, respiration, body movements and other physiological parameters. *Conclusions* The wearable integrated physiological monitoring system realizes the long-term and the dynamic detection of the physiological parameters. The system also realizes the tracking and observation of real-time life information. As a result, the system has a broad application prospect at military medicine, rescue, sports training and rehabilitation medicine.

Keywords Wearable · Physiological parameters · Integrated

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1 Introduction

Physiological signals in the body contain a wealth of human health information, such as ECG, respiration and body movements [1]. Continuous monitoring of physiological parameters provides the information of the human physiology and pathological conditions, and the collaborative monitoring of multiple physiological parameters will provide a richer data [2–4]. It is necessary to study these physiological signals whether it is a single-phenomenon study or a comprehensive human body system. However, the traditional equipment is difficult to achieve a long-term work and continuous monitoring of multiple parameters in the condition of daily life [5, 6]. In this study, multiple physiological parameters acquisition technology and daily clothing are combined, which can detect the body's ECG, respiration, body movements and other parameters in the form of clothes and chest belt. The system meets the needs of different test conditions and provides a technical platform for dangerous environment operations, sports training, medical rehabilitation and other related personnel [7].

2 Technical Methods

ECG measurement: ECG is measured by using the potential measurement on the body surface skin. The method uses fabric electrode sensing measurement unit, by measuring the surface potential, to achieve ECG signal detection. According to the RR interval within the time of ECG signal, the heart rate test is completed.

Respiratory rate measurement: Select an appropriate position of the chest and then measure the physical changes in the chest respiration through the fabric-respiration sensor. So the respiratory signal detection and respiratory rate measurement are finished.

Position measurement: Detect position changes by the three-axis acceleration sensor, and the three-axis acceleration of human movement is calculated through the measurement compensation algorithm.

Communication method: Bluetooth communication protocol and hardware interface are used in communication. The terminal will upload the detected physiological data and measured environmental perception parameters to the host computer. After that, the abnormalities of subject's physical and psychological stress and the abnormal warning and prejudgment of environmental parameters will be obtained through the algorithm analysis.

3 System Design

3.1 ECG

The measurement of ECG signal uses fabric electrode sensor. The fabric electrode belongs to the dry electrode, and it is in direct contact with the body surface. Compared with the medical AgCl viscous electrode, the measurement signal has nothing to do with other conductive media, and it does not change with the change in detection time. As a result, it is suitable for dynamic and long-term ECG signal detection. In addition, the fabric electrode is comfortable and reusable, and it can be washed several times. Conductive textile fabric is the basic material of the fabric ECG sensor, which is the fore end of the ECG measurement. The conductive textile fabric is based on the fibre cloth, which is covered by electroplated metal coating after the pre-treatment to have a metal characteristic. Taking the comfort and cost of the measurement into account, silver-plated conductive textile fabric is chosen to be ECG sensor material. And the ECG test signal is shown in Fig. 1.

The heart rate is calculated based on the number of R waves in a cycle time (1 min) of the ECG signal. The differential threshold method is used to achieve heart rate detection and calculation for technical system.

Fig. 1 ECG test signal

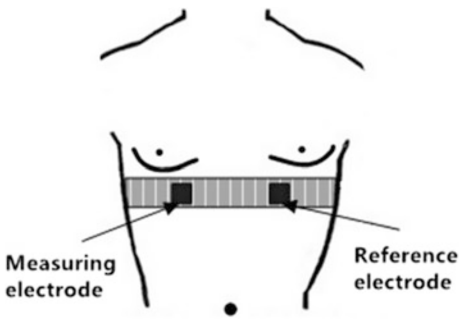
3.2 Respiration

According to the Cole–Cole theory of biological tissue impedance, the impedance characteristics of human is determined by the resistance and capacitance, and the impedance will show different characteristics with the changes in the frequency of the loaded electrical signal. Based on the regularity of the modulus value of the human impedance and the phase changes with the frequency, the 100 kHz high-frequency signal is selected to measure the impedance changes in the chest, which can achieve the measurement of the human respiratory movement and the respiratory signal. Fabric electrode is selected to be the measuring sensor in the chest resistance measurement, and it is a conductive fabric-filled sponge flexible. The fabric electrode is fixed on the elastic fabric belt to form the respiratory signal measuring and sensing device. The position where the elastic fabric placed in the human chest is shown in Fig. 2.

100 kHz signal, which is generated from the high-frequency signal source, is loaded into the human body through the fabric electrode, and the chest impedance will produce modulation of this high-frequency signal when the body breathes. Then the fabric electrodes collect the modulated signal, and the original signal turns to an analogy signal with high SNR through the follow-up circuit amplification, filtering and other processing, which will be sent to the ADC sampling. The DFT algorithm is used to return the real and imaginary data of the measured frequency point, and the measured impedance value is obtained by mathematical calculation. The flow of the algorithm is shown in Fig. 3, and the test curve is shown in Fig. 4.

In calculation process of the respiratory rate, due to external disturbances and other factors, the noise jamming signals often appear in the respiratory signal, affecting the accuracy of the calculation. The respiratory rate is calculated by the peak threshold method. After the respiratory signal is amplified, shaped and digitized, the microcomputer calculates the peak values of the respiratory signal in the first eight cycles and takes the average of the peak values as the comparison threshold. Then calculate the difference between the peak values and threshold. If the difference is greater than 1/2 of the peak value, the point is called the deliberate

Fig. 2 Respiration measurement by the method of chest impedance



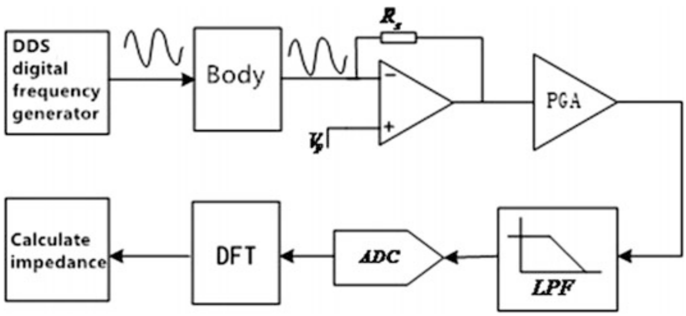


Fig. 3 Flow of the chest impedance algorithm

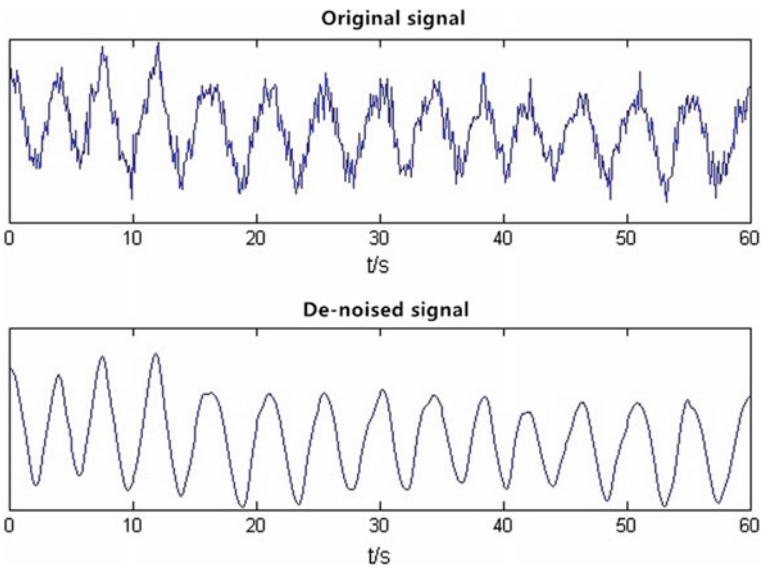


Fig. 4 Test curve

interference point. As shown in Fig. 5, A point is the suspicious interference point. Then calculate the sum of the second and third peak points on both sides of A, take the average and compare the average with the peak value of A point. If the peak of A point is greater than 1/2 of the average, the point A is an interference point. Remove the A point when calculate the respiratory rate in unit time.

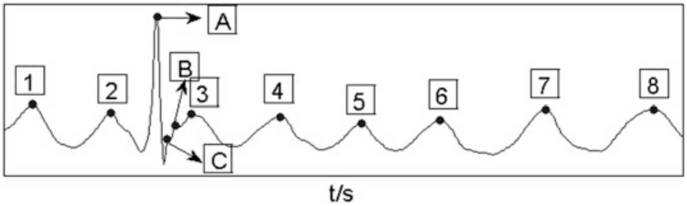


Fig. 5 Respiration measurement by the method of chest impedance

3.3 Body Movement

The MPU6050 (six-axis motion detection integrated chip) is used in the signal acquisition and processing circuit. The MPU6050 can measure the three-axis acceleration and three-axis angular velocity signals in real time and can output the fusion calculus data with the format of six-axis or nine-axis rotation matrix, the quaternion, Euler angle in digital form. The circuit of signal acquisition in body movement is shown in Fig. 6.

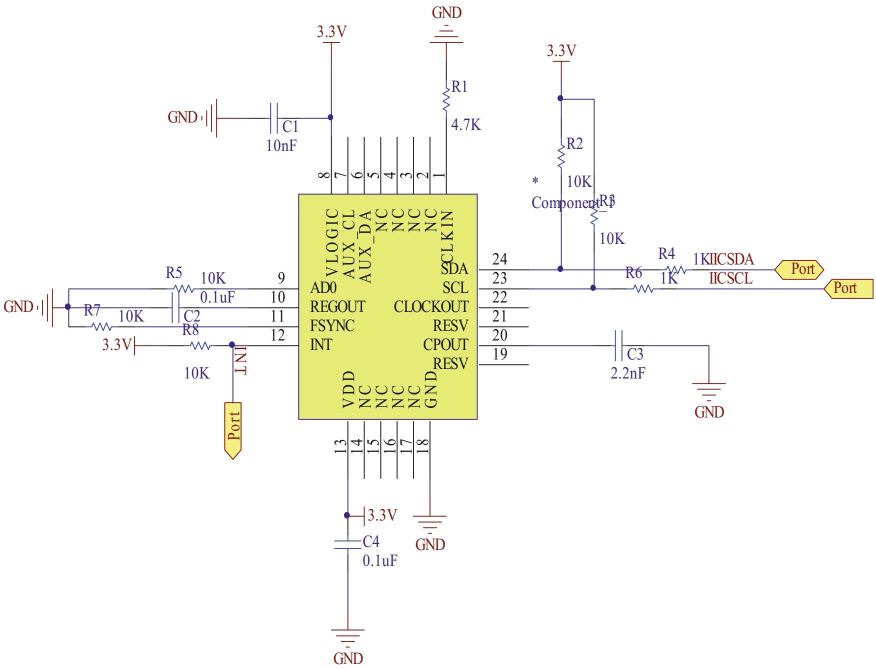


Fig. 6 Circuit of signal acquisition in body movement

4 Conclusions

In this study, physiological information acquisition technology and wearable technology are combined to design an wearable integrated multiple physiological parameters monitoring system, which realizes the long-term and dynamic acquisition of basic physiological parameters, such as ECG, chest and abdomen respiration, body position and body movement. The system can realize the tracking and observation of real-time life information, which has a broad application prospect in military medicine, rescue, sports training and medical rehabilitation.

Acknowledgment 5 acknowledgement This research is supported by National Key R&D Program of China (2016YFC0802807).

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The Design of Low-Load Human Flexibility Test System

Yichao Du, Baihai Zhang, Yuhong Shen and Chenming Li

Abstract *Objective* To realize the acquisition of the response time, the movement frequency and the trajectory of the human at a low load, the human flexibility test system is designed. *Methods* The NodeMCU is used as the node controller in the signal acquisition. And infrared ranging sensor is used to collect data, which is transmitted by TCP protocol to smart phone or tablet computer, while the high-power router is used to ensure the signal coverage of 50 m. *Results* The designed system can realize the acquisition of the response time, movement frequency and movement trajectory of the human during the movement. *Conclusions* Low-load human flexibility test system is a flexible and stable method to simulate different types of training and analysis, and it has a broad prospect in the agile training and rehabilitation training for athletes and soldiers.

Keywords Flexibility · Infrared sensor · Eclipse

1 Introduction

Flexibility plays a very important role in the process of movement. Flexibility refers to the ability to quickly change the position and transform the action and the contingency during the movement [1, 2]. It is a physical quality of the comprehensive manifestation of the movement and a quality that cannot be covered by other special qualities. It relates to the spatial positioning and the ability to predict and react to the feeling of time. For athletes, in the fast-changing and complex game, if they want to determine the field changes accurately and use the technology

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flexibly according to the situation on the field, they need to have a high degree of flexibility [3–5]. For the soldiers, with greater flexibility, in the ever-changing battlefield, they can effectively protect themselves against the enemy. Therefore, the flexibility of the test and training in the process of low-load movement has a very important significance. At present, the training methods for flexibility are mainly qualitative acceleration, deceleration and change training, and it cannot quantify the flexibility [6–8]. This system measures the reaction time by using an infrared sensor, which can reflect the flexibility of a person during the movement. The record of the reaction time, and the movement frequency and movement trajectory will be returned to the tablet computer. The system is flexible, convenient and accurate measurement of the flexibility of different sports state, and it has a broad application prospect in the movement to change agility training and rehabilitation training for athletes or soldiers.

2 Design of Hardware

There are 16 light nodes in the hardware part of this system. Each node contains a NodeMCU, two infrared sensors, a lithium battery and LED dot matrix, which is shown in Fig. 1.

NodeMCU is an open-source hardware prototype platform with firmware and development board, which is interactive, programmable, low cost, simple, and so on. NodeMCU provides a high-level hardware interface to avoid complex hardware configuration and register operations. And interactive Lua script is used, which makes the preparation of hardware code simple. At the same time, NodeMCU has ultra-low-cost WIFI module and occupies a huge advantage in cost. In this system, NodeMCU is used as the main controller, including WIFI, ADC, UART, I2C and many GPIOs.

There are two different infrared sensors in the system: sharp 2–15 cm infrared sensor module and 10–80 cm infrared sensor module. Taking into account the thickness of the light node, the test distance will be 0–80 cm. The accuracy of the infrared sensor is 0.001 s. When working, the two modules are connected to the same ADC pin, and when the data of one module are specified by the server task mode, the other module is disconnected.

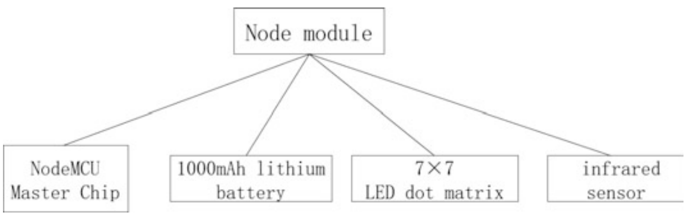


Fig. 1 Composition of the node

7×7 LED dot matrix is used to display the letter number, which is specified by the server. When the cluster mode is used, the nodes are assigned to the corresponding cluster at the server, such as A, B and C. If the nodes belong to the A cluster, they all display "A." When the node is blocked, it will send back the signal with the light off. The display of LED dot matrix is shown in Fig. 2.

Lithium battery with 1000 mAh capacity can be repeated charge and discharge, and its output is 5 V.

3 Design of Software

The software part is mainly designing an App in the smart phone or Tablet PC, which can achieve the setting and control of the light nodes, and store the data from the sensor. Huawei M3 is selected for its Android system as the mobile terminal, and the App is designed by Eclipse.

The communication between App and the light nodes is TCP protocol for data transmission, while the use of high-power routers is used to ensure the signal coverage of 50 m. The communication process between App and the light nodes is shown in Fig. 3.

The initialization process includes the following two aspects:

(1) Open the router, App, server and nodes.
(2) The nodes connect to the server, and the server shows the nodes connection (Fig. 4).

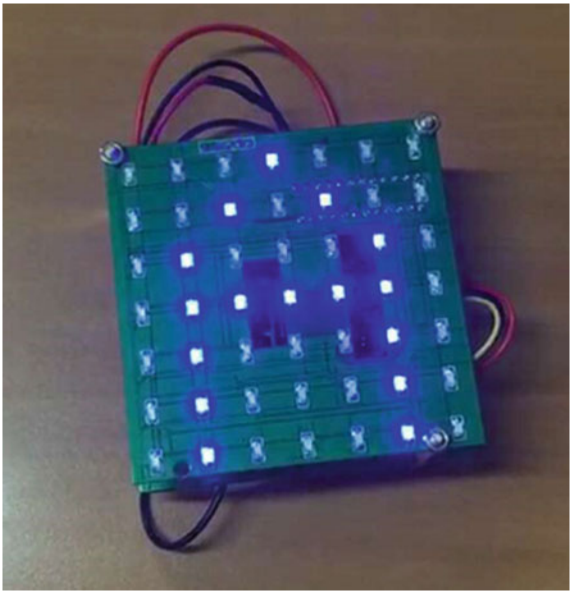


Fig. 2 Display of LED dot matrix

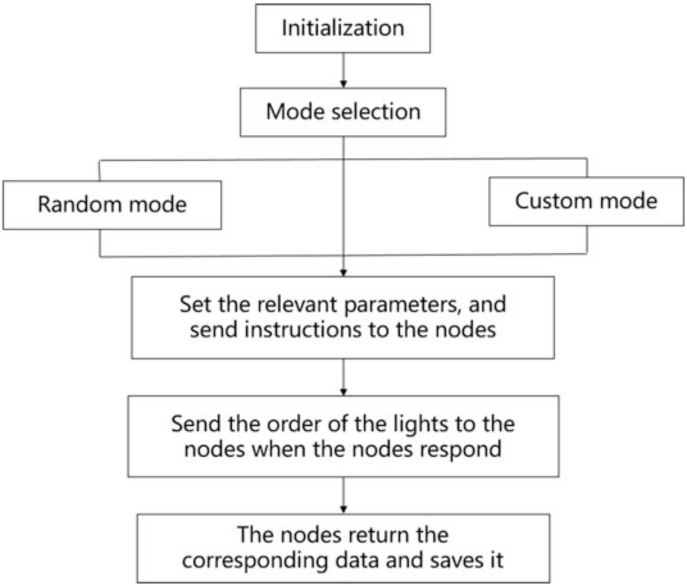


Fig. 3 Communication process between App and the light nodes

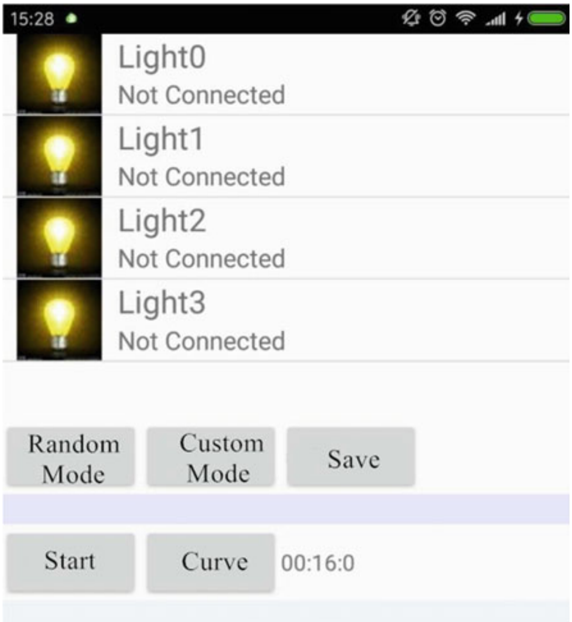


Fig. 4 Initialization interface

There are two modes of this system: random mode and custom mode. For random mode, the random sequence is generated by the system automatically, which determines the order of the lights. For the custom mode, the order of the lights is controlled by users based on the test results. After the mode selection, the parameters of the nodes need to be set, including the sensing distance (the maximum distance at which the light node senses to block and extinguishes), the timeout time (if the time sensor does not sense the occlusion, it is time-out and recorded), sound (buzz) reminder and interval time (the interval between two lights). When the App receives the data from the nodes, save it and generate the corresponding curve.

The processes of two modes are as follows:

For random mode,

(1) Set the generation range of the random number, and the time interval between two random numbers.
(2) Send the mode code and the relevant setting information and wait for the nodes to respond.
(3) The nodes send a response data frame, indicating that the setting is completed.
(4) App generates a random number, lights the corresponding node, and waits for the nodes to return time information. If the timeout occurs, record the information and proceed to the next step.
(5) Repeat (4) until the end.

For custom mode,

(1) Set the node sequence, and the time interval between two consecutive nodes.
(2) Send the mode code and the relevant setting information, and wait for the nodes to respond.
(3) The nodes send a response data frame, indicating that the setting is completed.
(4) Light the corresponding node as the node sequence, and wait for the nodes to return time information. If the timeout occurs, record the information and proceed to the next step.

4 Experiment

Select six light nodes and place on the ground as A–F in Fig. 5. Then select three subjects standing at the O points for flexibility comparison, where OA = OB = OC = OD = OE = OF = 1.5 m. The parameters of the nodes are: the sensing distance is 20 cm; the timeout time is 5 s; the interval is 7 s; and sound (buzzer) reminder. Figure 6 shows the flexibility curves for the three subjects.

As shown in Fig. 6, subject 3 is slightly more flexible than the other two subjects.

Fig. 5 Placement of nodes

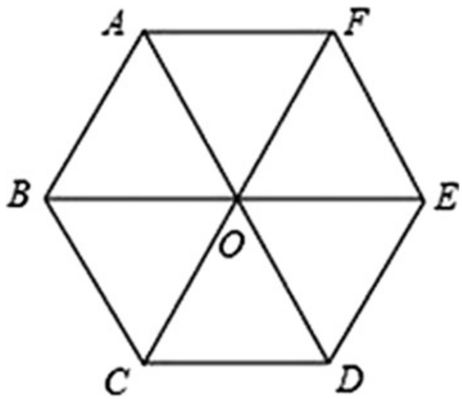
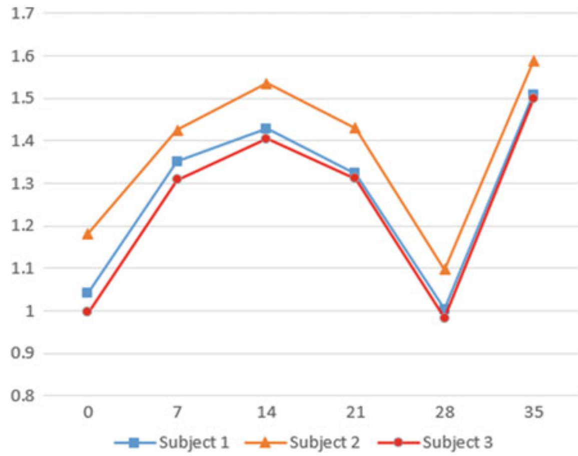


Fig. 6 Flexibility curves for the three subjects



5 Conclusions

An App is designed by Eclipse in Huawei M3 in the system, and the App sets the parameters to control the order of the light nodes. The time from lighting to lighting-off measured by infrared sensors can assess the flexibility of people in the process of movement. Through the comparative experiment, low-load human flexibility test system is a flexible and stable method to simulate different types of training and analysis, and it has a broad prospect in the agile training and rehabilitation training for athletes and soldiers.

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Study on the Design of Healthy Learning Chair Based on the Physiological Characteristics of Teenagers

Ping Zhang, Sanren Jin, Fengyi Liu, Ya Wen and Quan Yuan

Abstract The spine bending deformation is a serious problem for teenagers because of working longtime behind desk, which even affects their growth healthfully. So it is important to design a scientific, healthy, comfortable learning chair for the teenagers. Through analyzing and synthesizing students' learning posture, physiological characteristics and psychological characteristics, this project obtains abundant data and creates a new-style chair by combining the theory of ergonomics to the chair that can adjust the position and shape of cushion and backrest to fit the posture of the user. By adjusting dynamically the physiological features of teenagers, it can help teenagers develop good learning habits and improve learning efficiency.

Keywords Adjusting dynamically · Teenagers · Physical characteristics · Learning chair · Ergonomics

1 Introduction

Most of the teenagers in China study for more than 12 h behind the desk every day. From primary school to high school, parents try to choose suitable learning chair for their children constantly, but there is often no better choice. 12–18 years old is an important growth period for teenagers, and it is also an important period of spine growth, but also a crucial stage of learning. After investigation, we found that many students bore the spine bending deformation because of learning longtime and uncomfortable sitting posture. At present, some domestic study institutes and chair production plants were in a low level in researching and developing teenagers' chair. Some imitated foreign chairs, and some modified simply from adult chairs.

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Not only the chair size cannot meet the requirements of Chinese teenagers, but also the chair cannot meet other needs, such as physiological characteristics, etc.

At present, the study of teenagers' healthy chairs mainly focuses on ergonomics study of static chairs and sitting posture correction of teenagers, and there is no research on intelligent or dynamic function to make teenagers more comfortably when they keep sitting for a longtime. The paper named "The influence of chair design on teenagers scoliosis" (Wang Fen, Feng Xi) according to the difference body size between teenagers and adults, as well as the influence of action fields on daily behavior and daily sitting posture, got the design of the chair suitable for teenagers in this age. And then, by virtual simulation technology, to determine whether the shape of seat is fitting the human sitting posture or not, we finally obtained the most effective data about the sitting posture. The study named "Design study and practice of primary and secondary school desks and chairs" (Xu Danni) discussed on the shortcomings of the use of desks and chairs in primary and middle school students, summarized the design key points of desks and chairs for primary and middle school students according to the functional needs of theirs, and proposed the solutions to meet the physiological and psychological needs. The paper named "Seat comfort study with the consideration of body pressure distribution of boundary manikins" (Zhang Xiaoyi) discussed the goal of improving the static chair comfort and the means of pressure distribution, and focused on the influence factors of different figure drivers and lumbar support by combining the study of subjective evaluation test and simulation test.

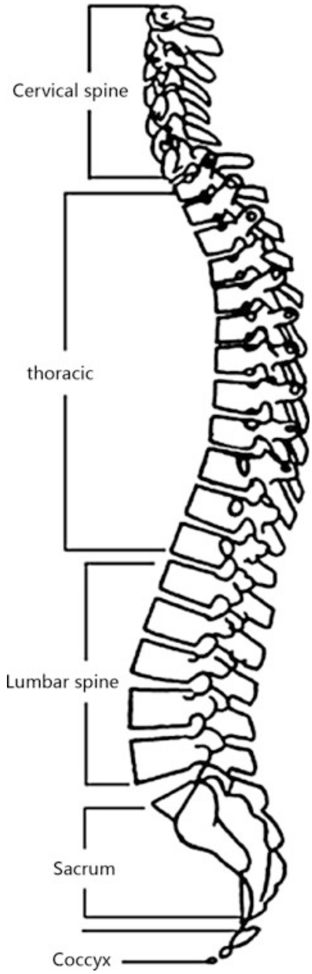
Through analyzing and synthesizing learning posture, physiological characteristics and psychological characteristics of students, this project obtained rich data and then combined the theory of ergonomics to create a kind of chair which can adjust automatically to adjust the posture of the user. By adjusting dynamically the physiological features of teenagers, it can help teenagers develop good learning habits and improve learning efficiency.

2 Physiological Characteristics Analysis of Teenagers Sitting Posture

2.1 Structure of Spine

When sitting, the main structures that support the human body are spine, pelvis, legs and feet. The spine is an important physiological structure of the human body, located in the midline of the back, consisting of 33 pieces of short cylindrical vertebrae, 7 pieces of cervical vertebrae, 12 pieces of thoracic vertebrae, 5 pieces of lumbar vertebrae, 5 pieces of sacrum vertebrae and 4 pieces of tail bones. They are connected with each other with the tendon and cartilage (Fig. 1). In normal posture, the lumbar part of the spine is convex forward, while the sacral spine is concave backward. Sitting a well posture, the pressure distributed properly on each

Fig. 1 Shape of the human spine



intervertebral disk and the muscle tissues stand even static load. When keeping off-normal position, pressure distribution is not normal within the intervertebral disks, leading to lumbar pain, fatigue and discomfort [1].

2.2 Analysis of Correct Sitting Posture

In resent research, there are more than 100 kinds of diseases related to the spine and spinal disease shows the tendency of the young. Because students need to do homework for a longtime daily, all sorts of bad posture are easy to keep the spine in the flexion position or in some specific positions for a longtime, which not only makes the spinal intervertebral pressure increase, but also make the spinal muscle ligament in non-coordinated stress state, and finally leads to lateral bending. The physiological study of sitting posture shows that the normal shape of the lumber curve is the point to get comfortable sitting position. Because the normal lumber curve has a slight protrusion, in order to keep a minimum deformation, the chair should provide two supports behind the part of lumbar spine.

When teenagers learning, the correct sitting posture should be: keeping head, neck and trunk straightly, holding two shoulders evenly and the keeping head forward slightly; keeping back straightly, lifting breast and keeping breast away from the edge of table for a distance of a fist, putting two feet on the floor with the width of shoulders; holding arms on the table, and keeping one foot distance from the eyes to desk. The dotted line shows the correct writing posture, and the solid line shows the reading or resting posture. At this time, the chair can provide support on the lumbar (Fig. 2).

2.3 Biomechanical Analysis of Sitting Posture

The vertebrae are connected by nearby muscles and tendons. Vertebrae fix position by the force of muscle tendon. Once the spine deviates from its natural state, the muscle tendon will be subjected to mutual pressure (tension or compression), which will increase the muscle activity, resulting in fatigue. When tendon tissues are stressed, tan active potential will be produced. According to the results of EMG recording, we can see that the muscle activity of the lumbar spine is high when sitting upright, because of the muscle tension pulling forward. But the activity of the lumbar spine reduces significantly after the lumbar spine being supported by the backrest. When the trunk leans forward, the activity of muscles of upper back and shoulders is high and it cannot be reduced by supporting on the desktop by arms.

Meanwhile, the uneven distribution pressures of the chair cushion tell us that the cushion pressures should be designed in accordance with the principle that the different parts of buttocks stand different pressures. That is, the pressure value is maximum at the field of ischium and reduces gradually to the periphery areas, until to a minimum value at the thigh position. Figure 3 (left) shows the pressure distribution curve of the chair back and the conception design of the back shape according to the curve. Figure 3 (right) is the pressure distribution curve of hip and the conception design of the chair's cushion shape according to the curve.

Through the study of the relationship between human and the chair, we can find that the most comfortable way is to sit down and get up slowly instead of a state of stress while the chair dumps and bounces up suddenly when sitting down and getting up (Fig. 4), so it requires that chair cushion and chair back keep movement in nonlinear way [2].

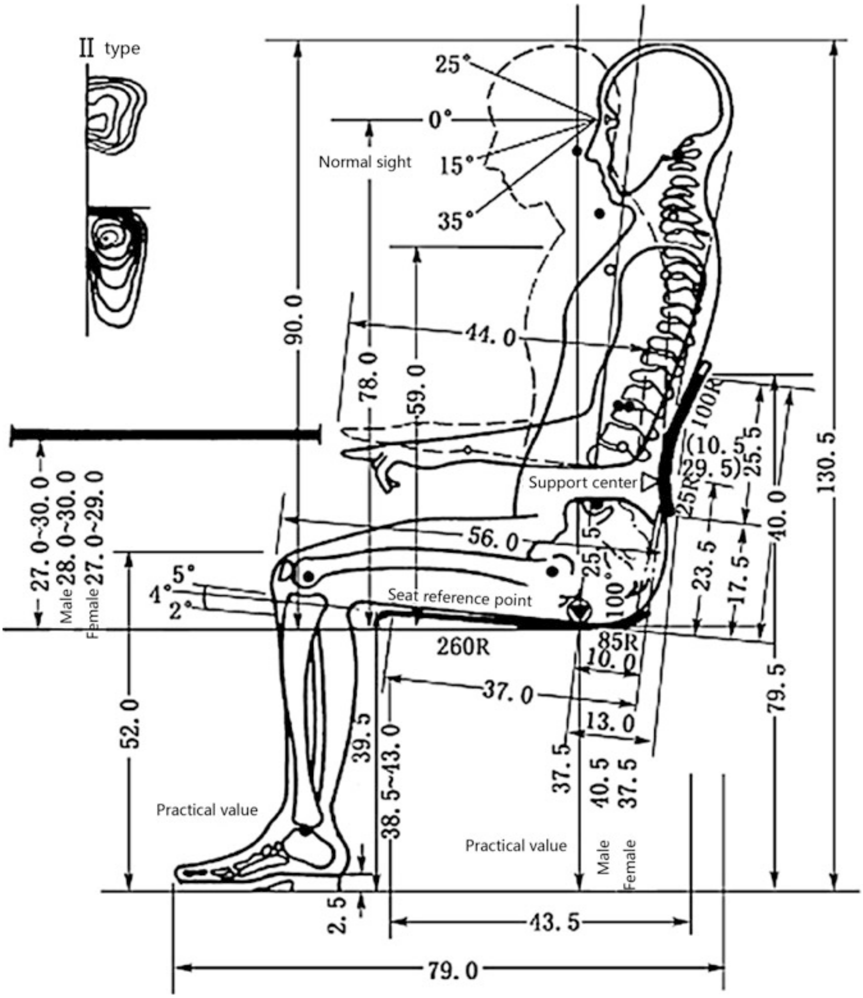


Fig. 2 Correct sitting posture at the time of learning

3 Design of Healthy Learning Chair Which Adjusting the Physiological Characteristics of Teenagers Dynamically

After investigating and analyzing, the design target mainly focuses on domestic teenagers. By the theory of ergonomics, the healthy learning chair, which embodies physical characteristics and psychological characteristics of teenagers, is suitable for teenagers to keep learning posture well. This chair is intelligent, in some degree, to achieve automatic adjustment to match the posture of the user, and to help

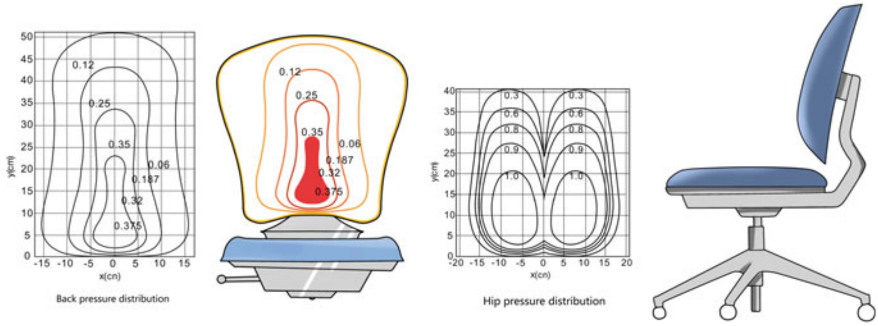


Fig. 3 Pressure distribution curve and the chair design

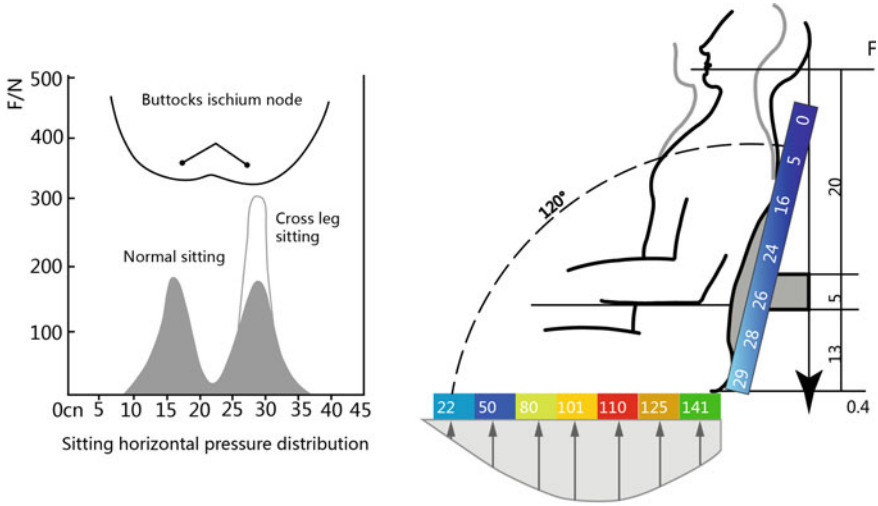


Fig. 4 Pressure distribution in nonlinear in side view

parents give the healthy guidance to teenagers, and to help them improve learning efficiency [3].

3.1 Adjustment Design of Chair

As we know, students' body sizes and learning postures are different from different ages, so according to the physiological characteristics of them, we plan to choose adjustable dimensions for the chair, such as the height, the depth and the backrest (Fig. 5).

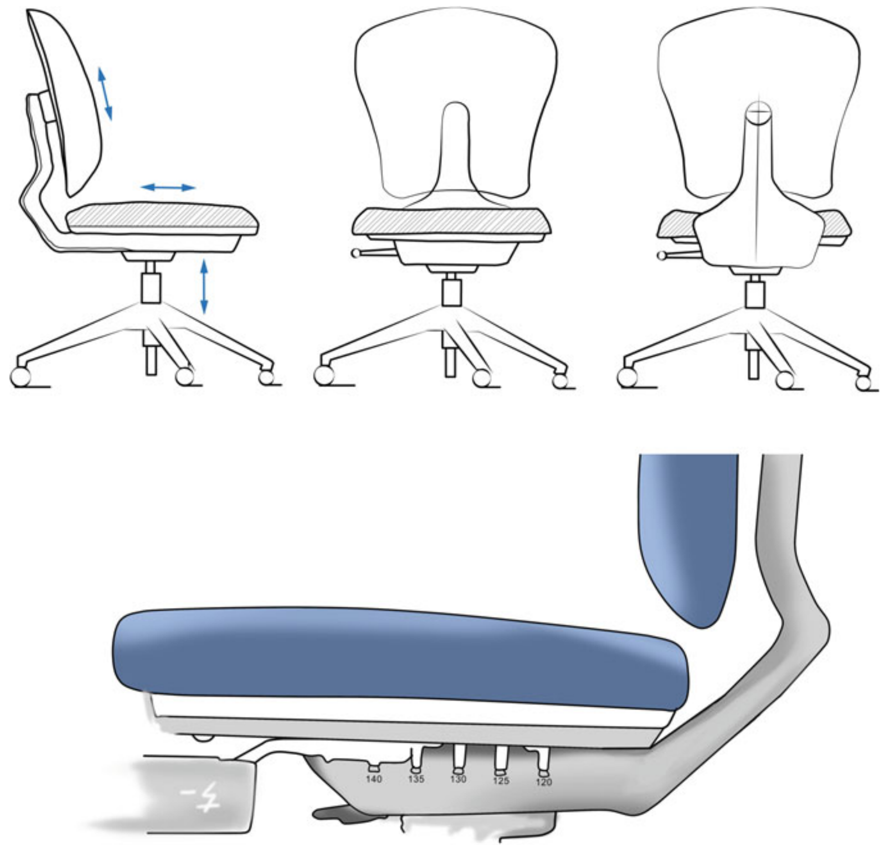


Fig. 5 Adjustable dimensions of the chair: height, depth and backrest height

At the same time, the height data of 12–18-year-old teenagers can be obtained from relevant data (Table 1).

The range of female's height can be included in the data of male, and the data changes from 1.381 to 1.839 m. According to the ergonomics standard, chair height should be between 300 and 480 mm; adjustment range is 180 mm [4].

At the same time, as the height increases, the chair depth should be increased accordingly; similarly, the chair depth can be adjusted in 150 mm. The height of the lumbar pad affects the comfort of the user directly; depending on the deferent heights, the lumbar pad height adjustment range is 80 mm [5].

Table 1 Height data of 12–18-year-old teenagers (unit m)

P3	P50	P97	P3	P50	P97
1.318	1.519	1.66	1.402	1.524	1.645
1.613	1.727	1.839	1.504	1.606	1.707

3.2 Back Design of Chair

By the structure of human spine, spine bending range is limited greatly. In fact, the adjacent two pieces of vertebrae can only change a small angle and must change smoothly. They can be approximated as discrete points of a continuous function. However, there is not a public "spine curve" which is suitable to all, because the curve of the spine is different from the posture changing of the people, while the dimensions are not the same by people. Through researching a large number of documents, finally the Bezier curve is selected to match the design requirements (Fig. 6).

Figure 7 shows the chair back which simulates the human body curve by using the Bezier curve to fit and transit smoothly. The back of chair fits body structure of oriental teenagers, it can provide convenient lumbar support, make the spine to maintain coordination, avoid back pain, and reduce fatigue when students are working, reading, writing or resting.

3.3 Chair Design of Multi-module Cushion and Backrest

This chair cushion can provide multi-point movable supporting. The main parts of chair cushion and backrest are made of modular structure. The cushion is divided into 6 modules and 3 modules in the lumbar pad. The connection between the modules is filled with springs and some materials which neither too hard, nor too soft. Each module is equipped with automatic driving device that can adjust the angle and position of the module at any time to realize the transformation of different forms of cushion, in order to fit the users' back and buttocks perfectly. By the control system, the position and the shape of the cushions are automatically adjusted, similarly to the lumbar pads. So as to realize the function that the chair can adjust the posture of the user actively, see Figs. 8, 9 and 10.

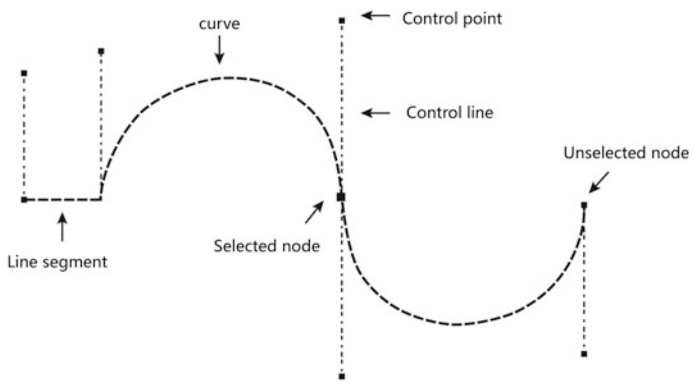


Fig. 6 Characteristics of Bezier curve

Fig. 7 Bezier curve fitting chair back

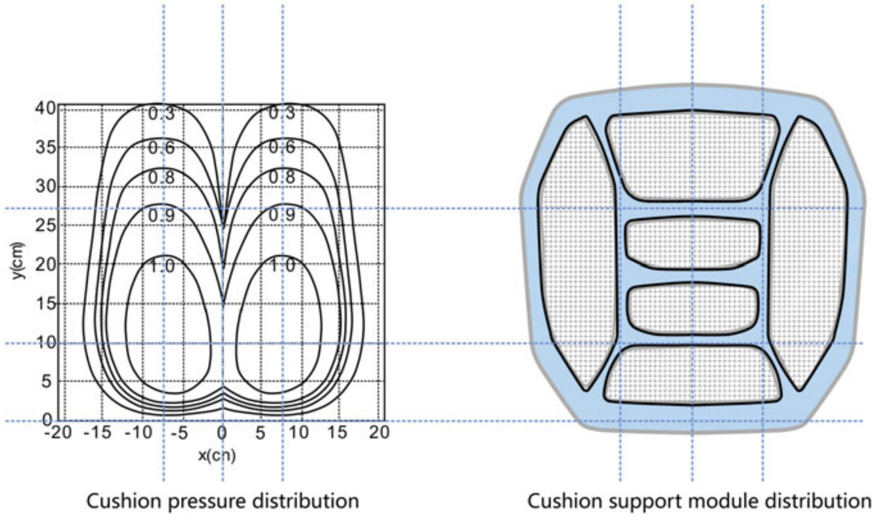


Fig. 8 Diagram of multi-module cushion

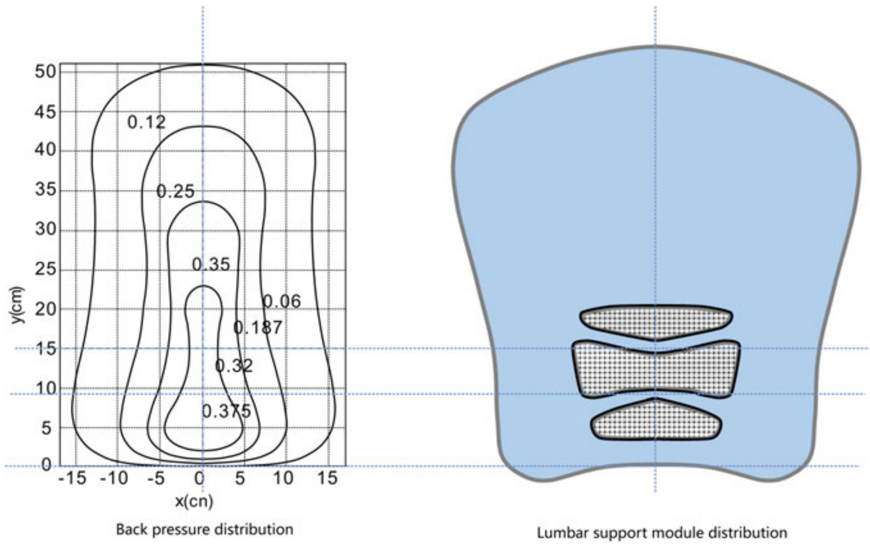


Fig. 9 Diagram of multi-module lumbar pad

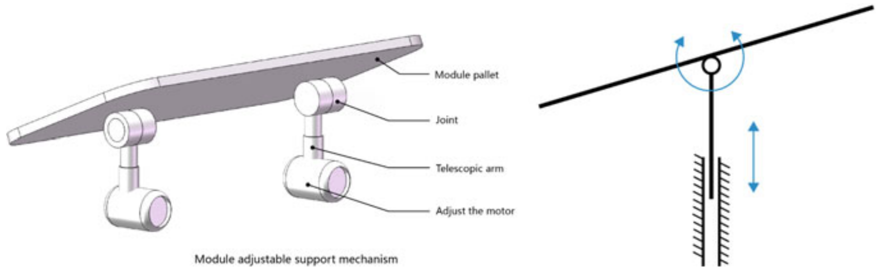


Fig. 10 Regulating mechanisms of lumbar pad and cushion

In the process of application, the chair cushions and the lumbar pads are set in two modes:

1. Manual mode

After selecting this mode, the user can adjust the height and position of each module through the control buttons, until making themselves comfortable.

2. Auto-cycle mode

The system presets three forms of chair cushion. After selecting this mode, the control system will adjust cushion shape to the next state automatically every certain period of time, to make people change a posture unconsciously. By changing the center of gravity of the human body, it can reduce fatigue when teenagers are working for a longtime [6].

4 Conclusion

Through the research on the students' working posture, physical characteristics, psychological characteristics and comprehensive analysis, we create a healthy learning chair which can adjust the physiological characteristics of teenagers dynamically based on ergonomics. The chair has the characteristics of intelligence, and the control system can adjust the position and shape of the cushion and the backrest automatically to realize the function of adjusting the chair position. Health and growth is an eternal topic accompanied with teenagers, so it is important to provide teenagers with a healthy and comfortable working environment for them growing healthily [7].

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Adaptive CLAHE Image Enhancement Using Imaging Environment Self-perception

Haoting Liu, Beibei Yan, Ming Lv, Junlong Wang, Xuefeng Wang and Wei Wang

Abstract A novel Contrast Limited Adaptive Histogram Equalization (CLAHE) image enhancement method which uses the environment self-perception mechanism is proposed. First, the typical degraded image datasets are collected. Second, several Image Quality (IQ) evaluation metrics are used to assess the imaging effect of these datasets above. Third, a BP network is employed to build the connection between the IQ evaluation results above and the optimal control parameters tuning results of the classic CLAHE. The optimal control parameters tuning results are gotten by the subjective evaluation and the setting of the control parameters of the classic CLAHE. The expert experiences of the optimal enhancement are used as the evaluation benchmark. Finally, when a new degraded image is captured, its IQ evaluation metrics will be computed and its optimal control parameters will be forecasted by the BP network and the computed IQ evaluation metrics. Many experiment results have shown the effectiveness of proposed method.

Keywords Image enhancement · CLAHE · Environment perception · Adaptive algorithm · Environment adaptability

1 Introduction

The image enhancement technique [1] can be utilized to improve the output quality of the degraded images. The image degraded reasons derive from many factors, such as the atmosphere, the optic system or the electronic system of camera, or the improper strong light source, etc. In general, a good output effect means the abundant image detail, the correct image color, and no geometric distortion. In this

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paper, the image enhancement for the atmosphere-caused image degeneration is discussed. That means it is supposed the working state and the fixation position of camera are proper; no strong light source exists and the optic or the electronic system will not influence the imaging quality of camera seriously.

Many research works have been done to improve the imaging effect. In [2], the related enhancement techniques of fog removal were reviewed. The state-of-the-art techniques were analyzed and the development trend was provided. In [3], a kind of single image dehazing method was proposed. The optimal transmission map with scene priors was considered in that model. After an extensive research of the image enhancement methods, it can be found that the current methods still have shortcoming: the adaptive processing abilities of these methods are limited; once the imaging environment changes, the related algorithm may become invalided.

A new Contrast Limited Adaptive Histogram Equalization (CLAHE) method [4] is proposed. First, the typical degraded image datasets are collected. Second, some Image Quality (IQ) evaluation metrics [5, 6] are computed. The metrics include: the image brightness, the image region contrast, the image edge blur, the image color quality, and the image noise. Third, a BP network [7] is used to build the connection between the IQ evaluation metrics above and the CLAHE optimal control parameters. The CLAHE optimal control parameters are tuned by the subjective experiences of experts. Finally, once a new image is captured, its IQ evaluation metrics will be computed and its optimal control parameters will be forecasted by the BP network. Then a kind of optimal enhancement can be realized.

2 Proposed Computational Framework

The proposed computational framework is shown in Fig. 1. The corresponding processing steps have been addressed in Sect. 1. Regarding Fig. 1, in contrast to the traditional method, this method has two characters. The first one is it uses the blind IQ evaluation metrics to percept the imaging environment. Because the blind IQ evaluation metrics are independent to the image content, the processing effect of them will be acceptable. The second one is this method uses the BP network to forecast the proper optimal control parameters of CLAHE. The training of BP

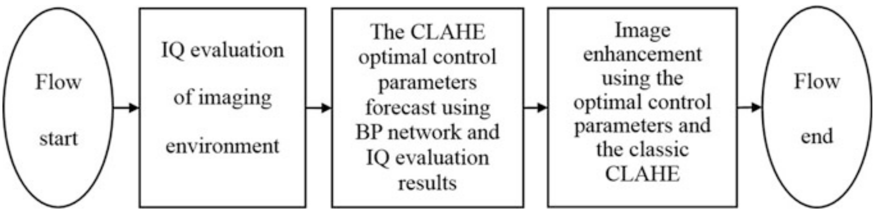

Fig. 1 Proposed computation flow chart of CLAHE using the environment self-perception

network can be carried out before the application of the image enhancement system. Obviously, the BP network can encapsulate the visual experiences of human.

3 Adaptive CLAHE Image Enhancement Method

3.1 Environment Self-perception Method

The blind IQ evaluation metrics are utilized to percept the imaging environment. Table 1 shows the computation methods of these metrics. From Table 1 it can be seen that the IQ evaluation can represent the image environment in the full scale; the image luminance, the image details, the image saliency, and the image color can all be described quantitatively. The computations of the corresponding IQ evaluation metrics do not have any optimization processing which guarantees its real-time application character for the outdoor enhancement in future. Here the outdoor enhancement indicates the influence of complex atmosphere.

Table 1 Calculation methods of environment self-perception metrics

Num	Name	Equation
1	Image brightness degree M_{IBD}	$M_{IBD} = \left\{ \sum_{n_1=1}^{N_1} \sum_{n_2=0}^{255} h_{n_1 n_2} \times (n_2)^s \right\} \Big/ N_1$ where h_{n1n2} is the pixel quantity of the gray value n_2 in the histogram of the ${n_1}^{th}$ image block; s is a parameter, s = 3; N_1 is the number of sample blocks, in this paper N_1 = 50 and the size of sample block is 100
2	Image region contrast degree M_{IRCD}	$M_{IRCD} = \sum_{k=1}^{N_2} \left[\left(I_k^{\max} - I_k^{\min}\right) \big/ \left(I_k^{\max} + I_k^{\min}\right) \right] \big/ N_2$ where I_k^{max} and I_k^{min} are the maximum and the minimum gray values of the kth image block; N_2 is the number of sample block, $_{N2}$ = 100
3	Image edge blur degree M_{IEBD}	$M_{IEBD} = \max_{I \in \Theta} \{ \arctan[(I(i_1, j_1) - I(i_2, j_2))/W_{12}] \}$ where Θ is a set of the image block. $I(i_1, j_1)$ and I(i_2, j_2) represent the gray values of the first and the second image blocks; W_{12} is the width of the edge-spread points (i_1, j_1) and (i_2, j_2)
4	Image color quality degree M_{ICQD}	$M_{ICQD} = \sum_{i=1}^{K} \sigma_i^C \big/ K$ where σ_i^C is the ith standard deviation of the component intensity in the HSV color space; K is the channel number, K = 3
5	Image noise degree M_{IND}	$\sigma_n = w_5 \times \lg\left(w_6 \times \frac{255}{M_{IBD}} \right) \times \min_{k \in \Theta} \sigma_k,\ M_{IND} = \frac{\sigma_n}{M_{IBD}}$ where σ_k is the kth gray standard deviation of the image sample block, the size of image sample block can be 5 × 5; w_5 and w_6 are the parameters, w_5 = 1.8, w_6 = 1.1; $min(\cdot)$ means to calculate the minimum value; Θ is the set of image block

3.2 The Classic CLAHE Enhancement Method

The classic CLAHE limits the enhancement intensity of local histogram by the control of local histogram height; then, the over enhancement of local contrast can be avoided. Its computation steps include: first, the original image will be separated into several tiles. The tiles will not overlap to each other. Second, the local histogram of each tile will be computed and a clip limit will be estimated. The clip limit will restrict the local histogram in the way that the height of local histogram will not beyond the clip limit. One of the computation methods of the clip limit β is shown in (1). Then a new local histogram will be calculated. Third, the histogram equalization will be applied to the new local histogram. Finally, a linear interpolation will be implemented to update the intensity value of each pixel.

$$\beta = (M/H) \times \{1 + [\alpha \times (s_{\max} - 1)]/100\} \tag{1}$$

where α is a clip factor, $\alpha \in [0, 100]$; M is the pixel numbers in sample block; H is the number of bins in histogram; s_{max} is a maximum slope, s_{max} can be 1, 2, 3, or 4.

3.3 The Improved CLAHE Method Using Environment Perception

When carrying out the improved CLAHE, first the image data will be transformed from the RGB color space into the HSV color space. The HSV color space is used here comes from the fact that it accords with the human ocular characters. The improved CLAHE will be carried out only in the V component of HSV space. The computation flow chart of improved CLAHE is shown in Fig. 1. The control parameters of improved CLAHE include the tile size parameters (height and width), the clip limit, or the distribution parameters, etc. For the sake of simpleness, only the clip limit is regarded as the main control parameter of the improved CLAHE, i.e., the parameters α and s_{max} are tuned when implementing the enhancement computation. Thus, regarding the BP network, its input training data is [M_{IBD} M_{IRCD} M_{IEBD} M_{ICQD} M_{IND}] and its supervising data is [α s_{max}].

4 Experiments and Discussions

4.1 Experiment Data

The long-range outdoor surveillance data of the visible light CCD camera are used to test the validity of proposed method. Obviously, the long-range surveillance data suffer from the degraded influence of the atmosphere easily. Figure 2 shows the image samples captured between 7:20 and 12:20 of a winter day in north China. The surveillance distance is about 2000 m. The sample frequency of this dataset is one image per minute.

4.2 Subjective Evaluation Experiment

The subjective evaluation of IQ and the hand-tuning of CLAHE optimal control parameters play the important roles when implementing the improved computation of CLAHE in this paper. Figure 3 shows the hand-tuning results of Fig. 2. Obviously, to get these results the subjective evaluation of IQ and the hand-tuning of optimal control parameters should be carried out in parallel. Table 2 gives out its corresponding tuning results of the optimal control parameters. From Fig. 3, it can be seen the subjective tuning of CLAHE algorithm can get a comparable good processing effect. The subjective evaluation and tuning are the time-consuming tasks. After some experiment investigations, the ergonomics experiment method can be used to get these optimal enhancement results.

When implementing the optimal evaluation and tuning of image enhancement effect, three subjects and an experiment designer will participate in this experiment. First, the experiment designer will tune the control parameters of the proposed algorithm to generate the enhanced images. For each degraded image, the designer will try his best to create at least 3 enhanced image candidates. The enhanced image candidates should have a good imaging effect. Second, the subjects will perform a

Fig. 2 Experiment data samples; the sample interval is 40 min

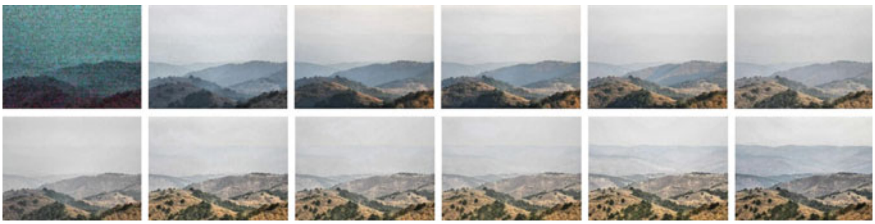

Fig. 3 Image enhancement results of Fig. 2 which are tuned by hand

Table 2 Optimal control parameters setting of the classic CLAHE method

Capture time		7:20	8:20	9:20	10:20	11:20
MOCPs	α	−48.8	−49.2	−49.4	−32.8	−49.0
	s_{max}	3	3	3	4	3

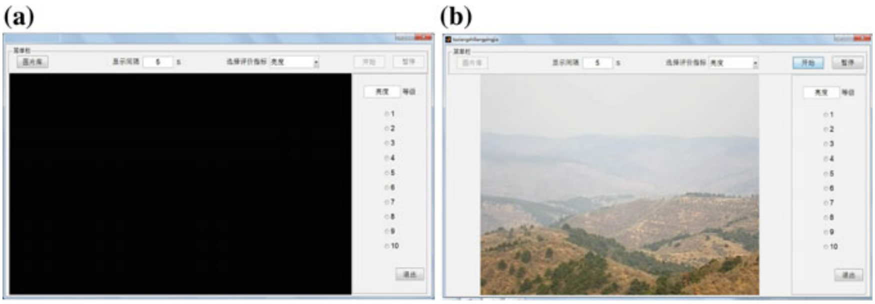

Fig. 4 Interfaces of the subjective IQ evaluation software, **a** is its basic software interface and **b** is its application in our proposed method

subjective image quality evaluation experiment to select only one image as the final data from the candidates above. A subjective image quality evaluation software in Fig. 4 is utilized to guide the evaluation and selection of image data. Finally, by traversing all these degraded images, the optimal evaluation and tuning of image results can be gotten.

4.3 Image Enhancement Experiment Results

The image enhancement effects are shown in Fig. 5. In Fig. 5, (a) and (b) are the original degraded images; (c) and (d) are the processing results of the classic

Fig. 5 Image enhancement results comparisons

Table 3 Comparisons between the hand-tuning results and the BP network forecast results of the CLAHE optimal control parameters

Num	MOCPs		Capture time
1	α	s_{max}	8:00
	−33.24	3.8	
	α'	s'_{max}	
	−31.47	4.1	
2	α	s_{max}	12:00
	−32.1	4.0	
	α'	s'_{max}	
	−32.17	3.9	

CLAHE method; (e) and (f) are the results of the hand-tuning-based CLAHE; (g) and (h) are the results of proposed method. From Fig. 5, it can be seen that the proposed method can get a similar processing effect like the hand-tuning-based method and it can improve the image detail, image luminance, and the image color; while the classic CLAHE cannot get that calculation effect. Table 3 shows the comparison between the hand-tuning optimal control parameters and the BP network forecast control parameters. From Table 3, it can be seen that the proposed method can get the similar processing result of CLAHE optimal control parameters like the hand-tuning results.

The proposed method is also effective to the images captured by a dynamic camera. Figure 6 shows the corresponding processing results. In Fig. 6, the images (a)-1 to (a)-6 are the original degraded images. They are suffered by the environment light, the fog, or the mist. The images (b)-1 to (b)-6 are the results which are processed by the classic CLAHE method. The images (c)-1 to (c)-6 are the results which are computed by the improved CLAHE. From Fig. 6, it can be seen the proposed method can get a better processing effect because the over enhancement problem can be avoided while the image details still can be kept. The reasons the

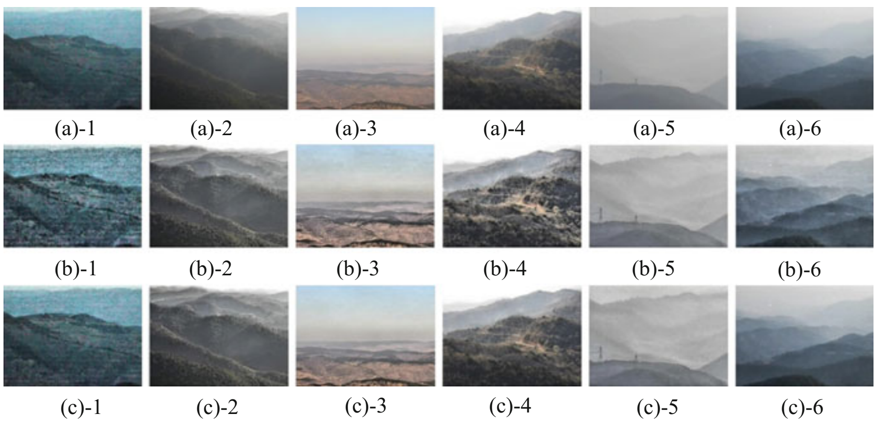

Fig. 6 Image enhancement results using the data captured by a dynamic camera

proposed algorithm has a better processing effect come from two facts: the first one is the IQ evaluation metrics are used to represent the imaging effect under complex atmosphere quantitatively; the second reason is the BP network encapsulates the visual experience of human eyes. The proposed method also has some shortcomings; for example, it depends on the hand-tuning degraded dataset. With the accumulation of dataset, its processing effect will be improved definitely.

5 Conclusion

A new CLAHE enhancement algorithm which uses the blind IQ evaluation metrics as the environment perception feedback is proposed. Five blind IQ evaluation metrics are computed to describe the imaging environment. The BP network is used to build the connection between the blind IQ evaluation metrics and the optimal control parameters of CLAHE. The expert experiences of the optimal image enhancement are encapsulated in this algorithm. In future, other blind IQ evaluation metrics and the machine learning technique can be used to improve the computational effect of proposed method.

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Risk Analysis of Subway Stampede on Grey Clustering Method

Qiquan Wang, Songli Yang and Jiaxin Wu

Abstract To analyse the risk of subway stampede and determine the main factors that induced the stampede accident, a grey clustering method was used to establish an evaluation model by combining the whitening weight function obtained from dangerous states. After collecting the information of a Beijing subway, the data were applied to access. The result showed that grey clustering method was a process that could not only analyse the intrinsic relations among the influencing indexes, but also provide a directive function on how to reduce the risk of subway stampede events.

Keywords Subway station · Stampede · Risk analysis · Grey clustering method

1 Introduction

With the increasing population of China's cities, the growing contradiction between the increasing traffic volume and the limited public transport space is becoming more and more prominent. In subway, because of its underground closed environment, the crowd's evacuation is limited, crowded stampede events are particularly serious [1].

In the research of subway crowd and stampede, D. Helbing and other researchers focused on the panic-stricken people who have caused stampede and put forward a mode named "social force" in Germany; Canadian scholars C.M. Henein and T. White improved Kirchner cells automata model to analyse the behaviour of people in the evacuation process using the computer model based on multi-agent technology in their study [2]. On the domestic, Kou Liping of the People's Public Security University of China has analysed the causes of the group stampede in detail and raised the corresponding measures to avoid the occurrence of similar events [3]. Hu Zhiying, in Tongji University, concluded that the main cause of

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crowded accidents is large-scale social activities and proposed a large-scale activities crowded accident prevention system based on the whole process of centralized management [4].

As for the assessment of subway congestion and stampede, HuoYumang, Song Shouxin and so on, using analytic hierarchy process and entropy method to determine the weight to get conclusion that the density of crowd and the ratio of the number of people who walks on opponent way are the two most important factors of subway congestion and stampede [5]. After the statistical analysis of the domestic typical subway crowded stampede accident, QiuZhida, Song Rui, etc., established index system by using accident tree. What's more, they also came up with a subway congestion stampede evaluation method under the combination of data envelopment analysis method [6]. Wang Yan found out the character of the flow in the subway in different times and its factors of influence. On this basis, she analysed the evolution mechanism of the stampede [7]. In general, most of the domestic and foreign research focuses on crowded stampede accidents of large public places, and these places have the highly crowded characteristic. Foreign research more focuses on crowd dynamics and the domestic research of subway crowded stampede is in the development stage.

In order to analyse the risk of overcrowding accident in the subway accurately, based on the grey weight whitening right function, this paper establishes the grey clustering evaluation model of the congestion risk of the subway station. Select some Beijing subway as sample stations, deeply analyze the impact of various factors on the sample station crowded stampede the risk, in order to further reduce the risk of crowded stampede and provide guidance information.

2 Construction of Grey Clustering Model for Risk Assessment of Subway Stampede Event

Grey clustering is one of the contents of grey system theory, and it is a method based on the production of grey whitening function [8]. Grey clustering analysis is a systematic analysis method of clustering objects to summarize the whitening values owned by different clustering indexes and according to K grey categories, so as to judge the categories of clustering objects. The grey clustering method is particularly suitable for complex environments with multiple input and multiple outputs. In the application of the risk assessment of the crowded trampling accident in the subway station, the risk factors of the crowded stampede events can be considered as the input vector, the risk of the crowded stampede event can be treated as the output vector. And then establish a planning model to achieve the purpose of evaluation for the decision-making unit..

2.1 Establishment of Evaluation Index System

Referring to the article Research on Crowded Stampede Accident Risk at Subway Based on Empowering Related Degree Method [9] written by Wang Qiquan, and with the idea of system safety engineering, delimiting the main induce factors to the subway crowded stampede of four aspects, which are identified as human, equipment, environment and management, known as the primary indicators. The four first-level indicators are subdivided into 13 secondary indicators as crowd crowded, alarmed, retrograde, falls and collisions, quarreling; elevator malfunction, road slippery, power off; lighting defects, bad weather; emergency management defects, error information and carry place excessive items, respectively. Specific evaluation index system is shown in Table 1.

2.2 Determine Grey Class and Whitening Function of Indicators

According to people's acceptance of risk, we divided the risk state into four states—the higher the risk the higher the level. There are four classes of grey, namely k(k = 1, 2, 3, 4), and the value 0–10 indicating the score of each index. Considering security is a relative state, in other words, there is no absolute safety in the world. Combined with the requirements of the specific classification of grey, point the degree of =0, =3, =6, =9 to value the whitening weight function in its value area

Table 1 Subway crowded stampede accident evaluation index

Subway crowded stampede accident evaluation index (x)	
Primary indicators	Secondary indicators
Human (x_1)	Crowd crowded (x_{11})
	Alarmed (x_{12})
	Retrograde (x_{13})
	Falls and collisions (x_{14})
	Quarreling (x_{15})
Equipment (x_2)	Elevator malfunction (x_{21})
	Road slippery (x_{22})
	Power off (x_{23})
Environment (x_3)	Lighting defects (x_{31})
	Bad weather (x_{32})
Management (x_4)	Emergency management defects (x_{41})
	Error information (x_{42})
	Carry/Place excessive items (x_{43})

from 0 to 10 is the indicator for ij, (i for the primary index, j for the secondary index) belongs to the kth grey class whitening weight function. The first, second, third and fourth grey whitening weights are Eqs. 1–4.

$$f_{ij}^{1}\begin{cases} 0, & \text{others} \\ \frac{3-x}{3}, & 0 \le x \le 3 \end{cases} \tag{1}$$

$$f_{ij}^{2}\begin{cases} 0, & \text{others} \\ \frac{3-x}{3}, & 0 < x \le 3 \\ \frac{6-x}{3}, & 3 < x \le 6 \end{cases} \tag{2}$$

$$f_{ij}^{3}\begin{cases} 0, & \text{others} \\ \frac{x-3}{3}, & 3 < x \le 6 \\ \frac{9-x}{3}, & 6 < x \le 9 \end{cases} \tag{3}$$

$$f_{ij}^{4}\begin{cases} 0, & \text{others} \\ \frac{x-6}{3}, & 6 < x \le 9 \\ 1, & 9 < x \le 10 \end{cases} \tag{4}$$

2.3 Determine the Weight of Evaluation Factor

In Research on Crowded Stampede Accident Risk at Subway Based on Empowering Related Degree Method [9], under the statistical results of subway crowded stampede events, taking the number of accidents' casualties and the main influencing factors into account, the risk state of various factors score was given. The higher the score is, the higher the degree of danger. As the score was aimed at the high incidence of accidents in subway, the conclusions had no representation. The author summed up the risk factors and then overall values to make the outcomes normalized. Finally, we got the weight of each layer of indicators as presented in Table 2.

n_{ij} is the weights of the degree of influence of crowded stampede events. Among them, human factors are crowd crowded (20.7%), alarmed (7.0%), retrograde (13.0%), falls and collisions (22.4%), and quarreling (1.7%). Environmental factors are lighting defects (2.2%) and bad weather (4.0%). Equipment and facility factors are made of elevator failure (4.7%), road slippery (6.9%) and power off (2.0%). For management, there are emergency management deficiencies (10.6%), incorrect information transmission (3.7%) and carry/placing overweight items (6.3%). The percentage in parentheses refers to the number of factors contributing to the formation of the subway congestion.

Table 2 Hazard state score

Influencing factors/places		Hazard state				
		Escalator	Transfer stairs	Get off the door	Overall state	Weights
Human (x_1)	Crowd crowded (x_{11})	62	69	64	195	0.197
	Alarmed (x_{12})	66	0	0	66	0.067
	Retrograde (x_{13})	23	37	62	122	0.123
	Falls and collisions (x_{14})	81	71	59	211	0.213
	Quarreling (x_{15})	16	0	0	16	0.016
Equipment (x_2)	Elevator malfunction (x_{21})	44	0	0	44	0.044
	Road slippery (x_{22})	0	65	0	65	0.066
	Power off (x_{23})	19	0	0	19	0.019
Environment (x_3)	Lighting defects (x_{31})	21	0	0	21	0.021
	Bad weather (x_{32})	0	38	0	38	0.038
Management (x_4)	Emergency management defects (x_{41})	62	0	38	100	0.101
	Error information (x_{42})	35	0	0	35	0.035
	Carry/Place excessive items (x_{43})	18	0	41	59	0.060

Combining weights (x_{ij}) is a weight of each two indexes of crowded and stampede events(x) to evaluate their possession of weight (such as the combination weights for x_{11} equal to its weight 24.4% divided by all secondary indicators and then sum up), The hierarchical weight for x_{11} came out with its combined weights to divide by each secondary indicator on the lifestyle layer then summed up, as presented in Table 3.

2.4 Calculate the Whitening Weights of Each Indicator

The paper, 'Research on Crowded Stamped Accident Risk at Subway Based on Empowering Related Degree Method' [9], chose the transfer station of Beijing subway as the research object. The station is located in the junction between urban and rural areas, which has two exports, two entrances, eight escalators and four transfer to the stairs. The characteristic of the station is obvious that the passenger flow peaks are at a high level in the morning and evening, so inside station was swarmed. During the early peak period, the flows which come from the suburb lines to their work places which lie in the centre of the city become the main force. And because the station is surrounded by technology companies, therefore, the traffic

Table 3 Weight analysis

Influencing factors/Weights		Weights	
		Hierarchical weight	Combining weights
Human (x_1)	Crowd crowded (x_{11})	0.320	0.197
	Alarmed (x_{12})	0.109	0.067
	Retrograde (x_{13})	0.2	0.123
	Falls and collisions (x_{14})	0.346	0.213
	Quarreling (x_{15})	0.026	0.016
Equipment (x_2)	Elevator malfunction (x_{21})	0.341	0.044
	Road Slippery (x_{22})	0.512	0.066
	Power off (x_{23})	0.147	0.019
Environment (x_3)	Lighting defects (x_{31})	0.356	0.021
	Bad weather (x_{32})	0.644	0.038
Management (x_4)	Emergency management defects (x_{41})	0.515	0.101
	Error information (x_{42})	0.179	0.035
	Carry/Place excessive items (x_{43})	0.306	0.060

that outbound and inbound is also considerable [10]. According to the actual operation and in the light of expert comments on the accident place, the Table 4 is gained. Then evaluate the subway of the value ranging from 0 to 100 points, the higher the score is, the higher the degree of danger is. Similarly, the author sums up and weighed the overall to average score in the Table 4.

Then, bring the values in Table 4 into the Whitening Weights came out the Table 5.

3 Results Analysis

Count $\sigma_i^k = \sum_{j=1}^{n} f_{ij}^k(x_{ij}) * \eta_{ij}(\mathrm{k} \in \{1, 2, 3, 4\})$, named σ_ι^κ as the k grey class's grey variable weight clustering coefficient of object "I" and find out the weights of the influencing factors in the same layer. Then, define the weight of η_{ij} as the index ij which has been told in Table 4. Table 6 shows the clustering coefficient in the same levels, and Table 7 gives the weight of factors between the same layers.

Then use $\sigma_i^k = \max_{1 \le k \le s}\{\sigma_i^k\}$ to cluster, if $\sigma_i^k = \max_{1 \le k \le s}\{\sigma_i^k\}$, that means the object i belongs to the first k grey class.

Table 4 Expert Scoring

Influencing factors/Places		Experts rating				
		Escalator	Transfer stairs	Get off the door	Overall state	Weighted average
Human (x_1)	Crowd crowded (x_{11})	78	81	71	230	7.7
	Alarmed (x_{12})	27	35	29	91	3.0
	Retrograde (x_{13})	0	49	66	115	3.8
	Falls and collisions (x_{14})	58	62	51	171	5.7
	Quarreling (x_{15})	7	3	8	18	0.6
Equipment (x_2)	Elevator malfunction (x_{21})	39	0	0	39	1.3
	Road slippery (x_{22})	0	42	20	62	2.1
	Power off (x_{23})	6	1	2	9	0.3
Environment (x_3)	Lighting defects (x_{31})	1	5	2	8	0.3
	Bad weather (x_{32})	0	5	11	16	0.5
Management (x_4)	Emergency management defects (x_{41})	49	30	29	108	3.6
	Error information (x_{42})	3	15	5	23	0.8
	Carry/Place excessive items (x_{43})	21	0	30	51	1.7

Table 5 Whitening rights function

Index		First grey	Second grey	Third grey	Fourth grey
Whitening Right Function Value	X11	0.000	0.000	0.433	0.566
	X12	0.000	0.000	0.000	0.000
	X13	0.000	0.733	0.267	0.000
	X14	0.000	0.100	0.900	0.000
	X15	0.800	0.800	0.000	0.000
	X21	0.567	0.567	0.000	0.000
	X22	0.300	0.300	0.000	0.000
	X23	0.900	0.900	0.000	0.000
	X31	0.900	0.900	0.000	0.000
	X32	0.833	0.833	0.000	0.000
	X41	0.000	0.800	0.200	0.000
	X42	0.733	0.733	0.000	0.000
	X43	0.433	0.433	0.000	0.000

Table 6 Subway congestion stampede risk clustering at all levels

Influencing factors/Grey	σ_1	σ_2	σ_3	σ_4
Human (x_1)	0.021	0.202	0.503	0.181
Equipment (x_2)	0.479	0.479	0.000	0.000
Environment (x_3)	0.856	0.856	0.000	0.000
Management (x_4)	0.264	0.676	0.103	0.000

Table 7 The factors of weight between same layer

Influencing factors/Grey	Weights			
	σ_1	σ_2	σ_3	σ_4
Human (x_1)	0.01	0.09	0.83	1.00
Equipment (x_2)	0.30	0.22	0.00	0.00
Environment (x_3)	0.53	0.39	0.00	0.00
Management (x_4)	0.16	0.31	0.17	0.00

3.1 Grey Clustering Analysis on the Factors Affecting the Subway Stampede

The author chooses the transfer station of Beijing subway as the research object. The site is located in the junction between urban and rural areas, which is the only transfer station between ex-urban country subway lines and the city subway. The station has two exits, two entrances, six escalators, four transfer stairs to the station. In 2015, the station is on the list of the top 10 in and out of the station of Beijing metro traffic station and 10 interchange stations. The site has the obvious characteristics of tidal flow. In and out of traffic and interchange flow is very big in morning and evening rush, and the station is more crowded. During the morning rush, passengers go to work from ex-urban country metro line transfer to the city subway constitute a morning rush "mainstay". Due to the science and technology enterprise around the site is relatively intensive, in and out of the station traffic are also considerable.

(1) **Grey Analysis in Human Factors**

Combined with Tables 6 and 7, in horizontal comparison, we can see the human factors have values in all four grey classes and has the highest score of 0.503 in third grey. With the risk level increased, the score value rises first and then falls. The third grey class is in more dangerous level, and the consequences of accident are uncontrollable and accompanied with death. This just matches with the large traffic flow, the concentration of travel time and the complex passenger type in this subway. Vertical contrast, the proportion of human factors is lower in the first and second grey, so the risk level is smaller. There comes a conclusion that once the person's behaviour is no longer subject to or slightly affected by equipment, facilities and environmental and management constraints, the risk level will be greatly enhanced.

(2) **Grey analysis in Equipment and Environment Factors**

Equipment and environmental factors get the same clustering scores in the first and second grey, for the third and fourth clusters are both zero, due to its nature. As can be seen from Table 4, scores given by experts share the low weight. Considering the actual situation, the facilities and equipment is relatively perfect in the subway. The elevators guided signs and flow control facilities operating in a reasonable and efficient way. In addition to extreme weather, the impact by the environment is weak. And most equipment is equipped with alarm devices and emergency stop devices; the event can be found and controlled by taking measures immediately. So that the scope of the accident will not expand. From the view of safety, equipment and environment is taken into second grey.

(3) **Grey Analysis in Management Factors**

Management Factors values zero in the forth grey, but get scores in the other grey classes and has the highest scored in the second grey. In general, management factors and human factors have the same trend in the fourth grey (first rise and then decline). In the first grey, the proportion of management is not great. As the proportion of human factors increased, the management raised in the same time in the second grey. Due to the environment and equipment factors disappear in third and fourth grey, management factors are gradually reduced to 0.

After comprehensive analysis, put the subway station-crowded stampede risk into the level two.

3.2 Recommendations for Control Measures

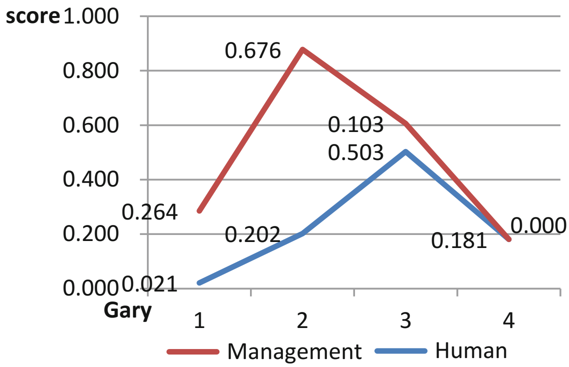
(1) **For Human**

The human factor has always changed its risk level as its weight changes. If you want to reduce the risk level of crowded stampede events, it is necessary to reduce the proportion of people to precede. Seen from the Whitening Rights Function Table, once the environmental factors and equipment factor fail, the proportion of crowded crowds will be greatly increased and the risk level will be increased. To reduce the risk, humanized management system and equipment is vital. A comfortable environment can prevent passenger from quarreling, getting scared and other bad emotions, while reducing passengers who retrogrades, falls and the occurring of other accidents.

(2) **For Equipment and Environment**

Passenger's travel can be facilitated by reasonable equipment. But in the subway, the large flow, complex passenger composition, long time and high audit operation of facilities, hard not to lead to malfunctions. In this case, under the premise of safety, devices can be chosen for its efficiency. And regular maintenance of the

Fig. 1 Human factors and management factors grey scale charts



equipment to ensure that alarm device and emergency stop system is working. For weak parts of the fault, it should be subjected to real-time monitoring. Affected by rain and snow weather, due to the characteristics of the stampede, the road slippery becomes a big cause of stampede. Rain intrusion and water seepage and other phenomena are prone to happen in subway for its special geographical location, intelligent facilities should be equipped to prevent the occurrence of such bad weather.

(3) **For Management**

Management factors works are closely related to human factors. According to the score in 6, comparing the human factors and management factors, draw the Fig. 1. Although the management and human have the same trend, the management factor score peaks before human. This indicates the advance of management, thus reaction should be taken before human changes. At the same time, management works rely on facilities, institutional and rules in a specific environment of specific objects. When an accident occurs, what the manager need to do is quickly respond to the emergency accident, understand the location of the accident, the scene and the scope of the situation and convey the situation to the location of the subway to stabilize the mood of passengers and to prevent the expand of personal factors.

4 Conclusions

(1) A grey clustering model for the risk analysis of subway crowded stampede was established. The analysis overcomes the limitations and solves the problem of cannot calculate the connotation between the various factors. The model connects various factors into linkage and provides a new method for the crowded stampede risk assessment of subway stations.
(2) The grey clustering model is applied to a number of sample stations in Beijing subway, and the evaluation results are basically consistent with the actual

situation. This model can not only evaluate the overall risk of crowded stampede accident, but also get the root cause and failure of the accident according to the evaluation result. For the other subway stations, according to the actual targeted to modify the evaluation index, the cause of the subway crowded stampede can be found and targeted measures can be put forward.

(3) The analysis of the risk of subway crowding accident is complex system engineering. The indicators and weights of grey clustering evaluation should be further adjusted and revised to ensure results of the subway crowded stampede accident risk analysis is scientific and reliability.

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Risk Assessment Research Used in Subway Crowded Stampede with Grey Analytic Hierarchy Process (AHP)

Qiquan Wang

Abstract In this paper, mathematical model is considered to be used. Evaluation index system is constructed on the basis of analyzing the subway crowded stampede from the people and things, environment and management factors in a large number of objective classifications. The subway crowded stampede modeling analysis and assessment are quantified with grey hierarchical analysis method, concluding that the evaluation results of assessment instance of crowded stampede risk are in intermediate levels. During the process of evaluation instances actual operation, traffic in commuting is huge and passenger transfers of stairs and elevators are very crowded, which has high risk of stampede and need to strengthen the control to prevent crowded stampede. The safety evaluation results are fundamental identical to the actual state. Evaluation analysis results show that grey hierarchical analysis method has certain practicability, which is worth to promoting.

Keywords Subway · Crowded stampede · Grey analytic hierarchy process (AHP) · Assessment

1 Introduction

As a modern means of transport, subway traffic has the advantages of convenient, fast, stable and large volume. Around the world in the modern city, the subway traffic has been more and more widely used, bearing the more and more important passenger transport tasks. The low cost of subway attracted to more and more people, making the subway appeared unprecedented "crowded." According to the statistical data of Chinese urban rail transit association in the end of 2014, 95 subway stations in 22 cities have been built with 2900 km operation mileage.

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Beijing, Shanghai and Guangzhou have entered the rail transit network. Expanding subway network, the number of passenger is rising at the same time. On March 2013, Beijing subway traffic breaks through 10 million person-times, becoming the world's busiest subway.

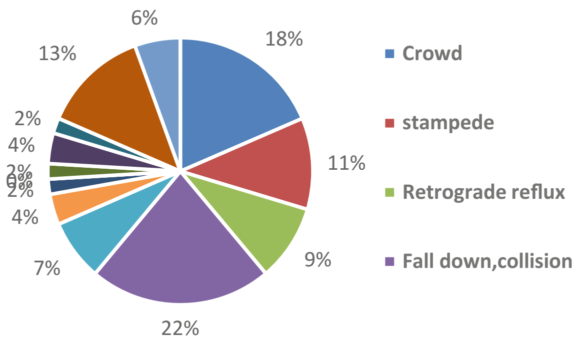
Every line of subway tunnels is such crowded in the morning and evening rush hour. A huge passenger flow gathering to the platform and channel of the narrow space, once affected by accidental factors, which is likely to cause safety accidents such as trample. Therefore, research on the risk assessment of subway crowded stamped effectively prevents crowded stampede and has great significance improving the level of the subway operation safety management.

Foreign researches on crowded stampede mainly include R.S.C. Lee and R.L. Hughesin Australian, introducing the continuous lines of traffic model and quantitative analyzing crowded and trampled by instances, respectively, and then predict the behavior of the crowd. Researchers L. Heibing of German are analyzed the stampede crowds in panic, putting forward the "social force" model [1]. C.M. Henein and T. White in Canadian proved Kirchner cellular automata model in the study, based on the analysis of crowd evacuation behavior with multi-agent technology by computer model. L.H. Eigeas and other scholars in French propose two crowds gathered phenomenon in the study, setting up a relevant model and analyzing the crowded stampede predisposing factors [2]. Domestic researches on subway crisis management and safety management theories mainly include Zhang et al. [3] and Jiao and Song [4] who analyzed the crowded stampede risk control efficiency by using data envelopment method (DEA) to establish evaluation model from the aspects of technical efficiency, scale efficiency and the comprehensive efficiency. Wang [5] analyzed the evolution mechanism and rot holes of the subway stampede and proposed preventive and emergency measurements. Huo et al. [6] used the entropy weight method to determine the combination of subjective and objective factors weight of the subway crowded stampede. Peng and Jiang [7] studied warning and challenges of crowded stampede in urban rail transit station. The above studies focused on crowded stampede behavior mechanism of the research or predisposing factors, evolution mechanism and risk control efficiency of subway crowded stampede, and quantitative analysis of the subway crowded stampede risk is not deep. With the increasing degree in the subway traffic crowded degrees, needs to be carried out the analysis and study of risk assessment method specifically for the subway crowded stampede.

2 The Risk Assessment Index System of Subway Crowded Stampede

On the basis of the survey analysis, the subway typical crowded stampede accidents for nearly ten years were statistically analyzed, and the crowded stampede main reasons as shown in Fig. 1.

Fig. 1 Factors inducing stampede accidents in subway



According to statistics analysis with historical data, the subway crowded stampede mainly occurred in intensive period of time such as commuting time and holidays. Accident place areas mainly include the escalators, transfers, up and downstairs and the boarding gates. The factors induced subway crowded stampede are mainly about four aspects which are human, objective, environment and management including crowd, stampede, retrograde reflux, fall down, collision, elevator fault, stair and road slip, quarrel, electric short/circuit, lighting defect, bad weather, emergency management defect, error in information transmission and carrying excess placing items [8]. Subway crowded stampede incentive is complex. It is a multifactor, multivariable and multi-level man–machine–environment system. On the basis of lots of researches and historical accidents statistics and experience summaries, using the idea of safety system engineering, four levels of evaluation indexes and 13 secondary safety evaluation index systems are set considering with the human factors, objective factors, environmental factors and management factors [8]. Risk assessment index systems of factors are shown in Table 1. The analytic hierarchy process (AHP) is used for distribution of the weight in the table, and the DPS systems are used for calculation [9].

Table 1 Metro stampede assessment factors weight table

First-level index	Second-level index	Weight	First-level index	Second-level index	Weight
Man factors 0.35	Crowd	0.25	Objective factors 0.28	Elevator fault	0.58
	Stampede	0.15		Stair and road slip	0.27
	Retrograde reflux	0.20		Electric short/circuit	0.15
	Fall down, collision	0.29	Management factors 0.23	Emergency management defect	0.56
	Quarrel	0.11		Error in information transmission	0.30
Environment factors 0.14	Lighting defect	0.42		Carrying excess placing items	0.14
	Bad weather	0.58			

3 The Model of Subway Crowded Stampede with AHP Assessment Analysis

According to the grey analytic hierarchy process (AHP), the influence factors of the subway crowded stampede are divided into three levels. According to the principle of analytic hierarchy process (AHP), Table 1 shows multiple evaluation indexes with the different grouping attributes. Each group set as a level, aligning the evaluation index system ranked as target layer (w), standard layer $(U_i,\ i = 1,2,3,4)$ and index layer $(V_{ij},\ i = 1,2,3,4;\ j = 1,2,\ldots,n_i)$. S is on behalf of comprehensive evaluation value of evaluation object. U is on behalf of the set of U_i as $U = \{U_1, U_2, U_3, U_4\}$, and V_i $(i = 1,2,3,4)$ is on behalf of the set of V_{ij} as $V_i = \{V_{i1}, V_{i2}, \ldots, V_{im}\}$. Constructing evaluation mode program is as follows [10, 11]:

(1) Determine the rating criteria of evaluation index V_{ij}. While evaluating the subway crowded stampede, because of the qualitative indicators of V_{ij}, a unified evaluation criterion has not formed yet. Therefore, to transfer index V_{ij} into quantitative index and to divide quality grade of assessment index to excellent, good, medium and poor level, corresponding as 4, 3, 2, 1 points. The index levels are between two adjacent levels as 3.5, 2.5 and 1.5 points. Specific grade standard depends on the experiences of experts.

(2) Determine the weight of assessment index U_i and U_{ij}. According to the standard of evaluating index system, the degree of importance of the index W in target layer the index U_i in standard layer and index V_{ij} in target layer are different, the analytic hierarchy process (AHP) can be used to determine weights of factors.

(3) Organize the experts to evaluate. Set serial numbers of evaluation experts as m, $m = 1,2,\ldots,p$, which means to grade each evaluation level with p experts as index measured values and expert experiences and fill in evaluation expert's evaluation table.

(4) To evaluate sample matrix. According to assessment result of evaluation experts, index V_{ij} is valued d_{ijm}, and the evaluation matrix D of the sample object are obtained.

(5) Determine evaluation grey classes. That is to determine the grey class, grey numbers and white functions of the grey classes. According to actual analysis, evaluation index levels adopt four evaluation grey classes. Grey class serial numbers are e, $e = 1,2,3,4$, presented as excellent, good, medium and poor in which grey number and white function are shown as follows:

The first grey class "excellent" (e = 1), set grey number as $\otimes 1 \in [4, \infty]$ and white function as f_1, whose expression is shown as follows:

$$f_1(d_{ijm}) = \begin{cases} \frac{d_{ijm}}{4}, & d_{ijm} \in [0, 4] \\ 1, & d_{ijm} \in [4, \infty) \\ 0, & d_{ijm} \in (-\infty, 0] \end{cases}$$

The second grey class "good" ($e = 2$), set grey number as $\otimes 2 \in [0, 3, 6]$ and white function as f_2, whose expression is shown as follows:

$$f_2(d_{ijm}) = \begin{cases} \frac{d_{ijm}}{3}, & d_{ijm} \in [0, 3] \\ 2 - \frac{d_{ijm}}{3}, & d_{ji} \in [3, 6] \\ 0, & d_{ijm} \notin (0, 6] \end{cases}$$

The third grey class "medium" ($e = 3$), set grey number as $\otimes 3 \in [0, 2, 4]$ and white function as f_3, whose expression is shown as follows:

$$f_3(d_{ijm}) = \begin{cases} \frac{d_{ijm}}{2}, & d_{ijm} \in [0, 2] \\ 2 - \frac{d_{ijm}}{2}, & d_{ji} \in [2, 4] \\ 0, & d_{ji} \notin (0, 4] \end{cases}$$

The forth grey class "poor" ($e = 4$), set grey number as $\otimes \in [0, 1, 2]$ and white function as f_4, whose expression is shown as follows:

$$f_4(d_{ijm}) = \begin{cases} 1, & d_{ijm} \in [0, 1] \\ 2 - d_{ijm}, & d_{ijm} \in [1, 2] \\ 0, & d_{ji} \notin (0, 2] \end{cases}$$

(6) To evaluate grey evaluation coefficient. Assessment index V_{ij} belongs to e the grey evaluation coefficient as X_{ije} and the total number of grey evaluation of the total grey classes of the individual assessment of grey classes, then

$$X_{ije} = \sum f_e(d_{ijm}), \quad m \in [1, p]$$

$$X_{ij} = \sum X_{ije}, \quad e \in [1, 4]$$

(7) Calculate grey evaluation weight vector and weight matrix. The whole evaluation experts argue the grey evaluation weight of e the grey class with assessment index V_{ij} as r_{ije}, then $r_{ije} = X_{ije}/X_{ij}$. The grey class is 4, which are $e = 1, 2, 3, 4,$ then the assessment index V_{ij} of evaluated objects to grey

evaluation weight vectors $r_{ije} = \left(r_{ij1}, r_{ij2}, r_{ij3}, r_{ij4}\right)$ to get evaluated objects V_i in index V_{ij} with grey evaluation weight matrix of evaluation grey classes

$$R_i = \begin{bmatrix} r_{i1} \\ r_{i2} \\ \cdots \\ r_{i4} \end{bmatrix} = \begin{bmatrix} r_{i11} & r_{i12} & r_{i13} & r_{i14} \\ r_{i21} & r_{i22} & r_{i23} & r_{i24} \\ \vdots & \vdots & \cdots & \vdots \\ r_{im1} & r_{im2} & r_{im3} & r_{im4} \end{bmatrix}$$

If the weight of "q" is the maximum in r_{ij}, namely $r_{ijq} = \max\left(r_{ij1}, r_{ij2}, r_{ij3}, r_{ij4}\right)$, then assessment index V_{ij} belongs to the weight of "q."

(8) Evaluate index level V_i, setting comprehensive evaluation result as B_i, then $B_i = A_i R_i = \left(b_{ij1}, b_{ij2}, b_{ij3}, b_{ij4}\right)$

(9) Evaluate index layer U, comprehensive evaluation result B_i of index layer V_i, the standard layer U to grey evaluation weight matrix of evaluation grey classes are

$$R_i = \begin{bmatrix} B_1 \\ B_2 \\ B_3 \\ B_4 \end{bmatrix} = \begin{bmatrix} b_{11} & b_{12} & b_{13} & b_{14} \\ b_{21} & b_{22} & b_{23} & b_{24} \\ b_{31} & b_{32} & b_{33} & b_{34} \\ b_{41} & b_{42} & b_{43} & b_{44} \end{bmatrix}$$

Therefore, the standard layer U can be comprehensive evaluated, which is B, then

$$B = AR = (b_1, b_2, b_3, b_4)$$

(10) Calculating comprehensive evaluation results. Base on the comprehensive evaluation results B, according to maximum principle to determine the grey class rank evaluation object's grey classes and the comprehensive evaluation values can be obtained first

$$S = BC^T$$

In expression above, C is the vector of grey class level according to the "grey level" assignment as $C = (4, 3, 2, 1)$. Referring to the grey class level, the comprehensive evaluation of the object system is calculated.

4 Risk Assessment Instance Analysis of Subway Crowded Stampede

Based on the analysis of the subway crowded stampede AHP assessment model, the transfer station of Beijing subway is selected as the research object. The station is located in the junction between urban and rural areas, which has two exports, two entrances, six escalators and four transfer to the stairs. The site has the obvious characteristics of tidal flow. Morning and evening rush transfer traffic and passenger flow are very big and crowded. During the morning rush, passengers from exurban county metro line transfer to the city subway constitute a "mainstay" morning rush to work. Due to the relatively intensive site around science and technology enterprise, the station traffic is also considerably huge [12].

(1) To determine the evaluation for the object class
According to Table 1, determine the evaluation for the object class.
(2) To determine the structure of the underlying element combination weight
The weight of evaluating index U_i and V_{ij} shown in Table 2 is as follows:

$$A = (0.35, 0.28, 0.14, 0.23)$$
$$A_1 = (0.25, 0.15, 0.20, 0.29, 0.11); \quad A_2 = (0.58, 0.27, 0.15)$$
$$A_3 = (0.42, 0.58); \quad A_4 = (0.56, 0.30, 0.14)$$

Table 2 Total table of index score and the grey weight vector

Expert assessment score						Grey evaluation coefficient/Grey evaluation weight vector							
	1	2	3	4	5	x_{ij1}	r_{ij1}	x_{ij2}	r_{ij2}	x_{ij3}	r_{ij3}	x_{ij4}	r_{ij3}
V_{11}	1	1.5	2	1.5	2.5	2.125	0.1814	2.833	0.2321	5.250	0.4300	2.000	0.1638
V_{12}	2	3.5	2	3	1.5	3.000	0.2368	3.667	0.2895	5.500	0.4342	0.500	0.0395
V_{13}	3.5	4	3	3.5	3.5	4.375	0.2958	4.167	0.2817	6.250	0.4225	0	0
V_{14}	1.5	2	2.5	3	1.5	2.625	0.2039	3.500	0.2718	5.750	0.4466	1.000	0.0777
V_{15}	4	3.5	3	3.5	3	4.250	0.2818	4.333	0.2873	6.500	0.4309	0	0
V_{21}	3	2.5	4	3	2	3.625	0.2493	4.167	0.2865	6.750	0.4642	0	0
V_{22}	4	3.5	3	2.5	3.5	4.125	0.3084	2.500	0.1869	6.750	0.5047	0	0
V_{23}	3	4	3.5	3	4	4.375	0.2958	4.167	0.2817	6.250	0.4225	0	0
V_{31}	4	2.5	3.5	2	3	3.750	0.2632	4.000	0.2807	6.500	0.4561	0	0
V_{32}	2	3	2.5	3	1.5	3.000	0.2143	4.000	0.2857	6.500	0.4643	0.500	0.0357
V_{41}	3	1.5	2.5	2	3.5	3.125	0.2280	3.833	0.2796	6.250	0.4559	0.500	0.0365
V_{42}	1.5	3	3.5	2.5	1	2.875	0.2110	3.500	0.2569	5.750	0.4220	1.500	0.1101
V_{43}	3	2.5	3	1.5	2	3.000	0.2143	4.000	0.2857	6.500	0.4643	0.500	0.0357

(3) Organize five experts to score and the results are shown in Table 2.

(4) Calculate grey evaluation coefficient. As evaluation index V_{11}, evaluated system belongs to grey evaluation coefficient X_{11e} of e;

$$\begin{aligned} e = 1, x_{111} &= f_1(1) + f_1(1.5) + f_1(2) + f_1(1.5) + f_1(2.5) \\ &= 2.125 \end{aligned}$$

Identically, $e = 2$, $x_{112} = 2.833$; $e = 3$, $x_{113} = 5.250$; $e = 4$, $x_{114} = 2.000$
Evaluated V_{11} belongs to the total grey evaluation number of each evaluation grey class, so:

$$X_{11} = 2.125 + 2.833 + 5.250 + 2.000 = 12.208$$

Identically, grey evaluation coefficient and the total number of grey evaluation can be obtained by the same method to calculate other indicators.

(5) Calculate grey evaluation weight vector and matrix

$$e = 1, r_{111} = 2.125/12.208 = 0.1814$$

Identically, $e = 2$, $r_{112} = 0.2321$; $e = 3$, $r_{113} = 0.4300$; $e = 4$, $r_{114} = 0.1638$
Then, based on grey evaluation weight vector of each grey class to, calculate V_{11}

$$r_{11} = (0.1814, 0.2321, 0.4300, 0.1638)$$

Identically, other grey evaluation weight vector can be obtained.
Weight matrix R_1 to V_1 made by vectors r_{11}, r_{12}, r_{13}, r_{14}

$$R_1 = \begin{bmatrix} 0.1814 & 0.2321 & 0.4300 & 0.1638 \\ 0.2368 & 0.2895 & 0.4342 & 0.0395 \\ 0.2958 & 0.2817 & 0.4225 & 0 \\ 0.2039 & 0.2718 & 0.4466 & 0.0777 \\ 0.2932 & 0.3909 & 0.3159 & 0 \end{bmatrix}$$

Identically, V_2, V_3, V_4 can obtain weight matrix R_2, R_3 and R_4, and results are shown in Table 2.

(6) Evaluate the index layer V_1, V_2, V_3, V_4

$$
\begin{aligned}
B_1 &= A_1 R_1 \\
&= (0.25, 0.15, 0.20, 0.29, 0.11)\begin{bmatrix} 0.1814 & 0.2321 & 0.4300 & 0.1638 \\ 0.2368 & 0.2895 & 0.4342 & 0.0395 \\ 0.2958 & 0.2817 & 0.4225 & 0 \\ 0.2039 & 0.2718 & 0.4466 & 0.0777 \\ 0.2932 & 0.3909 & 0.3159 & 0 \end{bmatrix} \\
&= (0.2314, 0.2796, 0.4214, 0.0694)
\end{aligned}
$$

$$
\begin{aligned}
& B_2 = A_2 R_2 = (0.2722, 0.2589, 0.4689, 0.0000) \\
\text{Identically: } & B_3 = A_3 R_3 = (0.2348, 0.2836, 0.4609, 0.0207) \\
& B_4 = A_4 R_4 = (0.2210, 0.2736, 0.4469, 0.0585)
\end{aligned}
$$

(7) Evaluate the standard layer
Matrix R is made of B_1, B_2, B_3, B_4

$$
R = \begin{bmatrix} 0.2314 & 0.2796 & 0.4214 & 0.0694 \\ 0.2722 & 0.2589 & 0.4689 & 0 \\ 0.2348 & 0.2836 & 0.4609 & 0.0207 \\ 0.2210 & 0.2736 & 0.4469 & 0.0585 \end{bmatrix}
$$

$$
\begin{aligned}
B &= AR \\
&= (0.35, 0.28, 0.14, 0.23)\begin{bmatrix} 0.2314 & 0.2796 & 0.4214 & 0.0694 \\ 0.2722 & 0.2589 & 0.4689 & 0 \\ 0.2348 & 0.2836 & 0.4609 & 0.0207 \\ 0.2210 & 0.2736 & 0.4469 & 0.0585 \end{bmatrix} \\
&= (0.2409, 0.2730, 0.4461, 0.0406)
\end{aligned}
$$

(8) To evaluate comprehensive evaluation result

$$
S = BC^T = B\begin{bmatrix} 4 \\ 3 \\ 2 \\ 1 \end{bmatrix} = (0.2409, 0.2730, 0.4461, 0.0406)\begin{bmatrix} 4 \\ 3 \\ 2 \\ 1 \end{bmatrix} = 2.7154
$$

The evaluation result of the subway crowded stampede risk is S= 2.7154, which is between medium level and good level. The subway crowded stampede possibility is not high, but crowded stampede has great randomness and easily sudden happen. It is recommended that the subway escalator, transfers to the up- and downstairs and boarding gates are relatively densely populated places in the early rush hour and strengthen the control, preventing crowded stampede.

5 Conclusions

The paper uses the grey analytic hierarchy process (AHP), building a grey hierarchical analysis model for the evaluation of subway crowded stampede and taking the evaluation and validation of instance analysis conclusion in the subway station. Conclusions are as follows:

(1) The subway crowded stampede factors involve human, objective, human, management factors and so on, and statistical analysis of the subway typical crowded stampede for nearly ten years is made, which summarizes the subway crowded stampede predisposing factors. On the basis above, the crowded stampede risk assessment index system is used with the grey analytic hierarchy process (AHP) to construct and determine the weight.

(2) Using the grey analytic hierarchy process (AHP) to evaluate risk of subway crowded stampede, the result value of analysis instances is 2.7154, which lies between medium and good level. In the process of actual operation of evaluation instances, tidal traffic during commuting is huge. Passenger transfer of elevators and stair is very crowded, and the risk of stampede is quite high. The evaluation results are basically identical with the actual state of safety. This method is certain practical, which is worth using in the risk assessment of subway crowded stampede.

(3) The grey analytic hierarchy process (AHP) combines qualitative and quantitative analysis of the assessment, which can be implemented through the computer programmed with the DPS data computing systems. It can rapidly calculate the assessment results of evaluation factors, laying a certain foundation of the popularization and application of this method.

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Harmonic Detection Method of Electric Equipment Malfunction

Wen Zhang and Biaocan Ling

Abstract In modern mass production, the safe and normal use of electrical equipment is the necessary condition to ensure the stable operation of production line. Electrical equipment is the basic unit of the power system. Conventional methods of stopping, splitting, touching and maintaining electrical equipment on a regular basis have some drawbacks. So a new non-contact electrical fault detection method—harmonic detection method is adopted. We can as far as possible to avoid accidents and economic losses due to electrical equipment failures, If we use high-order harmonics to carry out electrical equipment fault diagnosis. This technique can be used for non-contact detection of remote equipment, occlusion equipment, underwater equipment and so on.

Keywords Electrical equipment · Fault diagnosis · Harmonic detection

1 Introduction

With the continuous development of science and technology, the level of automation of industrial production continues to increase, the role of electrical equipment in modern production and the impact is growing. Take the necessary detection measures of equipment running state and advance detection safety hazards of equipment. These are essential to correct diagnosis of equipment failure and timely troubleshooting [1]. Failure or failure in the operation of electrical equipment not only results in significant economic loss, but may even lead to catastrophic casualties and adverse social impacts. So the security and reliability of equipment or system are extremely important. In the actual production, in order to ensure stable operation of electrical equipment. As a new type of fault diagnosis technology, harmonic diagnosis is of great significance to reduce the cost, reduce the outage time and reduce the maintenance cost by diagnosing the deterioration state of the

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motor and frequency inverter by using the current harmonics [2]. This method can greatly satisfy the electrical equipment does not have to stop, split and contact the equipment for fault diagnosis. The diagnostic method can quantify the degradation degree and performance of the equipment and diagnose and predict the reliability of the equipment [3, 4], which is the biggest difference from the traditional detection method. ZKLK energy technology companies to introduce Japan's invention patent in China, "for electrical equipment, harmonic diagnostic methods," and its whole machine ATC-KS series of electrical equipment fault harmonic detector [5].

2 Electrical Equipment and Harmonic

In principle, Harmonics can occur through the spatial harmonics in the rotating machine such as generators and motors, while in a stationary device such as a transformer, the nonlinearity of the core occurs. Stress aging caused by abnormal operation of the equipment is the main cause of harmonic generation. Stress aging mainly includes thermal aging, voltage stress aging, mechanical stress aging, environmental stress aging and composite stress aging, so harmonic technology is used to diagnose the aging of electrical equipment.

Internationally recognized definition of the harmonic is the sinusoidal component of a periodic electric quantity, and the frequency is an integral multiple of the fundamental frequency. In the generator, motor, frequency converter and other electrical equipment used in the process, will inevitably produce harmonics. These current waveforms, including harmonics, are called distortion wave [2].

According to the Fourier series expansion of distortion wave, you can decompose into a number of different frequency sine wave, which can be decomposed into various harmonics. Usually the distortion wave of the electrical circuit is symmetrical. And it is an odd function (odd function: the parity of mathematical function). That is, only odd harmonics occur in most normal electrical circuits as shown in Fig. 1.

The even-order harmonic currents shown in Fig. 2 are limited in the present situation. The harmonics present in the electrical circuit are all odd times. Electrical

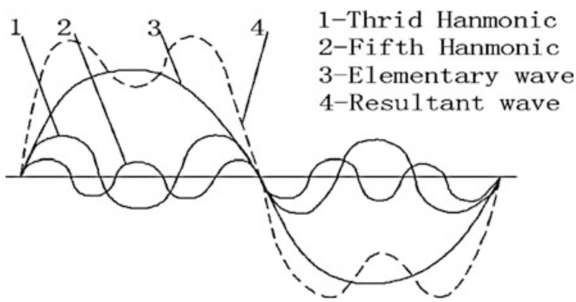
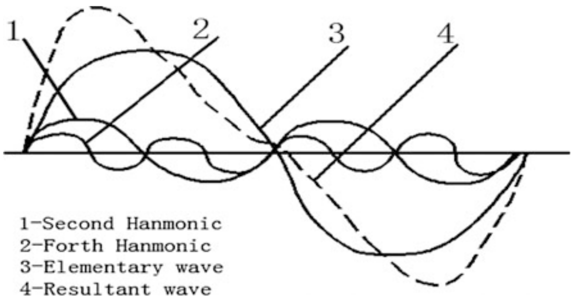


Fig. 1 Odd harmonic current

Fig. 2 Even harmonic current



equipment is composed of electrical parts of the coil (conductor is covered by insulation) and as the core of the magnetic circuit or rotary shaft and bearings and other mechanical parts [3].

3 Detection Methods and Technical Characteristics

The dynamic harmonic detection method of the electric power equipment is to use the harmonic sensor to carry on the signal acquisition to the equipment power bus. ATC-KS series of electrical equipment fault harmonic detector will automatically record and analyze the collected harmonic signal, compared with the expert database, and the user can automatically obtain the device status report [5]. The sample of experts database has more than 32,000. The main technical features are as follows:

(1) No downtime, no need to crack the equipment, detection of production equipment completely intact, no impact on the production process.
(2) Real-time collection of harmonic signal of equipment in operation, get the most intuitive equipment running state.
(3) Expert database automatically generates equipment status report, without complex manual analysis, the user access to ATC-KS nearly 50 years of electrical equipment failure harmonic detection experience.
(4) Generate trend management report automatically, accurate tracking the bad installation, aging and fault status of equipment.
(5) Can accurately analyze the motor and its primary load, frequency converter and inverter, transformers, generators, industrial capacitors, UPS, high-power battery packs and industrial transmission cables aging and fault status.

4 Harmonic Fault Diagnosis of Typical Electric Drive System

Electric drive system consists of frequency converter, inverter, motor and its load composition [6]. The aging or failure of any component in the system will affect the current harmonic characteristics of the transmission line. Analysis of harmonic characteristics by ATC-KS series of electrical equipment fault harmonics detector. We can get the system components of the fault characteristics and aging characteristics, test reports generated by the KS software automatically [7]. The parts can be tested in Tables 1, 2, 3, 4, 5, 6, 7 and 8.

Table 1 Test items of frequency converter/inverter

Test items	Aging and failure
Smoothing (electrolytic) capacitor	Charge and discharge of smoothing capacitor
Control circuit	Control circuit from AC to DC, from DC to AC
Electric element	IGBT, etc.
Operating circuit	AC–DC, DC–AC operation of the circuit

Table 2 Test items of motor

Test items	Aging and failure
Rotor, bearing and fixing device	Rotor eccentricity, poor fix (damage to the bearing on the counter load side)
Coil insulation (interturn/interturn) vibration	Insulation bad of interturn/interturn, voltage imbalance or thermal vibration
Damage of bearing and bearing box	Damage of the bearing (mainly the load side), bearing deformation
The gap of air is not uniform vibration	Dust adhesion, rotor eccentricity, heating and air vibration

Table 3 Test items of load

Test items	Aging and failure
Coupling abnormal, low coaxial	Bearing wear, uneven, couplings and belts are too loose
Bearing damage, foreign body attached	Bearing wear, foreign matter mixing and attached to the internal load
Rotary axis is abnormal, the contact parts wear	Bad spindle, wear and foreign matter attached to the internal load
Damage of gears and belt damage	Gear rotation, damage to the transmission belt

Table 4 Test items of transformer

Test items	Aging and failure
Coil insulation (interturn/interturn) vibration	Coil insulation aging, local overheating of the coil (vibration) and electromagnetic vibration (iron core)
Efficiency, heat, insulating oil and vibration	Low power due to insulation aging, eddy current, heating and thermal vibration

Table 5 Test items of generator

Test items	Aging and failure
Rotor, bearing and fixing device	Rotor eccentricity, poor fix (damage to the bearing on the counter load side)
Coil insulation (interturn/interturn) vibration	Insulation bad of interturn/interturn, voltage imbalance or thermal vibration
Bearing, bearing bracket (motor box)	Damage of the bearing (mainly the load side), bearing deformation
Gap is not uniform vibration	Dust adhesion, rotor eccentricity, heating and air vibration

Table 6 Test items of prime mover

Test items	Aging and failure
Coupling abnormal, low coaxial	Bearing wear, uneven, couplings and belts are too loose
Bearing damage, foreign body attached	Bearing wear, foreign matter mixing and attached to the internal load
Revolving axle is abnormal, the contact parts wear	Bad spindle, wear and foreign matter attached
Gear, pulley system aging	Gear rotation, damage to the transmission belt

Other important parameters of the diagnosis:

(1) Three-phase imbalance diagnosis of motor current;
(2) Three-phase imbalance diagnosis of motor power;
(3) Load capacity of frequency converter, inverter, transformer and drive;
(4) Load capacity of motors and generators.

Table 7 Test items of ups

Test items	Aging and failure
Smoothing (electrolytic) capacitor	Charge and discharge of smoothing capacitor
Control circuit	Control inverter circuit
Electric element	IGBT, etc.
Operating circuit	Inverter operating circuit

Table 8 Test items of capacitor

Test items	Aging and failure
Insulation of capacitor	External insulation of capacitor
Power of capacitor	Capacity change of capacitor, aging of electrolyte

5 The Difference Between Harmonic Detection, Vibration Method and Infrared Method for Drive Electrical Equipment

Compared with the vibration method, the high-order harmonic method has wider applicability and can accurately judge the electrical deterioration of the equipment. Compared with the infrared method, the high-order harmonic method can detect the signs of potential deterioration of the motor and the generator earlier, and it is easy to prevent and adjust the maintenance plan at the early stage, and the diagnosis is more accurate [5]. The ATC-KS system uses expert libraries to quickly generate reports that provide trend management and adapt to modern industry trends in equipment trend management (Table 9).

Table 9 Comparison of the detection range between harmonic method, vibration method and infrared method

Test items	Harmonic method	Vibration method	Infrared method
Revolving axle, bearing	√	√	√
Fixing device	√	√	√
Dust adhesion	√	×	√
Abnormal wear of revolving axle	√	√	√
Bearing damage, foreign body attached	√	√	√
Damage of gears and belt damage	√	√	×
Coil insulation vibration	√	×	×
Damage of bearing box	√	√	×
The gap of air is not uniform vibration	√	×	×
Coupling abnormal	√	×	√

(continued)

Table 9 (continued)

Test items	Harmonic method	Vibration method	Infrared method
Special motor diagnosis	√	×	×
Smoothing (electrolytic) capacitor	√	×	×
Control circuit	√	×	×
Operating circuit	√	×	×
Electric element	√	×	×
Rectification component	√	×	×

√ item can be detected
× item cannot be detected

6 Conclusion

Electrical equipment such as electric motors, frequency converters, transformers, generators, in different states of deterioration and different working conditions, will produce different high-order harmonics. After careful attention and detailed analysis of the harmonics generated by various. And found that the electrical equipment generated by the higher harmonics and equipment state has a direct correspondence. It can provide the basis for maintenance. According to the diagnosis time given by the harmonic diagnosis technology, it can realize the targeted maintenance and repair, greatly reduce the abnormal downtime of the production equipment and reduce unnecessary waste of time and spare parts. This method is mainly used for various electric drive equipments online condition monitoring and can be widely used in electric power, chemical industry, machinery transportation and rail transportation and other fields.

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The Feasibility Study of Airborne Image Recordings for Aircraft Accident Investigation

Lin Yang

Abstract Several safety recommendations in the Final Report of aircraft accident investigation recommend that provisions for the availability of image recordings be included in International Civil Aviation Organization (ICAO) document Annex 6. The issues leading to these recommendations vary from a lack of data not available on the flight recorders to analyse human performance, to the accident aircraft was not equipped with a flight recorder, or where it was unclear what was displayed to the flight crew during the occurrence. Meanwhile, it was concerned that the protection for image recordings was not adequate and agreed to postpone discussions of these proposals until the conclusion of the work of the safety information protection. In the light of the progress made with the provisions for the protection of accident and incident records, these issues were again discussed the need including recordings of information displayed to the flight crew and bulk erase function for both CVRs and airborne image recordings. The discussion on the technical and social aspects related implementation of airborne image recording is still existed.

Keywords Airborne image recordings · Aircraft accident investigation · Human–machine interface (HMI)

1 Introduction

On 29 November 2013 at 09:26 UTC, an Embraer ERJ 190-100 IGW/C9-EMC conducted a flight from Maputo airport to Luanda, Angola [1]. The flight operations were normal until the Namibian radar data revealed that the aircraft commenced a

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sudden descent from the normal cruising level of FL 380. Radar contact and voice contact were lost with Air Traffic Services (ATS). The investigation found that the inputs to the control panels by the captain, who remained alone in the cockpit when the first officer went out to the restroom, caused this Embraer ERJ 190-100 IGW to depart from FL 380 and subsequent collision with the terrain. A contributing factor is the deviation to airlines standard operating procedures as a result of a single pilot living in the cockpit. One of the safety recommendations is that "ICAO" should review the feasibility of installing image recorder inside and outside the flight cockpit. The image recorder inside should capture the information on who was flying the airplane when the event occurred, the image recorder outside should provide what happened within the cabin and whether these actions were in relation to the plane's normal operations.

On 23 August 2013 at 17:17 UTC, a Eurocopter AS332L2 Super Puma helicopter G-WNSB with 16 passengers and 2 crews onboard crashed during approaching to Sumburgh airport, Shetland Islands [2]. Pilots unnoticed the decreasing airspeed until the helicopter engine power insufficient and lose of control in-flight. The pilots performed an unsuccessful recovery. Finally, the helicopter struck the water approximately 1.72 nm to airport. Four passengers were fatally injured. Pilots could not situate their recollection of the accident, and recorded data from combination recorders did not deliver the information of the cockpit. One of the safety recommendations has reiterated the need for airborne image recordings to record pilot conducts during flying within the flight compartment, in aircraft that shall have flight recorders.

On 2 September 1998, a MD-11/HB-IWF conducted Swissair Flight 111 from JFK, New York, to Geneva, Switzerland [3]. Because of smoke and fire in the flight compartment after take-off, the pilots decided to divert to alternative airport in Halifax, Nova Scotia, Canada. Before landing to this alternative airport, it crashed in the sea. The investigators found that the fire and smoke from ceiling, forward and rear of bulkhead in the cockpit lead to lose of control. It took 4 years and over 50 million Canadian dollars [4] to carry out a search and rescue, and investigation. The accident investigation authority believes that airborne image recording would largely help this accident investigation. They would determine promptly what happened by means of this information.

This article discusses the feasibility study on airborne image recordings and aimed to objectively and rationally uncover the strengths and weaknesses of airborne image recordings.

2 Additional Tools for the Investigation

2.1 Assessment of Airborne Image Recordings

Flight recorders have helped determine the reason of an accident or incident. Yet, certain categories of aircraft are still not equipped with these critical technologies. In other cases, flight data and/or cockpit voice recorders may have been present, but some information could only have been provided from an image recorder. Image recordings can help to fill in the gaps by providing first-hand knowledge of crew activities.

Airborne image recordings can significantly contribute to the analysis of the behaviour of crew with regard to the conditions encountered, the actions taken and the results obtained during the flight. Though it does not make it possible to directly understand natural mental processes, such as instinctive, emotional or cognitive processes, image recording gives access to the observable part of the crew interactions, i.e. actions and communications. Some markers of these interactions (pointing to an object with the finger, thumb up to acknowledge, manipulation, actions through human–machine interface (HMI), etc.) are not easily accessible or are inaccessible through FDR and CVR recordings.

An image recording can help the type of actions being recorded and record those that are not followed by effects on aircraft systems. In the light of the investigation on the AF447 accident in 2009 [5], it is stated that review of the information stemmed from flight recorders is challenging to establish the displays that were available to the flight crew on their control panel and instrument at that time, especially the directives from the Flight Director when they appear again. It is also incapable to know if flight crew had made any endeavour to start again the auto pilot. Airborne image recordings would help clearly identify the actions performed on the aircraft selectors, the result of these actions on the aircraft and the crew performing the action, especially in the absence of verbalization from the crew.

In addition, flight crews may be required to manipulate data carriers that are not integrated into the aircraft and whose elements are inaccessible via the FDR. The use of Electronic Flight Bag (EFB), iPADs or paper documentation is difficult to analyse via existing recorders. The information collected from image recordings could also help operators improve operational and safety oversight.

2.2 Airborne Image Recordings Solutions

Airborne image recording of the flight compartment is a technology that is approaching fully developed. Appareo Vision 1000 is a self-contained flight recording solution that records flight data, cockpit voice and airborne images in one box. It is small and light, assisted by the ALERTS ground support software, which can be used to readout and analyse the flight operations and identify operational deviations. If the deviation or unsafe events were to occur, the recorded information is a priceless investigation resources, giving the investigator the information on what happened and largely reduce the investigation duration and cost. It has Type Certificates (TCs) on the aircraft of Airbus Helicopters, AgustaWestland and Piper. Also, it has FAA Supplemental Type Certificates (STCs) on the aircraft of Bell 206, Airbus Helicopters, AgustaWestland, Diamond and Cessna.

Another product is Sentinel Crash Survivable Memory Unit (CSMU) series manufactured by ETEP Company, which is fully integrated solution for flight data, airborne image, cockpit voice communications and storage on various military or flight test applications. The Sentinel CSMU ED-112 series is lightweight which is following the ARINC 767 specification.

2.3 Standards on Airborne Image Recordings

ICAO has developed policies regarding the applicability and operation of 3 types of airborne image recordings. A Class C AIR or Airborne Image Recording Systems (AIRS) which is able to record flight data on instruments and control panels exhibited to the pilot(s) has been accepted as an option for the installation in turbine-powered aircraft to capture flight data and has been incorporated into Annex 6, Parts I, II and III [6]. Class B catches data-link communication. Also, the current specification in Annex 6 for Class A airborne image recording is to capture the cockpit environment and provide information additional to flight recorders. To consider pilots privacy issue, the recording of such images shall not capture some parts of pilot body, such as their upper torso, while they sat in the pilot seats. Currently, provisions for the carriage of Class A are not included in Annex 6.

The current specification in the European regulations ED-112A [7] and ED-155 classified airborne image recorders into 6 classes from Class A to Class F based on the purpose of the image recording system. It requires Class A airborne image recorder to capture information additional to flight recorders, such as human factors; Class B records data-link communication. Class C records flight data on instruments and control panels. Class D captures the head-up display, and Class E captures other camera images beyond the cockpit, such as cargo or cabin compartment images; Class F provides external view, for example, to capture forward view or aircraft parts such as landing gear.

Several States has been closely monitoring this regulation development and will keep working with ICAO and industry to guarantee the conformity of ground rule being introduced when appropriate. Civil aviation authorities of States will deliver formally a regulatory amendment of the requirement to equip airborne imaging recorders in cockpits of airplane.

2.4 Response to Airborne Image Recordings

Although it has been debated more than a decade between investigators and regulatory agencies, the regulators continue unchanged the position which is not convinced by the new improvements that airborne image recordings would benefit to air safety. ICAO Annex 13 *Aircraft Accident and Incident Investigation* has been revised to give the protection and non-disclosure to the image recordings, opposition against legislation still exist.

Federal Aviation Administration (FAA) in the USA also appears reluctant to respond. They consider that there is no conclusive confirmation to mandate airborne image recording installation. The deficiency file is assigned a dormant status.

Also, the multi-national Airline Pilots Association has their own position on airborne image recording. While the International Federation of Air Line Pilots' Associations (IFALPA) strongly supports initiatives to improve safety, it believes that the use of airborne image recordings would not provide significant value to an accident investigation. Visual data are also subject to misinterpretation, which can lead the investigation astray and use for purposes beyond the investigation activities. Considering extremely low rate of accidents in commercial aviation, the information provided by airborne image recordings in an accident investigation would be minimal and has not been proven to enhance safety, but the massive infringement of privacy represented by video recordings, as well as the fundamental personal rights of the flight crews.

Therefore, until the recordings and transcripts have been effectively protected, IFALPA will remain strongly opposed to any image recorders which capture any part of the crew. The Federation supports taking advantage of the existing technology of the aviation recorder to provide a better understanding of the environment of the aircraft and believes that safety management is the most effective way ahead for proactive safety improvement.

2.5 Efforts on the Proposals

In Europe, the protection of CVRs from exposure in an accident or incident investigation is stipulated in Regulation (EU) No 996/2010. With the implementation of safety management among airlines, it is realized that CVR recordings have the possibility to replay and analyse beyond investigation activities in order to maintain or improve air safety. Consequently, Regulation (EU) No 965/2012 has been revised in order to strengthen the effectively protection and prevent the unsuitable use and exposure of CVR recordings. The levels of protection existing for CVRs shall be broadened to airborne image recorders.

On 1 April 2016, ICAO issued a State letter (AN 6/1.1-16/20) on the adoption of Amendment 15 to Annex 13. Some of the key elements and considerations of the amendment include: enhancement of the protection of investigation records in

Annex 13, while balancing the objectives of the investigation and other public interests; effective means to protect records in the custody of or under the control of the accident investigation authority; support to States in the administration of the "balancing test" by the designated competent authority; recognition that different circumstances require different protective safeguards and that full protection may be counter-productive; accommodation of different legal systems and States' practices in implementing effective protection of investigation records.

3 Conclusion

Critical changes need to reduce transportation accidents and save lives and expand use of recorders to enhance air safety. Under the global CVR/FDR rulemaking initiative, both civil aviation authorities and the industry develop requirements to supported the accident investigation authorities' safety recommendation to reach a proposal and to supplement the current flight recording requirements, that is, to provide provisions for the recording of control panels exhibited to the pilots, as well as operation of switches and selectors by the pilots. The proposal includes a provision for a bulk erase function for both CVRs and AIRs.

The applicability of airborne image recorder is limited to the aeroplanes with a maximum take-off mass of above 27,000 kg, and the application for type certification put forward to a Contracting State not before 2023. The aeroplane that meets both requirements shall have a crash-protected flight recorder which shall record images of the flight deck exhibited to the pilots, as well as operation of switches and selectors by the pilots as defined.

Meanwhile, on or after 1 January 2023, a flight crew-operated bulk erase function shall be provided on the flight deck which, when activated, modifies the recording of a CVR and AIR, while this recording is not able to be download or readout by general methods. The installation shall be designed to prevent activation during flight. Furthermore, the bulk erase function shall not be active when an accident or incident occurred.

The operation of switches and selectors and the images displayed to the flight crew from electronic displays shall be captured by image sensors or other electronic means. The recording of operation of switches and selectors by the flight crew shall include any switch or selector that will affect the operation and the navigation of the aircraft; selection of normal and alternate systems. The images displayed to the pilots shall include the primary flight and navigation displays; aircraft system monitoring displays; engine indication displays; traffic, terrain, and weather displays; crew alerting systems displays; stand-by instruments; and installed EFB.

At the same time, the recording of such images shall not capture some parts of pilot body, such as their upper torso, while they sat in the pilot seats.

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Research on the Joint Operation of the Radar Jamming Equipment and the Air Defense Radar

Kun Li, Tian Yang, Wei Yu, Shujie Zhang and Xinpeng Chen

Abstract *The purpose* through the research in the way of synergy between the Radar Jamming Equipment and the Air Defense Radar, to achieve the joint operations of air defense force and electronic countermeasure force. *The method* by consulting the correlation data, in the process of collaborative operations of air defense force and electronic countermeasure force, the Radar Jamming Equipment often interferes with the Air Defense Radar. To solve the problem, this essay, by taking the joint operation of the Radar Jamming Equipment and the Air Defense Radar as an example, adopts frequency domain, time domain and space domain methods to analyze and calculate. *The result* in this way, the joint operations of air defense force and electronic countermeasure force can be better achieved, and a high degree of integration of electronic air defense and firepower air defense can be realized. *The conclusion* the results of this analysis give guidance to the joint operation of the Radar Jamming Equipment and the Air Defense Radar and enable them to give full play to their combat capabilities.

Keywords Air Defense Radar · Radar Jamming Equipment · Joint operation · Coordinated method

1 Introduction

As one of the most important weaponries of the electronic countermeasure force, Radar Jamming Equipment (RJE) can weaken the operational effectiveness of the enemy's radar through interfering and deceiving all kinds of their radars so that friendly forces, weapons and important targets can be well protected [1]. Regarded as the generic term of various kinds of radars that are used in air defense combats, the Air Defense Radar (ADR) is one of the most crucial equipments which provide air information and control other weapons. In the process of joint operations of air

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defense force and electronic countermeasure force, the electromagnetic space in the battle field congests with various radar signals and electromagnetic interference signals, making the electromagnetic environment quite complicated [2]. Under such circumstances, this essay adopts coordinated methods to analyze how to bring the combat capability of the RJE and the ADR into full play without affecting each other's operation so as to achieve electromagnetic compatibility.

2 The Coordinated Method Based on Frequency Domain, Time Domain and Space Domain

Frequency domain, time domain and space domain are three fundamental elements to the joint operations of the RJE and the ADR. In the process of joint operation, the RJE and the ADR will interfere with each other only when frequency domain, time domain and space domain meet relevant conditions. The operational control authority should adopt different measures based on these elements to achieve effective joint operation.

2.1 Coordinated Method Based on Frequency Domain

This method means that in order to secure different equipments' frequency channels, the operational commander should give managerial control on frequency of the RJE and the ADR to avoid the disturbance from relevant equipments. Frequency domain overlapping is the precondition of disturbance. The RJE covers a wide range of frequency spectrums, among which many frequency bands are used in ADR. Therefore, coordinated method based on frequency domain is the most commonly used and fundamental method.

(1) Informing frequency information

Air defense force and electronic countermeasure force should cooperate and get familiar with the specific information of the ADR and the RJE, such as radar frequency range, frequency hopping modes and jamming patterns. The electronic countermeasure force also needs to report enemy's frequency list to the command which has frequency spectrum administration authority and to provide the basis to adjust the frequency for the command [3].

(2) Confirming the protected frequency

US military regulations: Joint Restricted Frequency is a function, network and frequency list which is geographically structured, time sensitive and protective. To ensure that friendly forces achieve their goals, the required frequency should be confined within its minimum number [4]. The protective frequency of the ADR should be part of the Joint Restricted Frequency. It can be determined by the air defense forces and implemented after it has been approved by the command of the spectrum management authority. These frequencies are crucial for the work of the radar. The disturbance from electronic countermeasure force should be banned unless it is absolutely necessary, and under the circumstances, it must be approved by the headquarters to interfere. It must be noted that the protective frequency is usually time sensitive and should be updated regularly.

(3) Strengthening frequency management

Air defense force needs to develop a strict frequency plan, clarify the right timing for the use of protective frequency and the relevant approval authority, and notify this information to the electronic countermeasure force. The equipment operators are strictly forbidden to use the protective frequency without approval. At present, the radar working frequency can be directly managed or set in the operating system of some new Air Defense Radar equipment, which is quite convenient to operate. But operators need to be very cautious to prevent operational mistakes.

2.2 Coordinated Method Based on Time Domain

This method means that the RJE and ADR have joint operation in combat timing, duration and sequence, so that the overall air defense operation is unified and well organized. With the improvement in the performance of modern weapons, the reaction time left to the air defense system in the war is declining, requiring the air defense force and the electronic countermeasure force to cooperate with each other with higher accuracy and efficiency.

(1) Having consistent combat time

Consistent combat time is the basis of time domain coordination, which is directly related to the accuracy of the air defense force and the electronic countermeasure force. Current RJE and ADR have their own local clock. Crystal oscillator frequency of different equipments may have some deviation because of the temperature and electromagnetic interference. RJE and ADR can draw support from BeiDou Navigation System, BPM timing system and other methods to calibrate their own clock, keeping high-precision synchronization in time.

(2) Planning precise collaboration time

Relevant personnel can plan precise collaboration time according to the air raid target situation, RJE and technical performance of ADR. First, set up a specific time to unify the action of the time point, that is, with a clear point of time to unify the different directions of RJE and ADR in different positions or make them attack the same target. Second, divide an operation into different stages and make different operation plans for RJE and ADR in different stages.

(3) Adjusting the coordination time promptly

Air raid and anti-air combat battlefield environment is not static, and relevant personnel should keep obtaining combat information, analyzing and calculating key time nodes of the next action. They should control air defense combat coordination time in accordance with the overall combat plan and time node, timely detect time deviation and make it back on track so that the plan can proceed strictly in accordance with order and time.

2.3 Coordinated Method Based on Space Domain

This method means that the combat configuration, the zone of action, the direction and the height of the RJE and the ADR are reasonably stipulated, so that the radar power range and the disturbance zone are reasonably overlapping, closely connected and supporting, and at the same time, ensure electromagnetic compatibility between them. Yet, because of different operational mission and equipments' performance, the specific requirements toward the RJE and the ADR are also different. The operators need to be flexible. Here the author will only discuss the configuration which ensures the electromagnetic compatibility.

(1) The bit error ratio of the ADR

When receiving noise interference from the RJE, the bit error ratio that the ADR receive is [5]:

$$\frac{P_{rj}}{P_{rs}} = \frac{P_j G_j}{P_t G_t} \cdot \frac{4\pi\gamma_j}{\sigma} \cdot \frac{G_t'}{G_t} \cdot \frac{R_t^4}{R_j^2} \cdot \frac{\Delta f_r}{\Delta f_j}. \tag{1}$$

In the formula, P_j refers to the launching power of the RJE; G_j refers to the gain of the RJE's antenna in radar's direction; γ_j refers to the interference signal to the polarization coefficient of radar's antenna for the, generally $\gamma_j = 0.5$; R_j refers to the distance between the RJE and the radar; Δf_j refers to disturbance bandwidth; P_t refers to the launching power of radar; G_t refers to the gain in the direction of the main lobe of the radar antenna; σ refers to effective reflection area of the target; R_t refers to the distance between the target and the radar; Δf_r refers to the bandwidth of the radar receiver; and G_t' refers to the gain of the radar antenna in the direction of the RJE.

What is different from the confrontation between air jammer and ground radar is that the targets of the RJE and the ADR combat targets are both air targets. Since it is rare to have the situation when the main lobe of the RJE interferes with the main lobe of the radar, the major consideration should be the interference of the RJE to side lobe of the radar. It can be calculated in three ways: The first way is to calculate according to the antenna direction pattern of the radar and the RJE; considering that the direction patterns are different and the expressions are complicated, the second way is to calculate according to simplified antenna pattern [5]; the third way is to divide the relative position of the RJE and the radar into four situations: the main lobe of the RJE to the main lobe of the radar, the main lobe of the RJE to side lobe of the radar, the side lobe of the RJE to the side lobe of the radar and the side lobe of the RJE to the main lobe of the radar [6]. When the side lobe interference occurs, it should be calculated by taking a gain interval of the side lobe or taking the average gain of the side lobe. When it comes to the main lobe of the RJE to the main lobe of the radar situation or the side lobe of the RJE to the main lobe of the radar, then in formula (1), $G_t' = G_t$.

If the interference is valid, the bit error ratio should be greater than or equal to the pressing factor K_j, which is

$$\frac{P_{rj}}{P_{rs}} \geq K_j. \tag{2}$$

The suppression coefficient is the ratio of the minimum interference signal required by the input end of radar receiver to the radar echo signal power, when the radar detection probability drops to 0.1 [7]. It is

$$K_j = P_j / P_r|_{P_d = 0.1}. \tag{3}$$

The suppression coefficient is a comprehensive function which is composed of the modulation pattern of the interference signal, the interference signal quality, response characteristic of the receiver and the signal processing method. In document 7, the suppression coefficient values of the automatic radar and the radar which uses wide-angle or distance monitor as the terminal device is analyzed. In document 8, the noise interference suppression coefficient with different modulation styles is calculated. In document 9, it is pointed out that for conventional pulsed radar, agile frequency radar and frequency diversity radar, interference suppression coefficient is normally 3 dB.

(2) The modification to the model based on non-ideal interference signal

In the calculation of formula (1), the interference signal input by radar receiver is Gaussian noise. In terms of information theory, the best interference wave is the one with the largest entropy, which is uncertain. Under circumstances of fixed average power, Gaussian noise will reach its top entropy in random wave, which makes Gaussian noise the ideal interference wave. But in practice, it cannot be achieved because the amplitude of the random variable of Gaussian noise distribution is infinitely great [7]. Document 10 suggests that noise quality can be used to measure the quality of the actual interference signal. The noise quality factor represents the ratio of the power P_{j0} required for the ideal interfering signal and the interference power P_j required for the actual interference signal under the same masking effect, which means

$$\eta = \frac{P_{j0}}{P_j}. \tag{4}$$

Usually, the noise quality factor is ≪1 [7]. The results of the jammers in service or being tested show that the noise quality of the actually interference signal has a loss of 17 dB compared to the ideal Gaussian noise [8], which is $\eta = 0.02$.

(3) Modification of the model from pulse compression technique

When all other conditions are the same, the results of the suppression coefficient will increase B times when adopting pulse compression technology because the matching filter will have filtering effect on broad pulse [9]:

$$B = \frac{\tau_s}{\tau_{sc} \cdot K_o}. \tag{5}$$

In this formula, τ_s refers to the width of the pulse signal at the input end of the receiver; τ_{sc} is the width of the pulse signal after pulse compression; and K_o is a coefficient which results in changes in rectangular parameter when the width of radar transmitting pulse is widened.

3 Case Study

In joint operations of the RJE and the ADR, the commander should analyze possible frequency conflict according to the performance parameters of the RJE and the ADR. Take a certain type of RJE and short-range surface-to-air missile guidance radar as an example. The RJE completely covers the frequency range of the guidance radar. Guidance radar parameters are $P_t = 10\,\text{kw}$ and $\Delta f_r = 3\,\text{MHz}$. For $\sigma = 1\,\text{m}^2$, the farthest valid distance to the target is 25 km. The pulse width can be reduced from 6 to 0.3 μs by adopting pulse compression technology. The main lobe gain is 37 dB. When the side lobe is interfered, the side lobe gain of the guidance radar will be −10 dB. The parameters of the RJE are set to $P_j = 1000\,\text{kw}$; the noise interference bandwidth is $\Delta f_j = 1000\,\text{MHz}$; the main lobe gain of the RJE is 14 dB; and the side lobe gain is set to −6 dB. The interference suppression coefficient is set to 3 dB. The relative positions of the RJE and the radar can be divided into four situations: the main lobe of the RJE to the main lobe of the radar, the main lobe of the RJE to side lobe of the radar, the side lobe of the RJE to the side lobe of the radar and the side lobe of the RJE to the main lobe of the radar. When the 1 m^2 targets are 25 km from the guidance radar and when the spacing of the RJE and the radar is between 100 and 10000 m, the results of bit error ratio are shown in Fig. 1.

The results show that when relative positions between the RJE and the radar are the main lobe of the RJE to the main lobe of the radar and the side lobe of the RJE to the main lobe of the radar, the RJE will have great impact on radar, making radar lose its ability to work. In these situations, the spacing between the RJE and the

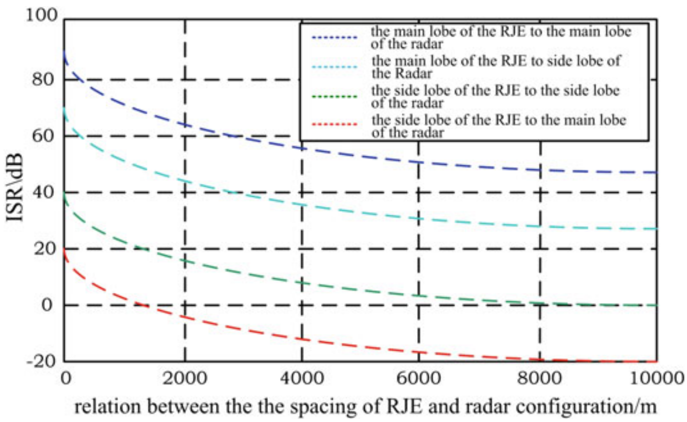

Fig. 1 Relation between the bit error ratio and the spacing of RJE and radar configuration

radar is meaningless in real combat. When deciding other joint operational methods, commanders need to take frequency domain and time domain into consideration. When relative positions between the RJE and the radar is the main lobe of the RJE to the side lobe of the radar and the distance between them is above 7500 m, the interference from the RJE will be very small. When relative position between the RJE and the radar is the side lobe of the RJE to the side lobe of the radar and the distance between them is above 750 m, the interference from the RJE is very small. Therefore, as the distance decreases, the impact from the RJE increases rapidly.

Therefore, in joint air defense operations, commanders should avoid some situations such as the main lobe of the RJE to the main lobe of the radar, the main lobe of the RJE to the side lobe of the radar and the side lobe of the RJE to the main lobe of the radar. In other words, the main lobe of the RJE's antenna cannot point to the radar and the main lobe of radar's antenna cannot point to the RJE. However, in real battle, it is impossible to avoid the above situations because the antenna of the radar or the RJE will do circular searches. But the interference time is short, the scope is limited, and the interference angle is confined within the scope of both the RJE and the radar's main lobe. Commanders can use other coordinated method such as frequency domain method and time domain method as a supplement to reduce those impacts. Under normal circumstances, the side lobe of the RJE and the side lobe of the radar point to each other. In this situation, according to the specific technical performance of these equipments, commanders need to keep the distance between the RJE and the radar above the required level to guarantee their electromagnetic compatibility.

4 Conclusion

Frequency domain, time domain and the space domain are indispensable factors when it comes to the joint operations of the RJE and the ADR. They relate to each other closely. Operators shall never use any one of those three methods alone. Instead, they should use one of them as the main method and take the other two as auxiliary methods. Only in this way, the joint operations of air defense force and electronic countermeasure force can be better achieved, and a high degree of integration of electronic air defense and firepower air defense can be realized.

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Design of Human Memory Test System

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Abstract To solve the existing human memory test tools' problems that the test subjects is not comprehensive enough and the test scheme is not flexible enough, and meet the memory data collection needs of different personnel selection, an integrated test system for human memory is proposed from the system overall structure, function module implementation path, and the option of development platform. The test subjects of this system include words short-term memory, digital short-term memory, image short-term memory, orientation short-term memory and working memory. The test system proposed in this paper considers synthetically the characteristic that the memory data collection needs of different personnel selection is different, provides the custom function of the test scheme and the score calculation, is able to meet the memory data collection needs of different personnel selection, and has the characteristics of versatility and universality.

Keywords Personnel selection · Memory · Test

1 Introduction

As a basic psychological process, memory plays an important role in guaranteeing human's normal work and life. According to the length of information retention, memory includes three types: instantaneous memory, short-term memory and long-term memory [1]. Research finds that the short-term memory span is related to many complex cognitive activities, and can predict the performance of complex cognitive tasks. Therefore, short-term memory has attracted much attention forming a lot of research productions that are widely used in selection, recruitment, as well as education and clinical diagnosis [2–4]. In 1974, Baddeley and Hitch, two British psychologists, proposed the concept of "working memory" on the basis of the experiment of simulating short-term memory impairment [5]. Many studies have

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shown that working memory span can better predict the performance of complex cognitive tasks than short-term memory span.

In the test of short-term memory span and working memory span, the traditional methods used “human to human dialogue” of “experimenter-testee” with memory scale that one of the most famous is the Wechsler Memory scale [6]. Because there are many shortages of manual mode such as large subjectivity, non-standardization and large labor intensity, a large number of specialized memory test equipments and computer-aided test systems have been constantly emerging [3, 4]. However, most of the equipments or software systems conduct the research focusing on one certain side of short-term memory or working memory, and the comprehensive test equipments or systems are relatively rare. The traditional test tools make inconvenience for the different occupation users. Therefore, it is of practical significance to develop a relatively complete universal memory test system. In view of the deficiency of the existing memory test tools, this paper proposed a relatively complete memory integrated test software system programme in order to meet the needs of different professional users.

2 Overall Structure of Memory Test System

The test system consists of three modules: test, training and background management. Among these, the test and training module consists of five functional sub-modules: words memory, digital memory, image memory, orientation memory and working memory. Background management consists of three functional sub-modules: personnel information management, performance analysis, data base management. The system overall structure is shown in Fig. 1.

3 Implementation Path of Function Module

3.1 Digital Memory Sub-module

There are a series of numbers showing on the screen randomly (it shows one number each time for 0.5 s, and the interval between two number is 1 s). After the present, testee is asked to key in the numbers on the designated area of screen in accordance with the original number order. The test starts with the length of the number 2, every length of number has three times to try to key in. When three times all failed, the test is over. The longest number series length is 12. After the test, the system calculates the scores of the testee.

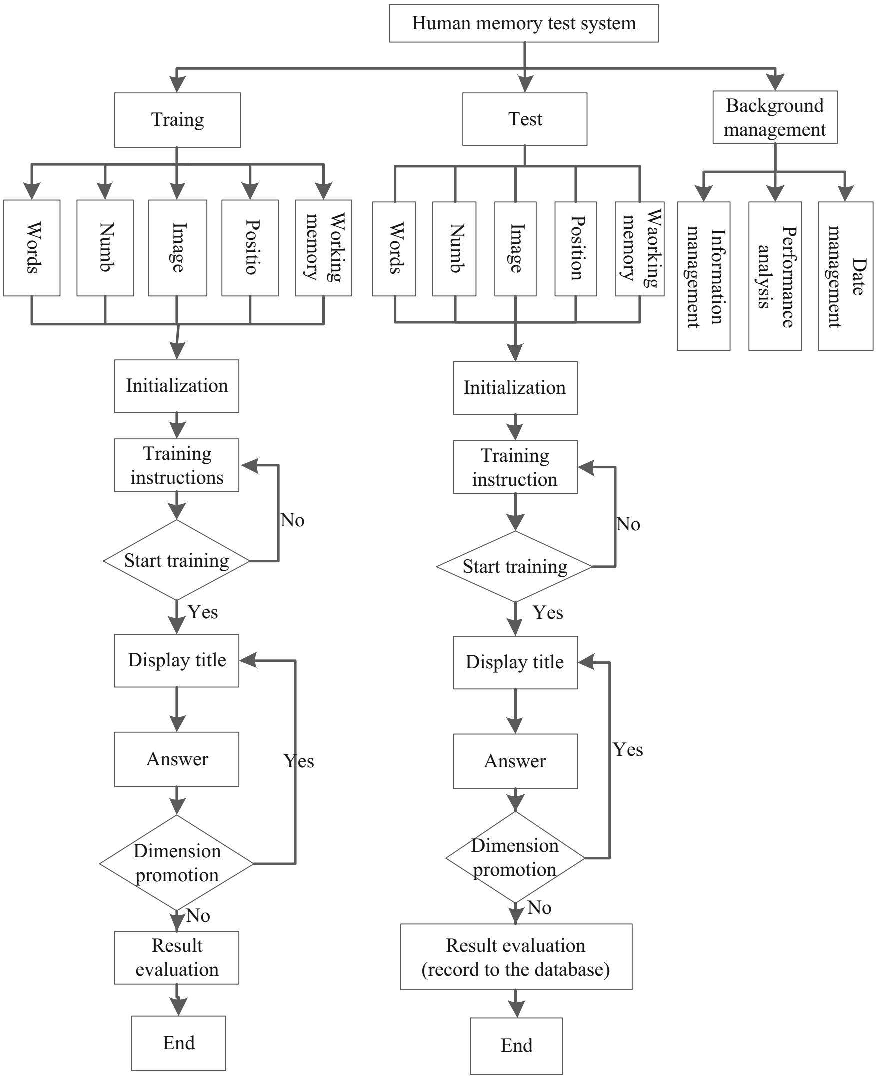

Fig. 1 Memory test system overall structure

3.2 Words Memory Sub-module

There are a series of double words of Chinese characters on the screen randomly (it shows one word each time for 0.5 s, and the interval between two words is 1 s). After the present, the words series are shown in a row in accordance with the random order on the center of screen completely and there's an input box below every word. The testee is asked to key in the numbers of words into the corresponding input box in accordance with the original words right order. The test starts with the length of the two words series, every length of words series has three times to try to key in. When three times all failed, the test is over. The longest words series length is 12. After the test, the system calculates the scores of the testee.

3.3 Orientation Memory Sub-module

There are nine (three in row and three in line) squares on the computer screen, representing nine orientations: East, South, West, North, Centre, Northeast, Southeast, Southwest, and Northwest. Some square flashes 0.5 s indicating some orientation. After the different squares flash constantly and randomly, the testee is asked to tunk the 3×3 numeric keyboard in the same position of the key. The number of consecutive flashes is the number of orientation changing which is from 2 orientations to 9 orientations so that the breadth of orientation memory can gradually improve. The test starts with the length of two orientations, each orientation has three times. When three times on one orientation all failed, the test is over. After the test, the system calculates the scores of the testee.

3.4 Image Memory Sub-module

There are a series of images showing on the screen (it shows one image each time for 0.5 s, and the interval between two images is 1 s). After the present, the image series are shown in a row in accordance with the random order on the center of screen completely and there's an input box below every image. The testee is asked to key in the numbers of images into the corresponding input box in accordance with the original and right images order. The test starts with the length of the two image series, every length of image series has three times. When three times all failed, the test is over. The longest images series length is 12. After the test, the system calculates the scores of the testee.

3.5 Working Memory Sub-module

There are a simple arithmetic problem (two positive integers add or subtract, and the answer is one positive integer, for instance, $5 + 3$, $7 - 2$, etc.) and a box with black spots in the 3×3 grid showing on the computer screen. The testee is asked to key in the answer, meanwhile, he need remember the position where the black spots are in the grid. After answering, the testee need press the Enter key, then the arithmetic problem and the grid with black spot disappear, and there will be next arithmetic problem and grid with black spot on the screen. The interval between the

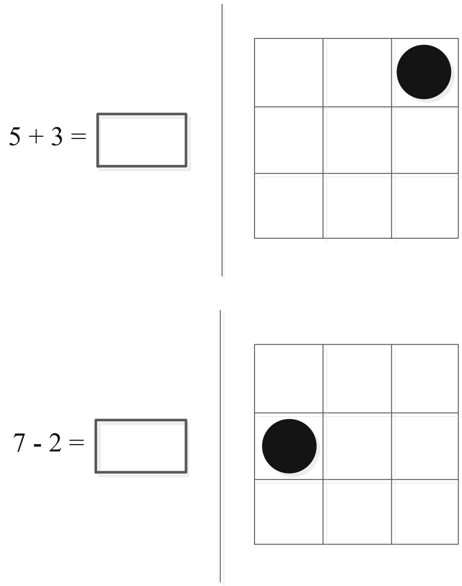

Fig. 2 Stimulative materials of working memory span

arithmetic problem and the grid with black spot showing on the screen and the testee pressing the Enter key is 5 s. If the time is out, it will shows the next arithmetic problem and grid with black spot. During the whole test, half of the arithmetic problems are the additive formula, the other half are subtraction. When each group of test finishes, there is a 3×3 grid on the screen, and the testee is asked to click out the position where the black spot appeared just now with mouse in the blank grid (the testee can click out the position without their original order, and the black spots' positions will not repeat in a group of arithmetic problems). The test start with two arithmetic problems (the degree of difficulty is Level 2) (Fig. 2), then the degree of difficulty increases gradually until the testee has made two mistakes in a certain degree of difficulty. The highest level is Level 7. After the test, the system calculates the scores of the testee.

3.6 Background Management Module

Background management module consists of three sub-modules: personnel information management, performance analysis, data base management. The sub-module of personnel information management enables the addition, modification, and deletion functions for personnel information of those who participate in the test. The sub-module of performance analysis enables the functions of the basic analysis for the test performance and showing the test results. And it has the function to export the test scores as Excel, which can lay the data foundation to the further analysis. The sub-module of data base management enables the functions of modifying the test items as well as adding and deleting the stimulus materials. For purpose of image data storage, the system adopts the method of converting the image into binary data stream writing into the data base so that the bearing capacity of data base decreases and the operating efficiency of software increases.

3.7 Test Scores Calculation Model

3.7.1 Individual Score Calculation Model

The short-term memory score calculation model is,

$$F_{\mathrm{s}} = 1 + \frac{X}{3} \tag{1}$$

where,

F_{s} Short-term memory scores;
X The total times of testee remembering correctly.

Working memory scores calculation model is,

$$F_{\mathrm{w}} = 1 + \sum_{i=2}^{n} \frac{x_i}{i} \tag{2}$$

where,

F_{w} Working memory scores;
i The level of degree of difficulty;
x_i On the Level i, the times of testee being correct;
n The highest level of the testee accomplishing.

3.7.2 Comprehensive Scores Calculation Model

The results of the comprehensive memory of the testee are obtained from the weighted sum of individual items. The calculation model is,

$$F = \sum_{k}^{m} \omega_k F_k \tag{3}$$

where,

F Comprehensive memory scores;
F_k The standard score of the kth memory scores;
ω_k The weight of the kth test items;
m The numbers of items that the testee is tested.

The numbers of items that the testee is tested and the weight of test items can be set by the users using the background management model.

4 Development Platform

VS2010, an integrated development environment launched by Microsoft Corp, is currently the most popular integrated development environment for Windows platform application, adopting the way of click-and-drag to complete the interface design and supporting C#, C++, VB. It is suitable for medium and small software development and has the characteristics of easy to learn and package. The Microsoft Office Access database is a relational database management system issued by the Microsoft Corp with the simple structure as well as the good compatibility and permeability as VS2010, which has accelerated the development efficiency of software thus ensuring the system's progressiveness and scalability. Therefore, this paper chooses VS2010 as the programming tool to realize the software program of human memory test system.

5 Conclusion

In view of the deficiency of the existing memory test tools in the application, and based on the VS2010 development environment, the software platform of human memory test system is designed for the needs of different professional personnel selection. The system has a relatively complete test items and flexible performance calculation function, so it can provide support for different professionals to test the memory.

Compliance with Ethical Standards The study was approved by the Logistics Department for Civilian Ethics Committee of Air Defence Forces Academy.

All subjects who participated in the experiment were provided with and signed an informed consent form.

All relevant ethical safeguards have been met with regard to subject protection.

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Risk Identification of Motorized Marching's Vehicle Safety

Leiming Yao, Chang Mei, Lili Wang, Weifei Wu and Zhenguo Mei

Abstract Vehicle safety guarantees the success of military motorized marching, and it also contributes a lot to military training practice and combat power generation. In the recent years, since the power of armies is gradually strengthened and competitive training is extensively adopted, motorized marching in armies is seen more and more frequently, and we face increasing risks in the vehicle safety of military motorized marching. Carrying out risk identification and strengthening risk management are quite significant. Based on the risk management theory and the characteristics of motorized marching's vehicle safety, this thesis starts from the basic risk factors and focuses on the work flow and specific implementation of risk identification, so as to provide guidelines and practices for armies.

Keywords Motorized marching · Vehicle safety · Risk factors · Risk identification

Motorized marching is an important way to deliver troops. It plays an important role in field training competitive maneuvre and other major activities. Vehicle is the important carrier in motorized marching. Vehicle safety determines whether marching tasks can be successfully completed and whether military activities can be carried out on time [1]. Therefore, it is very significant to strengthen the risk

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identification research in motorized marching's vehicle safety and to scientifically investigate the risk factors. In this way we can further provide basis for risk assessment and management and guarantee the success of both marching and training.

1 Risk Factors

According to the basic characteristics of risk and the occurrence law of vehicle safety accidents, the basic risk factors of motorized marching's vehicle safety are mainly as follows.

1.1 Personnel Factor

The personnel risk in motorized marching mainly refers to the risk caused by vehicle driver, cadres on the vehicle and passengers. In this factor, driver's unsafe operation accounts for a large proportion. People in the traffic environment and other drivers are also important aspects. Personnel factor is mainly affected by a person's age, driving age, thoughts, body, personal habits, education, driving skills, knowledge of traffic rules, sense of responsibility, safety awareness, knowledge of laws, etc.

1.2 Vehicle Factor

Vehicle risk mainly refers to the risk caused by military motor vehicles, tractors, equipment vehicles and other equipment. This factor is mainly affected by vehicle's model, service life, condition, active safety and passive safety. Active safety includes vehicle's power, braking, handling stability and tire performance; passive safety includes vehicle's safety body design, fire safety measures, member restraints and other security settings. In addition, the over-height, over-length and overweight of some vehicles cannot be ignored [2].

1.3 Road Environment Factor

Road environment risk mainly refers to the risk caused by road condition, natural conditions and other driving environment. Road condition is mainly affected by road's nature, width, steepness, curvature and other personnel activities (such as illegal road operations, stall selling, sitting in the shade on the road, drying grain, etc.); natural condition is mainly affected by adverse climatic conditions (snow, wind, fog, sun, etc.) and natural disasters (landslide, tsunami, debris flow, typhoon, volcano, etc.); other driving environment mainly refers to the condition of local vehicles and traffic, such as overloading and speeding.

1.4 Organization and Management Factor

Organization and management risk mainly refers to the risk caused by driver management, vehicle management and marching organization. Driver management includes driver selection, technical training, safety education, driving discipline and security awareness; vehicle management includes vehicle maintenance, use of vehicle, operation management, safety inspection and service life management; marching organization includes marching program design, route selection, sorting, adjusting post-arrangement, rest planning and safety inspection.

2 The Steps of Risk Identification

Risk identification is constituted by a series of activities and can be divided into five steps.

2.1 Determining the Object of Identification

Determining the object of identification is the first step. Based on the marching program, related task arrangement and the occurrence law of risks, we can determine the units, vehicles and people involved. Then we analyze the distribution of risk factors and find the key point in risk identification.

2.2 Collecting Data

Collecting data is a necessary process for risk identification. In order to better identify the risks, we need to master the related data of military motorized marching. First we need to pay attention to the parts where risks used to lie in, the time, every steps of the marching, the occurrence law of accidents and managing experience. Second we mind the task arrangements and possible road environment.

2.3 Choosing a Method of Identification

An appropriate identification method can ensure the result is scientific. Identification methods that are commonly used include checklist method, flowchart method, field survey method and expert method. Checklist method requires us to make a risk checklist according to the characteristics of risks and check the risks on the list one-by-one. Flowchart method requires us to draw the task flowchart and interpret the risks according to the chart. Field investigation method means to make field check for the risk condition. Expert method means to invite experienced and professional experts in the related fields to meet and discuss, and then analyze the risks. Different types of risks need different methods, we need to grab the characteristics of the risks in motorized marching, make sure the method is simple, practical and easy to operate, and comprehensively use these methods [3].

2.4 Making in-Depth Investigation and Analysis

In-depth investigation and analysis is the key to derive risk identification results. It is necessary to carry out detailed inspection on relevant people, vehicles and marching plans. We need to conduct comprehensive investigation and analysis on safety problems that are likely to cause risks and check the existence, occurrence and extension data of different risks in time. In this way we can provide sufficient data support for the final result.

2.5 Getting the Result

The result of the study is the final part of risk identification. Data got from survey and analysis are sometimes too general, not precise enough, and have few focuses. This requires further research and confirmation. We can invite experts in related fields, professional and technical personnel and backbone officers to participate in this step, having brainstorming, in-depth discussion, analysis and estimation to confirm the final result.

3 The Implementation of Risk Identification

The implementation of risk identification is based on the basic process of risk identification, and uses various scientific risk identification methods to analyze and identify the risk factors of vehicle safety in military motorized marching, and finally find out the potential risk [4]. We will combine the real condition of the motorized marching in an air defense force (Army A) to identify the single and multifactor risks.

3.1 Identifying the Single-Factor Risks

Single-factor risks refer to the static risks that the risk points are relatively simple and stable. If factors like people, vehicles, environment, organization and management are separate, then they all belong to single-factor risks. For this type of risks we can use checklist method to identify them. We make a risk checklist according to the possible risk points and identify the risks through survey, questionnaire analysis and expert meeting. The results are shown in Table 1.

Single-factor risk identification for motorized marching's vehicle safety is in fact a careful security check for relevant preparations. The identification process serves also as the safety education for officers and soldiers, and as the rectification of risk problems. Single-factor risk identification must be comprehensive. Since the workload is heavy, we need the support of organizations at all levels and the participation of officers and soldiers. At the same time they are required to provide objective and accurate data [5].

3.2 Identifying the Multi-factor Risks

Multifactor risks refer to the risks caused by the combination of two or more risk factors, and they are instable and dynamic. For these risks, we can adopt flowchart method to identify them. After analyzing what accidents may happen, what the consequences are, what impacts we will see, what causes lead to these accidents, we can finally identify the risks. The results are shown in Table 2.

We can see from Table 2 that multifactor risk identification is related to many uncertain factors. In the process of identification, we need to not only use the extensive historical data, but also flexibly combine flowchart method, expert method and survey method to deeply analyze these factors.

Table 1 Results of single-factor risk identification of motorized marching's vehicle safety in Army A

Source	Cause	Possible result
Personnel	1. Lack of standby drivers	Fatigue driving
	2. Some drivers' driving ages are short (30 drivers) and have poor driving skills	Improper disposal of unexpected situations
	3. Few cadres on the vehicle. Some vehicles only have sergeants as leading officers. Some cadres are not responsible enough	Lack of supervision on drivers' improper operation
	4. Some safety officers have no clear duties and poor security awareness	Passengers are not safe
Equipment vehicle	1. Some artilleries and radar tractors are old and cannot meet standards	Cannot meet the requirements of driving on long distance and complex roads
	2. Some pneumatic brakes are damaged and are not repaired in time	The brakes do not work and lead to accidents.
	3. Some signal and fog lights are damaged	Increasing danger in bad weather
	4. Some safety equipments are not fully equipped, e.g., extinguishers	Increasing danger in unexpected situations
Environment	1. Having 200 km county road and provincial highway. The roads are narrow, there are few vehicles on the road, and the driving speed is fast	Threats from local vehicles.
	2. Having 82 km rural road. The road is soft in the ground, land desertification is quite serious	Vehicle breakdown
	3. There is a small to moderate rain two days before departure	Slippery road
	4. Dust storms during marching	Affect drivers' sight and marching command
Organization and management	1. The plan for rest time and place are not clear	Affect drivers' physical and mental adjustment
	2. Having many vehicles and the fleet is long. Present communication devices can only be used within short distances and are not well tamper-proof. Lack of standby devices, communication cannot be guaranteed	The fleet is disordered
	3. Programs and time for vehicle safety inspection are not detailed	Vehicle troubles and safety problems
	4. Little safety education for related people like drivers and leading cadres on vehicles	Lack of safety awareness and skills
	5. No specific rules for marching	Affect prejudgment

Table 2 Results of multifactor risk identification of motorized marching's vehicle safety in Army A

Potential accident	Cause	Possible result
Rear-end collision and rub cut within the fleet	Drivers' inattention; speeding; vehicle spacing is too short; heavy rain, fog and other adverse weather; roadside parking when vehicles have troubles; warning signs are not obvious	Injuries of people; vehicles are damaged
Rollover of artillery and radar vehicles	Fail to connect the pneumatic brake or the brake is damaged; slippery road or damaged road which is not repaired; driving speed is fast and facilities are not adjusted properly	Injuries or deaths of people; vehicles have to be scrapped
Vehicles bash into ground staff	Confused command; leading officers on the vehicles and security staff fail to observe carefully	Injuries or deaths of related people
Passengers are thrown out of the vehicle	Irresponsible officers and security staff; passengers fail to tighten their seat belts or break the rules	Injuries or deaths of related people
Rub cut or collision with local vehicles	Drivers break traffic rules; arrangements are not reasonable; local vehicles and people go into the fleet without permission	Injuries or deaths of related people; disputes between the army and local people

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A Collision Warning Device Based on the Emergency Braking Behavior Prediction

Shaobin Wu, Wenhao Wang, Zhiwei Li and Li Gao

Abstract Rear-end collisions are the most common type of car accidents. In this paper, the anti-rear-end collision warning device based on emergency braking behavior prediction was designed to reduce the occurrence of rear-end collision. Through analyzing drivers' braking behaviors in the car-following process, the anti-rear-end collision method based on emergency braking behavior prediction was proposed. The emergency braking model was established based on the change rate of acceleration pedal's and clutch pedal's displacement. The anti-rear-end collision warning device consisting of the sensors on the pedals, capture card, IPC and emergency brake lamps was developed. The rear-end collision warning device was tested on the roads. The road test results show that the emergency brake lamps are lighted in advance about 0.1–0.3 s compared with the conventional brake lamps and warn the drivers to brake earlier. The device could reduce the incidence of rear-end collisions effectively and improve road safety.

Keywords Emergency braking behavior prediction · Driving behavior · Emergency brake lamp

1 Introduction

Traffic accidents have become a global harm. About 1.24 million people were killed on the world's roads in 2010 [1]. It is expected that road traffic deaths will increase to 240 million in 2030, which will become the fifth leading cause of death unless urgent actions are taken. There are many factors influencing road traffic safety; among them, the reaction time and processing of the emergency situation are two of the important factors [2, 3]. The statistics data show that rear-end crashes account for approximately 33.4% of all highway accidents in China and 40% of economic losses.

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Anti-rear-end collision systems are divided into two types: active collision avoidance and passive collision avoidance. Active collision avoidance system needs sensors to measure the distance between leading vehicle and following vehicle, which are relatively expensive [4]. Passive collision avoidance system includes conventional brake lamps and new type brake lamps based on the switch control of the acceleration pedal [5, 6]. The drivers take appropriate measures to avoid rear-end crashes after seeing the front brake lamps lighting. The new type brake lamps are controlled according to whether the driver steps on the acceleration pedal. If the driver does not step on the acceleration pedal, the new type brake lamps will light. In this paper, an anti-rear-end collision warning device based on emergency braking behavior prediction was designed to predict emergency brake intentions in advance and could prevent or reduce the occurrence of rear-end collisions.

2 Model

2.1 Braking Process Analysis

In the car-following process, the emergency braking process of the adjacent vehicles is shown in Fig. 1. Emergency braking process could be divided into four stages: driver's response action to the onset of brake lamp, braking action, continuous braking and braking release [7].

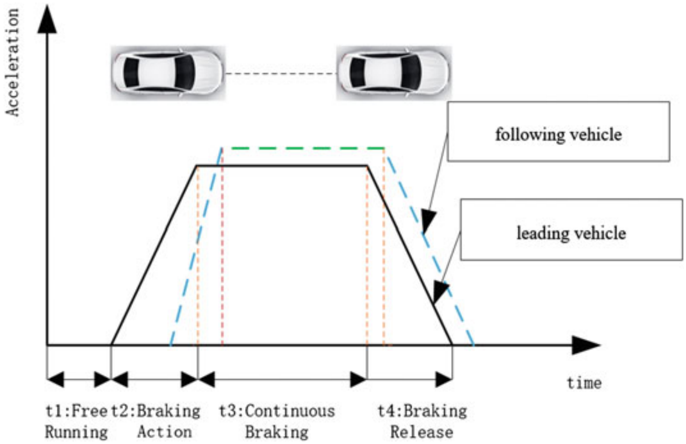

Fig. 1 Braking process of the adjacent vehicles in car-following model

According to the analysis of braking process, after the following car driver sees the emergency braking of the front vehicle, the moving distance in the free running stage S_1 is as follows:

$$S_1 = V_0 \cdot t_1 \tag{1}$$

The braking distance in braking action stage S_2 is as follows:

$$S_2 = V_0 \cdot t_2 - \frac{1}{6} a_1 \cdot t_2^2 \tag{2}$$

The braking distance in continuous braking stage S_3 is as follows:

$$S_3 = \frac{V_0^2}{2a_1} - \frac{1}{2} \cdot v_0 \cdot t_2 - \frac{1}{8} \cdot a_1 \cdot t_2^2 \tag{3}$$

Sum of braking distances of three stages together, $\frac{1}{24} a_1 t_2^2$ is omitted due to the very small t_2, and the equation of total braking distance S is as follows:

$$S = \frac{1}{3.6} \cdot V_0 \cdot t_1 + \frac{1}{7.2} \cdot V_0 \cdot t_2 + \frac{V_0^2}{25.92 a_1} \tag{4}$$

where t_1 is driver's response time, a_1 is maximum brake deceleration, V_0 is initial braking speed, t_2 is build-up time of braking force. Equation (4) shows that four main factors determine the braking distance and affect the occurrence of rear-end collision, namely driver's response time t_1, braking action time t_2, maximum brake deceleration a_1 and initial braking speed V_0. Maximum brake deceleration, initial speed and braking action time are related to vehicle performance, but it will not be considered temporarily in this paper.

The driver's response time t_1, namely brake lag time, includes the time of identification, response, decision judging and shifting the feet after the driver realizes the emergency situation(usually 0.3–1.0 s). After the brake lag time, the vehicle starts braking process and the brake lamp is lighted to remind the following vehicle driver to take appropriate measures at the same time. If the two vehicles are too close, rear-end collision accident is possible to happen.

Therefore, if the driver's emergency brake intention can be predicted, and the brake lamp will be lighted in advance, and then the time that the following vehicle driver sees lamps lighting will also advance, then time difference between the braking behavior of the two vehicles will reduce. So the vehicles can still keep a certain distance even in emergency braking condition, and finally, rear-end collision accident is prevented effectively.

2.2 Emergency Brake Model

The data on emergency braking, conventional braking and accelerating shifting behaviors on roads were collected including the displacement of acceleration pedal, brake pedal and clutch pedal etc. The change rate of acceleration pedal displacement of emergency braking and accelerating shifting behaviors was much larger than that of conventional braking behavior, and both acceleration pedal and clutch pedal were engaged for accelerating shifting behavior, while clutch pedal was seldom engaged for emergency braking behavior (Fig. 2); thus, emergency braking behavior could be predicted by the change rate of acceleration pedal displacement and the displacement of clutch pedal.

Table 1 shows the displacement rate of acceleration pedal on emergency braking and conventional braking processes. For different initial acceleration pedal opening, the mean rate is 6.597 and 0.61 V/s for emergency and conventional braking processes. Although the change rate of acceleration pedal will rise to mean value of 7.462 V/s on acceleration shifting process, the displacement of clutch pedal will remain unchanged. The emergency brake model was introduced by the sequence of change rate of the pedals' displacement as follows:

$$K_1 \geq 6.5\,\mathrm{V/s}. \tag{5}$$

$$\Delta K_2 \geq 0.15\,\mathrm{V/s} \tag{6}$$

where K_1 is the change rate of the acceleration pedal's displacement, ΔK_2 is the change rate of the clutch pedal's displacement. For the vehicle with manual transmission, if Eqs. (5) and (6) are satisfied at the same time, the emergency braking behavior can be predicted. For the vehicle with automatic transmission, the emergency braking behavior can be predicted if Eq. (5) is satisfied.

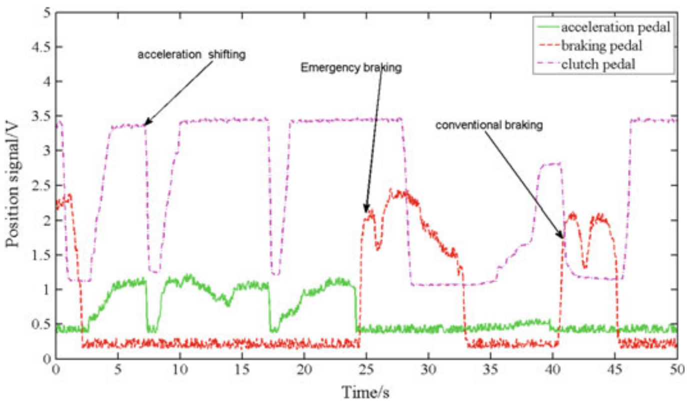

Fig. 2 Conventional braking, emergency braking and accelerating shifting process

Table 1 Displacement change rate of acceleration pedal for two braking situations

Acceleration pedal initial opening (%)	Emergency braking		Conventional braking	
	Time (s)	Rate K (V/s)	Time (s)	Rate K (V/s)
100	0.3	6.356	3.5	0.621
75	0.225	6.442	2.62	0.598
50	0.15	6.525	1.75	0.603
25	0.09	6.582	1.0	0.614

3 Design

3.1 *Working Principle*

According to the emergency braking behavior prediction model, the driver's emergency braking intention could be predicted by the change rate of the displacement of accelerator pedal, brake pedal and the clutch pedal (Fig. 3). Only when the change rate of the displacement of accelerator pedal exceeds a certain threshold and the displacement of the clutch pedal does not change, the emergency braking behavior will be predicted to conduct and the emergency brake lamps will be lighted. If the emergency braking behavior prediction is wrong, emergency brake lamps will be put out after lighting for 1 s.

3.2 *Hardware*

The collision warning device consisted of driving behavior sensors, industrial personal computer (IPC), PCI1711 data acquisition (DAS) card and emergency brake lamps (as shown in Fig. 4). IPC was chosen as the central control unit. Driving behavior sensors included the sensors on the acceleration pedal, brake pedal and clutch pedal, which were used to measure the displacement of the acceleration pedal, brake pedal and clutch pedal. Emergency brake lamps were activated by DC 12 V.

3.3 *Design of Software*

The software of the device was designed with Visual Basic. In consideration of the programming and the maintenance, the whole program was written by the modularization mode, including A/D transformation capture module, emergency braking calculate module and D/A control output module. The A/D transformation capture

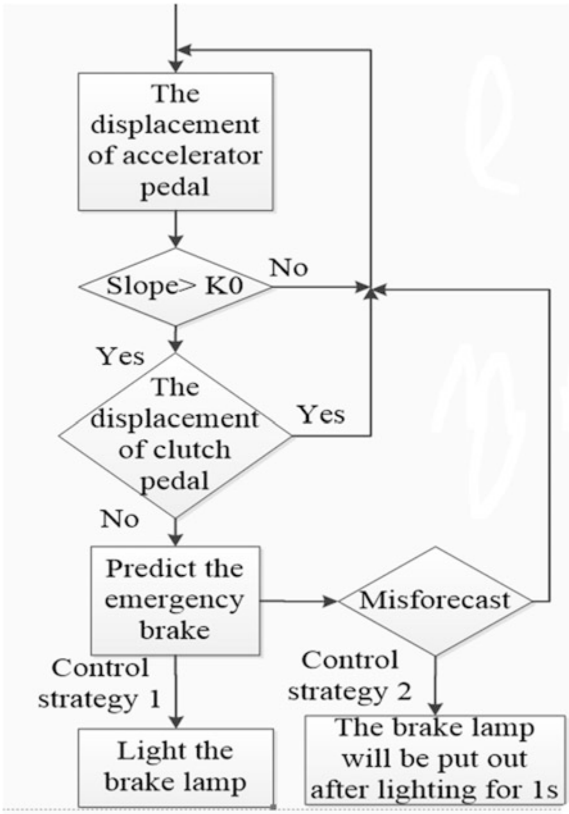

Fig. 3 Working principle diagram of the device

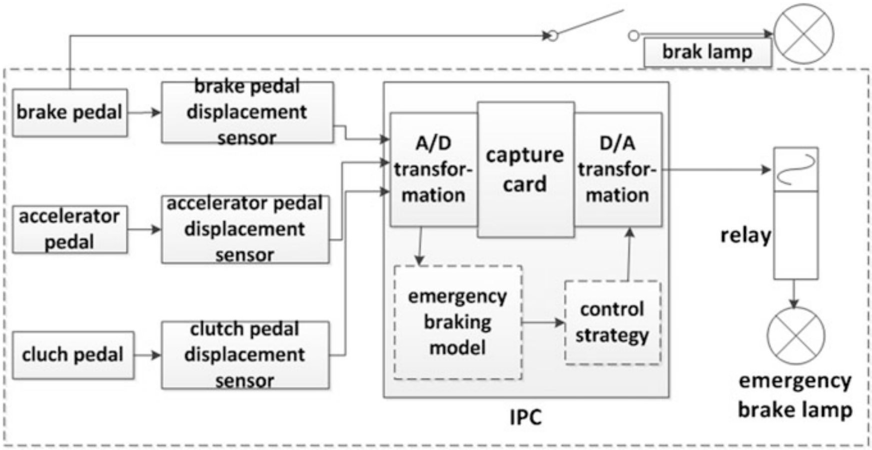

Fig. 4 Hardware of rear-end collision warning system

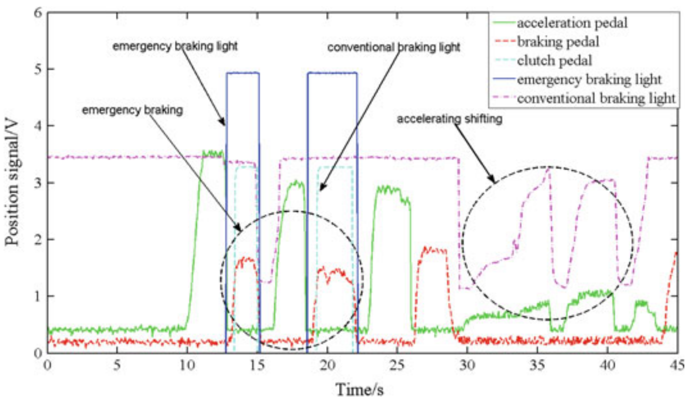

Fig. 5 Experiment result of rear-end collision warning device test

module was used to collect the information of the driving behavior. The emergency Braking calculate module was used to analyze the rate of the change of displacement data. The D/A control output module was used to control the emergency brake lamp.

4 Test

The rear-end collision warning device was tested on roads. The data of emergency braking, conventional braking and acceleration shifting behaviors and the status of brake lamps were collected. Results show that the rear-end collision warning device can accurately distinguish acceleration shifting, conventional braking and emergency braking behaviors, and the emergency brake lamps were lighted in advance about 162.5 ms to compare with the conventional brake lamp (Fig. 5).

5 Conclusion

In this paper, through the analysis of emergency braking process, the method of anti-rear-end collision based on the emergency braking intention prediction was proposed, and the emergency braking model considering the change rate of accelerator pedal displacement and clutch pedal displacement was developed. The rear-end collision warning device consisting of driving control sensors, capture card, IPC and emergency brake lamps was developed. The road tests verified that the effectiveness of the anti-rear-end collision method and emergency braking model, and the rear-end collision warning device can predict driver's emergency brake intentions and light the brake lamps about 0.1–0.3 s in advance, thus reduces the incidence of rear-end collisions effectively and improve the road safety.

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The Application of Information Security Encryption Technology in Military Data System Management

Xiaoli Zheng

Abstract Followed by the continuous growing of computer technology and computer network technology, the data formation and management were used the previously complicated method. But the data management had a common issue, which became completely relied on computer network technology. Additionally, because of the significant specificity of military data, the security of data management became a main issue that needs to be solved. Therefore, more study carried out on the security management of military data systems may provide significant practical understanding and direction on manipulating and managing the military electronic file data systems securely and accurately. This paper covered all the disadvantages and security risks of controlling the military file data system via computer network technology currently. Moreover, the paper focused on the practical application of the information security encryption technology in managing the military file data. This paper may provide a further step on protecting the security of military data and promoting progress of computer scientific knowledge.

Keywords Military electronic file · File management · Information security

With the rapid development of science and technology, especially the extensive application of computer technology, digitalization and networking have been deep into the military file information management at all levels. Networking technology has become a basic mean for the military file information management and storage, thus greatly improving the efficiency of military file classification, retrieval and storage.

However, because the network itself is open and virtual, some malicious software and hackers can use the vulnerabilities of the computer system to attack, modify and steal the file information. Therefore, to strengthen the file information

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security management and improve the confidentiality of the military file information is an effective guarantee to avoid the attack and steal of the military file by illegal intruders [1].

1 Defects of Military File Information Management System and Characteristics of Electronic File

1.1 Defects of Military File Information Management System

Military file information management system, by computer technology and communication technology, through the computer network is used for classification, entry and management of file information. All the file information is in the form of electronic documents in the network system; electronic document is a kind of electronic file sorted and converted from paper file in a certain way, while electronic document is recorded tape, disk, CD and other carriers in the form of coding and can be accessed in the computer network system and transmitted on the communication network information. The transmission path of the electronic file information is uncertain, and there are many transmission paths from one computer to another. The information, from the sending node to the destination node, is going through a number of nodes. This information transmission mode cannot guarantee the security and confidentiality of archival information in the transmission among nodes. Additionally, hackers and viruses are present everywhere and it will attack into the computer with weak defense system and result in lacking security.

1.2 Basic Characteristics of Electronic File

1. Big storage capacity and extensive records
   A small DVD disk has storage capacity of up to 10G. In daily business, user can use the computer office software Word or Excel and other formats to form a text file or spreadsheet or other electronic file stored in the computer or make a document in the form of video, photographs and others saved on the CD.
2. Easily saving and accessibility at any time
   The required documents in the business are available and checkable at any time, and user can also use the computer to export the data and burn the document into a CD.
3. Important file's retention period is not subject to time limit
   With the extensive use of paperless office systems, the use of electronic files and documents through the computer network becomes more convenient and

practical. Once the file is lost, you may query through electronic documents and electronic files, without time limit.

2 Security Threats Faced by Military Electronic File Information Management

The military electronic file is created in the electronic document management system, and the information content it records can be separated from the carrier and dependent on the document (e.g., application of database technology). The contents of the electronic file information can easily be copied, deleted and stolen, and tampering and stealing will not leave traces [2]. In addition, the information in the electronic file during the computer network transmission process may be illegal tampered or intercepted [3]. This poses a significant threat to the management of electronic file information, and such threat can be divided into internal leak and external leak.

2.1 Internal Leak

Internal leak is divided into unintentional leak and intentional leak. Unintentional leak means that insiders will disclose confidential electronic documents in their own circumstances, and the most common cases include the internal computer and the Internet illegal outreach, and installation of software unauthorized by the security department and cross-use of mobile storage media. In such cases, hackers have the opportunity to intercept the file, restore secret file and thus steal confidential content and information of electronic file.

Intentional leak refers that internal staff through a variety of ways obtains secret electronic documents and takes the initiative to pass out. For example, they may directly copy secret file to the U disk, CD and other media or disclose to others by downloading through the network, screenshots, pictures, etc.

2.2 Leak to External Environment

The network attack is the major form of the external leak including network hacker and malicious code.

3 Application of Information Security and Confidentiality Technology in Military File Management

3.1 Create a File Information Generation Control System

The file information generation control system is the technology of application of data encryption, identity authentication, digital signature, information hiding and firewall; database security management technology, information leak prevention technology and anti-credit technology can ensure that the contents of the file information are of authenticity, authenticity and security. Information encryption technology is to protect the network of data and file password in the transmission process effectively; in other words, it helps convert the common text into a ciphertext before the use of information encryption algorithm and encryption key and then encapsulate the ciphertext data into data packet for transmission on the network so that the receiver can decrypt the algorithm and decryption key to restore the ciphertext into the original data. The encrypted data in the transmission process are safe and reliable to ensure that the information system cannot be tampered or stolen. If there is no decryption key, even if a file is copied, the stealer will see messy codes.

Information authentication is the effective identification of electronic documents received digital signature through the identification to ensure the integrity and authenticity of electronic files.

At the same time, user can also install a network security filter to block those malicious programs and information in the system, improve the security of transmission and enhance the level of network operation and management.

3.2 Establish File Information Security Testing and Audit System

The user shall establish a adaptive security defense system for complete file generation, transfer, collection, collation and storage, use system security detection technology for the operation log, damage prevention technology for the operation system and the effective backup technology and disaster recovery technology for system information. In the file information management system, user shall conduct multiple protection for the file resource database file and data, install anti-virus software and anti-Trojan program, update the latest patch to reduce bugs and repair the bugs in timely to prevent the loss and deletion of electronic file information.

At the same time, user shall strengthen the internal network audit, take the means of network audit in accordance with regulatory requirements, conduct real-time monitor and audit for the operation of electronic file and timely block and alarm for a variety of illegal operations in time.

3.3 Establish a File Information Use Control System

User shall use "File information use control system" to control user rights. In the server, the administrator can set the management strategy and the readable, writable and operable permissions of the U disk and CD, and dynamically adjust the security level of the protected object. In the client, the user can encrypt the file through a key encryption function or enter into client's advanced encryption interface to set the file modification, copy, print and other permissions and flexibly adjust the life cycle of the file level of confidentiality.

3.4 Establish a File Information Security Evaluation System

Electronic files are usually stored in the dedicated data hard drive, and the computer itself can ensure the physical storage of data security only if it has achieved a certain security requirement. The data on the computer are vulnerable to external attacks, and illegal user can log the internet network through the fire to copy and modify the relevant data, resulting in data leakage, damage and tampering. In such cases, software security cannot be under real-time monitoring and management; therefore, user must establish a file security assessment system [4, 5].

The file information security evaluation system includes evaluations on physical security, software security and data security. The purpose is to prevent the electronic file in the data host transmission process from being attacked or blocked so as to effectively solve the information channel congestion, while preventing the occurrence of fraud and other issues for tampering of IP address and improving the security level of the system user.

3.5 Establish a File Information Management Software Upgrade System

In the military file information management, the software upgrade has gradually become a key link. Electronic file management software upgrade is subject to two basic requirements. The first is certain compatibility to make the management software of the electronic file compatible with its equipment and operating platform of each system and usable. The second is certain degree of unity. After software upgrade, it shall have a relatively complete electronic file information security management system, and among different regions and different units, the system shall prevent differences in information security management of the electronic files so as to achieve the sharing of all electronic documents in the electronic file.

4 Conclusions

To sum up, the security and authenticity of information management of military electronic files are directly related to the healthy development of military files. As the information security of electronic file is restricted by various factors such as network environment, physical conditions, management system and security technology, during the process of military electronic file information management, we will strengthen the management of military file information security and establish a perfect network security prevention system and promote the software upgrade of electronic files. This should be an effective measure and means to ensure the security of military electronic file information.

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An ECG-Derived Respiration Method Based on Signal Reconstruction of R, S Amplitudes and Filtering

Yue Gao, Hong Yan, Zhi Xu, Lin Zhang and Meng Xiao

Abstract An ECG-derived respiration (EDR) algorithm based on signal reconstruction and filtering is presented and applied to derive the respiratory signals from single-lead ECG. The ECG features, R-peak amplitude, S-peak amplitude, and R-peak position are used to reconstruct the signal by cubic spline interpolation. The EDR signal is obtained by applying a Kaiser filter to the reconstructed signal at last. The method is evaluated on data from the MIT-BIH polysomnographic database and validated against a "gold-standard" respiratory obtained from simultaneously recorded respiration data. Correlation coefficient (C) and magnitude-squared coherence coefficient (MSC) are used to assess the performance of the methods. The statistical difference is significant among the method presented in this study and the EDR methods based on wavelet and empirical mode decomposition (EMD), proving that the algorithm introduced in this article outperforms the others in the extraction of respiratory signals from single-lead ECGs.

Keywords Signal reconstruction · Filter · EDR method

1 Introduction

Respiration signal is an important physiological signal, it plays an important role in diagnosis and treatment of many diseases. The traditional respiratory signal-recording methods are unmanageable in certain applications such as stress testing, ambulatory monitoring, and sleep studies due to the use of some cumbersome devices that may interfere with natural breath [1]. Compared with the traditional methods, the EDR (ECG-derived respiration) method extracts the respiratory

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wave through ECG, and the ECG signal has the advantages of being convenient in collection and having little interference to normal respiration, etc. Thus, the EDR method is very much applicable for home monitoring and ambulatory monitoring. As an advanced human body measurement technology, the EDR method has a wide application prospect in the man–machine–environment system engineering field.

The theories of the EDR method are as follows: (1) The motion of the electrodes relative to the heart during the respiratory cycle. (2) The thoracic impedance variations caused by the volume changes in the lungs. (3) Respiratory sinus arrhythmia (RSA). The heart rate increases in inspiration and decreases in expiration [1].

Due to these factors, many scholars proposed a series of EDR algorithms. The first EDR algorithm based on morphology variation information is proposed by Wang et al. [5]; they used the vectorcardiogram (VCG) to detect the respiratory rate and respiratory depth. Then many EDR algorithms based on the amplitude of the ECG features were proposed, including the methods for restoring the respiratory wave based on R wave peak amplitudes, RS amplitudes, QRS area [3], etc. Some scholars used RSA to get the EDR signal by combining with the methods of S-transform [4], etc. It is commonly believed that the EDR method based on ECG filter is the simplest way to get the respiratory wave through ECG. Yi et al. [6] extracted the ingredients of which the frequency was between 0.2 and 0.4 Hz in ECG by wavelet, and took them as the respiratory wave. The EDR signal obtained by this method had extremely high similarity with the actual respiratory wave through experiments. However, because of the complexity of the ECG, the ingredients of 0.2–0.4 Hz obtained by wavelet may also contain the other ingredients besides the respiratory signals, which causes big errors between the EDR signal and the actual respiratory wave. To overcome the above defect and get the EDR signal which is more similar to the actual respiratory wave, this paper proposed an EDR method based on signal reconstruction of R and S amplitudes and filter.

2 Method

2.1 Database

The MIT-BIH Polysomnographic Database includes 18 continuous records which come from 16 male subjects who suffer from sleep apnea. The records are digitized at 250 Hz with 12-bit resolution and continue between 2 and 7 h. Because the 16 subjects all have the sleep apnea diseases of different degrees, there are abnormal data caused by apnea and respiratory disorder in parts of the ECG and respiratory wave. In these data, the relationship between ECG and the respiratory wave is not clear, and thus, the EDR algorithm is not applicable. Therefore, this article took advantage of the data without apnea or respiratory disorder all of records for algorithm comparison.

2.2 EDR Methods

As mentioned above, the ECG signals were influenced by the respiration, and the influences on the R wave and S wave were the most significant. Thus, this paper chooses the information of the R and S wave amplitudes and the R wave peak position as the basis for signal reconstruction, and then uses the Kaiser low-pass filter for filtering the reconstruction signal to get the EDR signal. The detail of the algorithm is given as follows.

2.2.1 EDR Method Proposed in this Article

(a) Data preprocessing

The method of this paper needs to use the information of the R wave peak amplitude, S wave peak amplitude, and the transverse coordinate positions of the R wave peak, and thus, it firstly needs to detect the features of ECG. The algorithm for feature points detection of the paper is the ECG feature points detection algorithm based on wavelet proposed by Yang et al. [7]. The algorithm is outstanding in time consumption, detection precision, etc., and is very much applicable to this paper.

(b) Signal reconstruction

The R wave peak amplitude (RA), S wave peak amplitude (SA), and the transverse coordinate of R wave peak (RP) are expressed by the following formula:

$$\mathrm{RA}(i), \quad i = 1 \cdots m \tag{1}$$

$$\mathrm{SA}(i), \quad i = 1 \cdots m \tag{2}$$

$$\mathrm{RP}(i), \quad i = 1 \cdots m \tag{3}$$

Then, interpolation processing is carried out to RA, SA and RP, and RA′, SA′ and RP′ are obtained. The processing method is as follows:

$$\mathrm{RA}'(i) = \begin{cases} \mathrm{RA}\left(\frac{i+1}{2}\right), & \text{for odd } i \\ \left(\mathrm{RA}\left(\frac{i}{2}\right) + \mathrm{RA}\left(\frac{i}{2}+1\right)\right)/2, & \text{for even } i \end{cases}, i = 1 \cdots 2m-1 \tag{4}$$

$$\mathrm{SA}'(i) = \begin{cases} \mathrm{SA}\left(\frac{i+1}{2}\right), & \text{for odd } i \\ \left(\mathrm{SA}\left(\frac{i}{2}\right) + \mathrm{SA}\left(\frac{i}{2}+1\right)\right)/2, & \text{for even } i \end{cases}, i = 1 \cdots 2m-1 \tag{5}$$

$$RP'(i) = \begin{cases} RP\left(\frac{i+1}{2}\right), & \text{for odd } i \\ round\left(\frac{RP(i/2) + RP(i/2+1)}{2}\right), & \text{for even } i \end{cases}, \ i = 1 \cdots 2m-1 \tag{6}$$

To make the respiratory information included in the reconstruction signal to be more significant, the RA′ and SA′ sequences are operated as follows. The processed sequences are expressed as RA″ and SA″.

$$\mathrm{RA}''(i) = \mathrm{RA}'(i) - \min(\mathrm{RA}'(i)) \times 0.95, \quad i = 1 \cdots 2m - 1 \tag{7}$$

$$\mathrm{SA}''(i) = \mathrm{SA}'(i) - \max(\mathrm{SA}'(i)) \times 0.95, \quad i = 1 \cdots 2m - 1 \tag{8}$$

Sampling reconstruction is carried out to the RA″ and SA″ sequences to get the reconstruction sequence, and it is expressed as sig.

$$\mathrm{sig}(i) = \begin{cases} \mathrm{RA}''(i), & \text{for odd } i \\ \mathrm{SA}''(i), & \text{for even } i \end{cases}, \quad i = 2m - 1 \tag{9}$$

The signal *sig* is interpolated to 250 Hz by spline interpolation. The transverse coordinate of the *sig (i)* is RP′(i). Finally, we can get the last reconstruction signal which is expressed as *S*.

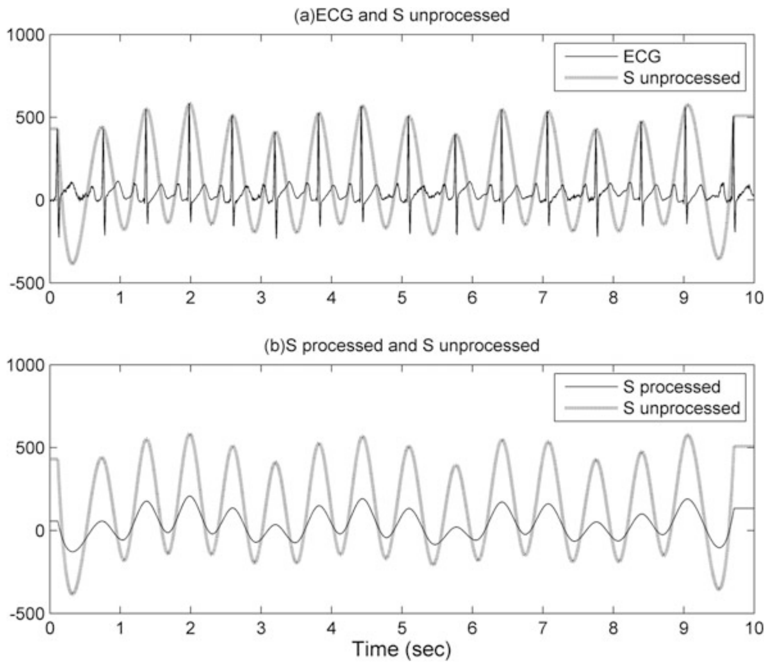

Fig. 1 Exhibition of ECG and S from the record slp02a (0–10 s). **a** the ECG and S unprocessed by formulas (7) and (8). **b** The comparison of S processed by formulas (7) and (8) and S unprocessed by formulas (7) and (8)

For explanation, Fig. 1 shows the reconstruction signal *S* which is not processed by formulas (7) and (8). The Discussion will introduce the reason why the data processing of formulas (7) and (8) is needed in detail.

(c) Filter

At last, the EDR signal can be obtained by applying Kaiser low-pass filter to the reconstructed signal *S*. Generally, it is believed the respiratory wave frequency is 0.2–0.4 Hz [6], and thus, the cutoff frequency of passband of the Kaiser low-pass filter is set as 0.4 Hz, the stop band starting frequency is 0.6 Hz, and the passband fluctuation and the stop band attenuation are, respectively, set as 0.01 and 0.001. The processing effect is shown as Fig. 2.

As shown in Fig. 2, the EDR signal and the reference respiratory signal are in the anti-phase relationship of which the detailed reason is explained in the paper [8]. This anti-phase relationship does not influence the acquiring of the EDR signal and the assessment of the algorithm effect, and thus, it is not deeply studied. However, it shall mention that not all of the other data in the database have the anti-phase relationship as shown in the figure.

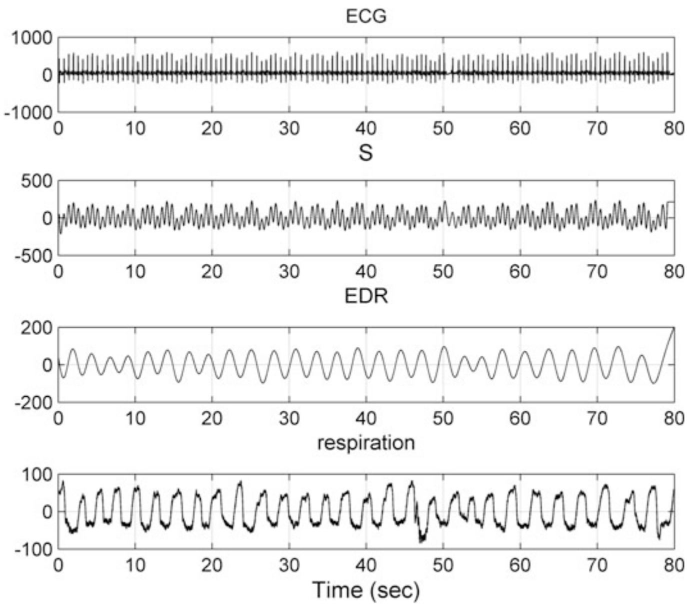

Fig. 2 ECG, S, EDR, and reference respiration signal from the record slp02a (0–80 s)

2.2.2 EDR Methods for Comparison

The method of the paper will be compared with the EDR method based on wavelet and the EDR method based on experience mode decomposition (EMD). The former decomposes ECG through the wavelet and extracts the ingredients for which the frequency is between 0.2 and 0.4 Hz [6], which are used as the respiratory wave. The db6 mother wavelet is chosen as wavelet basis function [6].

The EDR method based on EMD does not need to choose the wavelet basis function in advance, and thus, its application is wider than the EDR method based on wavelet. The EDR method based on EMD proposed by Labate et al. [2] firstly decomposes ECG into a set of intrinsic mode functions (IMF) and then visually screens out one IMF or the sum of a plurality of IMFs which are closest to the respiratory wave to be used as the EDR signal.

2.3 Assessment Indexes of Algorithm

The assessment indexes of EDR algorithms used by the paper are the correlation coefficients (C) and the magnitude-squared coherence (MSC). To avoid the possible time delay, we choose the maximum absolute correlation of which the time window is within 10s as the value of correlation coefficient (C). The reason for choosing 10s as the time window is that normal human's lowest respiratory frequency is about 0.1 Hz [6].

MSC is the index for calculating the coherence of signal in frequency domain and can be calculated by the following formula.

$$C\mathrm{xy}(f) = \frac{|P\mathrm{xy}(f)|^2}{P\mathrm{xx}(f)P\mathrm{yy}(f)} \tag{10}$$

The $P\mathrm{xx}(f)$ and $P\mathrm{yy}(f)$ are the power spectrum densities of the reference respiratory wave and the EDR signal, and $P\mathrm{xy}(f)$ is the cross-power spectrum density. The spectra are calculated using Welch's method using a 1024-point fast Fourier transform. The periodic Hamming window is used whose length was chosen to obtain eight sections of input signal. The overlap is 50%.

3 Result

Figure 3 shows the comparison of the results for the same ECG among the method proposed in this article and the other two methods. To be convenient for comparison, the EDR signal's amplitudes are normalized. As shown in Fig. 3, all of the

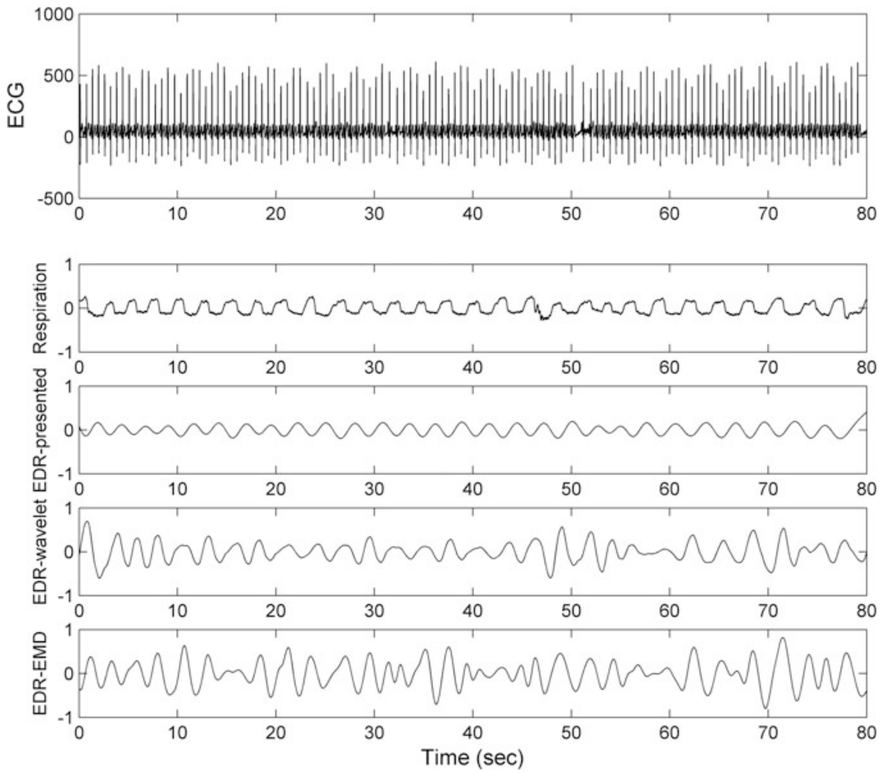

Fig. 3 ECG and reference respiratory signal from the record slp02a along with the three EDR signals. The figure shows the data from 0 to 80 s [from *top* to *bottom*: the ECG signal; the reference respiratory signal; EDR signal presented in this article; EDR signal based on wavelet; EDR signal based on EMD, imf15 is selected]

three methods can obtain the surrogate respiratory wave, but the respiration obtained by the method in this paper is more stable, and the appearance of the wave is more close to the reference respiratory wave.

Table 1 shows the quantitative comparison of the three EDR methods for all records in the database. The two-tailed t test is used to test for significant differences. The result proves that the method proposed in this article is better than the other two methods in the correlation coefficient and magnitude-squared coherence, and the difference is significant. At the same time, the EDR method based on wavelet is significantly better than the EDR method based on EMD.

Table 1 Comparison of all records $(\bar{x} \pm s, n = 18)$

Methods	C	MSC
EDR-presented	0.7442 ± 0.1107	0.9071 ± 0.0772
EDR-wavelet	0.5009 ± 0.2048*	0.7852 ± 0.1130*
EDR-EMD	0.3546 ± 0.1366*#	0.7154 ± 0.0645*#

*P < 0.05, as compared with EDR-presented; #P < 0.05, as compared with EDR-wavelet

4 Discussion

The respiratory signal extracted by the method of the paper is significantly better than the other two methods not only in wave shape but also in the quantitative comparison including correlation coefficients and MSC through experiments. The wavelet EDR method has the disadvantage that because of the complexity of the ECG, the 0.2–0.4 Hz component extracted by the wavelet may also contain the other information in the ECG besides the respiration information, and thus, the surrogate respiration obtained by the method may have big errors in many details. The EDR method based on EMD does not need to set the wavelet basis function in advance, and thus, it can be more widely applied. However, limited by the algorithm itself, the IMFs obtained by decomposition does not have specific frequency meaning, and at current, we can only select one IMF or the sum of some IMFs manually to construct the EDR. The method of the paper removes the interference of the other information in ECG by signal reconstruction. The reconstructed signal only contains the information of the respiration and the high-frequency information generated by interpolation which is similar to the modulation wave. Thus, the respiratory wave with excellent performance can be obtained by only using filter. In addition, no manual intervention is required for the method, and the automation is good.

As mentioned above, formulas (7) and (8) shall be used for processing the RA′ and SA′ sequences because of the following reasons: As shown in Fig. 4, in the spectrum of the reconstructed signal S, the power of the respiration is centrally distributed in the part of 0.2–0.5 Hz, and the part of 1–2 Hz is the high-frequency part generated by the interpolation which is similar to the modulation wave. In the spectrum of S after being processed by formulas (7) and (8), the low-frequency part expressing the respiration is not changed, the power of high-frequency part is reduced, and the ratio of the power of the respiration to the total power is increased, which provides convenience for identifying the respiration power spectrum and designing the filter. In addition, the EDR signals obtained before and after the processing of formulas (7) and (8) are not varied significantly, and thus, the processing of this step is practical and reasonable.

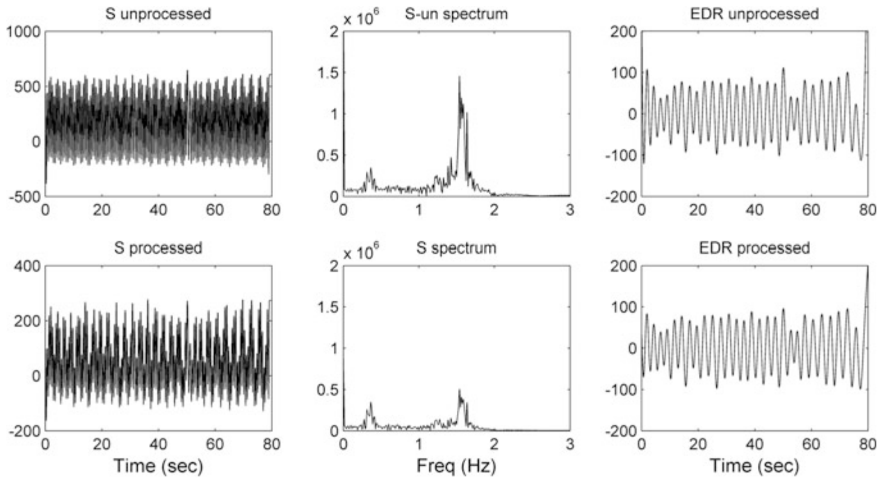

Fig. 4 Three figures in the *first row* show the S, the spectrum of S, and EDR unprocessed by formulas (7) and (8). The bottom three are the S, the spectrum of S, and EDR processed by the formulas

5 Conclusion

This article proposes an EDR method based on signal reconstruction and filter, which firstly uses the amplitudes of R and S waves and the position of the R wave peak for signal reconstruction, and then the EDR signal is obtained by the Kaiser low-pass filter. In the comparison with the EDR method based on wavelet and the EDR method based on experience mode decomposition, the algorithm of the paper restores the respiratory wave whose shape is more similar to the actual respiratory wave. And the algorithm proposed in this article outperforms the other two methods in the quantitative comparison. The method of the paper is very much applicable for the home monitoring and ambulatory monitoring with the advantages of simplicity for calculation, convenience in application, and having no use for any additional sensor. As an advanced human body signal measurement technology, the EDR method has a wide application in the man–machine–environment system engineering field.

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Part III
Research on the Environment Character

Greenhouse Gas Recovery from Coal Mines and Coalbeds for Conversion to Energy at PCG #8 Mine, China

Defang Yang, Guiqiang Zheng and Chao Zhang

Abstract The PCG Mine #8 already practice methane drainage are considered to drain their seam gases and reduce atmospheric emissions of methane, After studying the methane drainage system and Visualisation and analysing of mine ventilation data.real-time monitoring of ventilation and methane drainage at the longwall face B_{15}-13330. Analysis have shown that gas drainage in this face accounts for 38.3% of the total gas release and the ventilation air methane takes up 61.7%. On the other hand, ventilation air methane from the longwall face B_{15}-13330 represents 72.2% of methane in the whole district. Sealing and design of the drainage wells used can improve this efficiency as will be discussed. The dynamic information of mine gas geology is obtained, and how to improve this efficiency is also discussed. Finally, the implementation of coal mine drainage system is optimised.

Keywords Gas geology · Gas forecasting · Greenhouse gas recovery · Methane drainage system

1 Introduction

The PCG Mine #8 is located on the eastern side of the Pingdingshan mining area at coordinates 1130 22′ 9″–1130 30′ 13″ East and 330 45′ 13″–330 47′ 25″ North. To the East and South of mine field is an open alluvial–diluvial plain; ground elevation generally is around +75 to +80 m. To the north of the coalfield is Mapeng Mountain and Jiaozhan Zhai Mountain mostly of amaranthine Shiqianfeng sandstone and Pingdingshan sandstone. Elevation is generally around +360 to +460 m. The mine began development in 1966 and became operational in 1981; it has a design capacity of 3 Mtpa and life of 65 years.

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The main coal-bearing strata in the Pingdingshan coalfield are the Lower Permian Shanxi Formation and the Lower Shihezi Formation. The thickness of main coal-bearing strata is about 400 m, and the average total thickness of the coal seams is about 14.7–18 m. There are 4 minable coal seams ($B_{16–17}$, B_{15}, $C_{9–10}$, and $D_{5–6}$) at #8 mine, average thickness is 11–17 m, and the dip angle is 8°–22°. Being more gassy and outburst prone, and also based on the production schedule of the mines, longwall districts in seams B_{15} and $B_{16–17}$ were selected as the mining districts to concentrate upon for the purpose of the tasks covered which underpresents a representative stratigraphic column from two longwall districts at Mine #8 [1–4].

2 Performance Assessment of the Drainage System at PCG Mines

Longwall operations at Mine #8 were carried out in order to select the pilot methane drainage performance monitoring longwall face. Based on the data available, the longwall face LW13330, which already had horizontal pre-drainage boreholes installed from November 2011, was selected as the methane drainage-monitoring face in the project. This longwall has not benefitted from protection seam mining and therefore has not been pre-drained by being overmined. The in-seam boreholes are drilled and spaced 3 m apart, at 113 mm diameter and approximately 80–100 m length (Figs. 1 and 2).

Figure 2 above presents the details of long-hole drainage system installed at the Top Gallery at LW 13330. Here, the boreholes are drilled 1.5 m apart, and after 6 months of drainage the concentration of CH_4 in the drained gas ranged between 11 and 16% at 1.00 m^3/min. The boreholes used a standpipe length of 15 m, with 1-m foam at both ends and 10-m cement pumped between the foam. This roadway was ventilated separately to the longwall face.

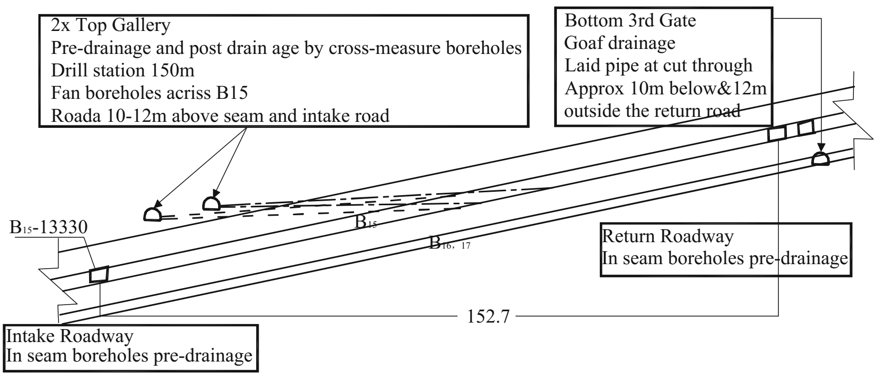


Fig. 1 Original design of the LW13330 methane drainage system

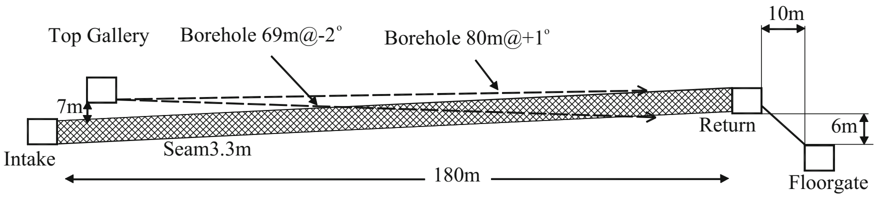


Fig. 2 Detailed design of the LW13330 long-hole methane drainage system from the *top* gallery

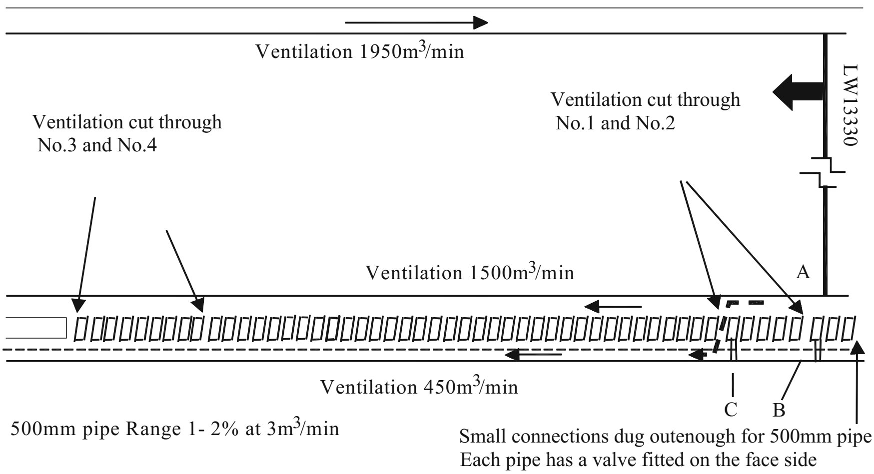


Fig. 3 Detailed design of the LW13330 floorgate drainage operation and interaction with ventilation

Figure 3 presents a detailed design of the LW13330 floorgate drainage operation and its interaction with the ventilation system. When LW reaches "A," the pipe range is broken at "B" and both ends are sealed; then, a wall is built at "C." Ventilation stops flowing through ventilation cut-through No. 1 and flows through cut-through No. 2, and this sequence continues along the floorgate length. As LW approaches each 500-mm pipe, the face-side valve is opened. The measurements have shown that the average methane concentration in the pipe is 1.5%, and the system does not have the advantages of conventional 3-gate ventilation system.

Figure 4 presents a set of readings of average daily methane concentrations from the mine electronic monitors at LW13330 in Mine #8 detailing methane emission contributions to the mine ventilation air from different gate roads.

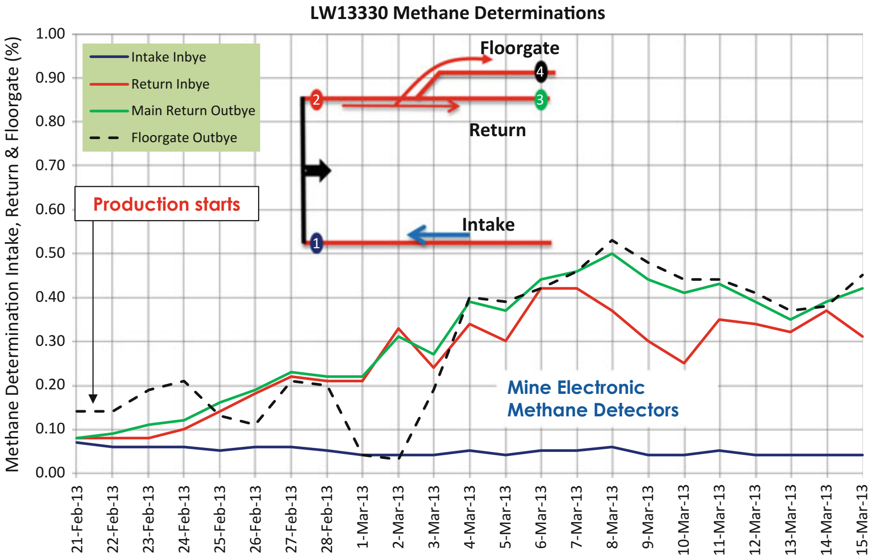


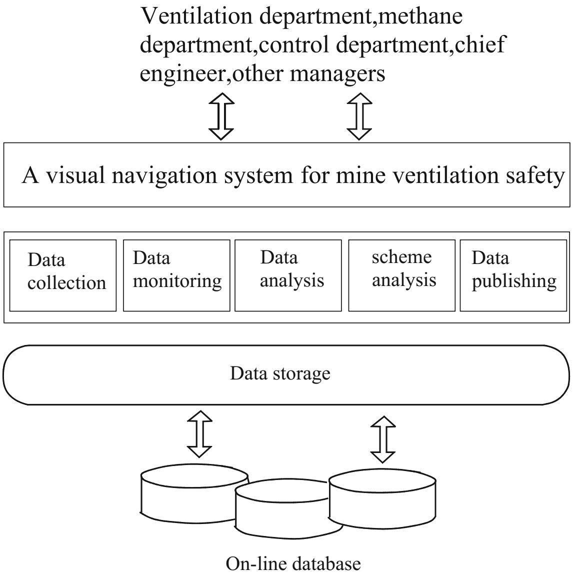
Fig. 4 Example readings of average daily methane concentrations from the mine electronic monitors at LW13330 in Mine #8 detailing the contributions from different gateroads

3 Visualisation and Analysis of Mine Ventilation Data at PCG Mine #8

Mine ventilation system is a dynamic system composed of the main fan unit and underground mine ventilation network. To ensure production safety and reduce costs, this dynamic system should maintain optimal operating conditions. However, constant evolution of the mine production layout is bound to affect the operational state of the dynamic system, leading to situations unfavourable for production safety and technical economics. This is a common situation in mine ventilation system in China; therefore, optimisation and transformation of mine ventilation system is of considerable importance [5, 6].

Based on the analysis of the ventilation systems in Mine #8, combined with the measurement data, the visualisation system of mine ventilation and fire prevention in Mine #8 was completed. The operational interface is presented in Fig. 5, which displays the measured ventilation parameters of the whole mine into the three-dimensional visualisation system and enables real-time calculation and display of mine ventilation.

Fig. 5 Technical flow diagram of the mine ventilation system



3.1 Real-Time Monitoring Data Display

Seamless connection with the mine monitoring system is achieved. The main monitoring sensors have been labelled in the three-dimensional system. And then through layered management, the system realises the layout and display management of the sensor.

Using the mouse to click the icon of the corresponding sensor, the relevant information is displayed. Figure 6 presents the 24-h gas sensor history of total return air in B3 mining area extension, drainage roadway in B15-13330 machine roadway, and the drainage station in B3 mining area extension, respectively.

3.2 Gas Analysis at the Project Monitoring Longwall Face B_{15}-13330 and the East Air Shaft

Measurements of airflow and gas concentrations at longwall face B_{15}-13330 on 6 July 2013 were 2190 m^3/min and 0.24%, respectively. Therefore, the face VAM was about 5.256 m^3/min. The total return air volume in the B3 mining area extension was 3688 m^3/min, gas concentration was 0.32% and the cumulative gas emission was 11.80 m^3/min. This suggests that gas drainage volume of B3 mining area extension accounts for 38.3% of the total volume and the VAM accounts for 61.7%, of which 5.256 m^3/min is from longwall face B_{15}-13330, accounting for 72.2% of the gas in the whole district. Gas emission from other regions takes up 27.8%.

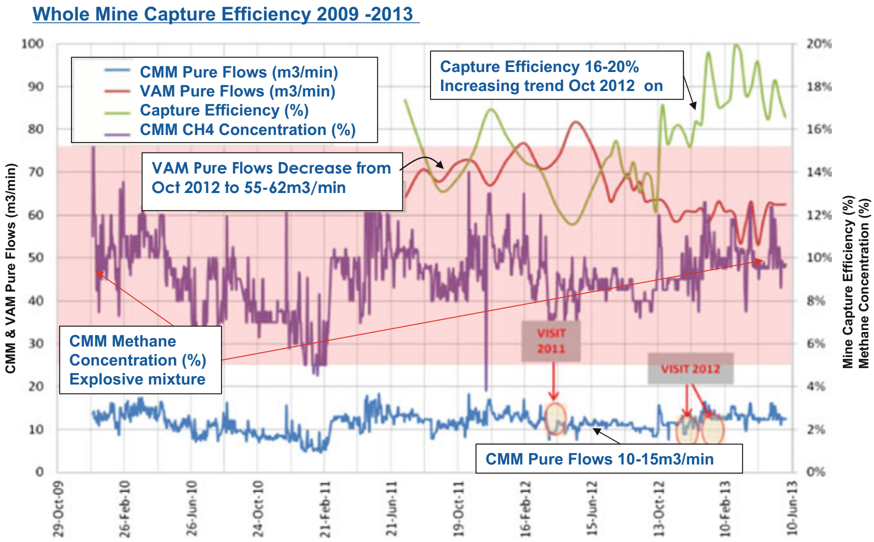


Fig. 6 PCG Mine #8 overall drainage capture efficiency in the long term before and during the project

The total return air volume in the East air shaft is 7656 m^3/min, gas concentration is 0.2% and the gas volume is 15.31 m^3/min. Thus, gas in this area is mainly from the B3 mining area extension accounting for 77.1%, the remainder coming from the B3 mining area.

4 The Efficiency of Methane Drainage Capture System

An automated continuous methane drainage-monitoring system was installed at a pilot longwall face at PCG mines, which monitored and transmitted performance data from an in-seam pre-drainage system for the entire longwall extraction period. Manual monitoring of individual in-seam boreholes was also carried out for performance assessment of the drainage installations [7].

Figure 6 presents the analysis of the whole mine drainage capture efficiency at Mine #8. Drainage efficiency at Mine #8 was in the region of 16–20% in the short and long term. This is consistent with the observations from the project monitoring longwall LW13330, and it is believed that better sealing and design of the drainage wells used can improve this efficiency as will be discussed.

5 Conclusions

Field monitoring of methane drainage performance at the pilot longwall face LW13330 at Mine #8 and the overall methane drainage capture efficiencies of both Mines #8 have shown that the captured gas purity was rather low, and a typical of most Chinese coal mines. Capture efficiency on an individual face basis was also noted as being low. This is believed to be caused by less-than-effective stand-piping and borehole sealing, as well as the in-seam pre-drainage boreholes being very closely spaced, besides the low permeability of the PCG coal seams.

This research has conducted real-time monitoring of ventilation and methane drainage at the longwall face B_{15}-13330. Analysis has shown that gas drainage in this face accounts for 38.3% of the total gas release, and the ventilation air methane takes up 61.7%. On the other hand, ventilation air methane from the longwall face B_{15}-13330 represents 72.2% of methane in the whole district.

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Study on the Performances of Supply Air for Uniform Air Supply Square Hood by Numerical Simulation

Jianwu Chen, Bin Yang, Shasha Liang, Zhenfang Chen, Yaru Sun and Tingting Zhang

Abstract The calculation model of uniform air supply square hood was drawn using Gambit, and the boundary conditions of numerical simulation for calculation model were determined combined with the actual situation. The uniform air supply of square hood was simulated for different velocity at hood by Fluent software. The air distributions of the uniform air supply square hood and the air distributions of the hood in the center line were put forward, and the change of the velocity with the distance from the hood face has better change regular, which was found. The hood size and the supply air velocity were non-qualified in order to eliminate the influence of different hood size and supply air velocity. At last, the change regular of supply air velocity with the distance from the hood face was put forward for the uniform air supply square hood.

Keywords Uniform air supply · Air supply square hood · Performances of supply air · Numerical simulation

1 Research Purpose

The uniform air push–pull ventilation system which consists of uniform air supply hood and local exhaust hood has been widely used [1, 2] since it can solve many technical problems, such as far poison control distance, the affected process operation and waste of resources [3–5]. Some scholars [6–8] have done a lot of research on the formation mechanism of uniform air supply, but the characteristics of the uniform air supply have not been studied. Therefore, it is necessary to study the air

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supply characteristics of the uniform air supply hood, which can provide the basic theory support for the application of the uniform air supply hood.

2 Research Methods

2.1 Overview

According to the actual situation, the 0.5 m × 0.5 m square uniform air supply hood is determined as the main research object and 0.5, 0.6, 0.7, 0.8 m/s is, respectively, set as wind speed of this square hood. After using Gambit to draw the mathematical model, the numerical simulation is carried out by Fluent and the results are analyzed by Excel. The influence of the hood size is eliminated by using the dimensionless method.

2.2 Establishment of Mathematical Model

In order to avoid the influence of space on the air supply characteristics, a 25-m-long, 4-m-wide and 4-m-high calculation field is set up. The air supply hood is located on the left wall, and the center of the air supply hood is 2 m high which also coincides with the center of the wall.

The 0.5 m × 0.5 m square uniform air supply hood model is drawn by Gambit and meshed by TGrid, as shown in Fig. 1. The air supply characteristics of 0.5, 0.6, 0.7, 0.8 m/s are simulated and calculated by Fluent.

2.3 Boundary Condition Setting

According to the actual situation, combined with the mathematical model and Fluent simulation method, the main parameters and boundary conditions of numerical simulation are determined as shown in Table 1.

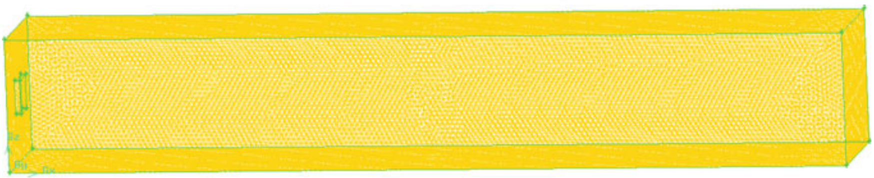


Fig. 1 Calculation model and meshing of uniform air supply hood

Table 1 Boundary conditions

Boundary conditions	Parameter setting
Solver	Segregated
Viscous model	k-epsilon
Energy equation	Off
Material	air
Velocity inlet (m/s)	0.5 (0.6, 0.7, 0.8)
Pressure outlet (Pa)	0
Turbulent intensity of inlet (%)	4.65
Hydraulic diameter of inlet (m)	1
Turbulent intensity of outlet (%)	4.45 (4.35, 4.27, 4.20)
Hydraulic diameter of outlet (m)	4
Pressure–velocity coupling	SIMPLEC
Momentum	First-order upwind

3 Research Results

3.1 Air Supply Characteristics of the Uniform Airflow Hood in Different Wind Speed

The contours of velocity magnitude of different wind speed (0.5, 0.6, 0.7, 0.8 m/s) are calculated by Fluent numerical simulation, as shown in Fig. 2.

As can be seen from Fig. 2, the wind speed decreases with the increase in the distance and the air supply has little influence on the flow field of the surrounding space. It is difficult to distinguish the influence of different wind speed on the air supply characteristics; therefore, when the wind speed is at different speed (0.5, 0.6, 0.7, 0.8 m/s), the wind speed on the center line of the hood is drawn, respectively, as shown in Fig. 3.

As can be seen from Fig. 3, the wind speed of the air supply hood in the range of 1.25 m is almost invariable, after 14 m it decreases to 0 m/s, between 1.25 and 14 m, and the wind speed decreases rapidly with the increase in distance. The greater the wind speed, the greater the rate of reduction.

3.2 Dimensionless Air Supply Characteristics of the Square Uniform Airflow Hood

In order to eliminate the influence of the hood size and air supply speed, the size of hood and air supply speed are dimensionless. That is, the ratio of the distance from air supply hood (L) and the hood side length (a) is x, and the ratio of the simulation values of wind speed (V) and the central wind speed (V_0) is y. The results which have been simulated and calculated by Fluent are processed, and then we get the data as shown in Table 2.

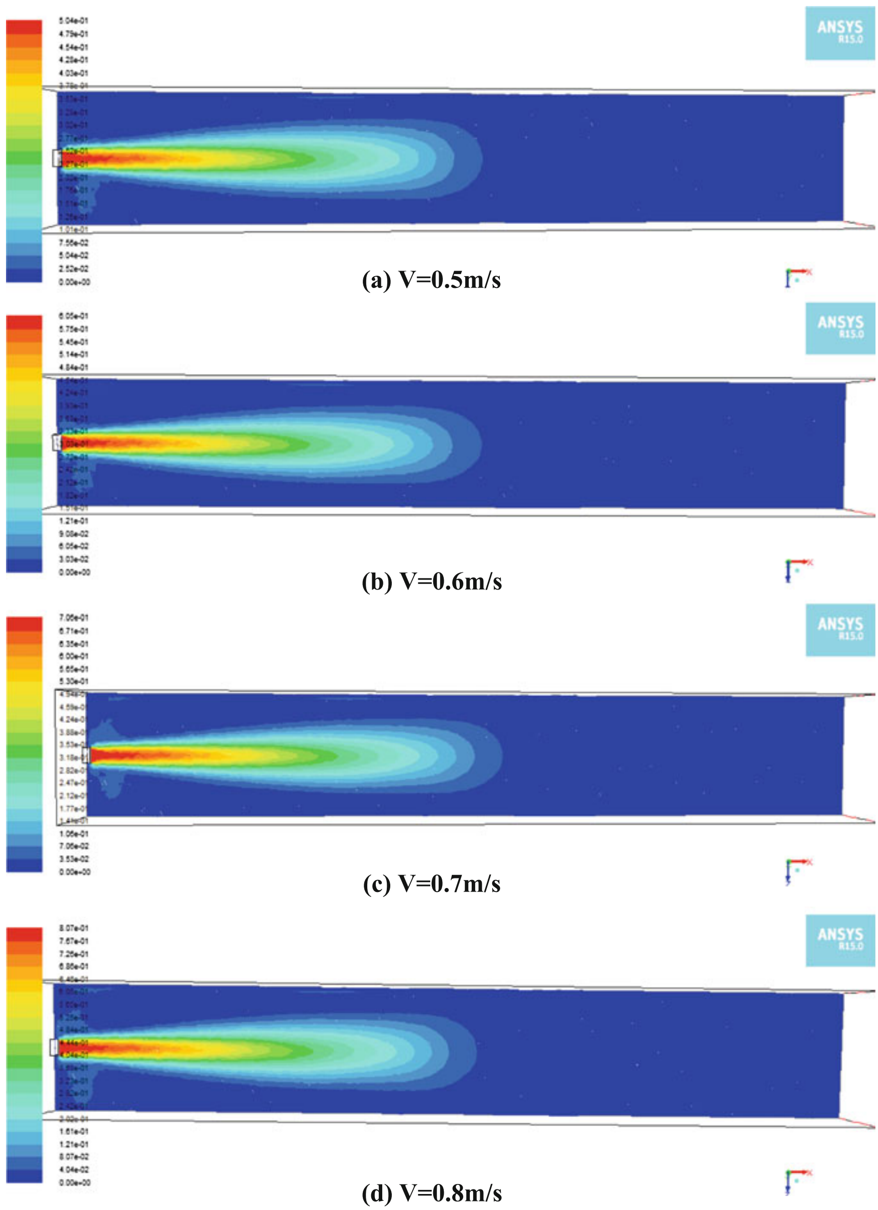


Fig. 2 Flow distribution for different velocity

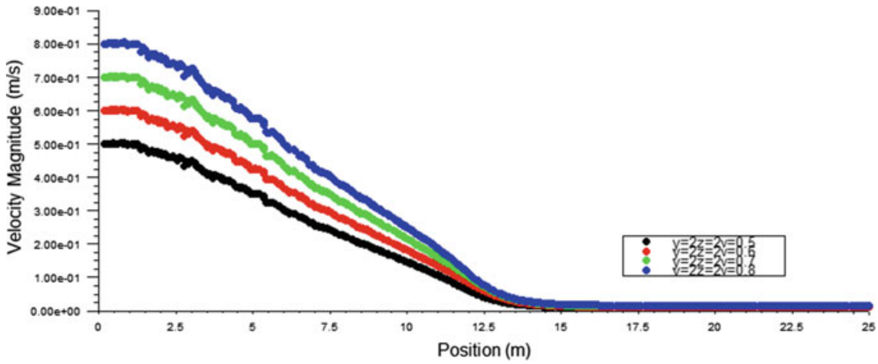
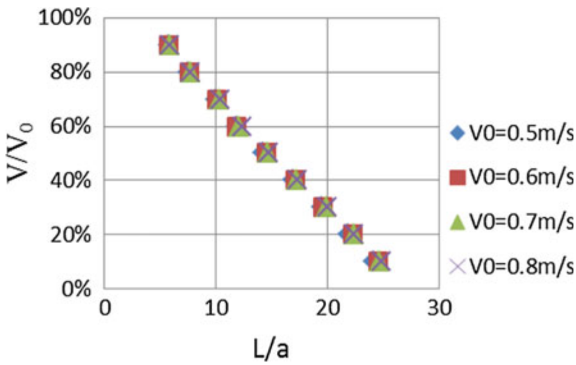


Fig. 3 Flow distribution for different velocity in the hood center line

Table 2 Characters of flow distribution for uniform air supply hood after non-qualified

V/V_0 (%)	L/a			
	V_0 = 0.5 m/s	V_0 = 0.6 m/s	V_0 = 0.7 m/s	V_0 = 0.8 m/s
90	5.70	5.78	5.80	5.80
80	7.52	7.58	7.68	7.72
70	10.00	10.08	10.34	10.40
60	11.84	11.88	12.00	12.38
50	14.20	14.54	14.64	14.78
40	16.90	17.12	17.24	17.32
30	19.48	19.62	19.92	20.04
20	21.86	22.24	22.42	22.42
10	24.18	24.60	24.68	24.82

Fig. 4 Performances of supply air for different velocity in hood face after non-qualified



Taking L/a as the x axis and the V/V_0 as the y axis, the distribution law of wind speed at different V_0 shown in Table 2 is drawn in the form of scatter plots, as shown in Fig. 4.

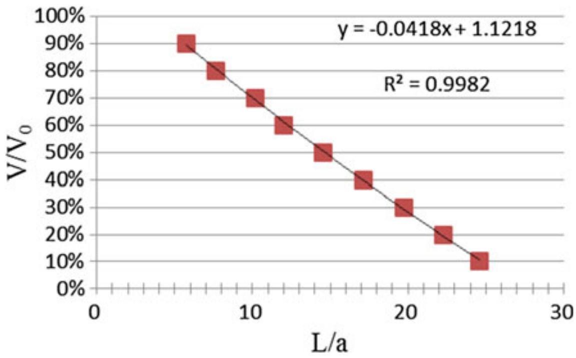


Fig. 5 Change regular of V/V_0 with L/a for uniform air supply square hood

As we can see in Fig. 4, firstly, after the dimensionless processing, the variation law between V/V_0 and L/a is almost unchanged when the wind speed of air supply hood is at different value and this variation law shows a good linear relationship. The results show that the variation law between wind speed of air supply hood and the distance from hood can be well reflected after the wind speed and distance are dimensionless. Secondly, the wind speed becomes 90% of the wind speed in hood mouth at the distance of about 5.8 times the length of the hood, the wind speed decreases by only 10%, and it can be considered that the wind speed in the range of 5.8 times the length of the hood is basically unchanged. At the distance of 24.6 times the length of the hood, the wind speed becomes 10% of the wind speed in hood mouth and decreases by 90%, and it indicates that the wind of the uniform air supply hood can blow up to 24.6 times the length of the square hood.

In order to eliminate the simulation errors and value errors and obtain the variation law of wind speed after 5.8 times the length of hood, the L/a is taken as x axis, the V/V_0 is taken as y axis, and the wind speed variation with distance is shown in Fig. 5.

Using Excel to add the trend line, the linear relationship between the V/V_0 and L/a is obtained, as shown in Eq. 1.

$$y = 1.8678x + 4.5117 \tag{1}$$

Among them, y is V/V_0, x is L/a.

Its R^2 = 0.9982, indicating that Formula 1 has good reliability.

4 Conclusions

When the wind speed of the air supply hood is at different value, the variation law between wind speed and distance from hood is obviously clear. After the dimensionless processing, the variation law between the wind speed of uniform air supply hood and the distance from hood conforms to the linear relationship, that is $V/V_0 = 1.8678\ L/a + 4.5117$.

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Spacecraft Electrical Signal Classification Method of Reliability Test Based on Random Forest

Ke Li, Ruicong Ran, Shimin Song, Jun Wang and Lijing Wang

Abstract The spacecraft electrical signal characteristic data exist a large amount of data, high dimension features, computational complexity degree and low rate of identification problems. This paper proposes the feature extraction method based on wavelet de-noising and the classification method based on random forest (RF) algorithm. Considering the time complexity, the method of wavelet de-noising is used to compress the data and reduce the dimension and then applied to classification. The random forest algorithm has superior performance in dealing with the large amount of data. The experimental results show that compared with other algorithms, the proposed method shows excellent performance in accuracy, computational efficiency, stability in dealing with spacecraft electrical signal data.

Keywords Spacecraft fault diagnosis · Electrical signal classification · RF

1 Introduction

After the spacecraft step into the orbit flight phase, fully working in high vacuum, cold black and strong solar radiation environment. When a spacecraft launch, we can impossible do a maintenance in orbit, so we need to make diagnosis and forecast for possible fault [1] Spacecraft electronic load systems are typically non-linear time-dependent systems, the coupling of internal components is highly nonlinear, which are complex and uncertain. The mutations of internal load signal occur frequently, and when the fault occurs in the system, the cause of the accident will be intertwined. If there is no reliable source of information and analysis

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methods, just relying on assumptions and speculation, it is difficult to determine the exact cause of the fault [2–4]. There are some problems that needed to be solved urgently such as large amount of testing data, high feature dimension, high computational complexity and low recognition rate in the identification process of spacecraft electrical characteristics monitoring system.

In the previous study, for example, Liu Y uses off-line fuzzy clustering and online support vector machine to recognize the spacecraft electrical data, and uses the weighted proximal support vector machine on the classification and recognition of the electrical data. In the process of recognition, the wavelet de-noising feature method is used to reduce the dimension of the data, and the results of classification are better. However, the sample set type is less, the amount of the data is small, and the classification accuracy is low [5–8].

Relative to other algorithms, the random forest algorithm has a great advantage in many data set. It can deal with high dimensional data, with good ability to learn for large amount data, and it can realize the learning and classification for nonlinear sample data. It has unique advantage in the identification of electrical characteristic signals. In actual diagnosis process, if the input of electrical characteristic data is too much, the training complexity will greatly increase. For the complex and high dimensional feature system, a large amount of data will affect the training and classification efficiency, and leads to the decline of recognition accuracy rate. How to obtain the sensitive features from the high dimension characteristics becomes one of the bottlenecks for the fast and accurate identification of electrical signals [9–13].

2 The Identification System

In this paper, the process of algorithm model consists of three parts: data acquisition, feature extraction, signal recognition. After collecting and preprocessing the data, using deep neural network to extract the feature vectors from training set and testing set. Then the random forest algorithm classification model is trained by training set, which means we can use the testing set for validation. And finally get the classification results. Specifically, the spacecraft is detected a total of 50-channel data and data from each channel is collected at rate of more than 30 MB/S. The flow chart of the algorithm is shown in Fig. 1.

3 Feature Extraction and Classification Algorithm

In the engineering application, the DNN system can be used on PHM spacecraft data for classifying fault signals and normal signals for which the class label has actual physical meaning. The basic network structure, the initialization of network parameters and the fine-tuning training are discussed in detail in the following section.

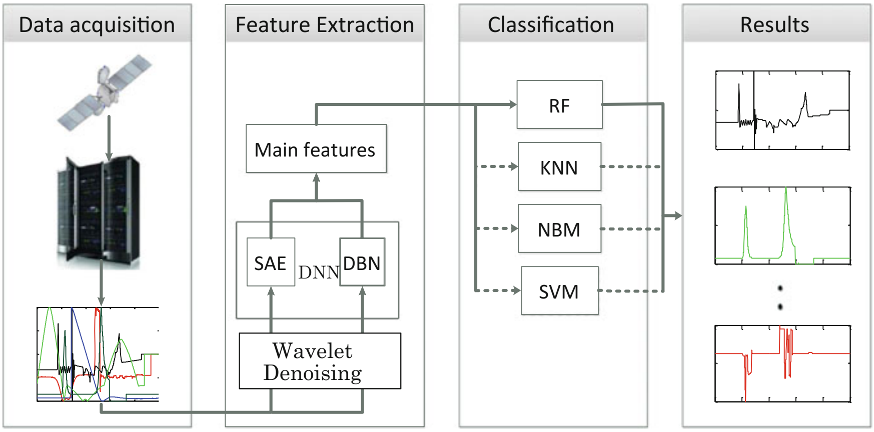


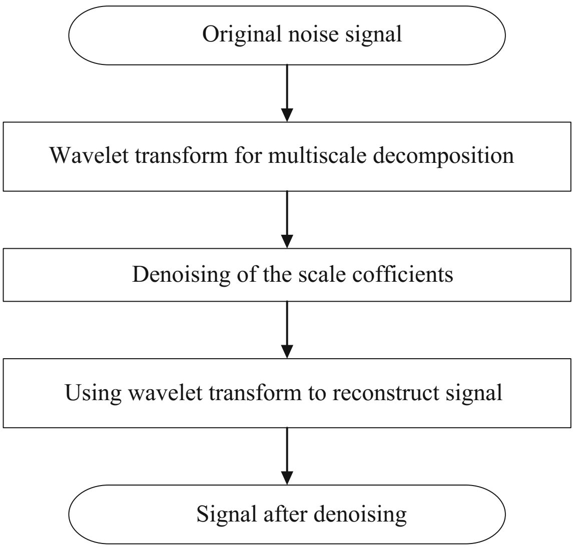
Fig. 1 The flow chart of algorithm by this article

3.1 *Wavelet de-Noising*

In the process of signal recognition and classification, the collected data may contain a lot of noise, in order to improve the accuracy of classification and recognition, digital filter is essential.

In this paper, the wavelet threshold de-noising method is used for data processing [14–16]. Wavelet threshold de-noising method is a process of using wavelet decomposition which make the separation of the original signal of high frequency and low frequency and then taken on the reconstruction process, has a better effect of the mutant noise. The flow chart of wavelet de-noising is shown in Fig. 2

Fig. 2 Flow chart of wavelet de-noising



Define each section of the spacecraft electrical characteristics data as vectors in the form of:

$$X = [X1, X2, \ldots, Xn] \tag{2.1}$$

In this paper, the threshold de-noising method is used to deal with the noise signal. The principle is that the wavelet coefficients of the original signal are processed by using the threshold value function. Threshold function reflects the above and below the threshold of wavelet coefficients from different processing strategies, according to different spacecraft electrical characteristic data, using hard threshold function or soft threshold function, so as to get a better filtering de-noising effect.

Set w as the wavelet coefficient, T is a given threshold, sign(*) is the symbol function, and the common threshold function as follows:

Hard threshold function of electric characteristic signal of spacecraft:

$$w_{new} = \begin{cases} w, & |w| \geq T \\ 0, & |w| < T \end{cases} \tag{2.2}$$

Hard threshold function of electric characteristic signal of spacecraft:

$$w_{new} \begin{cases} \operatorname{sign}(w)(w - T), & |w| \geq T \\ 0, & w < T \end{cases} \tag{2.3}$$

3.2 Random Forest Algorithm

Random forest is an ensemble classifier comprised by a group of decision tree $\{h(X, \theta_k), k = 1, 2, \ldots, K\}$, where $\{\theta_k\}$ is subject to independent and identically distributed random vectors and K is the number of decision trees. In a given electrical signal variable X, each decision tree classifier votes to determine the optimal classification result [17–19].Steps to generate random forest are as follows:

1. From the original electrical signal training data, using the method of bootstrap, selecting K new independent sample set randomly, and constructing K decision tree. The sample comprise K out-of-bag data which is not selected
2. Assume N characteristics, and then select m_{try} characteristics randomly $(m_{\text{try}} \leq N)$. By calculating the amount of information contained in each feature, we select the characteristic which has the best classification ability to do node splitting.
3. Each tree grows to maximum and does not do any cutting.

Given a set of classifier $h_1(X)$, $h_2(X), \ldots$, $h_k(X)$, the training set of each classifier come from original data(Y, X) which is subject to random distribution. The margin function is defined as:

$$\mathrm{mg}(X, Y) = av_k I(h_k(X) = Y) - \max_{j \neq Y} av_k I(h_k(X) = j) \tag{2.3}$$

where the $I(\cdot)$ is indication function.

The margin function is used to measure the degree of the average correct classification and the average error classification. The greater the margin value, the more reliable the classification prediction.

The generalization error is defined as:

$$PE^* = P_{X,Y}(\mathrm{mg}(X, Y) < 0) \tag{2.4}$$

In the formula: subscript X, Y represent that the probability P covering X, Y space.

With the increase of the number of decision trees in random forest, all sequences of $\theta_1, \theta_2, \ldots, \theta_k, PE^*$. ($\theta_k$ is an independent and identically distributed random variable) converge to:

$$P_{X,Y}\{P_\theta(h(X, \theta) = Y) - \max P_\theta(h_{j \neq Y}^{(\mathrm{X},\theta)} = j) < 0\} \tag{2.5}$$

The formula indicates that the random forest will not produce the over fitting problem with the increase of the decision tree, but it may produce a certain degree of generalization error [20, 21].

4 Experimental Results

4.1 Experiment Data Presentation

The experimental data comes from the typical electrical characteristics data of spacecraft electronic load system. In the process of spacecraft load test, the electronic load bus of the spacecraft is monitored by the electric characteristic monitoring platform, and record the original data. 6 different kinds of signals and sample label from the 13 mode of the spacecraft flying data are presented in this study. 22,800 samples are acquired, where each sample is containing 1000 features. Particularly, the physical meaning of the data is shown in Fig. 3.

The data set are firstly divided into two different sets that referred as the training set and the test set before classification. Namely, 12,800 original signals of total 56% used for model training and 10,000 original signals of total 44% used for testing the performance of the training model. The original data were normalized

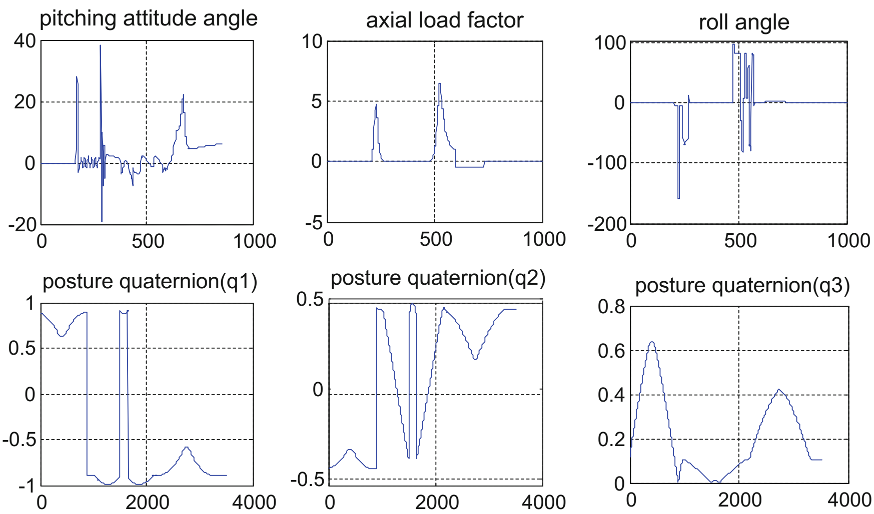


Fig. 3 Physical meaning of some electrical properties data

before training model. The classification model is then trained by using the training data set, and the testing data set is applied for model validation.

4.2 Number of Decision Trees Selection

In Fig. 4, we can see that the classification error rate decreases with the increase of the number of decision trees. After reaching the 100 trees, the classification error trends to be stable (about 0.01). However, the training time of the model will increase with the increase of the number of decision tree. Therefore, considering the problem of time complexity, select 100 decision trees consisting of random forest, classify and predict the electrical signal sample sets. It not only ensures the accuracy of classification, but also shortens the time needed for training and classification.

4.3 Number of Decision Trees Selection

Classification accuracy and classification time are the important symbols of evaluation algorithm. In this paper, we use the algorithms include Naive Bayesian Model, K-Nearest Neighbor, Support Vector Machine, and random forest to classify the spacecraft electrical signal data, and get the classification results of different algorithms. At the same time, wavelet de-noising is used for feature extraction, and

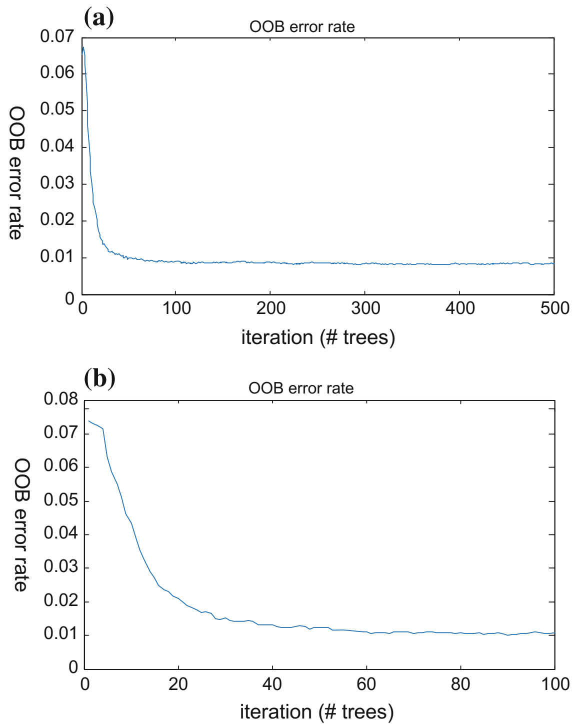


Fig. 4 Number of decision trees and OOB error rate curve

Table 1 Comparison of training time and forecast accuracy

Method	Accuracy (%)	Training time (s)
NBM	79.02	–
KNN	85.43	127.36
SVM	88.23	1873.80
RF	**98.9**	**189.93**
Wavelet -RF	**99.05**	**13.36**

then classify and recognize the electrical data. Comparing different algorithms' performance before and after the data by feature extraction. When the feature dimension of samples is too large, the classification accuracy will be low due to the dimension disaster. The dimension reduction of samples can not only improve the computational speed but also improve the classification accuracy. Table 1 shows the recognition results of different algorithms in this paper. The first column of the table is different algorithms, second is accuracy of corresponding to each algorithm, third is training time of each algorithm. RF, our algorithm, is random forest, and Wavelet-RF is wavelet random forest.

From Table 1, we can see that, before feature extraction, the classification accuracy of the NBM algorithm and KNN algorithm are 79.02 and 85% respectively. The classification accuracy of SVM algorithm is slightly higher. The random forest algorithm has highest accuracy rate of 98.9%, has better performance compared to other algorithms, which is also fast. After feature extraction, the data dimension and computational complexity is reduced, which makes the calculation speed and accuracy are improved significantly. Before and after the feature extraction, random forest algorithm both show excellent classification performance. The train time is short and the accuracy is guaranteed.

Principal component analysis is widely used for pre-processing the engineering data, but it is not good for processing the dimension reduction of nonlinear separable samples. We can see that for the methods we use, the data has better separability and faster computing speed, which is reduced dimension by Wavelet. The comprehensive algorithm operating results show that the random forest algorithm has the optimal performance in this multi class electrical characteristics in signal recognition.

5 Conclusions

In this paper, a combination of random forest algorithm and data reduction method is proposed, which can identify and classify the multi-class electrical signals of spacecraft well. The dimension reduction of spacecraft electrical characteristic data which has high dimension is realized. Then using random forest algorithm to recognize the spacecraft electrical characteristic data. It not only reduces the time needed for the computation, and further enhance the performance of the classifier. The algorithm is a simulation experiment of the original data of a certain spacecraft, which can be directly applied to the classification and identification of the spacecraft electrical signals. The experimental results show that the recognition method based on RF has higher classification accuracy and better recognition efficiency. Random forest algorithm has many advantages in dealing with the data, and it is very flexible and adaptive to deal with the fuzzy data which is specific rules. According to the algorithm of the model, which calculated complexity is still large. In future research, we can combine with other dimension reduction methods, test effectiveness of the test methods on different data sets, carry out further optimization in order to construct a better performance of the classifier.

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Cladding material of fuel element of fast neutron reactor

Fei Li, Lei Peng and Chuan Wang

Abstract Feasibility and benefits of applying grain boundary engineering (GBE) to the fuel cladding material 316 or 15-15Ti austenitic stainless steels of sodium-cooled fast reactor for reducing void swelling and creep are discussed. GBE can be used to greatly enhance the proportion of low Σ coincidence site lattice (CSL) grain boundaries that are mainly of annealing twins and its variants. The cladding pipes are normally subjected to 20% cooled working after solution annealing before using, which by virtue of providing a dislocation strewn matrix microscopic structure, contributes to the annihilations of irradiation-induced point defects. If the proportion of low ΣCSL grain boundaries are greatly enhanced prior to the cooled working, transfer of slip across the special-structured grain boundaries or pileup against them during deformation may alter the distribution of dislocations of the microscopic structure, which may accommodate more defects generated during being irradiated.

Keywords Grain boundary engineering (GBE) · 316Ti stainless steel · 15-15Ti stainless steel · Fuel cladding · Void swelling · Creep

China is one of the countries which own the biggest number of nuclear power stations under construction and believed to be the one where the nuclear power technology rises. The main pressurized water reactor nuclear power stations under construction take the UO_2 of which the uranium-235 enrichment is about 3% as the

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fuel. The uranium source of the type is limited and generates the nuclear waste of which the half life is long after fission combustion. Compared with the nuclear power technology of the third generation, the nuclear power technology of the fourth generation is more economic and safer, and the amount of the nuclear waste is little, the nuclear proliferation can be controlled, and the uranium utilization efficiency is high. The six types of rectors which are believed most to be used for the fourth generation are as follows: sodium-cooled fast neutron multiplication reactor (called as the fast reactor for short), lead-cooled fast reactor, gas-cooled fast reactor, super-high-temperature reactor, molten salt reactor and supercritical water reactor [1]. The independent research and development for the key material used for the nuclear power of the fourth generation will greatly support the nuclear power technology of next generation.

Three reactors in the six types of reactors of the fourth generation are fast reactors which cannot only use the nuclear energy for power generation but also can multiply the nuclear fuel and convert the uranium-238 which can generate nuclear fission into plutonium-239 which can generate nuclear fission, and also transmutes the nuclear waste of long half time generated by thermal reactor running, which is the necessary development process of the three steps (thermal reactor, fast reactor and fusion reactor) for using nuclear energy as well as the extremely significant step.

1 Fast Neutron Reactor Fuel Element Cladding Material

Austenite stainless steel has excellent high-temperature mechanical property, antioxidization performance and welding performance as well as outstanding compatibility with liquid metal sodium; thus, it is chosen as the fuel element cladding material of the fast reactor 930. When the fuel element cladding material works under the high-energy neutron radiation environment, the material performance will decrease, such as hardened material, decreased plasticity, increase of creep rate, etc., which is caused as follows: the vacancy concentration increases because of the radiation and then the vacancies mutually gather to form voids, and then macroscopic volume expansion, density decrease and radiation swelling are shown.

The fuel element cladding also contacts the liquid sodium of the cooling agent and the fission products (such as Cs, I, Te, Se, etc.,) and then is corroded and bears the stress generated by fuel swelling and fission gas expansion; thus, the anti-high-temperature creep performance of the cladding material is very important [2]. Under the high fluence rate fast neutron radiation environment, the main issue limiting the wide application of the Austenite stainless steel is its poor performance for resisting neutron radiation swelling. On the basis of the understanding of the radiation swelling phenomenon, some alloy design methods can be used for improving the neutron radiation swelling resistance of the Austenite stainless steel, including: (1) a little increase the nickel/chrome ratio, and simultaneously control the adding of trace alloy elements such as silicon which can limit the void and foreign matter compounds; (2) promote the precipitation caused by radiation and change the migration characteristic of the point defect; (3) add a little amount of titanium (mass fraction is lower than 1%), control the Ti/C ratio and increase the amount of the fine TiC precipitates because the interface between the fine TiC precipitates and the matrix can be the traps of the defect generated by radiation; (4) carry out a certain amount of cold processing deformation after the solution annealing treatment. Introduce dislocation into the microscopic structure to absorb the point defect generated by radiation and increase the traps absorbing the fission products; (5) add a little amount of phosphor to form the interface of the plate-shaped phosphide and the fcc Austenite matrix to be helpful for the nucleation of helium bubbles; thus, the voids caused by radiation can be absorbed. Indicated by above, the design idea of using one or a plurality types of alloy can improve the performance of the fast reactor fuel element cladding stainless steel material. As demanded by the fast reactor development, the fuel element cladding material is developed from 316 stainless steel to 15-15Ti stainless steel (15Cr-15Ni-Mo-Ti Austenite stainless steel, which is also called as D9 alloy). Based on 316 stainless steel, to the 15-15Ti stainless steel, the contents of titanium and silicon are controlled to be added, and also the chrome content is decreased, and the nickel content is increased [3]. Compared with the 316 stainless steel, the 15-15Ti stainless steel owns better resistance of neutron radiation swelling and creeping resistance (refer to Fig. 1, wherein dpa means the mean displacement times of each atom under the given fluence, i.e., displacement per atom) [4].

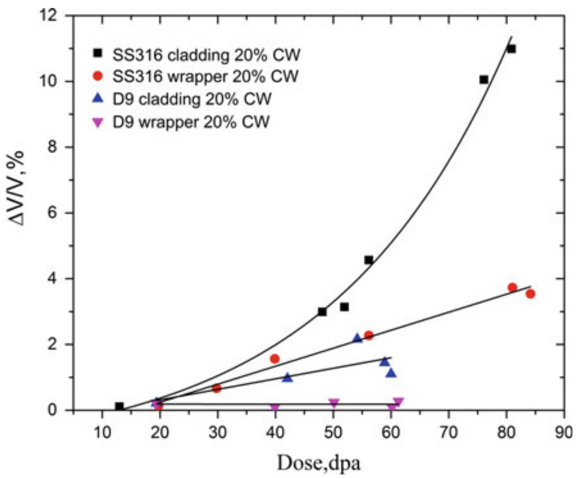


Fig. 1 Void swelling comparison between 316 stainless steel and 15-15Ti stainless steel during irradiation

2 Introduction of Grain Boundary Engineering (GBE) Technology

The grain boundary engineering (GBE) technology [5] may further improve the radiation swelling resistance of the Austenite stainless steel material on the basis of optimizing the material chemical ingredients, etc. Currently, in the fault energy face-centered cubic metal material (such as Austenite stainless steel, nickel-base alloy, etc.,) at the middle and lower layers, the study work on the GBE technology makes a great progress, and the mass production of the grain boundary of the low coincidence site lattice (CSL) in the crystallization process can be controlled and promoted by the deformation and thermal processing technology, wherein most of them are the crystal boundaries of the type of $\Sigma 3n$ (n = 1, 2, 3, …) of Σ3, Σ9 and Σ27 [6]. It needs to be explained that the low ΣCSL boundary means the CSL crystal boundary of $\Sigma \leq 29$. It is the reciprocal of the density of the grain lattice coincidence sites at both sides of the grain boundary.

Lin et al. [7] from Canada processed the nickel-base 600 alloy, and increased the low ΣCSL grain boundary from 37 to 71%, and decreased the corrosion rate of the material in the experiment of immersion corrosion of boiling ferric sulfate for 30–60%. The Canada company owning the technology patent has registered the GBE technology as the trademark GBETM. Lehockey et al. [8] carried out GBE processing to the lead alloy electrode plate of the lead acid battery, which increases the low ratio of theΣCSL grain boundary to be higher than 70%, and also the corrosion resistance is significantly improved, and the charging and discharging circulation times of the battery are increased for 13 times. The study results of Lehockey et al. [9] indicate after greatly increasing the low ΣCSL grain boundary ratio of the metal nickel, the stable creeping rate of the material is greatly decreased. Shimada et al. [10] from Japan increased the low ΣCSL grain boundary ratio of 304 stainless steel to be higher than 80%, and the intergranular corrosion rate is decreased for about 75%. Kumar et al. [10] from the USA established the method which predicts the material macro-performance by analyzing the grain boundary network microscopic structure, and formed patent technology. Indicated by the study results of Duh et al. [10] from Taiwan, China, to the 304 stainless steel after proton radiation, the lower the Σ value is, the less the chromium-depleted phenomenon at the CSL grain boundary will be. Sumantra et al. [10] from India studied the influence of the processing technology on the ratio and distribution of the special structure grain boundary of the 15-15Ti alloy. Besides, the data obtained in many laboratories also indicate the GBE technology can significantly increase performance between multiple low-layer fault enegery face-centered cubic metal material and the grain boundary.

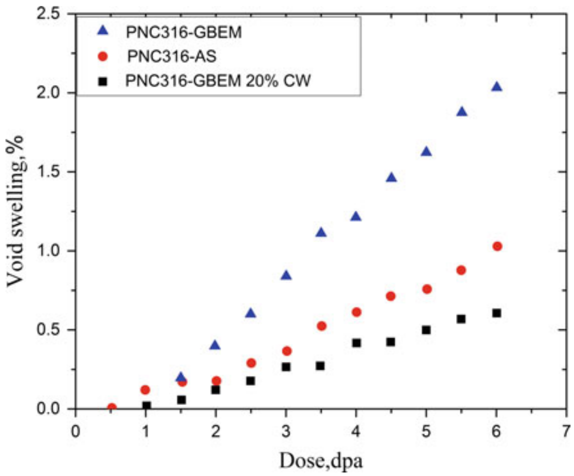
3 Feasibility of Using GBE Technology for Further Improving the Resistance of Fast Reactor Fuel Cladding Material for Radiation Swelling, Etc.

To the fast reactor fuel cladding pipe, about 20% of cold working deformation needs to be carried out after solution annealing processing no matter it is the 316 or 15-15Ti stainless steel pipe so as to introduce a great amount of dislocations in the microscopic structure to absorb the point defects generated by radiation and increase the traps for absorbing the fission products [11]. There is a special orientation relationship among the grains at both sides of the low ΣCSL grain boundary, when the material has plasticity deformation, the transmission of the slippage among grains and the accumulation of the dislocations at the grain boundary will be changed because of the special orientation relationship of the grain [12]. After the 20% cold working deformation, the arrangement and distribution of the dislocation of the material after GBE processing will be different from the material without GBE processing, and the characteristics of radiation swelling resistance will also be varied. Sekine et al. [13] studied the influence of the advanced GBE processing on the electron radiation swelling resistance of the 316 stainless steel after cold working (the experiment temperature is 550 °C). As shown in Fig. 2, the transverse coordinates are the electron radiation fluence, and the longitudinal coordinates are the swelling amount corresponding to the radiation. The sample GBEM means the material after GBE processing, the sample AS means the material without GBE technology processing but after the 20% cold working deformation, and the sample GBEM20%CW means after GBE technology processing and 20% cold working. The results show compared with the 316 stainless steel sample after the same 20% cold working but without GBE processing, the 316 stainless steel after GBE processing and 20% cold working has lower swelling rate after electron radiation. These studies show that the electron radiation and neutron radiation have good corresponding relationships with the influence on the material; thus, it is possible of using GBE technology for improving the neutron radiation swelling resistance of the Austenite stainless steel after cold working.

These studies indicate that compared with the common large-angle grain boundary, the size of the carbide precipitated from the low ΣCSL grain boundary is more finer and its distribution is more regular [14]. The interface between these precipitants and the matrix material is also the position absorbing the radiation defect; thus, the precipitation pattern, size and distribution of the second phase of the grain boundary can be influenced by increasing the low ratio of the ΣCSL grain boundary in the material, and also it influences the improvement of the radiation swelling resistance of the material.

When the sodium-cooled fast reactor fuel cladding runs at the higher temperature for a long time, the material generates creeping and radiation creeping under the together action of fuel swelling and the stress generated by the release of the gas fission products [2], the creeping resistance of the fuel element cladding material is also very crucial. To the Austenite stainless steel and the nickel-base alloy used in

Fig. 2 Effect of GBE treatment on the void swelling in 316 stainless steel during electron irradiation



the non-radiation environment, increasing the low ΣCSL grain boundary ratio of the material can effectively improve the high-temperature creeping resistance [9], which is mainly caused by follows: the orderliness of the low ΣCSL grain boundary structure increases its strength under the high temperature, the relative slippage tendency of the grains at both sides of the grain boundary is less, and the dislocation absorbs the point defect generated by the dislocation and then climb motion is generated; thus, the radiation creeping is generated. Because the layer fault energy of the Austenite stainless steel is low, and the dislocation climb motion is not easy, if the GBE technology processing is used for changing the dislocation distribution status to increase the capability for absorbing the void defects generated by radiation, then the radiation creeping resistance may also be increased.

Although the metal material in the body-centered cubic structure (such as the Martensite stainless steel) has better radiation swelling resistance than that of the Austenite stainless steel in the face-centered cubic structure, the strength of the metal material in the body-centered cubic structure at the high temperature is far lower than the metal material in the face-centered cubic structure. The nanometer oxide dispersion strengthened (ODS) steel has excellent stability and creeping resistance under the radiation environment, but its preparation technology is complex and there is still a long distance to actual application [15]. Thus, at present, it shall consider the GBE technology as follows: on the basis of the Austenite stainless steel used by the current fuel element cladding, the grain boundary in the special structure of the material and the dislocation distribution after deformation can be controlled to further improve the radiation swelling resistance and creeping resistance of the fast reactor fuel element cladding. The GBE technology does not need to adjust the chemical ingredients of the material; thus, there is no difference between the capability of the Austenite stainless steel after GBE technology processing with the high-temperature liquid sodium and fission products and the one of the Austenite stainless steel without GBE technology processing; thus, additional consideration can be saved. In addition, the intergranular corrosion resistance of the low ΣCSL grain boundary is better than that of the common large-angle grain boundary; thus, the intergranular corrosion of the inner wall of the fuel element cladding pipe caused by fission products can be significantly improved by increasing the low ratio of the ΣCSL grain boundary.

As discussed above, it is necessary of studying the GBE technology of the Austenite stainless steel (such as 316, 15-15Ti) pipe material for fast reactor fuel element cladding, and shall make the cladding pipe after GBE technology processing and 20% cold working deformation into fuel rods for the neutron radiation test to get the preparation technology of the Austenite stainless steel pipe for fast reactor fuel cladding with the independent intellectual properties.

4 Preliminary Results of Applying GBE Technology in the Fast Reactor Fuel Element Cladding Pipe

The study of GBE technology mainly focuses in the face-centered cubic metal material of the low-layer fault energy, and the low ratio of the ΣCSL grain boundary of the material is increased on the basis of forming the annealing crystal twin. Currently, there are mainly three technical lines as follows for the thin plate or the thin-wall pipe: (1) after the cold working deformation of 3–8%, anneal for a long time (10–100 h) under the condition of being close to the recrystallization temperature of the material [10]; (2) after the cold working deformation lower than 30%, anneal for a short time (3–60 min) under the condition of being higher than the recrystallization temperature of the material, and repeate the technology for 3 to times [10]; (3) carry out short time recrystallization and annealing after the cold working deformation of 5–10% at a relatively high temperature (it is equal to the solution processing temperature to the nickel-base alloy and Austenite stainless steel) [16]. These technologies have the advantage that the ratio of the ΣCSL grain boundary of the material can be greatly increased and multiple types of performance of the material relevant to the grain boundary can be improved by only adjusting the cold working deformation and thermal processing way without changing the material ingredients; however, the first technology needs the annealing of a long time, which is not helpful for the cost control of industrial production; the second technology needs repeated cold working and annealing, the technology is complex and cannot be easily controlled in industrial production; but the third technology is not only simple and can be easily realized, but also its annealing temperature is consistent with the solution processing temperature, and it can be linked up with the solution processing technology used in the current production of the nickel-base alloy and the Austenite stainless steel.

The third technology is used for GBE processing to 15-15 Ti Austenite stainless steel, and the grain boundary distribution graphs of different types are obtained by using the test of the electron backscatter diffraction technology. The material after

GBE processing contains many annealing crystal twins (Σ3 grain boundary) and its derivative multiple crystal twins (Σ9 and Σ27 grain boundaries), and they are connected mutually to form a great quantity of Σ3n type triple junction grain boundaries (such as Σ3-Σ3-Σ9 and Σ3-Σ9-Σ27 grain boundary) and also the grain boundary network distribution which is characterized in the large-size microscopic structure with clusters of grains with mutual Σ3*n* orientation relationship [17]. All grains have the Σ3 orientation difference relationship no matter they are adjacent or not, and the grain clusters are basically composed of random grain boundaries. The general low ratio of the ΣCSL grain boundary can be higher than 70% (72.3%). The mean grain size obtained by the equivalent circle diameter method is about 9 μm; thus, GBE processing can be carried out on the 15-15Ti Austenite stainless steel material.

The processing of GBE technology can be realized by only a little adjusting the technology flow for producing the nickel-base alloy and the Austenite stainless steel, and the low ratio of the ΣCSL grain boundary of the Austenite stainless steel can be greatly increased. In the process of combining with the actual industrialized production, it needs to consider if the selected technical parameters match the actual production condition and the requirement of the finished material, and also the grain size, the second phase precipitates of the carbide, the material structure status and other original microscopic structure of the material before GBE processing shall also be considered [18]. These original microscopic structure statuses not only influence the network distribution, grain size, etc., after GBE processing, but also can control the final distribution of the grain boundary characteristics, the grain size and other microscopic structure characteristics of the material by adjusting the original microscopic structure status to match the technical parameters of GBE processing.

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Research on Detection of Environmental Factors Based on IOT Technology

Qing Liu, Pinggen Wang and Jiatai Chen

Abstract The "man," "machine," and "environment" can be seen as the three elements of the man-machine-environment system engineering (MMESE). And the "environment" refers to the special conditions of people and machines (or computers), which includes both physical and social factors. The man-machine-environment system constitutes a very complex super giant system through the information transmission, information processing, and information control between three elements above. Consequently, the detection of environmental parameter plays a critical role in MMESE; in particular, the emergence of the Internet of things (IOT) technology makes the environmental factor detection development intelligent and quantitative. In our paper, we propose a design scheme of intelligent detection of environmental factors based on the IOT technology and embedded computer technology. The design of hardware circuit is integrated by the Cortex A8 chip module equipped with CC2530 wireless sensor module and the corresponding peripheral circuits, which also comprises 5 sensor nodes used to sensing environment parameters. The terminal node makes up the Zigbee wireless sensor network with coordinator node by means of star topology. And the collected data are transformed to central control gateway. Debugging through the integrated editing software IAR and visual interface designing by QT creator software within virtual machine VMware, finally we achieve intelligent detection and control of environmental factors.

Keywords IOT · Embedded system · Environmental factor · Intelligent detection · Sensor nodes

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1 Introduction

The man-machine-environment system engineering (MMESE) [1, 2] is a technique of system science and system engineering and is an academic discipline of comprehensive study on the optimal combination of man-machine-environment system, which can correctly handle the relationship between three elements human, machine, and environment. Under the guidance of the famous scientist and academician Qian Xuesen at 1981, the man-machine-environment system engineering was emerged in China and it was a comprehensive science of boundary technology. The so-called environment, which includes the influence of both physical and social factors, refers to the special conditions of people and machines (or computers). The MMESE regards the “man,” “machine,” and “environment” as the three main elements of the system, which forms a very complex super giant system by means of information transmission, information processing, and information control between the three factors above. Obviously, for any system, the total performance of the system depends not only on the individual performance of each component but also mostly on the correlation format of the three elements of the system that is on the means of information transmission, information processing, and information control.

Consequently, “environment” refers to the specific production or working conditions (such as temperature, humidity, noise, smoke, gas concentration, and vibration), which affects the management objectives of system “safe, efficient, and economic.”

In recent years, many scholars have devoted a lot of work to the monitoring of environmental factors. Especially, the emergence of the IOT technology leads to the trend of automation and intelligent coming about the environmental parameter detection. For examples, the author HE [3] designed a distributed environment monitoring system, which based on STM32 and CAN to solve the problems about the environmental management system of coal mine, but that system was complex and the monitoring points were scattered. Ji [4] used MCU ATmage16L and RF module XBee to establish a kind of design proposal for agricultural environment remote monitoring of wireless star-shaped sensor network based on ZigBee technology. And the system was implemented to meet the demand of real-time monitoring system of crop planting environment by monitoring temperature, humidity, illumination, and other information. Gao [5] proposed the design of environment monitoring system based on ZigBee wireless sensor networks to monitor the environment temperature and gas smoke, which consists of a sensor node and a coordinator node. The result is displayed by the coordinator transmitted to a PC. Cai [6] discussed the wireless sensor network nodes used low-power processors, Atmel ATmega1281 and AT86RF231 RF chip, eventually achieving a low cost, low complexity detection system, which can real-time detect environmental factors such as temperature and humidity. Dong [7] combined the IOT and environmental monitoring closely to construct a comprehensive, multi-level, and intelligent monitoring system based on the all-weather coverage. That system can monitor the main environmental factors, the main areas, key watersheds, and water quality standards for pollutants and so master the environmental quality status and trends. Wang [8] designed the wireless sensor network system for data acquisition with ultralow-power ATmega8 and SZOS wireless communication module as well as some environmental factor detection sensors. The network collected temperature, humidity, illumination, carbon dioxide, and acoustic emission (AE), which reflect the disease status of the crops, and transmitted through wireless way to the PC monitoring center on time. Liu [9] relied on the embedded Linux, ZigBee short-range communication, WEB server, RFID, and other related technologies, which realizes the remote monitoring and centralized management for the underground environment data. Then, the system can complete the positioning and tracking of the underground staff through the RFID technology.

The above studies have achieved certain results, but the numbers of sensor nodes are less; at the same time, the software system for analysis is few. Therefore, this paper puts forward research and design of real-time environmental factor monitoring system based on IOT and embedded system technology to solve the problem of environmental information. The rest of the paper is organized as follows. In Sect. 2, we provide a brief review of IOT and embedded system technology in the information domain. In Sect. 3, we propose a novel environment factors detection system using embedded system technology and IOT technologies. Section 4 presents our conclusion and analysis.

2 Related Technologies

2.1 IOT Technology

IBM Company puts forward the wisdom of the earth strategy for the U.S. Government at year 2008. In 2009 and in 2010, the European Commission proposed the EU action plan for the IOT, which clearly propose the research route and key research areas of the IOT. In 2009, the Chinese Government presents the concept of perception of China. And in 2010–2012, two sessions work report pointed out the striving to the development of the IOT industry. Furthermore, ministry of industry and information technology in 2012 released the IOT “in 12th Five-Year” development plan, which declared that constructing of intelligent environment monitoring system based on Internet of things, improving the level of modernization of environmental regulation, and promoting the construction of environmental information were the key current tasks of environmental protection.

2.2 Embedded System

An embedded system is a small system for controlling or monitoring large-scale equipment such as machines, devices, and factories. That is, its core is application, its basic is computer technology, its hardware and software can be cut, and so it is a special computer system that can meet the requirements of application system, such as function, reliability, cost, volume, and power consumption. The core of embedded system consists of hardware layer, middle layer, system software layer, and application software layer. With the improvement of real-time requirements and software scale rising, real-time kernel has been developed into a real-time multi-task operating system (RTOS). As a software platform, it has gradually become the mainstream of the international embedded system.

3 Environmental Factor Detection System Architecture

3.1 Environment Factor Detection Hardware System

This paper studies the construction of the system to complete the temperature and humidity, light, smoke, flame, combustible gas, and other environmental parameters monitoring. The collected data are uploaded to the central monitoring center through wireless sensor nodes and then provided an effective basis for intelligent security decisions. The system is an integrated system, which integrates the technology of IOT, embedded system, sensor, computer, and so on. Figure 1 shows the hardware architecture of the system.

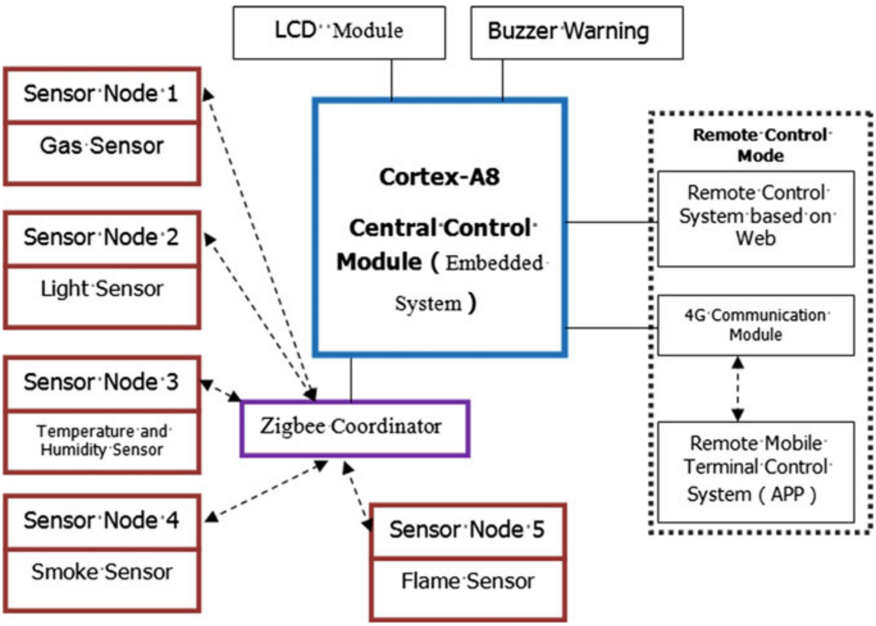

Fig. 1 Hardware architecture of environment detection system

As shown in Fig. 1, the system is composed of central control module, Zigbee coordinator, 5 terminal nodes, and remote control module. Inside the central control system is the core control system, which mainly composed of Cortex-A8 embedded gateway, Zigbee Coordinator, and whose function is data processing and controlling.

The physical structure of the control system is shown in Fig. 2, and A8 embedded gateway is the control center of the whole environment parameter detection system. It is equipped with 7-in. resistive touch display integrated screen, through which can control all the devices of the whole system. It has a friendly man–machine interface UI, and it is the information convergence center of all Zigbee nodes and the forwarding center of Internet data, in whose interior a small Web server was built, and enabling which supports the remote internet access.

The Zigbee coordinator connects with the A8 embedded gateway through the USB interface to realize data communication. Its function is to build Zigbee network and combine all the Zigbee nodes in the home together. It will forward the data uploaded to each node to the A8 embedded gateway; at the same time, all the instructions are received by the embedded gateway and forwarded to the corresponding Zigbee node, and finally completed the data transmission of Zigbee data layer.

There are 5 kinds of environmental factor detection sensors in our system, that is ambient temperature and humidity sensor, light sensor, smoke sensor, flame sensor,

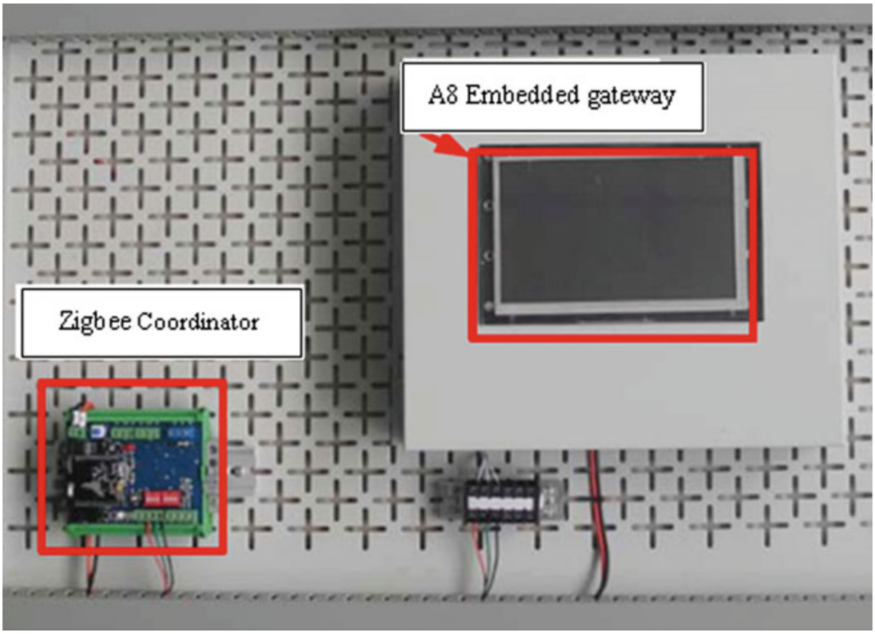

Fig. 2 Central control system

and combustible gas sensor. It is equipped with 5 wireless sensor modules or 5 terminal nodes, which collected, respectively, indoor illumination, temperature and humidity, smoke information, combustible gas information, and flame information. The information collection node can be set to the two state of arm or disarm; in the arm state, the central controller would send alarm information to the preset alarm user and the control node sends out alarm sound simultaneously when abnormal information was detected. Thereby the system achieved the functions of security monitoring as shown in Fig. 3.

The wireless sensor module used by the coordination node and terminal node is CC2530, which was the second-generation production of the 802.15.4/Zigbee in the 2.4 GHz band to support the IEEE chip system by TI company. As shown in Fig. 4,

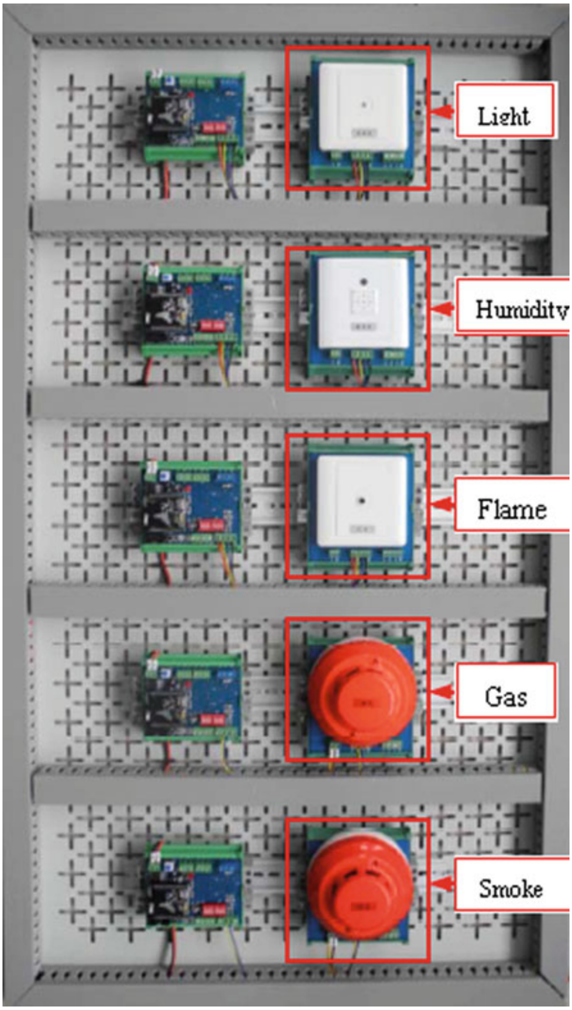

Fig. 3 Environmental parameter detection module

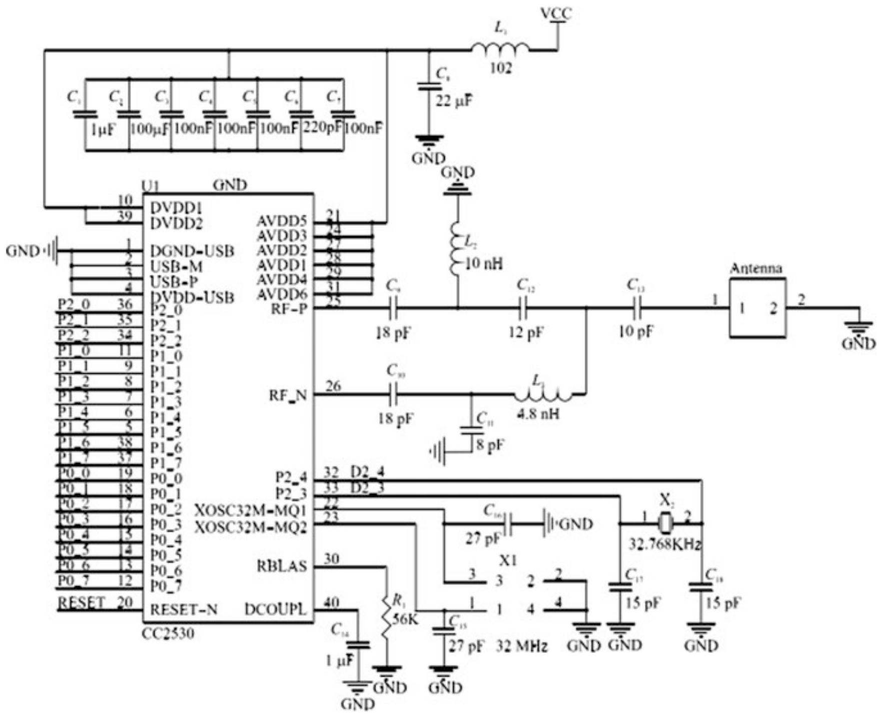

Fig. 4 The modular structure of CC2530

there is a data communication link between terminal sensor node and coordinator node, ZigBee network, which can be made up of three network topologies: star, tree, and mesh type. Because of the advantages of simple and convenient structure about star type, that is, it does not need routing, it can realize the independent power supply on the terminal node and realize the complete wireless network. Therefore, this paper studies the environmental parameters detection system to select the star WSN network topology.

3.2 Environment Factor Detection Software Design Flow

The software design mainly includes three parts: software design of embedded gateway system, coordinator node, and terminal sensor node. The hardware circuit of the embedded gateway connected USB port and PC through the CAN port, and the required application code was edited and debugged in the VMware player environment of the host computer after the system was written on the tablet and then through the serial port to download and run the code. Visual operation code was edited and debugged by QT creator software.

In fact, the core of the Zigbee node is a 8051 core microcontroller, whose software development environment was IAR Embedded Workbench. Of course, IAR Embedded Workbench also needs to cooperate with the ZigBee node debugger to complete the program download, debugging, etc. Figure 5 represents, respectively, the software design flow chart of the coordinator node and sensor node.

As shown in Fig. 6, the visual interactive interface of the gateway mainly composed of sensor data processing and display, node management, security

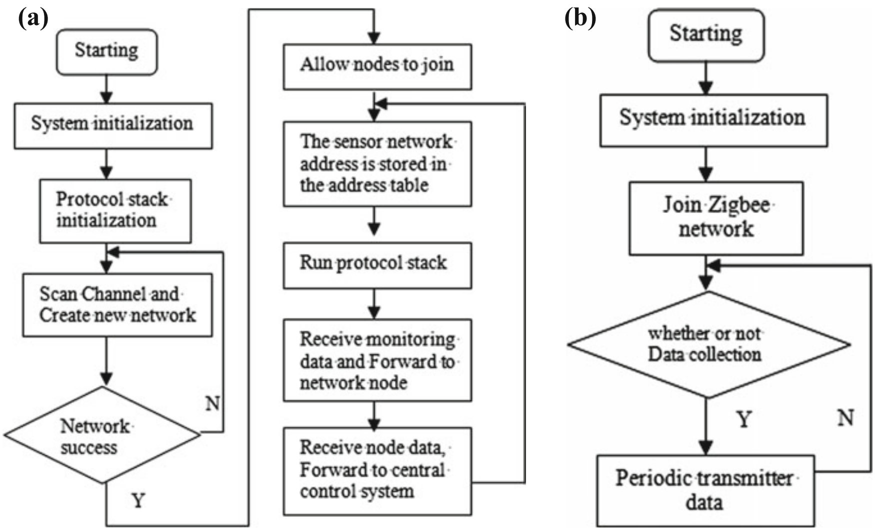

Fig. 5 **a** Flowchart of coordinator. **b** Flowchart of sensor node

Fig. 6 Visual interactive interface of central control gateway

settings, alarm settings, and other modules. By graphical button operation, the utility model can realize the functions of temperature and humidity, illumination, fire, combustible gas and smoke data display, processing and preservation; in addition, voice alarm settings can also be set when the environment factor exceeds the preset value.

4 Conclusions

In this paper, the environmental factor detection system is based on Cortex-A8, CC2530 chip, design of ZigBee wireless network, which complete the wireless monitoring of the temperature and humidity, combustible gas, smoke concentration, flame, and light in the environment. This system can provide a viable solution for remote monitoring and control of the environment. The next step will be to study the multi-node network mode in order to find an effective way of data transmission in wireless sensor networks.

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Research on Ventilation Antivirus Technology in a Washing Board Room Based on Numerical Simulation

Shasha Liang, Jianwu Chen, Bin Yang, Menglu Lin, Lindong Liu and Tingting Zhang

Abstract The concentration of toxic substances in the electronics industry washing board room exceeds the standard seriously, and it is due to the lack of effective ventilation protection technology. This article takes one electronics industry washing board room as the research object, and based on the software such as FLUENT, the problems existing in the original ventilation facilities are simulated and analyzed. This paper presents a method of calculating the airflow uniform ventilation type and the existing problems. The influence of *K* value on the push–pull ventilating system and the effect of toluene protection were studied by using simulation method, and when the *K* value is 2.5, the protection effect is the best and the electronics industry washing board room that has the effective toxic hazards protection has a good guiding significance.

Keywords Uniform flow · Push–pull ventilation · Washing board room · Ventilation and protection technology

1 Introduction

Screen printing is an important process of the current electronic components production. Normally, the printing baseplates need to be washed by manual cleaning with plate washing water [1]. As the plate washing water contains a large amount of organic solvents, workers are exposed to toxic concentration far above the national

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limit in a short period, increasing the risk of occupational diseases and acute poisoning. But nowadays, the bad influence of plate washing water on workers' occupational health has not yet attracted enough attention [2].

As the scrubbing space is small, the printing baseplate is large and some other problems also exist in manual washing; these all make it difficult to protect from the toxic hazards in washing plate effectively. This paper uses simulation analysis technology and puts forward the effective antivirus ventilation technology on the basis of analyzing the ventilation and antivirus facilities in the washing plate room.

2 Numerical Simulation and Analysis of the Existing Antivirus Ventilation Facilities in a Washing Plate Room

2.1 The Present Situation of Antivirus Ventilation Facilities in a Washing Plate Room

This washing plate room is equipped with upper air supply and axial flow fan exhaust ventilation system, as shown in Fig. 1.

2.2 Numerical Simulation Analysis of the Existing Antivirus Ventilation Facilities

Ignoring the airflow's interference in washing plate room, according to the actual size of washing plate room and the sizes of air supply and exhaust facilities, this paper uses GAMBIT to build the mathematical model. The airflow in washing plate room is turbulence, the wind speed in air supply outlet is 3.75 m/s, and the diameter

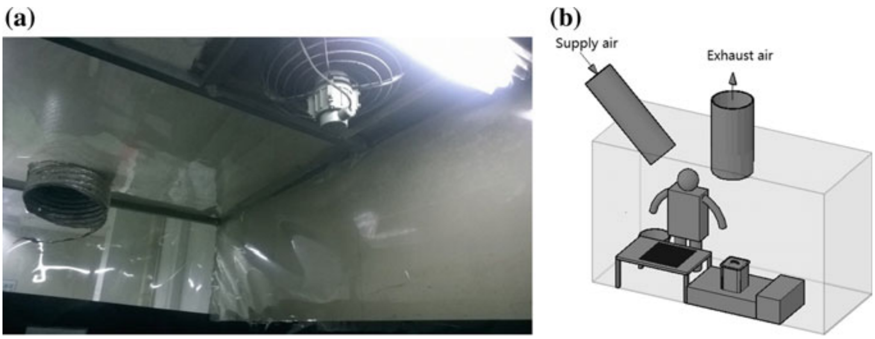


Fig. 1 Local ventilation system

of the air supply duct is 300 mm. The diameter of the air exhaust outlet is 3.53 m/s, and the diameter of the air exhaust duct is 400 m. According to the turbulence model ($k - \varepsilon$ double equation model), contours of velocity magnitude of different interface (as shown in Fig. 2) are simulated and calculated by using FLUENT; the wind speed unit is m/s.

It can be seen from Fig. 2 that the air supply effect of existing antivirus ventilation facilities is markedly strong, the airflow hits the left bottom corner and the wall and then rebound to the top of workshop area, and part of the airflow exhausts from outlet. Vortex regions are formed at the top and right area in workshop area. The airflow in the whole washing plate room is comparatively disordered.

In order to make further research on the problems of the existing antivirus ventilation facilities, based on the above model, a toluene source is added on the print baseplate. The diffusion rate of toluene is set to 0.5 m/s, and the mass fraction of toluene is calculated by FLUENT, as shown in Fig. 3.

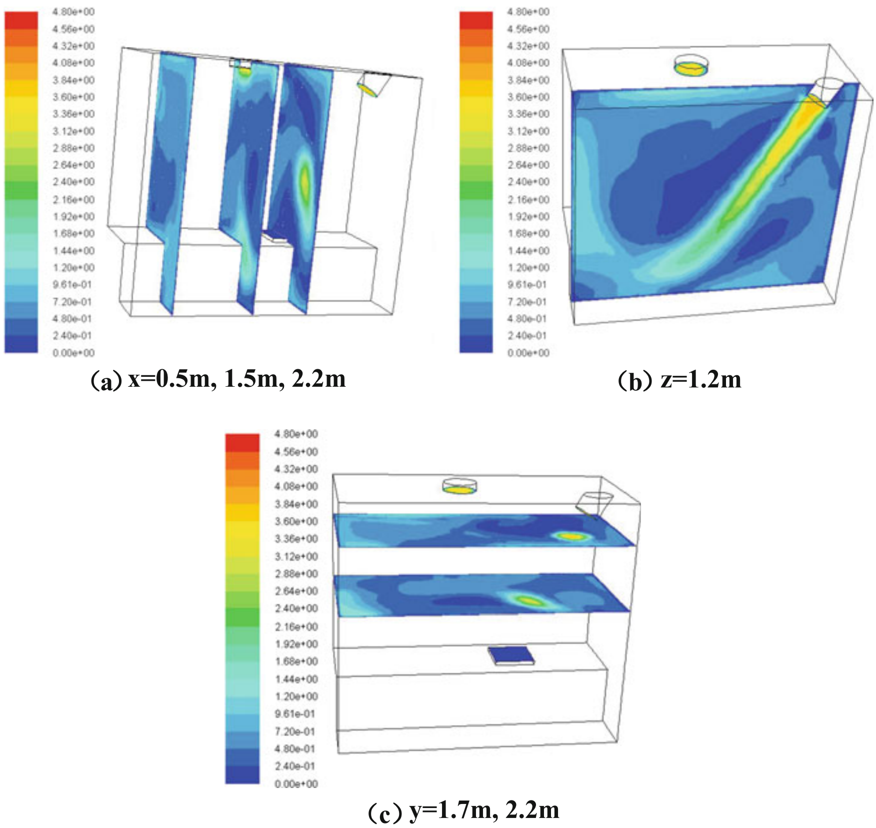
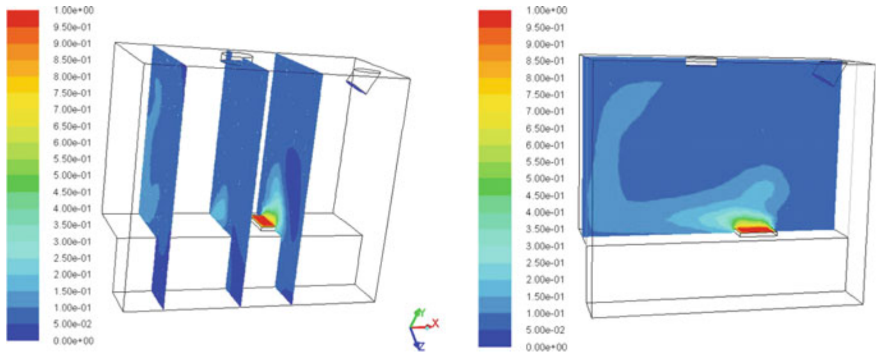


Fig. 2 Velocity magnitude in different interface



(a) x=0.5m, 1.5m, 2.2m (b) z=0.45m

Fig. 3 Mass fraction of toluene

Figures 2 and 3 show that toluene is blown away by wind. There is high toluene concentration in the top and left of washing plate because of the vortex, which leads the concentration of toluene to exceed the standard seriously. This illustrates that the existing antivirus ventilation facilities in washing plate room cannot achieve the desired effect and cannot meet the demand for toluene protection.

3 Study on Antivirus Ventilation Technology in Washing Plate Room

3.1 The Selection of Antivirus Ventilation Mode and Calculation Model

The working space of this washing plate room is narrow (the length, width and height are, respectively, 2.5, 1.5 and 2.5 m.), and the workpiece is large (both the length and width of printing baseplate are 0.8 m) which block the airflow movement. The airflow is influenced strongly in washing process, and ventilation facilities cannot make differences when workers are operating [3]. Due to the above reasons, this washing plate room is suitable for horizontal uniform airflow blowing–suction ventilation system. Because the air supply outlet and exhaust outlet of this blowing–suction ventilation should not be less than the size of workpiece, the size of air supply outlet and exhaust outlet is set to 0.95 m long × 0.95 m wide. Referring to the size of printing baseplate and washing plate room, the table size is set to 3.5 m long × 0.95 m wide. The size of toluene source on the printing baseplate is set to 0.7 m long × 0.7 m wide, and the toluene diffusion rate is set to 0.5 m/s. The calculation model of the blowing–suction ventilation system is shown in Fig. 4.

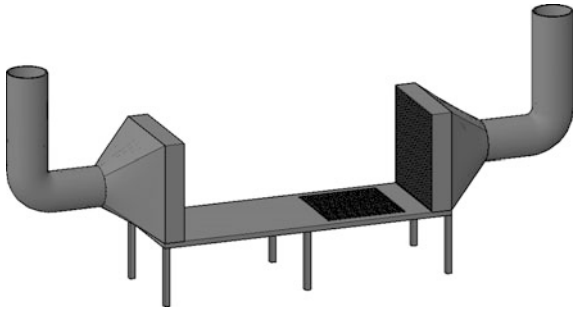


Fig. 4 Push–pull ventilation system

3.2 *Calculation Method of Blowing–Suction Ventilation System*

The uniform airflow blowing–suction ventilation system is calculated by the flow ratio method which is proposed by Japanese Bayashi Taro [4]. In this calculation method, the wind speed coming out from the uniform airflow hood is usually set to 0.5 m/s, so the wind speed of air hood in this washing plate is also set to 0.5 m/s.

Air supply volume = $V \cdot A = 0.5 \cdot A$
Among them, Q_1 is the air volume of air supply hood and the unit is m^3/s;

A is the area of air supply hood and the unit is m^2.

Air exhaust volume = $Q_2 = K \cdot Q_1$
Among them, Q_1 is the air volume of air supply hood and the unit is m^3/s;

Q_2 is the air volume of air exhaust hood and the unit is m^3/s;
K air supply volume/air exhaust volume and that is flow ratio.

The size of both air supply hood and air exhaust hood is 0.7 m × 0.7 m. The Design Standard and Management Manual for Local Exhaust and Blowing-Suction Ventilation Device, written by Iwasaki, puts forward the flowing standards [5].

(1) When the distance between blowing hood and suction hood is less than 4–5 times the short edge or diameter of air supply hood, K = 1–3.
(2) When the distance between blowing hood and suction hood is more than 4–5 times the short edge or diameter of air supply hood, K = 2–5.

It is difficult to select the appropriate K value according to experience when the distance between blowing hood and suction hood is 5 times longer than air supply hood length. Therefore, this paper uses FLUENT to simulate the antivirus ventilation effect in washing plate with different K values.

3.3 *Effect of* K *Value on Airflow*

In this paper, we simulate and analyze the airflow organization and poison control in this washing plate room when *K* takes different values (1.7, 1.9, 2.1, 2.3, 2.5, 2.7).

In the case of no pollution source, the wind speed distribution is simulated when *K* takes different values, and the wind speed distribution of the blowing–suction ventilation system in this washing plate room is shown in Fig. 5.

It can be seen from Fig. 5 that the wind speed of the exhaust hood increases gradually with the increase in the *K* value, the suction velocity is faster, and the airflow between blowing hood and suction hood is more uniform. The appropriate *K* value means when *K* takes this value, the concentration of toluene in respiratory

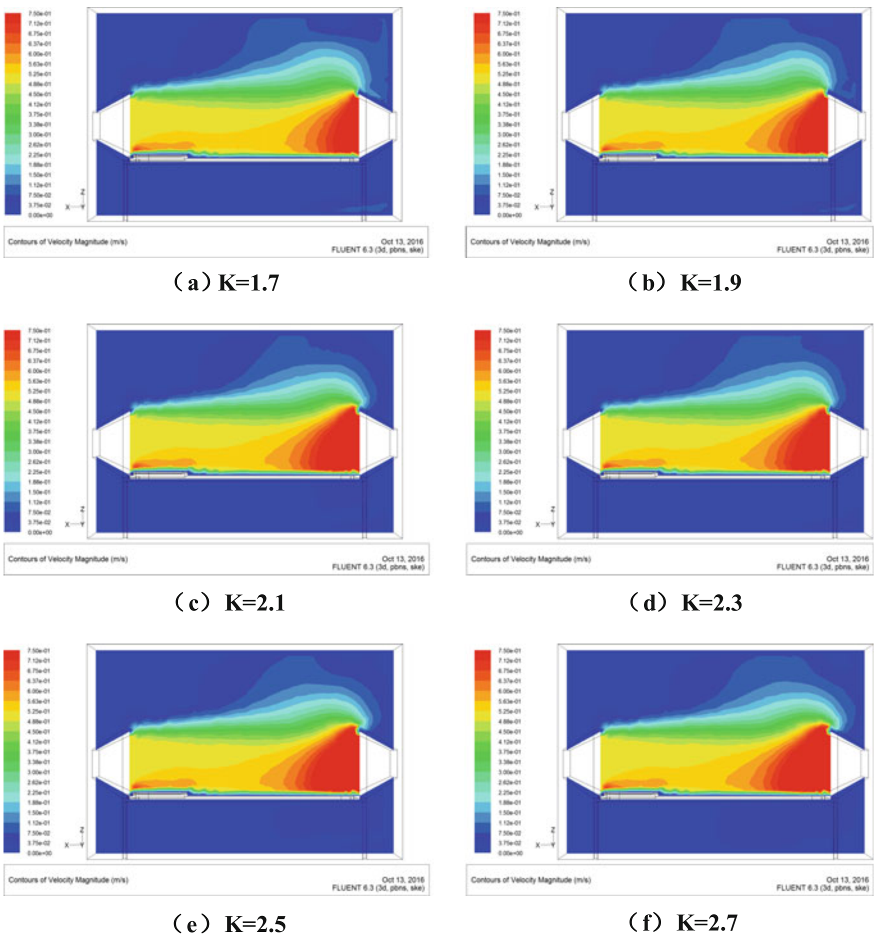


Fig. 5 Velocity magnitude of different *K* values

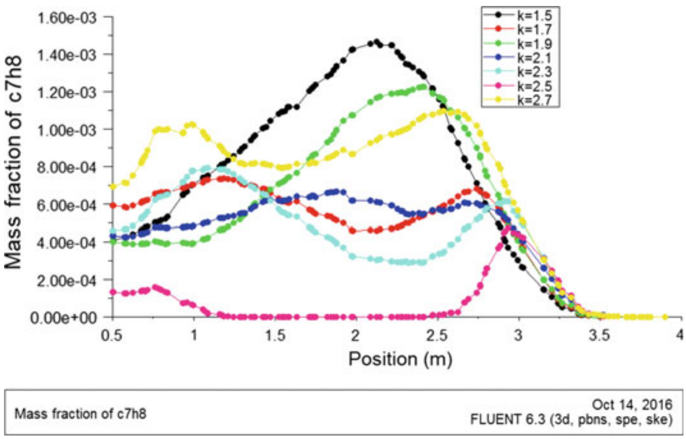


Fig. 6 Concentration profile of toluene at different *K* values

zone is the lowest, but it is difficult to determine it just according to the counters of velocity magnitude. Therefore, a toluene pollution source is added in the blowing–suction ventilation system. The appropriate *K* value can be determined by comparing the toluene concentration.

3.4 *Effect of* K *Value on Toluene Concentration*

In combination with the above models, a 0.7-m-long × 0.7-m-wide toluene source is set on the printing baseplate and FLUENT software is used for the simulation analysis. When *K* takes different values, the volume fraction distribution of toluene on the exhaust hood centerline at 1.5 m height (human respiratory band position) is shown in Fig. 6.

It can be seen from Fig. 6 that when $K < 2.5$, the volume fraction of toluene decreases with the increase in *K* value and the volume fraction decreases to a minimum at $K = 2.5$, while the volume fraction of toluene increases when $K = 2.7$. Then, simulation results show that when $K = 2.5$, the toluene can be controlled effectively. That is, the appropriate *K* value of washing plate room is 2.5.

4 Conclusions

This paper carries out numerical simulation analysis on the existing antivirus ventilation facilities of washing plate room and puts forward the problems of the existing ventilation system about toxic hazards protection. Then, a horizontal uniform airflow blowing–suction ventilation system is designed and a mathematical model is established. By using the numerical simulation, it is determined that when the *K* value is 2.5, the protective effect is the best. This paper provides an introduction for the electronics industry washing plate room on toxic hazard protection.

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The Research on Installation Test of Special Vehicle Temperature-Controlled Seats

Yaofeng He, Yuping luo, Haiyan Niu, Qingchang Chen, Yonggang Sun, Jianxing Bu, Guansheng Huang and Yajuan Bai

Abstract *Purpose* To provide technology support for the temperature-controlled seats installation and application in special vehicle. *Object and Method* The temperature-controlled seats cooling and heating effectiveness are analyzed and evaluated by testing the temperature of backrest and cushion. *Results* (1) Starting the seat when the test circumstances temperature is 12.2 °C, it tends to balance 8 min later and then continues to go up to 27.5 °C, and the cushion temperature can reach 26.6 °C maximum. (2) Starting the seat when the test circumstances temperature is 15.9 °C, it tends to balance 19 min later and then continues to go down to 17.0 °C maximum. The cushion temperature tends to balance 27 min later, and it can further go down to 18.4 °C maximum. *Conclusion* Vehicle test examination has proved the temperature-controlled seats have a good effect, and it can meet the operation requirement in high- and low-temperature circumstances and enhance operator's continuous working capability effectively.

Keywords Temperature-controlled seat · Special vehicle · Temperature-controlled effect

1 Preface

In the hot and cold environments, the temperature environment in the special vehicle, especially to the vehicle without air conditioner, is bad, which seriously affects the physical health and continuous working capability of the crews. The cooling and heating technology based on semiconductor is adopted to quickly and effectively control the temperature environment near the crews and effectively solve the problem of cold and hot protection for crews [1, 2].

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The cooling heating effect of temperature-controlled seat is analyzed and evaluated through temperature-controlled seat installation in special vehicle to provide technical support for the temperature-controlled seats installation and application in special vehicle, thus obviously improving the continuous working capability of crews.

2 Object and Method

2.1 Test Equipment

Special vehicle: 1 vehicle; temperature-controlled seat: 1 set.

2.2 Instrument and Equipment

See Table 1 for the test instrument and equipment.

2.3 Test Steps and Method

2.3.1 Test Method

The temperature sensors are set in the temperature-controlled system to record the temperature of the measure points at real time.

Ten sensors are installed at the measuring positions shown in Figs. 1 and 2, and the sensor shall be closely contacted with the measuring surface.

2.3.2 Test Steps

(1) Preparation before test

The temperature-controlled system is installed according to the coordinated technical requirements, checking the functions of the system to ensure that the system works normally.

Table 1 Test equipment

Equipment	Model	Number	Made in
Temperature sensor	DS1922L-F5	10	Domestic
Temperature and humidity tester	HMI41	1	Denmark

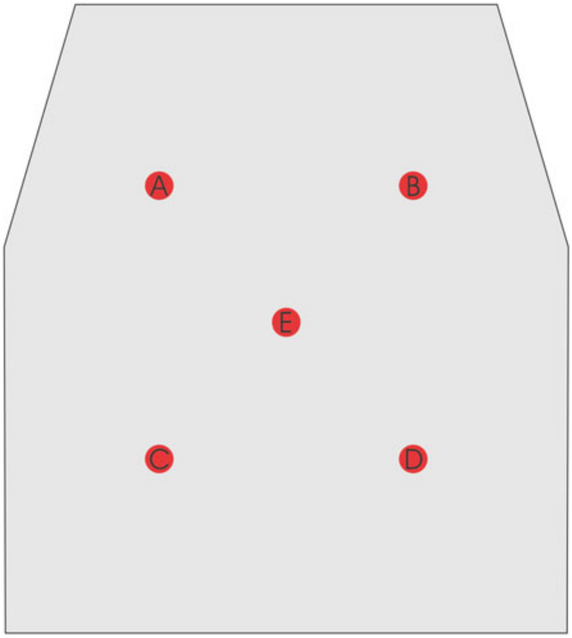

Fig. 1 Distribution of backrest measure point

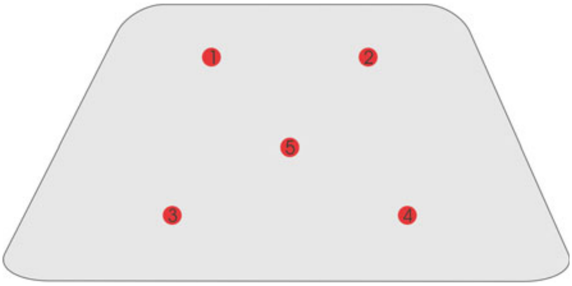

Fig. 2 Distribution of cushion measure point

(2) Installation and debugging of test system

The temperature sensors are installed according to the test guidance requirements, debugging the test system to ensure that the system works normally.

(3) Driving test

The driving test according to the regulated pavement and vehicle speed was conducted. The continuous driving time is 2 h, where the first hour is for temperature rise test, and the second hour is for temperature drop test; the temperature at the measure points of the temperature-controlled system is acquired at real time.

Table 2 Maximum temperature difference of each measure point and temperature balance time

		Heating-up		Cooling	
		Maximum temperature difference (°C)	Temperature balance time (min)	Maximum temperature difference (°C)	Temperature balance time (min)
Backrest	A	25.7	8	15.9	20
	B	28.5	7	17.6	19
	C	28.9	7.7	17.6	19
	D	25.5	8.2	15.6	19
	E	28.9	7.8	18.1	20
	Average	27.5	7.7	17.0	19.4
Cushion	1	26.5	8.1	18.1	29
	2	27.0	7.8	19.1	26.3
	3	25.5	7.3	18.1	25
	4	28.9	7.1	18.1	25
	5	25.3	8	18.5	29
	Average	26.6	7.7	18.4	26.9

3 Results

3.1 Temperature Test Results

The test is conducted for 2 h; refer to Table 2 for the maximum temperature difference and the time of reaching balanced temperature at the measure points in the backrest and cushion of the temperature-controlled seat. See Figs. 3 and 4 for the temperature change curve at backrest measure point E and cushion measure point 5.

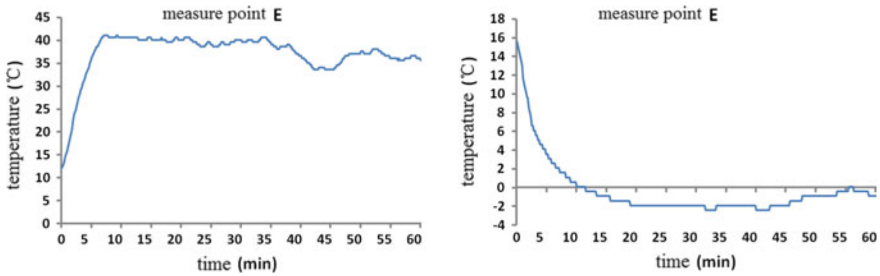

Fig. 3 Temperature versus time curve of measure point E (heating-up/cooling)

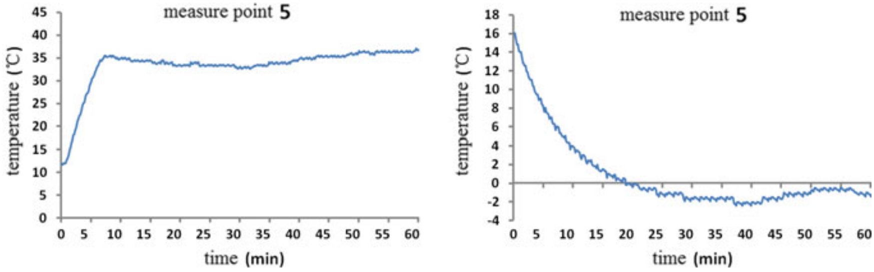

Fig. 4 Temperature versus time curve of measure point 5 (heating-up/cooling)

4 Discussion

When the environment temperature is 12.2 °C, starting the temperature-controlled seat, it tends to balance within about 8 min, and as time prolongs, the temperature still goes up, the backrest temperature of the temperature-controlled seat goes up to about 27.5 °C maximum, and cushion temperature of temperature-controlled seat goes up to about 26.6 °C maximum. When the environment temperature is 15.9 °C, starting the temperature-controlled seat, the backrest of temperature-controlled seat tends to balance within about 19 min, goes down to about 17.0 °C maximum, and the cushion of temperature-controlled seat tends to balance within about 27 min and goes down to about 18.4 °C maximum.

Due to the constraint of test condition, the environment temperature is not very ideal, and the performance of the temperature-controlled seat is not completely shown. However, viewing from the test results, the temperature rise/drop effect of the temperature-controlled seat is very obvious. In addition, compared with air conditioner and liquid cooling suit, the temperature-controlled seat features low power, no occupation vehicle space, and without wearing, and boasts very good value in promotion and application [3–5].

5 Conclusion

After the actual vehicle test, the temperature-controlled seat features very good effect and is capable of perfectly meeting the demands of using under high-temperature and extremely cold conditions of special vehicle and can effectively improve the continuous working capability of crews.

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The Measurement and Analysis of the Inside Noise Field Formed by a Special Vehicle

Yuping Luo, Ruiping Niu, Yajuan Bai, Yaofeng He, Qingchang Chen and Longtang Xu

Abstract Noise is one of the basic characteristic signals of vehicle. When the vehicle works, the noise forms two noise fields which are inside or outside of vehicle. The analysis of noise field has very important realistic meaning to vehicle. The noise inside the vehicle is an important realm content that influences personnel. In the noise reduction design, noise source identification is the primary work of noise control. Now the experimental data of special vehicle noise synthesizing field are very limited. According to this, in this paper, the typical special vehicle is taken as the object of study, and the spectrum characteristics of the noise inside the vehicle are analyzed by experiments. The results show that the noise inside comes from motive and activity.

Keywords Sound pressure level · 1/3 octave · A-weighed · Background noise · Steady noise

Preface

In accordance with the requirements listed in relevant standards [1], the allowed noise level of daily continuous exposure 8 h is 85 dB(A), which can protect over 90% personnel from hearing damage. It will cause organic disease of hearing organ and result in hearing damage after long-term exposure in the environment with noise over 85 dB(A) [2]. When driving the special vehicle, the noise intensity inside vehicle is about 110 dB(A), which exceeds the allowed noise standard. Therefore, measures shall be taken to drop the noise level inside vehicle. The reason for the high noise inside vehicle is because vehicle is one complicated structure with several noise sources and complicated sound transmission route. When the doors and windows are closed, the inside vehicle forms one closed cavity and sound reflects repeatedly in the vehicle and forms the reverberation sound field, which

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increases the sound pressure level inside vehicle [3, 4]. The sound field characteristic has close relation with the vehicle structure, working state and working environment. Taking the working state as an example, the gear, rotating speed of engine and driving speed may directly influence the sound field. In order to research the influence of the above factors on the vehicle sound field, a typical special vehicle is taken as the object of study, and the spectrum characteristics of the noise inside the vehicle are analyzed by experiments.

1 Tested Object

The tested object is a certain model of special vehicle, engine compartment is at the right front part of the vehicle body, the driving cabin is at the left side of the engine compartment, and the working cabin is at middle of the vehicle body.

2 Test Site

The straightaway is selected as the actual test road. The length is about 1000 m. The pavement is the smooth, straight, dry and clean gravel road with longitudinal gradient <l%. There is no reflecting object within 30-m range on both sides of the road central line.

3 Environment Conditions

The test day has sunny weather, relative humidity is 48%, and air temperature is 22.5 °C with calm wind.

Strong background noise will cause relatively big error for noise test. Therefore, during test, in order to ensure the data objective, the background noise is measured continuously for 30 s, and the average value is 42.0 dB(A). When the engine works idling, the average noise of this point is 67 dB(A). According to the requirement, when the tested noise level is over 10 dB higher than the background noise, the influence of background noise is negligible. Therefore, it does not need to correct the background noise for this test.

4 Test Method

Under full load of the vehicle, the noise is measured at 4 operator positions. Microphones are set according to requirements [5], since the inside space of vehicle is narrow; during test, according to the actual conditions of the vehicle, the microphones are set nearest to the regulated measure point, where measure point 1 is at the driving cabin, 800 mm above the driver seat surface, 50 mm to the engine bulkhead; measure point 2 is at the center of the working cabin, 800 mm above the seat surface; measure point 3 is at the right and rear side of the vehicle, 800 mm above the seat surface; and measure point 4 is at the left rear side of the vehicle, 800 mm above the seat surface.

The test is conducted in two kinds of conditions: starting in place and vehicle driving.

(1) Noise inside vehicle measurement under engine idling

The vehicle keeps at the test site, doors and windows are closed, at neutral, engine is started, the rotating speed increases from 800 rpm (holding for 30 s) to 1500 rpm by quickly stepping the throttle.

(2) Noise inside vehicle measurement under driving at uniform speed

The doors and windows of vehicle are closed, the engine works at the upper limit of the rotating speed, and vehicle drives at the uniform speed of 10, 20, 30 km/h with windows closed (holding time shall not <1 min).

5 Test Results and Analysis

Figure 1 is the noise change conditions inside vehicle at measure points under engine idling.

It is shown from Fig. 1, after increasing the rotating speed, the noise at the measure points in the vehicle increases accordingly. The A sound level of the measure points when engine idling, from high to low, is "engine compartment bulkhead-right rear part-left rear part-working cabin", which means that the engine noise is the main noise source. Additionally, vehicle rear part may easily radiate out

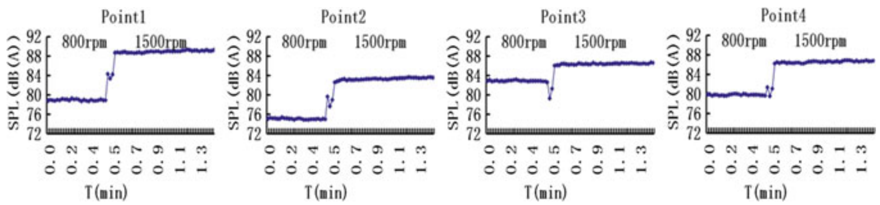

Fig. 1 A-weighed SPL (engine idling)

relatively big noise due to the vibrational excitation of engine compartment since the vehicle body wall is thin. The noise in the working cabin is relatively low since its position is relatively high. However, because the working cabin is close to the engine compartment, after increasing the rotating speed, the noise increase range is relatively big. The rear parts on both sides are relatively far to the engine compartment, and the noise increase range is relatively small as the increase in rotating speed.

Figure 2 is the noise change conditions at measure points inside vehicle under uniform speed.

It is shown from Fig. 2, as the increase in vehicle speed, the noise inside vehicle increases obviously. When the vehicle speed is 10 km/h, the noise is 85–90 dB(A), 95–100 dB(A) at 20 km/h and 98–104 dB(A) at 30 km/h. The A sound level of the measure points when the vehicle travels at the uniform speed, from high to low,is “engine compartment bulkhead-right rear part working cabin-left rear part”, comparing with the starting in place state, the noise at the right rear part (the side near the engine compartment) is obviously higher than the left side. When driving at high speed, the noise in the working cabin is slightly higher than the left side, which shows the obvious excitation effect of the engine compartment to the noise inside vehicle.

Figure 3 is the noise frequency spectrum at the measure points in the vehicle under different working conditions.

It is shown from Fig. 3 the frequency components of the noise at measure points are mainly 20–8 kHz, where the sound pressure in 20–160-Hz frequency range (1/3 octave center frequency, the same for below) is relatively high, and then the sound pressure in the 160–800-Hz frequency range and the sound pressure in 800–

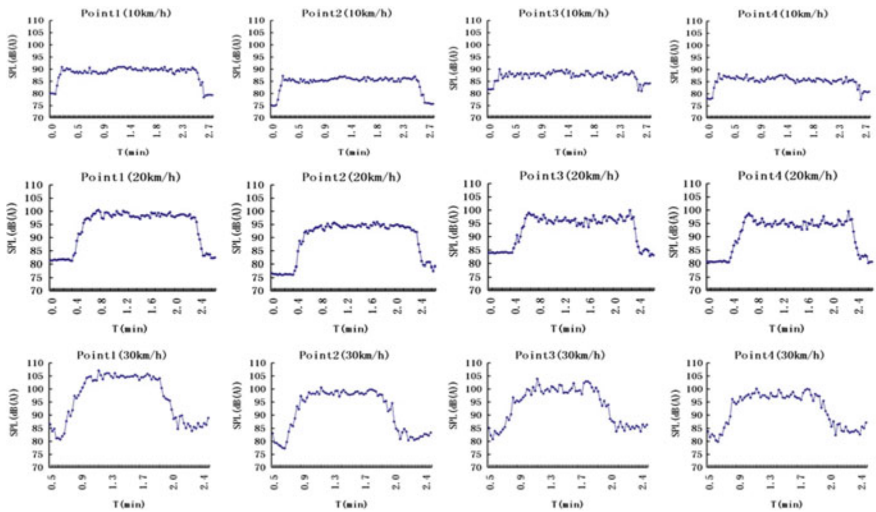

Fig. 2 A-weighed SPL (uniform speed)

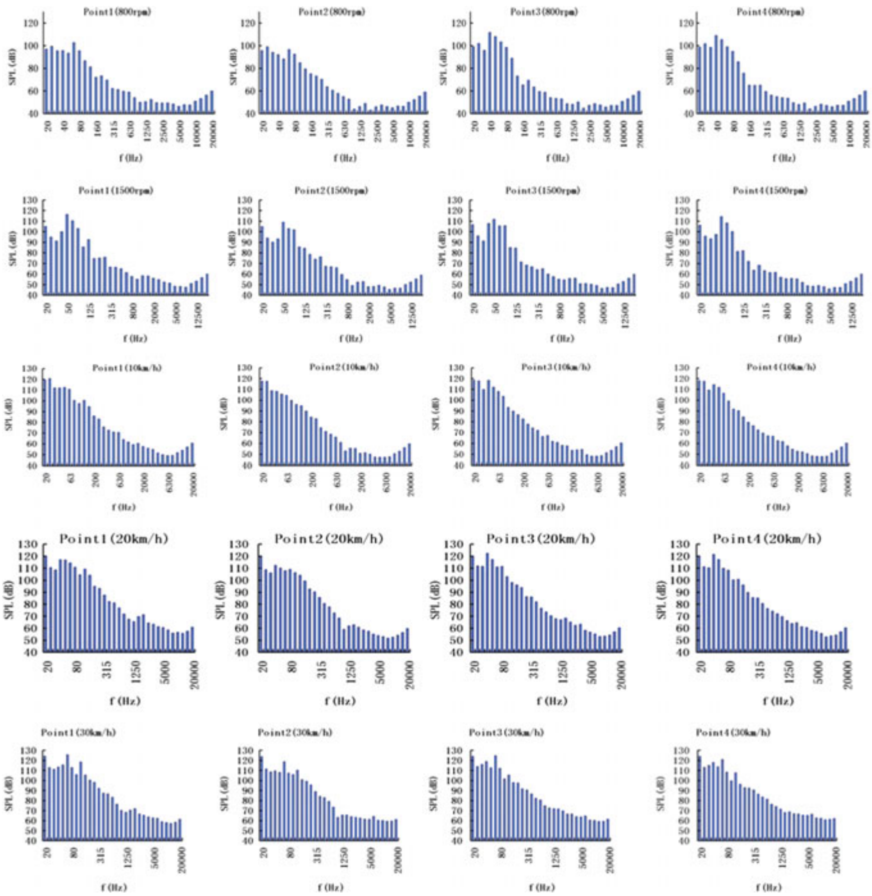

Fig. 3 1/3 octave SPL

8000-Hz frequency range are relatively low. Under starting in place and low rotating speed, the sound pressure in the 40–63-Hz frequency range at rear part of both sides is obviously higher than other measure points. Increasing the rotating speed and vehicle speed, the noise of different frequency ranges in the vehicle increases obviously. Additionally, when the vehicle keeps at the driving state, as the increase in vehicle speed, the noise of 5–20-kHz high frequency range increases obviously. This frequency range shall be the higher harmonic of varied fundamental frequencies and the high-frequency excitation of the pavement. Therefore, under the driving state, the noise inside vehicle is mainly from the higher harmonic of different parts under complicated excitation.

6 Conclusion

The main noise source of sound field inside vehicle is the engine compartment bulkhead caused by compartment and moving part, housing vibration and excitation. Under the starting in place state, the change of rotating speed mainly influences the sound field in the vehicle through low-frequency area and intermediate-frequency area; however, under the driving state, the excitation of moving part and the pavement greatly increases the noise component of high-frequency area.

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Part IV
Research on the Man–Machine Relationship

Experimental Study on Display Format of Target Range for HUD of Aircraft

Xiaochao Guo, Duanqin Xiong, Qingfeng Liu, Jian Du and Yanyan Wang

Abstract An experiment was conducted to explore the optimal display format of target range for HUD of aircraft. An integrated display format with trigon attached to the target designator was defined and compared with a separable display format of fixed scale with level linear indicator. The cognitive tasks were of extractive task versus integrative task in simulated flight with 2×2 within-subject experiment design. There were 151 Chinese male pilots participating in the human factor test. Results were found that the integrated display format of target range was recognized much better and faster in performance of 7.61% increments in correct reaction and 1.16s decrements in correct reaction time compared with the separable format and approved by 90.76% of the pilots. The conclusion was made that the integrated display format of target range could improve cognitive performance of target range information in HUD of aircraft on the basis of discussion.

Keywords Head-up display (HUD) · Display format · Target range · Aircraft · Pilots · Human factors

1 Introduction

Display formats of data impacted on interpretations of coming information and cognitive performance [1, 2], even situation awareness. The optimal format of display was therefore pursued with head-up display (HUD) or helmet-mounted displays (HMD) especially in aircraft cockpit for pilots [3, 4]. For example, GJB300 specified that the target range should be a range scale with an horizontal indicator in mode of missile attack presented on bottom of HUD field of view (FOV) [5], but MIL-STD-1787B required to display missile aiming reticle in which target range

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presented as circular bar around the inside perimeter of the aiming reticle as well as a fixed radar range scale with a moving caret to indicate target range [6]. A human factor experiment was conducted to choose a better display format of target range for HUD of aircraft in present paper.

2 Method

2.1 *Display Formats of Target Range*

There were 2 display formats of target rang as shown in Fig. 1. They were presented to participants of pilots dynamically in HUD pictures, which were defined as integrated format or separable format relative to target designator.

In Fig. 1, the R_{max} denoted the maximum launch range which included two different situations, the R_{min} indicated the minimum time of flight required for usage, and the closure rate shall be the departing from (+) or approaching to (−) a target which was defined in GJB300 or MIL-STD-1787B.

2.2 *Cognitive Tasks in Simulated Flight*

2.2.1 Experimental Design

Within-subject design was adopted with 2 × 2 treatments in which there were 2 display formats of target range mentioned above and 2 cognitive tasks to be tested. One extractive task was to declare the value of target range on real time, and another integrative task was to validate the state of mission with more parameters except target range after HUD watching by break-in technique.

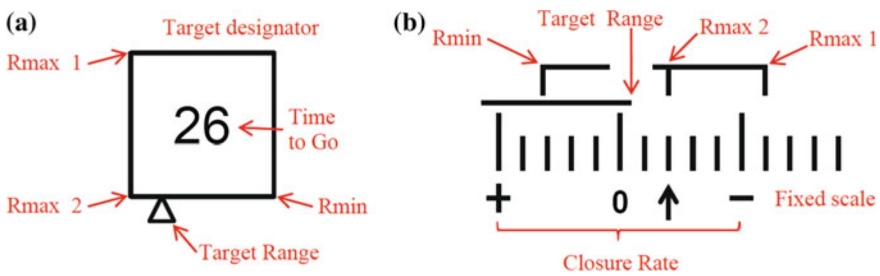

Fig. 1 Tested display formats of target rang **a** integrated format, **b** separable format

All cognitive tasks were programmed in phases of simulated flight running by PC.

2.2.2 Indices of Data

Human factor indices of data were recorded and analysed including rate of correct reaction (CR) and correct reaction time (CRT). Subjective ratings of usability were scored by participants of pilots after testing use.

2.3 Participants of Pilots

There were 151 male pilots participated in the experiment who aged 32.7 ± 4.9 years with 1381.1 ± 619.2 h of military aircraft flight time.

3 Results

The data are shown in Figs. 2 and 3.

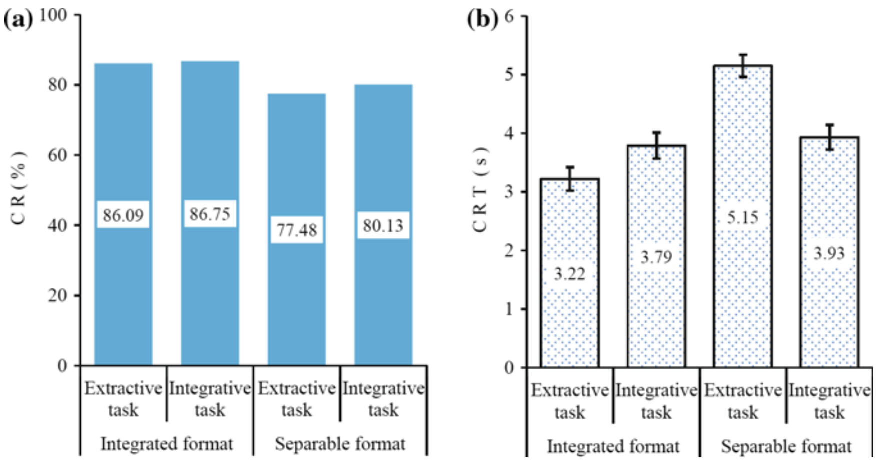

Fig. 2 Performances of 2 display formats with cognitive tasks **a** CR, **b** CRT

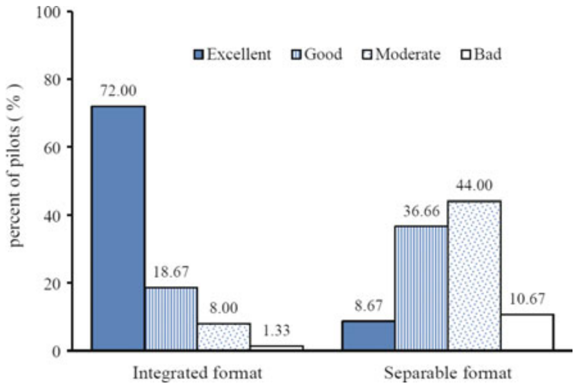

Fig. 3 Subjective ratings of pilots on different display formats after the test

4 Discussions

4.1 Integrated Format of Target Range with Higher Rate of CR

It was suggested that the main effect of display formats was significant in statistics ($\boldsymbol{F}(1,150) = 6.15$, $\boldsymbol{P} < 0.05$), and no other differences were found for the index of rate of CR (Fig. 2a), which meant integrated format of target range have a higher rate of CR than separable format, i.e. 86.42 versus 78.81% in average.

The rates of CR were 81.79 versus 83.44% undifferentiated for extractive task and integrative task generally in cognition.

4.2 Integrated Format of Target Range with Shorter CRT

For the index of CRT (Fig. 2b), it was found that the main effects were significant for display formats ($\boldsymbol{F}(1,74) = 29.94$, $\boldsymbol{P} < 0.001$) and cognitive tasks ($\boldsymbol{F}(1,74) = 4.76$, $\boldsymbol{P} < 0.05$); the interaction effect between the two factors was also significant ($\boldsymbol{F}(1,74)=7.11$, $\boldsymbol{P}<0.01$). The integrated format of target range had a shorter CRT than the separable format (3288 vs. 4450 ms) for the sample in present paper.

For the cognitive tasks, the extractive task revealed some difficulties with longer CRT than the integrative task (4085 vs. 3654 ms).

It was very interesting that the cognitive tasks accomplished with similar CRT in integrated format (3283 vs. 3743 ms) ($\boldsymbol{F}(1,113) = 2.71$, $\boldsymbol{P} = 0.10$), but dissimilar in separable format (5158 ms vs. 3799 ms) ($\boldsymbol{F}(1,95) = 26.76$, $\boldsymbol{P} < 0.001$). If the integrated format of target range was applied in HUD information design, pilots could cognize the cues faster for both of extractive and integrative task with superiority to the separable format as shown in Fig. 1.

4.3 Integrated Format of Target Range Chosen by Pilots

For the subjective ratings of usability (Fig. 3), it was found that the distributions of pilot's scores about integrated format were different from that of separable format significantly in statistics (Pearson $\chi^2 = 51.34$, $P < 0.001$). Totally 90.76% of pilots rated integrated format as excellent or good, while there only were 45.33% of pilots said yes for separable format.

The pilots chose the integrated format other than the separable format as shown in Fig. 1 as the optimal design for target range in HUD maybe because of better performances, i.e. higher rate of CR and shorter CRT in general.

The results were supported by other's finding of improved performance with integrated displays compared with separated displays [7, 8].

5 Conclusions

A display format of target range was designed for HUD of aircraft by attaching a trigon to the target designator in MIL-STD-1787B and GJB300 in which 3 of vertices in the square box denoted $R_{\max1}$, $R_{\max2}$, and $R_{\min}$, and the moving trigon denoted the changing target range.

An experiment was carried out to select better one from 2 display formats of target range for HUD pictures. 2×2 within-subject experiment design was cited with integrated format as mentioned above versus separable format of fixed scale with indicator, and extractive task versus integrative task in simulated flight cognitive tasks. The indices of CR and CRT were recorded in test and subjective rating of display formats after test. Results were found that the integrated format of target range was recognized much better and faster by 151 male pilots in performance compared with the separable format and approved by 90.76% of participant pilots. The integrated format of target range with trigon attached to target designator could improve cognitive performances of target range information in HUD of aircraft in present study.

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Research on the Effect of Mechanical Drawings' Different Marked Way on Browse and Search Efficiency Based on Eye-Tracking Technology

Canqun He, Zhangyu Ji and Jiafeng Gu

Abstract This study used eye-tracking technology to do research on the effect of mechanical drawings' different marked way on browse and search efficiency. Forty participants were randomly divided into two groups and assigned to perform visual browse and search tasks on mechanical drawings that are marked by text and digital. It was found that firstly, the browse efficiency of mechanical drawings that are marked by text is higher than marked by digital; Secondly, the search efficiency of mechanical drawings that marked by text is higher than marked by digital; Thirdly, the satisfaction of mechanical drawings that are marked by digital is higher than marked by text. The results of study have practical meaning for professionals to design drawings.

Keywords Eye tracking · Text annotation · Digital annotation · Browse efficiency · Search efficiency

1 Introduction

Now, the pursuit of fast pace and high efficiency in the study and work has become an inevitable trend. Therefore, the study on the impact of efficiency has become a hot research topic. The purpose of this study was to do research on the effect of mechanical drawings' different marked way on browse and search efficiency.

Many studies have explored factors that affect the efficiency of visual search.

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Location layout has an impact on search efficiency. Simonin et al. [1] studied the effects of different layouts on search efficiency and found that the elliptical layout scan path was the shortest. Song [2] studied the impact of web page information types and location on visual search. The results showed page information of figure type had higher search efficiency than text type.

Information and information density have an impact on search efficiency. Halverson et al. [3] found search time increased while search efficiency reduced when the user searched web page with large information density. Lu [4] studied the influence of web page information overload on visual search. It was found that the information overload reduced user's visual search efficiency, and user was more concerned with the upper area of the page under this condition.

Information presentation has an impact on search efficiency. Sheng et al. [5] found that graded presentation information can effectively improve the efficiency of information search. Zhao et al. [6] found that participants can respond more quickly and improve their search efficiency when the same scene layout was repeated and the target position was fixed.

The size of the information element has an impact on the search efficiency. Tseng et al. [7] considered screen size, icon size, and background complexity as independent variables to study search efficiency and found that large-size screens, icons, and a simple background can improve search efficiency.

In the above study, the experimental materials are mainly based on web pages and software interfaces, while existing researches lack study which uses professional drawings as stimulus object. Cheng et al. [8] have studied the impact of articles with or without illustrations and black and white illustrations and color illustrations on reading, but did not involve the study of pattern. Mechanical drawings are the most widely used in drawings. Therefore, this paper chooses the mechanical drawing as the research object and explores the effect of mechanical drawing marked by text and digital on learning and search efficiency, which is instructive for professionals to design drawings.

2 Experiment

2.1 Participants

Forty students (aged from 22 to 30), 28 males and 12 females, whose binocular corrected vision or naked eyesight was normal, did not have color blind, weak color, or other eye diseases, participated in this experiment. The participants were randomly divided into two groups, each group of 20.

2.2 Equipment

Tobii X120 desktop eye tracker whose sampling frequency is 120 Hz was used as laboratory apparatus, and a 23-in. LCD monitor with a refresh rate of 60 Hz and a resolution of 1920 × 1080 pixels was used as the monitor in this part.

2.3 Experiment Materials

The study was designed by two factors: 2 (mechanical drawings marked by digital and text) * 2 (two observation modes: purposeless browse and purposeful search). A total of 20 mechanical drawings of the same level of complexity were selected and processed into 20 * 2 illustrations with two marked ways, which ensures that the same drawings of different styles have the same figure ontology, marked text font, size, and word spacing, and the numbers of marked parts are all 12. Two examples of mechanical drawings that are marked by digital and text are shown in Fig. 1.

2.4 Experiment Design

The experiment was divided into two parts, eye-tracking experiment and the subjective satisfaction test after the experiment.

Participants were divided into two groups, and each group has twenty experimental materials including 6 drawings for purposeless browse experiment and 14

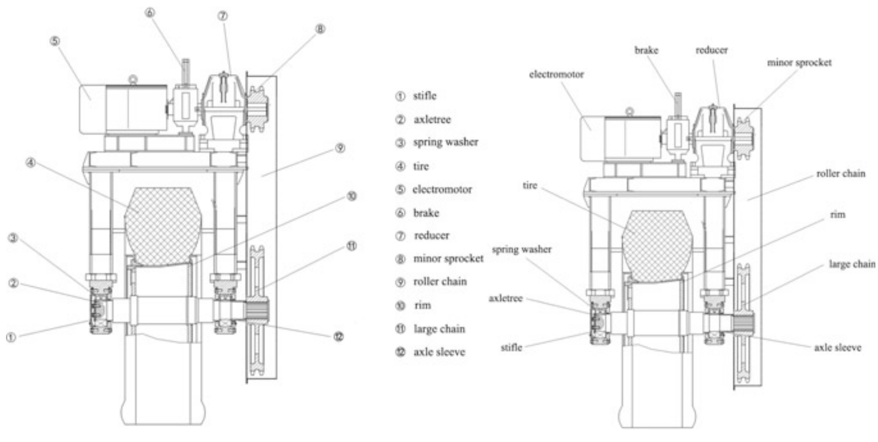

Fig. 1 Drawings examples that are marked by digital and text

drawings for purposeful search experiment. Purposeless browse requires that participants should browse the full drawing with their own reading habits and continue to browse by pressing the space bar. In a purposeful search process, a prompt appears on the previous page of the drawing to inform that participants should find the name of parts and then press the space bar to continue the experiment. Through comparative analysis of eye-tracking data of two drawings, the effect and regularity of them for observation and search can be obtained.

After the eye-tracking experiment, the subjective satisfaction of users was tested by a questionnaire which was presented in a 5-point isometric form.

2.5 Data Processing

There were totally 34 effective participants, 17 in each group. The dependent variables were the total length of fixation, the total number of fixation points, the time of entering ROI for the first time, and the number of fixation points before entering the first time. The experiment programming and data recording were completed by Tobii Studio Software. Eye-tracking data analysis was completed by SPSS 19, and the satisfaction test data were analyzed by EXCEL 2007.

3 Result Analysis

3.1 The Time of Purposeless Browse and the Number of Fixation Points

In the purposeless browse experiment, the participants' browse time and the number of fixation points were shown in Table 1.

The purposeless browse experiment results show that the average browse time under the condition of digital annotation and text annotation is 32.86 and 21.63 s, respectively. The conclusion is drawn as $F = 59.698$ and $p < 0.05$. The browse time in the form of text direct annotation is shorter than that of digital annotation.

Table 1 The browse time and the number of fixation points in purposeless browse experiment

	Browse time (s)		The number of fixation points	
	M	SD	*M*	SD
Digital annotation	32.86	11.45	65.83	43.54
Text annotation	21.63	9.18	42.67	30.16

The purposeless browse experiment results show that the average number of fixation points under the condition of digital annotation and text annotation is 65.83 and 42.67, respectively. The conclusion is drawn as $F = 19.511$ and $p < 0.05$. The number of fixation points of participants in the form of text direct annotation is less than that of digital annotation.

3.2 The Time of Purposeful Search and the Number of Fixation Points Before Entering the First Time

In the purposeful search experiment, the participants' search time and the number of fixation points before entering the first time were shown in Table 2.

The purposeful search experiment results show that the average search time under the condition of digital annotation and text annotation is 3.70 and 2.61 s, respectively. The conclusion is drawn as $F = 26.236$ and $p < 0.05$. It can be seen that search time in the form of text annotation is shorter than that of digital annotation.

The purposeful search experiment results show that the average number of fixation points before entering the first time under the condition of digital annotation and text annotation is 4.99 and 2.74, respectively. The conclusion is drawn as $F = 23.643$ and $p < 0.05$. The number of fixation points before entering the first time in the form of text annotation is less than that of digital annotation.

3.3 Purposeful Search for the First Time and Satisfaction

In the purposeful search experiment, the time of entering ROI for the first time and satisfaction were shown in Table 3. Satisfaction was obtained synthetically by the degree of clarity and beauty from the questionnaire, with a total score of 5.

The purposeful search experiment results show that the average time of entering the first time under the condition of digital annotation and text annotation is 2.34 and 1.41 s, respectively. The conclusion is drawn as $F = 30.638$ and $p < 0.05$. It

Table 2 The search time and the number of fixation points before entering the first time in the purposeful search experiment

	Search time (s)		The number of fixation points before entering the first time	
	M	SD	*M*	SD
Digital annotation	3.70	2.12	4.99	5.86
Text annotation	2.61	2.26	2.74	3.25

Table 3 The time of entering the first time and satisfaction in the purposeful search experiment

	The time of entering the first time (s)		Satisfaction	
	M	SD	*M*	SD
Digital annotation	2.34	2.08	4.09	0.66
Text annotation	1.41	1.23	3.32	0.81

can be seen that the time of entering the first time of the participants in the form of text direct annotation is shorter than that of digital annotation.

The experiment results show that the average satisfaction under the condition of digital annotation and text annotation is 4.09 and 3.32 (total score is 5), respectively. The conclusion is drawn as $F = 35.832$ and $p < 0.05$. Participants' satisfaction in the form of text annotation is lower than that of digital annotation.

4 Discussion

4.1 *The Effect of Different Marked Ways on Browse and Search Efficiency*

This study found the browse efficiency and search efficiency of mechanical drawings that are marked by text are higher.

The results can be explained from the following two aspects: information density and cognitive load. Halverson et al. [3] found that the search time significantly increased when users search for a web page with a high density of information in the study of web page visual design, and Liu et al. [9] have verified this view. In this study, independent variable is marked way only. The information density of digital annotation is greater than that of text annotation. The experimental results show that the search time of digital annotation is longer than that of text annotation.

Cognitive psychology believes that the level of cognitive load determines the efficiency of the user to complete the task. The intrinsic cognitive load is caused by the complex interaction between elements, and reducing the interaction can reduce the intrinsic cognitive load and improve efficiency [10]. In this study, there are three interactive processes during participants browse and search drawings marked by digital while there are two interactive processes during participants browse and search drawings marked by text. As a result, users have fewer interactive activities with drawings marked by text and have low cognitive load and high search efficiency.

The questionnaire showed that participants generally felt that drawings marked by digital were more clear, beautiful, neat, and orderly. The fixation track chart showed that participants generally chose from number 1 to start browsing drawings marked by digital, while they had no specific browse tracks and rules when browsing drawings marked by text, as shown in Fig. 2.

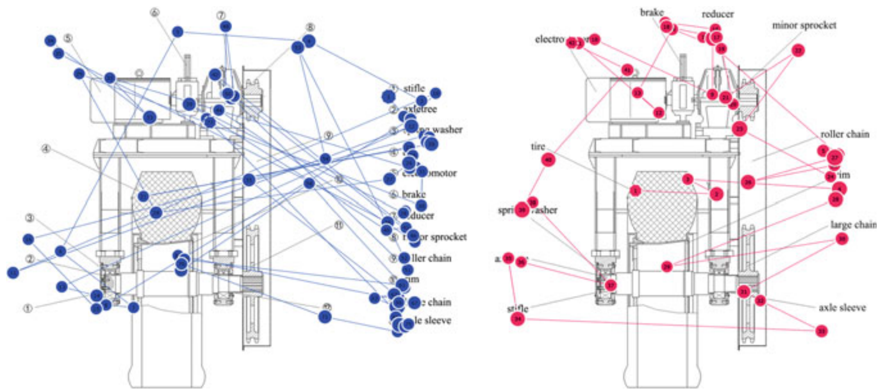

Fig. 2 The fixation track charts of a participant on the drawings in different marked ways (The *left* is digital annotation and the *right* is text annotation)

4.2 The Effect of Different Marked Ways on Eye-Tracking Index

In view of the number of fixation points, each part needs at least three fixation points: figure, digital, and text in drawings marked by digital, and each part needs at least two fixation points: figure and text in drawings marked by text. The more fixation points are needed, the longer the browse time is required.

In view of fixation track, in the purposeless browse experiment, participants generally choose from number 1 to start browsing when browsing drawings marked by digital, with long and regular track, but participants have different habits when browsing drawings marked by text, with short and irregular track.

In view of the hot map, the distribution area of hot spot in drawings marked by digital is obvious, and text area is obviously larger than figure area. The distribution of hot spot in drawings marked by text is uniform. This shows that participants pay more attention to the key information such as text than figure (Fig. 3).

4.3 The Effect of Cognitive Load on Reading Model

The purposeful search experiment has a total of two ROIs: the text area and figure area of the target part. The time of entering ROI for the first time was compared. The data totaled 280 groups. There are 154 groups of data corresponding to figure after text having been searched, which accounts for 55%. Further analysis finds that most participants are not familiar with mechanical drawings, and the average search time is 3.60 s. There are 12 groups of data confirming text after figure having been

Fig. 3 The hot spots of all participants on the drawings in different marked ways (The *left* is digital annotation and the *right* is text annotation)

searched, which accounts for 4.29%. Further analysis finds that the vast majority of participants are familiar with mechanical drawings, and the average search time is 3.18 s. There are 47 groups of data searching figures only, which accounts for 16.79%. Further analysis finds that two of the participants are mechanical professionals after in-depth interviews. The average search time is 1.59 s. There are 67 groups of data entering no RIO, which accounts for 23.93%.

The reason for this phenomenon is that with the improvement of professional level of learners, the intrinsic cognitive load will be reduced and the search efficiency will be improved.

5 Conclusions

Under the experimental conditions of this study, following conclusions are drawn. Firstly, browse efficiency of mechanical drawings that are marked by text is higher than marked by digital. Secondly, search efficiency of mechanical drawings that are marked by text is higher than marked by digital. Thirdly, satisfaction of mechanical drawings that are marked by digital is higher than marked by text.

There are some shortcomings and improvements of this paper. Firstly, when the satisfaction evaluation model is established, less indicators cannot fully reflect the satisfaction of participants on drawings marked by two different ways. Secondly, in this experiment, the number of marked icons of drawings is 12, and then, we can consider the number of marked icons as independent variables for further study. Thirdly, in this study, text annotation is placed on the right side of the page from top to bottom in a row in the drawings marked by digital, which is bound to have an impact on the experimental results.

Compliance with Ethical Standards The study was approved by the Logistics Department for Civilian Ethics Committee of the College of Mechanical and Electrical Engineering, Hohai University.

All subjects who participated in the experiment were provided with and signed an informed consent form.

All relevant ethical safeguards have been met with regard to subject protection.

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Experimental Study About Effects of Perceptive Modes on Crew's Information Processing Operation Performance

Junfeng Nie, Weiping Liu, Xixia Liu and Kaixuan Zhao

Abstract Based on self-developed information processing operation simulation and performance test system of armored vehicle, the influences of information perceptive modes, i.e., visual, auditory, and visual–auditory, on crew's information processing operation performance are analyzed by taking task completion time and error rate as evaluation indicators. The results show that the influences of different information perceptive modes on crew's information processing operation performance could be effectively discriminated by using the proposed method, and the visual–auditory mode should be used in actual operational environment. The results can provide reference for the information perceptive mode selection of vehicle-mounted display and control terminal and the training of armored vehicle crews.

Keywords Perceptive mode · Information processing · Operation performance

1 Introduction

With the wide application of vehicle-mounted display and control system in armored vehicles, the operation type of armored vehicle crew is changed from traditional manual work to information processing task [1]. Armored vehicle crew's information processing operation performance is directly related to the completion of task and even affects the success or failure of mission. The information processing operation performance is not only related to the cognitive ability of the crew, but also has a close relationship to the information perception mode. Therefore, it is necessary to study the relationship between perception mode and information processing operation performance.

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At present, scholars at home and abroad have carried out a series of researches on the information perception mode and found that different information perception mode will affect the operation performance. Kahneman first proposed the single-resource theory that when an information channel is stimulated, the information processing resources will change accordingly. It will affect the operation performance [2]. Zhuang established the visual information flow intensity model based on the mechanism of visual perception and analyzed the influence of visual information quantity on the operation performance by the method of variance analysis [3]. Wickens proposed the multiple-resource theory, which divides the information processing resources into several channels [4]. Karen found that the specific attention resources can be effectively activated when monitoring multiple channels in the experiment [5]. Guo compared the operation performance of 3 perception modes and found that auditory processing perception mode has more advantages than the other two modes.

To sum up, although the study of information perception mode has made some achievements, it has not given a unified definition of the relationship between perception mode and operation performance. Moreover, the existing research object is mainly aimed at the pilot, but the research on the armored vehicle crew is rare. In view of these, the author intends to adopt the ergonomics experiment method on the effect of perception mode on operation performance, avoids the negative effects of inappropriate perception mode brought on armored vehicle operation performance, provides reference for improving the combat effectiveness of the man–machine system.

2 Method

2.1 Participants

20 professional-grade tank commanders were recruited for the study (male, age range 20–26, mean age 24). All the participants were right-handed and healthy (without any movement disorders, normal vision or corrected vision, normal hearing) and in a good mental state. Before the experiment, all the participants were informed and agreed to participate in the experiment.

2.2 Experimental Setup and Equipment

The experimental system is a self-developed information processing operation simulation and performance test system of armored vehicle. Its main function is to provide a typical information processing simulation test environment for the crew, and to record the crew's operation performance (response time, error rate). The

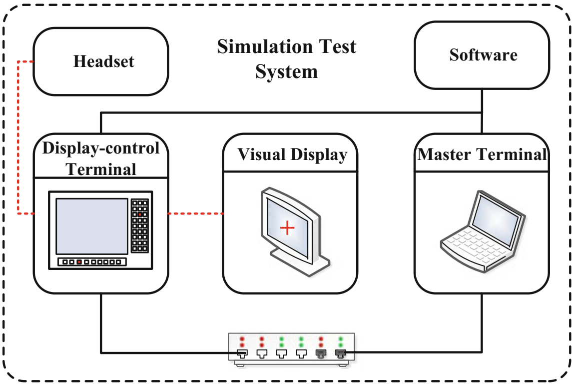


Fig. 1 Schematic diagram of simulation test system

Table 1 Basic hardware configuration

Name	Configuration
Master terminal	Lenovo YOGA2
Display–control terminal	Mitsubishi AA104XD02, Silicone Keyboard
Vision display	Samsung 743APLUS
Headset	Edifier K800

system is portable and modular. The utility model can be installed on a simulation experiment platform or a real vehicle. The system is mainly composed of the main control terminal, the display and control terminal, the visual display, the headset, and the simulation software, as shown in Fig. 1.

The basic hardware configuration is shown in Table 1.

The simulation software is developed based on Labview 2011, which consists of main control module, information terminal module, visual module, and data storage module. The information terminal module interface is designed reference of a main battle tank commander terminal interface. Visual module is created based on Creator. The data storage module uses MySQL 2008 database management software and Matlab R2009 to store and analyze the performance data. The modules are connected by TCP/IP protocol.

2.3 Experimental Design

The target input task has the characteristics of obvious emergency and typical operation, which is one of the most commonly used information processing tasks for armored vehicles. Therefore, the paper selects target input task as a typical

Table 2 Basic parameter settings

Parameter	Specific content
Task repetitions	5
Task time interval	3 s
Information presentation	Text, voice, text–voice
Information input way	Keyboard (right index finger)

Fig. 2 Experimental scenarios

information processing task. The task includes 4 basic operation units: type selection, attribute judgment, target information input, and information transmission. The basic parameter settings are shown in Table 2.

In Table 2, the text presentation mode corresponds to the visual perception mode, the speech presentation corresponds to the auditory perception mode, and the text–speech presentation mode corresponds to the visual–auditory perception mode. The contents of the target information are the target type (Armored transporter), the number of targets (3), the target position (North), and the target speed (28 km/h). The experimental scenario is shown in Fig. 2.

2.4 Experimental Process

The experimental process is divided into 2 stages. The first stage is the training phase. First to explain the purpose of the experiment, the basic steps and matters need attention. In addition, participants in the system for about 5 min of task training should be familiar with the work content. The second stage is the formal experimental stage. First, set the condition parameters. Then, begin the formal experiment, each mode 5 times. Finally, fill in the NASA-TLX evaluation scale.

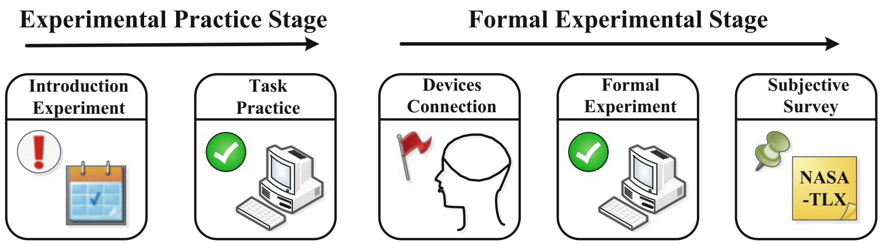


Fig. 3 Schematic diagram of experimental process

The experimental process of the 20 participants is exactly the same, and the schematic diagram of the experimental process is shown in Fig. 3.

3 Data Processing

The research of Kawado shows that information processing operation performance can be measured from comprehensiveness, timeliness, and accuracy. Therefore, the task completion time and operation error rate are selected as the operation performance evaluation indicators.

3.1 Task Completion Time

$$T_i = \frac{\sum_{j=1}^{20} t_{ij}}{N} \tag{1}$$

In the formula, i is the category of operation units, T_1, T_2, T_3, and T_4 are the type selection time, the target attribute judgment time, the target information input time, and the target information transmission time, respectively; t_{ij} is the ith operation unit average task completion time of the jth participant; and n is the total number.

$$T = \sum_{i=1}^{4} T_i \tag{2}$$

In the formula, T is the total task completion time.

3.2 Operation Error Rate

$$E_i = \sum_{j=1}^{20} \frac{e_{ij}}{N \times n_i} \tag{3}$$

In the formula, e_j is the ith operation unit error number of the jth participant; and n_i is the total number of the ith operation unit.

$$E = \sum_{i=1}^{4} E_i \tag{4}$$

In the formula, E is the total error rate.

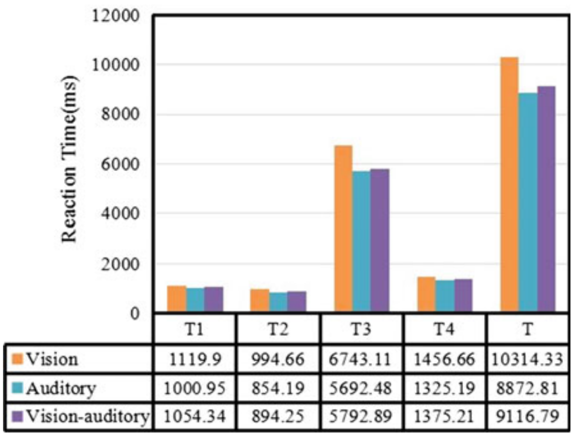
4 Experimental Results and Analysis

4.1 Operation Performance Data Analysis

Figure 4 shows the completion time of different information perceptive modes.

The Kolmogorov–Smirnov normal test was performed on the task completion time of 3 perception modes, as shown in Table 3.

Fig. 4 Task completion time



	T1	T2	T3	T4	T
Vision	1119.9	994.66	6743.11	1456.66	10314.33
Auditory	1000.95	854.19	5692.48	1325.19	8872.81
Vision-auditory	1054.34	894.25	5792.89	1375.21	9116.79

Table 3 K-S test values of task completion

Perception mode	Visual	Auditory	Visual–auditory
Sig.	0.230	0.133	0.421

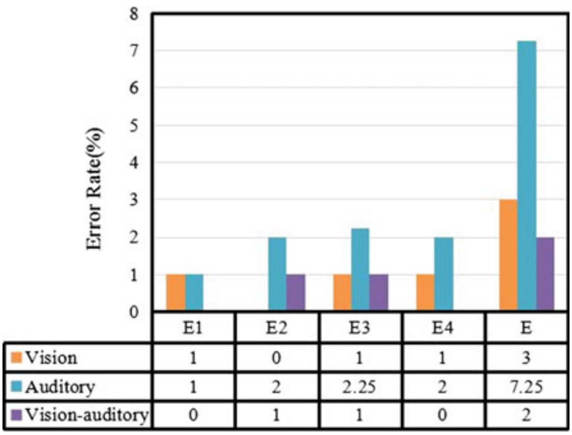


Fig. 5 Operation error rate

Table 4 K-S test values of operation error rate

Perception mode	Visual	Auditory	Visual–auditory
Sig.	0.000	0.000	0.000

As shown in Fig. 4 and Table 3, the data obey the normal distribution ($P > 0.05$). And the task completion time was increased according to the order of auditory perception, visual–auditory perception, and visual perception. In order to make a further analysis of the main effect of perception on task completion time, one-way ANOVA method was used. Results showed that auditory, visual, and visual–auditory tasks were significantly different ($P = 0.000 < 0.05$). However, there was no significant difference between auditory and visual–auditory task completion time ($P = 0.069 > 0.05$).

Figure 5 shows the operation error rate of different perceptive information modes.

The Kolmogorov–Smirnov normal test was performed on the operation error rate of 3 perception modes, as shown in Table 4.

As shown in Fig. 5 and Table 4, the data do not obey the normal distribution ($P < 0.05$). And the operation error rate was increased according to the order of visual–auditory perception, auditory perception, and visual perception. In order to make a further analysis of the main effect of perception on operation error rate, one-way ANOVA method was used. Results showed that there was no significant effect on the operation error rate ($P = 0.105 > 0.05$).

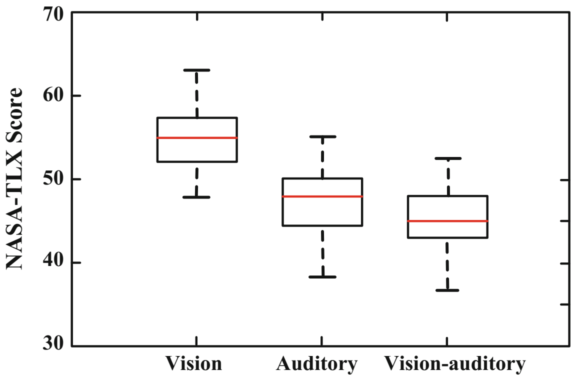


Fig. 6 Statistical results of NASA-TLX

4.2 NASA-TLX Data Analysis

In this paper, the NASA-TLX scale was used to investigate the subjective feelings of each participant under different conditions. The statistical results are shown in Fig. 6, the average scores were 53.455, 48.124, and 45.234, and this shows that single-channel perception needs more mental workload than multichannel.

5 Discussion

When the target information is presented in a text mode, the participant perceives it with visual perception. When the text appears, the participant's attention has been placed on the visual display screen and then transferred to the keys. When the target information is presented in a speech mode, the participant perceives it with auditory perception mode. When the voice appears, the participant's attention has been stuck on the keys, direct operated keys. As a result, the task completion time of visual perception mode is more than that of auditory perception mode. The error rate is basically the same.

As the speech presentation mode has certain hysteresis, when the information is presented in a text–speech mode, the information perception is according to the order of visual perception mode and auditory perception mode. When text and voice appear, participant focuses on the visual display. With the development of speech presentation, participant will quickly shift attention to the keys, direct operated key. Although the task completion time of visual–auditory perception mode is the same as that of auditory perception mode theoretically, the cognitive process will include the choice of perceptual mode. Therefore, the task completion time is slightly longer than that of auditory perception mode, but the task completion time is much shorter than that of visual perception mode. However, due to the multichannel, the channel will complement each other, and the operation error rate of visual–auditory perception mode will be greatly reduced.

6 Conclusions

This paper makes an experimental study on the relationship between perception mode and operation performance. The main conclusions are as follows:

- From the perspective of realizing system function, the effect of the 3 perception modes is consistent. But from the perspective of actual combating, the auditory perception single-channel mode is not reasonable, because the actual battlefield environment with a large number of random voice information will produce information loss phenomenon.
- In view of the significant differences in the task completion time and the error rate analysis, in the actual combat environment, we should adopt the text–speech mode to present the target information. The information should be distributed in several channels so as to avoid the superposition in the same channel. This can improve man–machine's work efficiency and reliability.

Compliance with Ethical Standards The study was approved by the Logistics Department for Civilian Ethics Committee of AAFE.

All subjects who participated in the experiment were provided with and signed an informed consent form.

All relevant ethical safeguards have been met with regard to subject protection.

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An Analysis of Human–Machine Interaction to a Lower Extremity Exoskeleton

Xiaojuan Zheng, Lan Xiao, Jing Qiu, Lei Hou, Hong Cheng and Youjun Chang

Abstract Lower extremity exoskeleton is to support the body of human and strengthen its users exercise ability. In recent years, the safety, the comfort, and efficiency to the lower extremity exoskeleton become an issue of increasing concern. In order to form a better view of the evaluation of the human exoskeleton system, not only the clinical data but also the analysis of the human gait is needed. In this paper, we give a more complete evaluation of the AIDER (AssIstive, DEvice for paRaplegic patient) exoskeleton based on the human gait analysis and the subjective questionnaires.

Keywords Exoskeleton · Human–machine system · AIDER

1 Introduction

Lower extremity exoskeleton is a wearable mechanical device, which integrated several sensor techniques, control techniques, information coupling techniques, human–machine interaction technique, etc. [1]. Lower extremity exoskeleton can support the human body and strengthen the exercise ability of its user. As research on robotic exoskeletons has rapidly expanded over the previous decade, the comfort, safety, and efficiency of the human exoskeleton system become an important issue. As Andre Schiele mentioned [2], one of the key problems of the exoskeleton is lacking design requirements, guidelines, and performance analysis tools for exoskeleton. Young and Ferris [3] also pointed that the preponderance of published literature lacks rigorous quantitative evaluations of exoskeleton performance. In this respect, Zeilig et al. [4] and Stephanie et al. [5] have evaluated safety and feasibility of the exoskeleton based on clinical evaluation and questionnaire. However, in order to form a better view of the evaluation of the human exoskeleton system, not

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only the clinical evaluation but also the analysis of the human gait is needed. Although many studies have been carried out to design control systems able to achieve static and dynamic balance for humanoid-legged robots, the implications of these two different modalities on kinematic and kinetic aspects have often been overlooked [6]. In order to remedy this vacancy, this paper tries to give a more complete evaluation of the exoskeleton. Our experiment used the AIDER(AssIstive, DEvice for paRaplegic patient) systems and to analyze the human-machine systems of gait parameters and the subjective questionnaires.

2 Method

2.1 Subjects

Our proposed method was based on the experiment recruited 20 volunteer participants from a high-educated university. All participants were physically and mentally healthy with an average age of 22, 174 cm mean height, and an average weight of 62 kg. These participants were grouped into two: group A, 10 people with walking test wearing the lower extremity exoskeleton; and group B, 10 people with walking test without wearing the lower extremity exoskeleton device. This study has been approved by Sichuan Province 81 Rehabilitation Center Medical Ethics Committee. All subjects have signed the informed consent.

2.2 Experiment Equipment and Material

The human movement data were captured by a Vicon motion capture system. Two force plates (BP400600 AMTI) measured the ground reaction force. The VICON system consists of 8 cameras and is designed to track and reconstruct these markers in 3-dimensional space. The experiment environment consists of 8 Vantage 5 camera and 2 force plates, shown in Fig. 1.

2.3 Procedure

2.3.1 The Device (AIDER 3.2)

The AIDER 3.2 (AssIstive, DEvice for paRaplegic patient) comprised a motorized exoskeleton, a battery unit, and a computer-based controller contained in a backpack, wireless crutches, and an array of sensors that measure upper-body tilt angle,

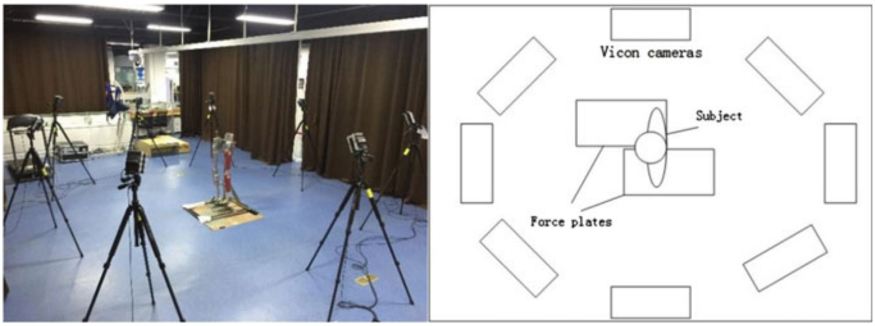

Fig. 1 The experiment environment and its top view

joint angles, and ground contact. The exoskeleton contains bilateral lateral uprights for the thigh and leg and the footplate. It uses a closed-loop algorithm software control. The motors control the movements at the hip and knee joints, but not the ankles that are articulated using a mechanical joint with spring-assisted dorsiflexion. Software design prevents rapid hip and knee flexion as may occur in a fall, and provides a controlled speed stand to sit. The suitable user of the ADIER is from 155 to 190 cm height and under 100 kg.

2.3.2 Training

The participants of group A with wearing the device were initially trained with four actions: stand up, walking, turn to left or right, and sit down. All the 10 tested people were trained 4 days with an average training time of 20 min a day. After the four days' training, every participant had used the device skillfully and can finished the walking test easily.

2.3.3 Experiment

The experiment was divided into two groups as aforementioned. First, as for group A, we measured the basic physical parameters, such as weight, height, length of the leg. Then, the experimental suit was put on the experimenter and pasted some motion capture markers, respectively. The experimenters need to finish a 40-m (40MWT) walk test in the constructed experiment environment. The markers position and the walking test were shown in Fig. 2. After finishing the walking test, the experimenters were invited to finish the NASA-TLX questionnaire [7, 8].

For group B, experimenters wear the experiment suit and finish the 6-meter walk test (6MWT) in the same experiment environment, but without the exoskeleton.

Fig. 2 Marker position and walking with the exoskeleton

2.4 Data Collection and Analysis

The data collected in this experiment include height, weight, length of leg, subjective questionnaire, movement of the markers, and the ground reaction force.

By importing the markers motion trail data and the ground reaction force data into OpenSim3.3 to establish a human–machine model, kinematics analysis includes gait parameters and gait cycle has been measured in the experiment. In addition, the differences of the gait feature between two groups have been calculated by SPSS software. The t-test was used to check for significant differences in the gait parameters and the heart rate between two groups with the significance level set to 0.05.

A subjective workload was attained from the NASA-TLX questionnaire, which has been used as a tool for workload assessment. The content of the NASA-TLX questionnaire used in the present study includes mental demand, physical demand, temporal demand, performance, efforts, and frustration.

3 Results

For group A, nine subjects finished the 40MWT with ADIER exoskeleton. Except two subjects were skilled user of the ADIER, seven subjects finished the training with the exoskeleton. One subject quit the test because of the personal reason. For group B, 10 subjects finished the 6MWT.

3.1 *Kinematics*

3.1.1 Gait Parameters

Parameters of experimenters with exoskeleton and experimenters without exoskeleton were shown in Fig. 3. The unit of length of single step and step width is millimeter (mm), and the unit of the walk speed is mm/s.

From the result, the values of the gait parameters in with-exoskeleton group are obviously lower than without-exoskeleton group. For single step length, the values of the gait parameters with-exoskeleton or without-exoskeleton group have significant differences ($t(9) = -14.745$, $p < 0.01$). For the walk speed, the values of the gait parameters with-exoskeleton or without-exoskeleton group have significant differences ($t(9) = -12.138$, $p < 0.01$); For the step width, the values of the gait parameters with-exoskeleton or without-exoskeleton group have significant differences ($t(9) = -2.718$, $p < 0.05$). In addition, the mean step width of the group with exoskeleton is 159 mm, lower than the mean step width of the group without exoskeleton (191 mm). In the gait analysis respect, lower step width means poor stability.

3.1.2 Gait Cycle Analysis

In the normal human gait cycle, stance phase occupies 60% of the whole cycle, swing phase occupies 40% of the cycle, and the first double support and the second double support occupy 20% of the whole cycle. In the human with exoskeleton gait cycle, stance phase occupies 75% of the whole cycle, swing phase occupies 46 of

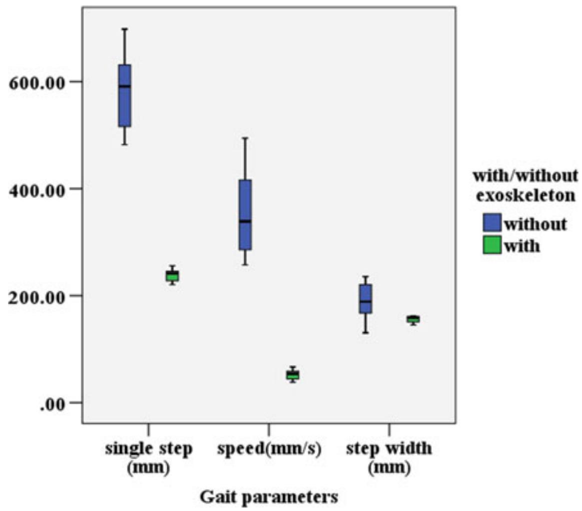

Fig. 3 Results for the gait parameters comparison

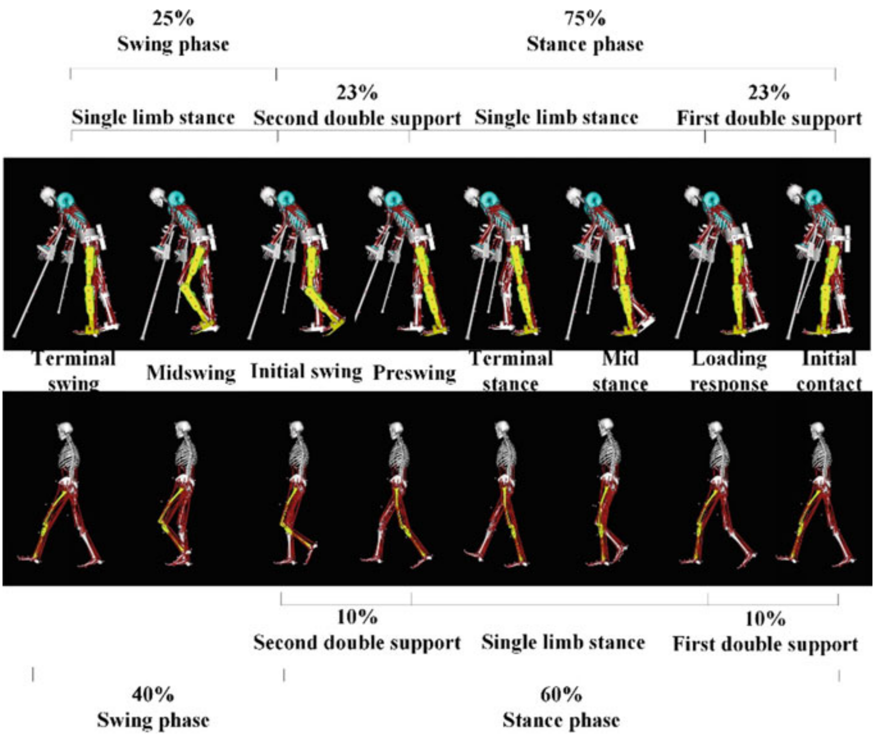

Fig. 4 Gait cycle analysis

the cycle, and the first double support and the second double support occupy 25% of the whole cycle, as shown in Fig. 4.

From Fig. 4, we could see that when subject performing a complete gait cycle with exoskeleton, the time of stance phase is longer; especially for the double-support phase, it needs two times time of the subject without exoskeleton. During the double-support phase, there are four points contact the ground when subject moving with the exoskeleton, including left crutch, right crutch, left foot, and right foot. During the single-limb stance phase, there are only three points contacting the ground because one of the crutches needs to move forward. In order to maintain a balanced position, the user intends to decrease the time of single-limb stance.

3.2 *Subjective Assessment*

3.2.1 Workload

A subjective mental workload was attained from the NASA-TLX questionnaire, which has been used as a tool for mental workload assessment. As Fig. 5 shown, 6

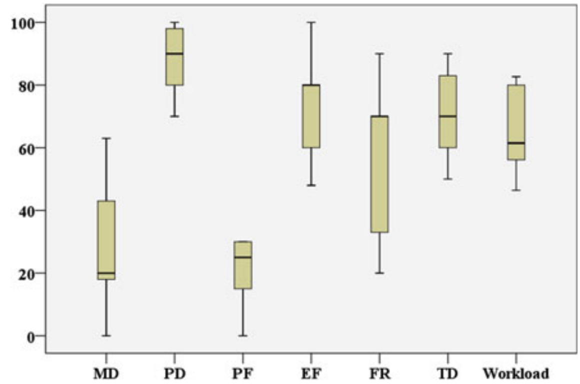

Fig. 5 Subjective workload (*MD* mental demand; *PD* physical demand; *TD* temporal demand; *PF* performance; *EF* efforts; *FR* frustration)

dimensions have significant differences. In addition, the value of physical demand is greater than other dimension of the workload.

4 Conclusions

In this study, the gait parameters of exoskeleton users were calculated. The users' physiological data and the subjective assessment were quantitatively analyzed. And all these factors were compared to the subjects walked without exoskeleton. When walking with the exoskeleton, the values of gait parameters (single step length, step width, and walk speed) are lower compared with the normal human without the exoskeleton. Moreover, improving the stability of the exoskeleton is a challenge as the step width is narrow. Based on the subjective assessment, the physical demand of the users is high. In future, the gait features and the mechanical structure of the AIDER need to be ameliorated to overcome the gait controlling and the high physical demand problem.

Compliance with Ethical Standards The study was approved by the Logistics Department for Civilian Ethics Committee of Sichuan Province 81 Rehabilitation Center.

All subjects who participated in the experiment were provided with and signed an informed consent form.

All relevant ethical safeguards have been met with regard to subject protection.

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Effects of Usability Problems on User Emotions in Human–Computer Interaction

Xiaojun Li, Zhongdong Xiao and Binbin Cao

Abstract A two-factor mixed design with usability problem type and severity rating as experimental factors was conducted to examine the effects of usability problems on user emotions. The usability problem type was varied from full classification (FC) in artifact component to FC in task component, and severity rating of usability problem was varied from low to high. Difference in emotional dimensions, valence, arousal, and dominance were realized as dependent variables. Results showed that effects of usability problems on user emotions differed by type and severity rating. Usability problems classified into FC in task component or with higher severity rating led to more negative and less dominance subjective feelings. Effect of type of usability problems on emotional valence was stronger when their severity rating was relatively low. These investigations suggest that usability problems classified into FC in task component or with higher severity rating should be assigned to higher priority in usability test and be eliminated as far as possible in the development process. Further studies may address the issue from different construct of emotion, e.g., physiological changes.

Keywords Usability problems · User emotions · Type of usability problem · Severity rating · Valence · Arousal · Dominance

1 Introduction

Emotion plays an important role and has been paid more and more attention in human–computer interaction (HCI). The previous studies investigated the relationships between users' emotional responses and system usability in HCI. However, the issue still needs to be addressed, mainly due to the following reasons:

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1. These studies mostly focused on the effects of perceived usability on users' emotional responses in HCI. However, there are obvious differences between perceived usability and situational usability employed in our study. According to Hertzum [1], the former concerns the user's subjective experience of a system and the latter focuses on the quality in use of a system.
2. To our knowledge, previous research rather paid limited attention to the effects on users' emotional responses of usability problems in terms of types and severity, even though investigations revealed that types and severity of usability problems were crucial for improvement of system usability [2].

To provide further insights into the relationships between users' emotional responses and usability problems in terms of type and severity rating in HCI, the present study designs two-factorial experiments to examine the effects of type and severity rating of usability problems on different user emotional dimensions, that is, valence, arousal, and dominance; especially, the issue is addressed in the concept framework of situational usability rather than perceived usability.

2 Background and Related Work

2.1 Usability Problems

Usability is defined as the quality in use of a system in a specific context of use and can be measured in terms of effectiveness, efficiency, and satisfaction [3, 4]. Given the definition of usability, usability problems are aspects of a system that may cause weak performance, increased costs, or decreased satisfaction during HCI in a specific context of use.

To support identifying usability problems and diagnosing the causes, various classification schemes of usability problems were provided. In usability problem taxonomy [5], usability problems can be classified from the following two aspects: artifact and task. Any problem can be classified into one of the following outcomes along a component.

1. Full classification (FC), it implies that a problem is classified in a subcategory in the deepest level.
2. Partial classification (PC), it implies that a problem is classified in either a primary category or a non-rightmost subcategory.
3. Null classification (NC), it implies that a problem cannot be classified in any primary category or subcategory along a given component.

Therefore, the final result of classification for a problem is a pair of outcomes that are composed of outcomes in the artifact component and task component separately.

Besides classification, severity rating is another important characteristic to describe a usability problem. In sum, two types of approaches were developed to estimate the severity: approaches based on data about the impact of a specific usability problem and approaches based on judgments of stakeholders, especially the users [2]. In the former approaches, measures of severity include problem-handling time, number of human errors, occurrence frequency of a usability problem, and so on. In the latter approaches, Nielsen's rating scale [6] is commonly accepted in related studies. The scale is an overall assessment of each usability problem and regards the judgment as integrated ratings on occurrence frequency, impact, and persistence of a usability problem.

2.2 User Emotions in HCI

Emotions are conceptualized as reactions to events and resulted in the extent to which the user's goals or needs are facilitated or hampered by the system in HCI [7]. And they are considered to be a multi-modal construct on the levels of physiological changes and subjective evaluations [8]. So information of users' emotional changes in HCI can support judging whether the user's goals are being satisfied and improving the relationship between human and computer.

Besides features of design, almost all of the aspects of HCI events, i.e. the characteristics of human, task, and environment may elicit emotional change in HCI [9–12]. Based on the above investigations, tightly controlled conditions are necessary in experiment design for related studies in HCI.

3 Methods

Two-factorial experiments were applied in our studies. Four office information systems were selected as tested objects. To control the effects of other HCI factors on the dependent variables, all the tests did take place in the same laboratory under same environmental conditions.

3.1 Participants

Forty-three individuals (all of them male, age from 21 to 23 years with a mean of 22.7 years) participated in the experiments. These participants were senior students in Xi'an Research Inst. of Hi-Tech, China. And they were skilled in computer applications.

3.2 Stimuli

Through application of the four systems in our design, we intend to induce different usability problems in terms of types and severity ratings. The tested applications and details of usability problems are shown in Table 1. And the classifications and severity ratings of each usability problem are given by five usability experts according to usability problem taxonomy and Nielsen's rating scale.

Table 1 Details and features of usability problems

System	Usability problem	Type	Severity rating
Software for text file edit	*Application 1*: unify the types of all the figures in word document 2 by use of macro	FC: object layout in artifact component NC in task component	3.2 ± 0.40
	Detail: the usability problem is related to menu structure. It is shown as that the tool is hard to be found due to the obvious difference between its actual location with its expected layout in user's mind		
Software for PDF file edit	*Application 2*: modify the title "1.1 Scraping Webpage" as " Editing Webpage" in 9th page of the document 1	NC in artifact component FC: function automation in task component	3.6 ± 0.49
	Detail: the usability problem is related to function automation. It is shown as that the software continuously show error alert when the format of modified title is not unified with the original. However, the system does not show the format of the original title automatically		
Software for CAJ file edit	*Application 3*: modify the format of the texts as Word format in 8th page of the document 1	FC: visual cues in artifact component NC in task component	1.2 ± 0.40
	Detail: the usability problem is related to icon design and menu structure. It is shown as that the icon is hard to be identified in the toolbar and the location of tool is hard to be confirmed in the menu structure		
Software for data recovery	*Application 4*: scan the USB flash drive D and check the pictures that have been deleted	NC in artifact component FC: interaction in task component	1.4 ± 0.49
	Detail: the usability problem is related to system workflow and shown as that the user could not select the types of the checked files before scanning. User has to scan all the files in drive D and then check pictures among them		

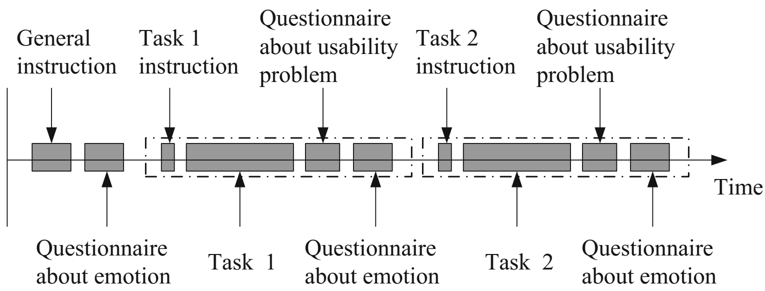

Fig. 1 Sequence of the trial for each participant

3.3 Design

A two-factor mixed design with usability problem type and severity rating as experimental factors was applied. The usability problem type, realized as the within-subjects independent variable, was varied on two levels, either as FC in artifact component or FC in task component. The severity rating of usability problem, realized as the between-subjects independent variable, was also varied on two levels, that is the rating was either low (Mean of subjective rating $\leq$ 2.0) or it was relatively high (Mean of subjective rating > 2.0).

All the participants were divided into two groups randomly: 19 individuals in group A and 24 individuals in group B. For each group, every individual was asked to complete two tasks, that is, applications 3 and 4 (Table 1) were assigned to individuals in group A and applications 1 and 2 (Table 1) were assigned to individuals in group B. The schema of the trial procedure for each participant is described in Fig. 1.

To balance the potential learning effect during HCI, the order of tasks was different from adjacent individuals for each participant in the same group. For example, if the order of tasks for a participant in group A is application 3 to application 4, then the order of tasks for adjacent ones is application 4 to application 3.

3.4 Measures

Emotion measures were obtained using the Self-assessment Manikin (SAM) scale [13]. The SAM, as a nine-point rating scale, can measure three emotional dimensions: valence, arousal, and dominance (0 represents happy, high arousal, and low dominance; 8 represents unhappy, low arousal, and high dominance). As a non-verbal pictorial assessment technique, its reliability and validity were verified by studies [8, 14] in the HCI domain.

Severity rating of usability problems were obtained using Nielsen's rating scale [6]. In the five-point rating scale, 0 shows that there was no problem and 4 shows that there was usability catastrophe.

Considering the complexity of usability problem taxonomy, the results of usability problem classification directly adopted experts' judgments as shown in Table 1.

3.5 Procedure

The experiment was conducted separately for every participant. After the individual arrived at the laboratory, he was informed about the contents of the experiment briefly and instructed to sign the informed consent voluntarily. And then he was seated in front of the computer and tasked to complete the questionnaire about emotion. The result was considered as the emotional baseline to assess whether he was within the abnormal emotion or otherwise.

He was informed the details of application for the first task and confirmed whether he got the instructions clearly. When these conditions were verified, the participant was asked to complete the task in 3 min. If the duration was longer than 3 min, he was considered to have failed and asked to give up the task. So when he completed the task or the duration exceeded 3 min, the participant was asked to complete the Nielsen's rating scale and the Self-assessment Manikin (SAM) scale in turn. For the second task, the participant followed the same schema described as above.

4 Results

One-way ANOVA with repeated measurements shows that the difference between severity ratings of usability problems in applications 1 and 2 is not significant ($p = 0.526 > 0.05$). The difference between applications 3 and 4 is also not significant ($p = 0.747 > 0.05$). One-way ANOVA shows that the difference between severity ratings of usability problems in applications 1 and 3 (belongs to the same type: FC in artifact component) is significant ($p = 0.000 < 0.05$). And the difference between applications 2 and 4 (belongs to the same type: FC in task component) is also significant ($p = 0.000 < 0.05$). In summary, the stimuli were effective in the experiments.

The results show that the emotional baselines of all the participants were normal, that is, valence < 6, arousal > 2, and 1 < dominance < 7.

Table 2 Means and standard deviations of valence ratings

Level of severity rating	Type of usability problems	
	FC in artifact component	FC in task component
Low	2.00 ± 1.56	3.68 ± 1.00
High	4.58 ± 1.38	5.29 ± 1.37

4.1 Valence

Means and standard deviations of valence ratings corresponding to different usability problems are shown in Table 2. A 2(type of usability problems) × 2 (severity rating of usability problems) analysis of variance with repeated measurements for type of usability problems and severity rating of usability problems was conducted with valence ratings as dependent variable.

The main effect of within-subjects independent variable, type of usability problems, turned out to be statistically significant, $F_{(1,41)} = 27.945$, $p = 0.000 < 0.05$, partial eta-squared = 0.405, observed power = 0.999. Usability problems that were classified into FC in task component elicited higher valence (more unhappy) than FC in artifact component. The main effect of between-subjects independent variable, severity rating of usability problems, was statistically significant, $F_{(1,41)} = 36.584$, $p = 0.000 < 0.05$, partial eta-squared = 0.472, observed power = 1.000. Usability problems with higher severity ratings tend to elicit higher valence (more unhappy).

The interaction effect between types of usability problems and severity rating of usability problems on valence ratings was statistically significant, $F_{(1,41)} = 4.649$, $p = 0.037 < 0.05$, partial eta-squared = 0.102, observed power = 0.558. Results of simple effect analysis showed that effect of type of usability problems was statistically significant with $F_{(1,41)} = 24.810$, $p = 0.000 < 0.05$, partial eta-squared = 0.377, observed power = 0.998 when severity rating was low and with $F_{(1,41)} = 5.543$, $p = 0.023 < 0.05$, partial eta-squared = 0.119, observed power = 0.633 when severity rating was high. That is, effect of type of usability problems on emotional valence was stronger when their severity rating was relatively low.

4.2 Arousal

Means and standard deviations of arousal ratings corresponding to different usability problems are shown in Table 3. A 2(type of usability problems) × 2 (severity rating of usability problems) analysis of variance with repeated measurements for type of usability problems and severity rating of usability problems was conducted with arousal ratings as dependent variable.

The main effects of types of usability problems ($F_{(1,41)} = 3.719$, $p = 0.061 > 0.05$, partial eta-squared = 0.083, observed power = 0.469) and severity rating of usability problems ($F_{(1,41)} = 0.835$, $p = 0.366 > 0.05$, partial

Table 3 Means and standard deviations of arousal ratings

Level of severity rating	Type of usability problems	
	FC in artifact component	FC in task component
Low	4.26 ± 1.10	3.95 ± 0.97
High	4.67 ± 1.37	4.21 ± 1.72

eta-squared = 0.020, observed power = 0.145) were not statistically significant. The interaction effect between types of usability problems and severity rating of usability problems on arousal ratings was also not statistically significant, $F_{(1,41)} = 0.126$, $p = 0.724 > 0.05$, partial eta-squared = 0.003, observed power = 0.064.

4.3 Dominance

Means and standard deviations of dominance ratings corresponding to different usability problems are shown in Table 4. A 2(type of usability problems) × 2 (severity rating of usability problems) analysis of variance with repeated measurements for types of usability problems and severity rating of usability problems was conducted with dominance ratings as dependent variable.

The main effect of within-subjects independent variable, types of usability problems, turned out to be statistically significant, $F_{(1,41)} = 43.258$, $p = 0.000 < 0.05$, partial eta-squared = 0.513, observed power = 1.000. Usability problems that were classified into FC in task component elicited lower dominance than FC in artifact component. The main effect of between-subjects independent variable, severity rating of usability problems, was statistically significant, $F_{(1,41)} = 68.801$, $p = 0.000 < 0.05$, partial eta-squared = 0.627, observed power = 1.000. Usability problems with higher severity ratings tend to elicit lower dominance. The interaction effect between types of usability problems and severity rating of usability problems on dominance ratings was not statistically significant, $F_{(1,41)} = 0.585$, $p = 0.449 > 0.05$, partial eta-squared = 0.014, observed power = 0.116.

Table 4 Means and standard deviations of dominance ratings

Level of severity rating	Type of usability problems	
	FC in artifact component	FC in task component
Low	6.05 ± 1.39	4.58 ± 1.07
High	3.08 ± 1.31	1.91 ± 1.31

5 Conclusion and Discussion

The outcomes of the study indicate that effects of usability problems on user emotions differed by type and severity rating. Concretely, usability problems that were classified into FC in task component led to more negative and less dominance subjective feelings. Also, usability problems with higher severity ratings also resulted in the same user emotional responses; especially, the effect of type of usability problems on emotional valence was stronger when their severity rating was relatively low.

On the one hand, according to Bradley and Lang [13], valence rating reflects participant's tendency to approach a HCI event, whereas unhappy reflects a tendency to withdraw, escape, or terminate the encounter. So the results suggest that users may be more inclined to give up the present task when usability problem of the design belongs to FC in task component or shows more severity rating. The interaction effect between type and severity rating of usability problems on valence ratings suggests that the difference of user tendency to escape corresponding to different types of usability problems may be more significant when severity rating is low. On the other hand, Bradley and Lang [13] deemed that high dominance was associated with the one holding maximum control in HCI. So the results also suggest that when a user is confronted with usability problem belonging to FC in task component or showing higher severity rating, his/her control in the situation may decrease. However, the present study showed that the type and severity rating of usability problem do not affect user emotional arousal significantly. Considering the relationship between judgments of arousal and stimulus intensity, it seems that the above factors do not change the intensity of usability problem as stimulus in HCI. The features of participants would contribute to lack of statistical significance in the emotional arousal. Thus, all of them were skilled in computer operation and experienced to deal with system faults or breakdowns. So they were able to calm confronting with usability problems in HCI.

Compared with previous studies, we argue that usability problem in the concept framework of situational usability rather than perceived usability and pay more attention to quality in use of a system. This means, the corresponding results may be more valuable for system design and usability improvement. However, it should be noted that this study has examined only the effect of usability problems on user emotions from the aspect of subjective evaluations. Notwithstanding its limitation, this study does suggest that future investigations should pay attentions to the relationships between usability problems and physiological changes of user emotions.

Compliance with Ethical Standards The study was approved by the ethics committee of Xi'an Research Institute of Hi-Tech and was carried out in accordance with the approved guidelines and regulations. All subjects who participated in the experiment were provided with and signed an informed consent form.

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Research of the Air Defense Fire Control System Man–Machine Interface Design

Hai Chang, Bingjun Zhang, Zhiqiang Zhang, Run Dong, Jie Xing and Qian Liu

Abstract The man–machine interface (MMI) design of air defense fire control system shall pose immediate influence upon the safe and efficient operation. Scientific and reasonable MMI design may promote the operating efficiency, and bring the performance of weapon system into full display. On the basis of analyzing the type, quantity, and key contents of man–machine interaction of the air defense fire control system, and from the angle of operator's strength, accessible field, visible range, and information-processing capability, this research deliberates on the design principles of the MMI manipulator and displayer of air defense fire control system, in order to provide reliable designing standards for the industrial sector.

Keywords Air defense fire control system · MMI · Designing principle

1 Air Defense Fire Control System and Its MMI

1.1 Use and Composition of Air Defense Fire Control System

As the command and control center of air defense weapon system, the fire control system is employed to search and track aerial targets, resolve firing data, and control the firepower system to intercept hostile targets, which generally comprises of radar system, photoelectric system, computer system, servo system, power supply, communication system, hydraulic system, and control panel [1]. Operators fulfill their air defense tasks by operating and controlling the aforementioned systems through the MMI of control panel.

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1.2 MMI of Air Defense Fire Control System

The MMI refers to the entire interfacial environment of the operator's working space, namely, the control panel of the air defense fire control system, mainly including the manipulator and the displayer [2].

1.2.1 Manipulator

The manipulator refers to the device with which operators control the status of weapon and equipment by their hands or other parts of their body. As the air defense operation is noticeably featured by very short opportunity for combat, manipulation of fire control system ought to quick and precise, and such hand-operated manipulators should, therefore, be prioritized as hand wheels, joysticks, tracking balls, push buttons, band switches, and toggle switches and so on.

1.2.2 Displayer

The displayer is a device that transmits the information of weapon and equipment to operators through their sense organ, which falls into 2 categories—displayer for visual sense and displayer for audio sense.

The displayer for visual sense refers to the interface with which operators obtain machine information through their visual sense. It is suitable for complex information and figure or graph signals transmission, and the transmitted information is timely and may remain as long time as needed, which is convenient obtain. Displayer for visual sense of the air defense fire control system includes PPI, TV, meter, and indicator of various kinds.

The displayer for audio sense transmits information fast. It is comparatively more cautionary and is suitable for information transmission when visual sense is blocked as it may immediately arouse the attention of operators. Displayer for audio sense includes alarming device and voice transmission device.

2 Information Categorization and Operation Procedure of Air Defense Fire Control System

2.1 Information Categorization

2.1.1 Target Information

Air defense weapon system is employed to engage with aircraft of various types. In target searching period, operators focus on how many batches of targets there are in the operational airfield, what azimuth and range are regarding each target, and which target poses greatest threat; in target tracking period, such information as the target's slant range, azimuth and elevation, altitude and speed, as well as the preparation of firepower units should be paid enough attention to, since they are relevant with the selection of the moment to fire.

2.1.2 Equipment Status Information

Equipment status information includes the information of equipment operation and that of equipment failure. Information of equipment operation includes voltage, current intensity, and system working mode, which should be monitored by operators at any time so as to ensure the correct operation on the fire control system. There should be necessary information when the fire control system malfunctions in order that operators locate the trouble as soon as possible.

2.1.3 Equipment Parameters Information

Operators ought to configure the parameters of the fire control system according to the battle space environment so that the fire control system search and track targets precisely, such as STC, CFAR, working frequency, and repetition frequency. The fire control system needs as well to input such information as meteorological parameters, gun baseline, and firepower system parameters.

2.2 Operation Procedure

2.2.1 Combat Preparation Stage

After booting up, the air defense fire control system automatically undertakes computer self-checking and completes the computer initiation. With the testing program, operators determine the working status of the system, and send various operation directives to the system and complete the initiation of the parameters of the fire control system through man–machine interaction.

2.2.2 Target Searching Period

When fulfilling air defense combat tasks, the air defense weapon system needs beforehand to conduct air search. The fire control system is usually equipped with various sensors, and operators may realize target searching through radar system, photoelectric system, and intelligence command system. The aforementioned operations must be done via the radar displayer or photoelectric displayer on the control panel.

2.2.3 Target Tracking Period and Firing Period

Upon finding aerial targets, operators need to select target/targets in accordance with the threat of the target/targets, or directives from higher echelon. When the fire control system has spotted aerial targets, operators need to judge friends from foes: If the target is a friendly aircraft, the FRIEND indicator shall be on and operators are reminded not to open fire. During the process of tracking, operators may adopt various countermeasures against enemy electronic jamming and switch tracking modes amongst radar, TV, and joystick tracking so as to ensure the stability of target tracking. Operators may press the button to open fire and control guns to fire at corresponding target when the OPEN FIRE indicator is on.

3 Principles of Air Defense Fire Control System MMI Design

The basic principle of air defense fire control system MMI design is the adaptability for operators and operation tasks. The design should not exceed the strength, accessible field, visible range, and information-processing capability of operators, and at the same time, safety and maintainability should be taken into account as well [3]. There are usually 2 operators for the control panel of air defense fire control system, so enough attention should be paid to the grouping of manipulators and displayers in order to improve the operation efficiency.

3.1 Design of Manipulators

3.1.1 Designing Principles

- Comfortable body gesture to lessen operators' fatigue. For instance, important manipulators should be mounted at such suitable position as the horizontal surface so that operators' arms are properly supported.
- Different shape, size, color, and position for different manipulators. Operation of manipulators should be coordinated with corresponding displayers.
- Suitable force, direction, speed, travel, and accuracy of manipulators operation adapted to human force and motion output characteristics.
- Multi-function manipulator with indicator so that manipulation and display could be integrated.

3.1.2 Configuration Requirement

- Manipulators should be configured in accordance with the importance, frequency of use, and manipulation sequence [4].
- Manipulators should be arranged within the reach of upper limbs of operators; those important and often-used should be there easy to reach; those frequently used should be in the best area, i.e., on the lower side and right side of the displayer, so as to prevent operators' arms from blocking their sight. For example, arrange the joystick on the lower side of the TV, buttons for other tracking modes on the right side of the joystick. Since air defense fire control system currently adopts a search-track-integration mode, a tracking ball has taken the place of hand wheels of azimuth, elevation, and range. Based on the fact the fire control system intercepts targets by means of radar allocation, the RADAR ALLOCATION button shall obviously be arranged on the left side of the tracking ball.
- Manipulators of related functions should be arranged together, and sequential buttons should be arranged from left to right or from top to bottom. Frame them if manipulators are arranged in group for the convenience of recognition.
- Manipulators should be arranged in the sagittal plane, not excess 40 mm on the left and right sides.

3.2 Design of Displayers

3.2.1 Designing Principles

- Type and amount of signal and displayer should comply with the characteristics of information.
- Signal should be distinct and easy to recognize.
- Use digital displayer for quantitative information to avoid error of analog display.

3.2.2 Configuration Requirement

- PPI and TV are the main displayers of air defense fire control system. In order that operators recognize information clearly, PPI and TV should be configured around the center of their LOS, while keeping the screen slightly upward, leaving the included angle between the axis of the screen and the horizontal line at about 15°–20°.

- Arrange the indicators for important information in the upper left periphery of vision of operators. The motion of human eyesight is of regular pattern, namely, from left to right and from top to bottom, the observation effect of the upper left area is, therefore, the best, if given equal deflection distance, when the eyes diverges from the center of FOV [5].
- Distinguish indicators with various colors to reduce operation mistakes, promote the competency of information acquisition, and improve operators' working efficiency. For example, use red color for such important indicators as FIRE and FRIEND, not only to increase the attention of operators, but to be easily recognized.
- Audio sense is faster in receiving and processing information than visual sense. Audio signal may transmit information no matter what operators are monitoring, and it can thus be employed as alarm. For instance, use both indicator and alarm to remind operators of anti-radiation missile detection so that corresponding measures could be taken as quickly as possible.

4 Conclusions

With the development of science and technology, the air defense fire control system is evolving rapidly, and the optimization of its MMI design becomes increasingly important. In order to improve the combat efficiency of air defense fire control system, this paper employs the thoughts and methods of man–machine–environment engineering theory to analyze the man–machine interfaces and puts forward scientific principles of air defense fire control system MMI design on the basis of grasping the characteristics and summarizing previous experiences and lessons.

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Study of the Evaluation Index of Air Defense Weapon System Man–Machine Interface

Rongzhi Yang, Bingjun Zhang, Hai Chang, Meng Kang, Chenliang Ye and Yuankang Sun

Abstract The man–machine interface (MMI) design of air defense weapon system poses immediate influence on the operation efficiency and the display of the combat efficiency of air defense weapon system. Concerning the major issues related to the evaluation of man–machine interface of air defense weapon system, this paper establishes the evaluation system of subjective evaluation and objective evaluation, works out the congruent relationship between the evaluation credit and evaluation index of various display elements, manipulation elements, and the control panel, and introduces the method of determining the weight of elements on various levels by using analytic hierarchy process. Findings of this study may provide beneficial conference for the evaluation of air defense weapon system MMI design.

Keywords Air defense weapon system · Man–machine interface · Evaluation index

1 Evaluation Method of Air Defense Weapon System MMI

Profound changes have taken place in the design of air defense weapon system MMI as traditional meters, CRT displayers, or hand wheels have been replaced by digital meters, LCD displayer, and joysticks, and its MMI design poses immediate influences upon the entire air defense weapon system as well as the operation efficiency.

Evaluation of air defense weapon system consists of both subjective evaluation and objective evaluation [1]. By analyzing the corresponding evaluation index, conducting evaluation of the man–machine interface of air defense weapon system, probable deficiencies could be found and the entire design would be perfected.

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2 Determination of Objective Evaluation Index

2.1 Objective Evaluation Index for Display Elements

Display elements of air defense weapon system are digital meters, LCD displayers, and indicators. Position of display elements should be convenient for operators to watch while turning their head slightly or without turning. Display elements should be arranged in different areas in accordance with their importance and frequency of use. Evaluation of display elements comprises of the evaluation of structural parameters and that of position parameters. The evaluation index and corresponding credits are shown in the following Table 1.

Table 1 The congruent relationship between evaluation index of display elements and corresponding credits

Evaluation index	Credits of evaluation								
	60	70	80	90	100	90	80	70	60
Structural parameters of digital meters									
Viewing angle of dial plate (°)	2.9	4.8	6.7	8.6	10.5	12.4	14.3	16.2	18.1
Viewing angle of codes on dial plate (°)	0.353	0.386	0.419	0.452	0.485	0.518	0.551	0.584	0.617
Structural parameters of LCD displayers									
Viewing angle of displayer diagonal (°)	19.2	20.4	21.6	23.8	25	26.2	27.4	28.6	29.8
Viewing angle of codes on displayer (°)	0.283	0.3	0.316	0.333	0.35	0.36	0.37	0.38	0.39
Position parameters of LCD displayers									
Horizontal viewing angle (°)	−45.0	−35.0	−30.0	−15.0	0.0	15.0	30.0	35.0	45.0
Vertical viewing angle (°)	−65.0	−55.0	−45.0	−30.0	−15.0	0.0	5.0	25.0	40.0
Sight distance (mm)	460.5	511.0	561.5	612.0	662.5	713.0	763.5	814.0	864.5
Structural parameters of indicators									
Viewing angle of indicators (°)	0.6	0.7	0.8	0.9	1	100			

Table 2 The congruent relationship between evaluation index of manipulators and corresponding credits

Evaluation index	Credits of evaluation								
	60	70	80	90	100	90	80	70	60
Structural parameters of buttons									
Width of pressing side (mm)	12.2	12.4	12.6	12.8	13.0	14.0	15.0	16.0	17.0
Position parameters of buttons									
Interval between buttons (mm)	18.1	18.2	18.3	18.4	18.5	18.6	18.7	18.8	18.9
Height of disconnect (mm)	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5
Height of connect (mm)	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8
Structural parameters of band switches									
Angle of turning (°)	18	21	24	27	30	42	54	66	77
Width of knob (mm)	100 if less than 25				25	0 if greater than 25			
Length of knob (mm)	0 if less than 25				25	100 if greater than 25			
Structural parameters of joysticks									
Deflection angle (°)	0 if less than 45				45	100 if greater than 45			
Height of knob (mm)	55	65	75	85	95	105	115	125	135
Diameter of knob (mm)	8	10	12	14	16	18	20	22	24
Position parameters of joysticks									
Distance from the front edge of control panel (mm)	145	155	165	175	185	195	205	215	225

2.2 Objective Evaluation Index for Manipulation Elements

Manipulation elements of air defense weapon system include buttons, band switches, and joysticks. The congruent relationship between the objective evaluation index and corresponding credits is listed in the following Table 2 in accordance with GB10000-88 Human Body Sizes of Chinese Adults [2].

2.3 Objective Evaluation Index for Control Panel

The crux of the objective evaluation of control panel is whether the positions of displayers and manipulators are within the normal working range of operators and whether they are convenient for observation and operation. The congruent relationship between the evaluation index of control panel and corresponding credits is given in the following Table 3, on the basis of GB/T14776-93 Designing Principle and Value of Ergonomic Operating Post Size [3], and the human body size of the 50th percentile [4].

Table 3 The congruent relationship between evaluation index of control panel and corresponding credits

Evaluation index	Credits of evaluation								
	60	70	80	90	100	90	80	70	60
Structural parameters									
Height of control panel (mm)	764	768	772	776	780	784	788	792	796
Depth of control panel (mm)	100 if less than 350				350	390	430	470	510
Included angle between the 2nd panel and the horizontal plane (°)	31.5	33.0	34.5	36.0	37.5	39.0	40.5	42.0	43.5
Height of the space for thigh (mm)	0 if less than 155				155	155 if greater than 155			
Breadth of the space for legs (mm)	0 if less than 480				480	100 if greater than 480			
Position parameters									
Space for cross range movement (mm)	0 if less than 1000				1000	100 if greater than 1000			

3 Determination of Subjective Evaluation Index

Subjective evaluation is categorized into the evaluation of MMI component and that of the MMI as a whole.

3.1 Subjective Evaluation Index for MMI Component

Subjective evaluation index for MMI component is understood as the subjective evaluation of single component, which lays the foundation of the overall evaluation of man–machine interface. According to long-term practical experiences, the paper puts forward the evaluation index for display elements as is shown in the following Fig. 1, and the evaluation index for manipulation elements as is shown in Fig. 2.

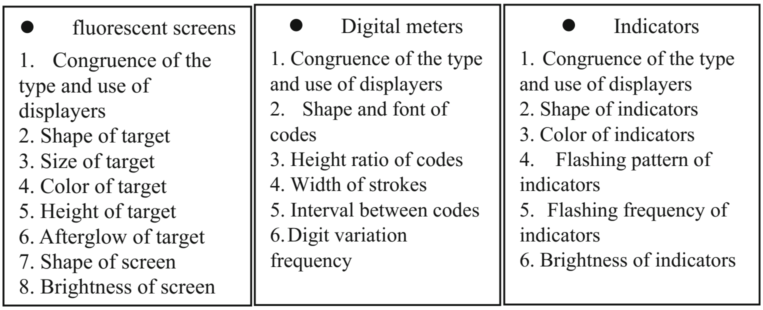

Fig. 1 Subjective evaluation index for display elements

● Buttons	● Band switches	● Joysticks
1. Congruence of the type and use of manipulators	1. Congruence of the type and use of manipulators	1. Congruence of the type and use of joysticks
2. Reasonable shape of contact surface	2. Reasonable shape of knob	2. Reasonable shape of knob
3. Reasonable visual texture	3. Reasonable visual texture	3. Reasonable visual texture
4. Reasonable color	4. Reasonable color	4. Attractive appearance
5. Attractive appearance	5. Attractive appearance	5. Sensitive response

Fig. 2 Subjective evaluation index for manipulation elements

3.2 Subjective Evaluation Index for MMI as a Whole

The function realization of air defense weapon system is related not only to component design, but also to the congruence between the arrangement and combination of displayers and manipulators and the operators' anticipation. The subjective evaluation index for MMI as a whole refers to the overall evaluation of the combination effect of displayer and manipulators as well as the control panel, as is shown in Table 4.

4 Calculation of the Weight of Evaluation Index of Air Defense Weapon System MMI

4.1 Analytic Hierarchy Process Method

The analytic hierarchy process method is mainly adopted to solve multi-attribute and multi-index decision-making problems, which divides complex problems into several hierarchies, introduces a scale of importance from 1 to 9, and quantifies the judgment of importance of various influencing factors through pairwise comparison. The AHP method ensures the continuance and consistence of judgment process by means of consistency check of judgment matrix, therefore preventing illogical judgment and realizing objective description of the weight of evaluation items [5].

4.2 Determination of the Weight of Various Components

The weight of the MMI of various components of air defense weapon system is determined by their respective importance and frequency of use.

Table 4 Subjective evaluation index for MMI as a whole

Item	Evaluation index
Efficiency and security	Quantity of information displayed
	Multi-channel displayed important information
	Easily recognizable codes displayed
	Misoperation protection and interlocking devices
	Handedness consideration
Displayers	Arrangement and combination in accordance with frequency of use
	Arrangement and combination in accordance with importance
	Congruence between arrangement and eyesight movement rule
	Easily perceived dangerous signals
	Easily recognizable codes
Manipulators	Accessible
	Simple to operate
	Arrangement and combination in accordance with frequency of use
	Arrangement and combination in accordance with importance
	Free of movement interference
Combination of displayers and manipulators	Responsive information for corresponding manipulation
	Manipulator in the proximity of displayer
	Congruence of special location between manipulators and displayers
	Congruence of movement direction between manipulation and display
	Free of blockage against eyesight while adjusting or operation
Coordination of the MMI as a whole	Congruence of the entire MMI arrangement
	Congruence of MMI geometric configuration
	Congruence of MMI color matching
	Congruence of MMI visual texture

Suppose there are n pieces of MMI components, the weight of importance of the component i is A_i, and its frequency of use is B_i. Then, the comprehensive weight of such a component is shown as:

$$G_i = A_i * B_i \tag{4.1}$$

Uniformize the G_i and it satisfies:

Then G_i represents the comprehensive weight of component i in the man–machine interface.

5 Conclusions

This study establishes the hierarchical structure of the man–machine interface of air defense weapon system on the basis of analyzing its composition, and puts forward the subjective evaluation index and objective evaluation index. By providing the congruent relationship between various evaluation index and the corresponding credits, the paper works out the comprehensive weight of each component in the hierarchical structure by AHP method and lays a solid foundation for quantifying the evaluation result of the man–machine interface of air defense weapon system.

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Human–Machine Interface Design of Metal Detector Based on SPI

Jun Shen, Rui Yan and Chuan Wang

Abstract According to the problem of the human–machine interface design from metal detector, human machine interface display system of metal detector has been designed in this paper, which uses SPI communication protocol as the core. Point of this paper is the study of the communication protocol SPI between metal locator DSP and MCU. Hardware circuit and software design of the human machine interface system have been studied. In the existence of mineral, the system circuit is verified. The experiment indicates that the MCU can accurately read data which are sent from DSP by SPI protocol, meanwhile turn the data into Chinese characters, thus displaying them on the LCD screen when the DSP is running at high speed; besides, it is also proved that the system can not only detect percent of metal in the mineral, the accurateness and the anti-interference performance is also high, the result reach the expected goals.

Keywords Human–machine interface · Metal detector · SPI

Preface

In the mining industry, metal detector works in a bad environment. In addition to the existence of large power consumption, inconvenient installation, and low sensitivity of the shortcomings, the man–machine interface is also a very significant issue [1]. An excellent man–machine interface can prevent the false warning of detector and improve the efficiency of metal detector [2]. The traditional mining metal detector's man–machine interface directly transmits data to each display chip through the DSP, not considered as a separate system. Therefore, it is easy to be affected by DSP, with shortcomings like poor anti-interference ability and possible

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malfunction [3]. Metal detector's man–machine interface is an area of mutual influence between people and detector, and the information communications between nature and metal detector are in the scope of human–machine interface [4]. At present, the demand of metal detector's man–machine interface in China is indeed very huge. However, China is not the market with the highest sales of man–machine interface products, because the low-end intelligent man–machine interface is becoming the mainstream of society and occupying a considerable share in the market. Non-intelligent metal detector's man–machine interface does not have a strong advantage.

In this paper, the author has designed a man–machine interface control system for metal detectors suitable for Industrial and mining industry. The hardware and software of the system are designed with the serial peripheral interface (SPI) protocol and single-chip control. The system can not only detect the existence of metal and improve the anti-interference ability without false warning, but also to a large extent reduce the complexity of the design and reduce the number of peripheral devices used.

1 Metal Detector System

1.1 System Block Diagram

The metal detector is used to detect the waste metal present in the bulk material conveyed on the conveyor belt. The discarded metal detected can be mechanically or automatically removed from the process flow by mechanical means [5]. Metal detector device consists of two parts: a bracket and a controller. The bracket is used to install the receiving coil and the transmitting coil, while the controller is the core part of the whole device, and the microcontroller is the single chip and DSP. The system of metal detector is shown in Fig. 1.

1.2 SPI Protocol

SPI is a synchronous serial interface technology that works in master-slave mode. The core of the system of a metal detector includes two parts: a DSP and a microcontroller, DSP and microcontroller SPI protocol to rely on communication. The DSP acts as a host, and the microcontroller acts as a slave. SPI's master device DSP controls data transmission by providing a clock signal with enable strobe signals, and the system can directly pull the enable strobe signal into low level. The communication between the DSP and the microcontroller is determined by the clock signal SCLK, so the microcontroller remains active. The hardware wiring of SPI protocol DSP and microcontroller between is shown in Fig. 2.

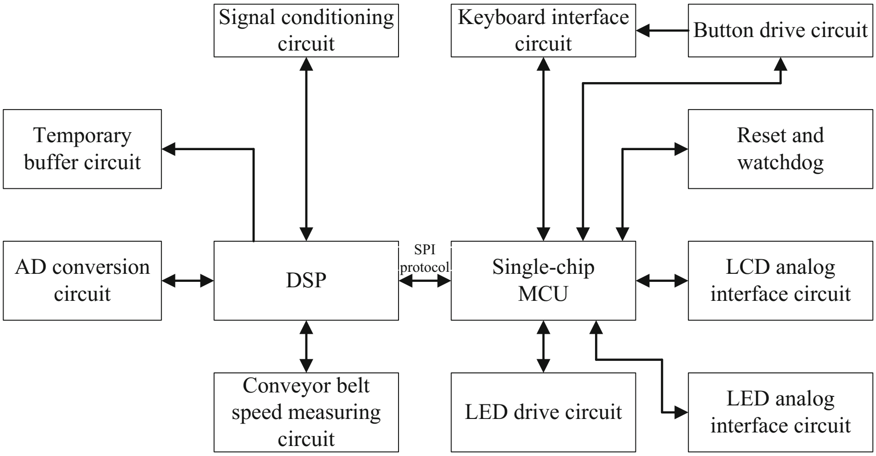

Fig. 1 Metal detector system block diagram

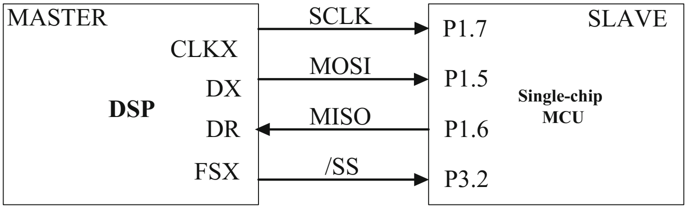

Fig. 2 SPI protocol hardware wiring diagram

Work process of metal detector system SPI: The host DSP write the information to be sent to SPI-sent data register DXR through the MOSI pin while starting the sending process of the DSP host and transferring the information to be sent under the control of the synchronic clock SCLK to the receiving pin RXD of the microcontroller one by one. When the RXD transfer is completed, an interrupt flag is set to notify the DSP of completion of information sending.

With the beat of synchronous clock SCLK, the slave microcontroller will transfer the data received by the displacement register SBUF to receiving buffer register one by one to move and copy the data to the receiving buffer register. When a complete data block is received, an interrupt flag is set to inform the slave microcontroller of the completion of receiving of the information block.

2 Hardware Design

The system consists of a single-chip system that provides an easy-to-use display for the operator in addition to controlling the transmitting and receiving signals, and automatically setting up and calibrating the system. Therefore, the system taking microcontroller as a chip is also known as the metal detector's man–machine interface system.

Metal detector's man–machine interface system takes single-chip STCl2C5A60S2 as a microprocessor, with a large memory (60 kB), a new generation of 8051 single-chip and capacity of high speed, low power consumption, and super anti-interference. The speed is the 8–12 times of traditional 8051 microcontroller, and all of the minimum system's programming port, power supply, LCD display, and LED indicators will change.

3 Software Design

3.1 SPI Protocol Flowchart

The microprocessor in the metal detector system is a slave of host computer DSP, receiving data from DSP through the SPI. The data receiving process of SPI in interruption model are shown in Fig. 3.

3.2 Man–Machine Interface System Software Flowchart

During the design of metal detector man–machine interface system, the use of modular design is conducive to development and clear programming thinking. The system development software is keil uVision4, and programming language is C language. DSP controls LCD and LEP indicator by data transmission by SPI to the man–machine interface controller. Metal detector man–machine interface system software flowchart is shown in Fig. 4.

4 Experimental Verification

4.1 Experimental Results

The results show that the SPI communication protocol enables the DSP to be well integrated with the microcontroller and the metal detector man–machine interface system can accurately detect the presence of two metal impurities in the ore when the metal detector device is in operation.

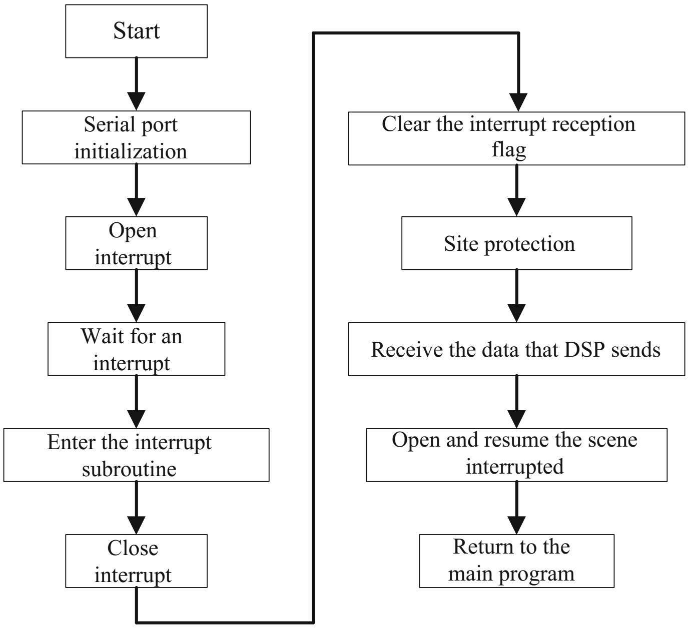

Fig. 3 SPI agreement interrupts flowchart

4.2 Contrastive Verification

In practices, the detection precision of the metal detector does not have to reach the millimeter level and centimeter level is okay. Iron ore is used as background in the actual applications, so the metal impurities to be detected are simulated with small metal balls. The distance between the launch panel and the receiving panel is adjustable (40–80 cm), so the distance between them is 50, 60, 70 cm, respectively, and the sensitivity of the metal detector is 5 here.

When using a small iron ball with radius of 1.5, 2.0, or 3.0 cm goes through the central of the detection area at even speed (which shall be consistent with the numerical value set for the detector), the highest of iron ball from the receiving panel is 15 cm. 50 tests are made in each case.

(1) With less interference in the outside (without iron ore background and conveyor belt), Table 1 is the conditions of omission of the system designed in this paper and the conditions of omission of the traditional man–machine interface system.

    Table 1 shows, in the case of minor external interference (without iron ore background and conveyor belt), there is no omission of system designed herein, while there is 1 omission for the traditional man–machine interface system.

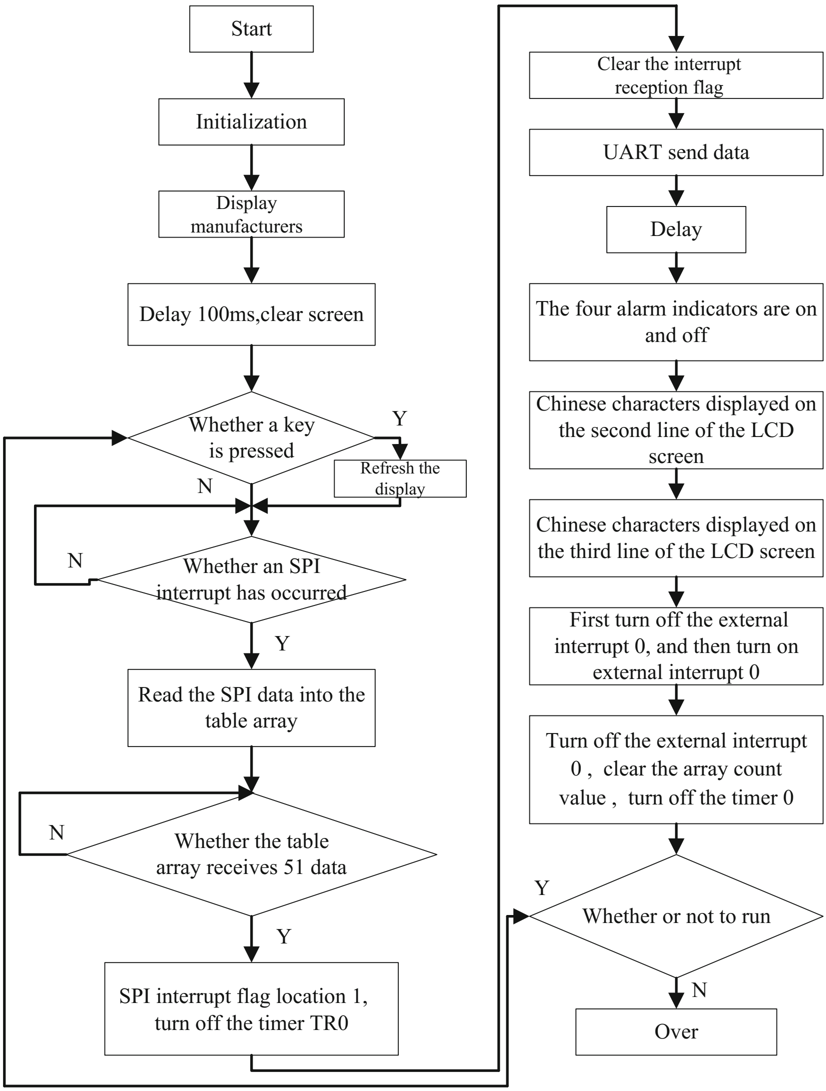

Fig. 4 Human–machine interface system software flowchart

(2) In the case of major external interference (with iron ore background and conveyor belt), Table 2 shows the contrast of omission conditions of small balls between the traditional system and the system herein.

Table 2 shows, in the case of major external interference (with iron ore background and conveyor belt), there is no omission of system designed herein, while there are 3 omissions for the traditional man–machine interface system.

Table 1 Ball omission of man–machine interface system designed in this paper and traditional

Small ball size (cm)	Plate spacing 50 cm		Plate spacing 60 cm		Plate spacing 70 cm	
	Traditional	This paper	Traditional	This paper	Traditional	This paper
1.5	0	0	0	0	1	0
2.0	0	0	0	0	0	0
3.0	0	0	0	0	0	0

Table 2 Ball omission of man–machine interface system designed in this paper and traditional

Small ball size (cm)	Plate spacing 50 cm		Plate spacing 60 cm		Plate spacing 70 cm	
	Traditional	This paper	Traditional	This paper	Traditional	This paper
1.5	0	0	1	0	2	0
2.0	0	0	0	0	1	0
3.0	0	0	0	0	0	0

The experiments made in the two phases show man–machine interface system designed in this paper is able to not only detect the number of metal items, but also resist interference. There is no omission of system designed herein regardless of the existence of metal ore.

5 Conclusion

The metal detector man–machine interface system designed in this paper takes the STC12C5A60S2 chip of the microcontroller as the controlling chip and uses a 128×64 LCD screen as display chip so as to design a fully functional man–machine interface system.

(1) SPI protocol communications are adopted between the microcontroller and DSP. When DSP is in high-speed operation, the microcontroller can accurately read the data sent by the host DSP through the SPI protocol and translate the data into Chinese information displayed in the man–machine interface of the metal detector in a very short period.
(2) The metal detector device can detect the metal balls with diameter no less than 1.5 cm with the man–machine interface system designed herein, and in the case of strong interference, the system will not have omission or false warning. This system is verified for its high precision, stability, and reliability during the detection process.

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Study on Color Coding Requirements for See-Through Displays in Simulated Aeromarine Flight

Duanqin Xiong, Qing He, Xiaochao Guo, Yanan Liu, Qingfeng Liu, Qin Yao, Jian Du, Yu Bai and Yanyan Wang

Abstract *Objective* To study the color coding requirements of displayed information in see-through displays during aeromarine fight. *Methods* One hundred and fifteen fighter pilots participated in the experiment. In virtue of color coding experimental procedure for see-through displays information in fighters, pilots selected colors for the display elements in the route and combat flight menu. *Results* (1) The pilots' color coding requirements of flight course menu were that green was the main color, longtime displayed and normal information was inclined to be green, dangerous and overrun information was inclined to be red, and latent dangerous and needing pilots' attention information was inclined to be yellow. (2) The pilots' color coding requirements of combat menu were that green was the main color, longtime displayed and attackable information was inclined to be green, and unattackable and overrun information was inclined to be red. *Conclusions* The pilots' color coding requirements for see-through displays in aeromarine flight were that green was the main color; longtime displayed and normal and attackable information was inclined to be green; dangerous, overrun, and unattackable information was inclined to be red; latent dangerous and needing pilots' attention information was inclined to be yellow. Above conclusions were only primary, and subjective and objective researches should be conducted later, so as to deeply verify the rationality of pilots' requirements.

Keywords Color coding · See-through display · Aeromarine flight · Pilots · Human factor

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1 Introduction

With the development and progress of display control technology, see-through displays (such as head-up display and helmet-mounted display) get more and more applications in aircraft. The pilot obtains various information contents from these displays to complete various operation and training tasks. Due to the display ability of images, the traditional see-through display is mainly for the monochrome (green) display, on which all information is displayed as the same color, while the colorful display can effectively improve the performance of search and recognition tasks; when a kind of information needs to be quickly located, the color is effective more than the shape, size, letter or number [1] so as to minimize cognitive load and response time of the display [2]. Some scholars have found that the weapons symbol with color coding in the lmet-mounted display has obvious advantages [3]. Therefore, the colorization of information on the see-through display will be a major design trend after the technological progress of the display.

Flying over the sea is the inevitable environment for a pilot to complete aero-marine missions. Through the study of the experience in using traditional head-up display, pilots generally complain that, due to the special color of the seawater, it is difficult to identify the pure green information in a head-up display, especially for warning and threatening information which more need color coding. In the information display of future of new see-through displays, it is possible to achieve color coding, which will be able to overcome the monochrome display which can be limited to using the shape, size, location, and other coding methods [4], and it will improve the pilots' ability to obtain information. There have been studies found that weapons symbols using color coding make the pilot's combat performance significantly enhanced [3]. But for a new type of see-through display with color coded display capability, for the special flight environment on the sea, with regard to which information needs color display and what kind of color coding is used, there are no relevant standards and norms. To this end, this study carries out color coding study for the see-through display over the sea to learn about the specific Requirements of pilots and provide reference of color design of information of see-through display in the future.

2 Method

2.1 Test Devices and Method

2.1.1 Task Design

In this study, two typical display menus of aircraft information were the experimental materials—route flight menu and combat menu. The route flight menu included nine categories of display elements and the combat one included ten categories of display elements by taking sea simulation image as the background. The pilot experimental procedure was programed. The pilots were required to use their own flight experience to designate the best color for various display elements of the two display menus including seven fixed colors and custom colors. The seven colors included red, green, blue, white, amber, magenta, cyan, and yellow; the custom color is freely selected by the pilot when the pilot thought that the display elements could not be displayed with these fixed colors.

2.1.2 Test Materials and Devices

2.1.2.1 A set of see-through display information color coding experimental procedure was used. The procedure included four modules: ① background information module, collecting the subject background information; ② practice module, providing subjects with similar exercise tasks to the formal test to enable them to be familiar with the test tasks and the entire test process; ③ test module, containing route flight menu (nine categories of display elements) and combat menu (ten categories of display elements) dynamic simulation procedure; and ④ data management module which will record, store, and export the test data.

2.1.2.2 Three sets of notebook computers (one of which is the server of the experimental procedure and two for the pilot experiment flats) and 3 mouses.

2.2 *Experiment Methods and Steps*

The experiment form is man–machine dialogue. Subjects first fill in the background information in the experimental procedure and then enter the exercise to be familiar with the entire experimental method, the form of tasks and precautions. After the completion of the exercise, they would enter the formal experiment phase to achieve the mission of selecting color for each display element in two dynamic menus.

The experimental procedure automatically recorded the values of the colors R, G, and B selected by each subject for each type of display element.

2.3 *Experimental Subjects*

The subjects included 115 male fighter pilots within 32.09 ± 5.72 years old with eyesight better than 0.8 and without color blindness.

2.4 Statistical Analysis

SPSS16.0 software was used to statistically analyze the experimental data. The values of the R, G, and B of each display element were identified as a certain color as a whole. The number of pilots who had selected certain color for every element was a statistical indicator of the experimental results.

3 Results and Analysis

3.1 Results of Color Selection for Various Categories of Display Elements of Route Flight Menu

For the route flight menu, according to the statistics of the number of the pilots who selected the best color for each category of display element, the results were shown in Table 1.

Among the nine categories of display elements in Table 1, categories 1–6 and 8–9 belonged to longtime displayed information, and only category 7 belonged to unlong-time displayed information that appeared in route flight. For those who have longtime displayed normal information, the number of pilots choosing green was clearly dominant; with regard to the dangerous and over-limit information, the number of pilots choosing red was clearly dominant; as to the information between normal display and over-limit display with the potential danger which requires the pilots to pay attention, the number of pilots choosing yellow was clearly dominant.

In above table, in addition to the green as the first choice of most of pilots in displayed information, there were several colors favored and chosen by a large proportion of pilots.

According to this, it could be initially considered in the sea background and conditions, and the pilot group had such requirements on the color coding of route flight menu elements of the see-through display: Green was the main color and favored for longtime displayed normal information, red for over-limit information, and yellow for information with the potential danger which required the pilots to pay attention.

3.2 Results of Color Selection for Various Categories of Display Elements of Combat Menu

For the combat menu, according to the statistics of the number of the pilots who selected the best color for each category of display element, the results were shown in Table 2.

Table 1 Number of the pilots who selected the best color for each category of display element in route flight menu (n = *115*)

No.	Displayed elements		Red	Green	Blue	White	Amber	Magenta	Cyan	Yellow	Custom color
1	Element 1 (longtime displayed information)		10	63	11	0	1	11	2	14	3
2	Element 2 (longtime displayed information)		7	62	13	2	1	5	2	21	2
3	Element 3 (longtime displayed information)		2	73	5	2	1	7	2	23	0
4	Element 4 (longtime displayed information)		7	49	13	2	6	14	2	21	1
5	Element 5 (longtime displayed information)		4	53	16	2	6	10	3	20	1
6	Element 6 (longtime displayed information)		5	79	5	1	3	4	2	16	0
7	Element 7 (unlong-time displayed information)	Element 7-1 (normal information)	4	81	4	2	2	7	4	9	2
		Element 7-2 (normal to overrun information)	2	28	6	1	3	10	10	52	2
		Element 7-3 (overrun information)	60	24	4	0	1	12	3	11	0
8	Element 8 (longtime displayed information)	Element 8-1 (normal information)	4	73	3	2	0	9	5	17	2
		Element 8-2 (overrun information)	60	30	3	2	0	6	5	9	0
9	Element 9 (longtime displayed information)		1	79	3	1	1	9	7	13	1

Table 2 Number of the pilots who selected the best color for each category of display element in combat menu (n = *115*)

No.	Displayed elements		Red	Green	Blue	White	Amber	Magenta	Cyan	Yellow	Custom color
1	Element 1 (longtime displayed information)		8	65	10	1	0	10	2	18	1
2	Element 2 (longtime displayed information)		4	68	12	3	0	5	4	19	0
3	Element 3 (longtime displayed information)		2	78	4	1	1	7	3	18	1
4	Element 4 (longtime displayed information)		7	53	16	1	2	12	4	20	0
5	Element 5 (longtime displayed information)		4	56	15	1	2	15	1	19	2
6	Element 6 (longtime displayed information)		6	78	6	1	2	5	5	11	1
7	Element 7 (longtime displayed information)	Element 7-1 (attackable information 1)	4	76	0	3	0	8	5	17	2
		Element 7-2 (unattackable information 1)	61	27	0	2	0	9	3	12	1
8	Element 8 (longtime displayed information)	Element 8-1 (attackable information 2)	32	40	7	1	1	11	4	18	1
		Element 8-2 (unattackable information 2)	30	30	3	2	3	10	4	30	3
9	Element 9 (longtime displayed information)	Element 9-1 (normal information)	21	48	6	1	2	9	4	20	4
		Element 9-2 (overrun information)	25	38	5	1	4	12	4	25	1
10	Element 10 (longtime displayed information)		0	72	3	2	4	9	6	16	3

Among the ten categories of display elements in Table 2, categories 1–6 and 9–10 belonged to longtime displayed information, and only categories 7–8 belonged to unlong-time displayed information that appeared in combat conditions. For normal information and attackable information, the number of pilots choosing green was clearly dominant; with regard to unattackable information 1 and over-limit information, the number of pilots choosing red was clearly dominant; as to the unattackable information, the number of pilots choosing red or green equaled to the number choosing yellow.

In above table, in addition to the green as the first choice of most of pilots in displayed information, there were several colors favored and chosen by a large proportion of pilots.

According to this, it could be initially considered in the sea background and conditions, and the pilot group had such requirements on the color coding of combat menu elements of the see-through display: Green was the main color and favored for longtime displayed normal and attackable information and red for unattackable and over-limit information.

4 Conclusion

This study mainly investigated in the color coding requirements of the pilots on the color coding of typical display elements of the see-through display based on the background of the sea flight, to provide reference for the color design of the information. The route flight menu and the combat menu, which are dynamically displayed in the simulated sea background, had been designed in the experiment, and the subjects are required to choose the best coding color for each category of display elements in the menu.

The results of the experimental study may draw following conclusions: In sea background conditions, green should be main color of the menu, and green is preferred for longtime displayed normal information and attackable information; red for the unlong displayed specific information with danger, unattackable information, and over-limit information; and yellow for the information with the potential danger, which requires the pilots to pay attention.

It should be noted that this study used only the subjective color selection by the pilots and does not consider the objective effect of the color arrangement of the menu, so above conclusion is only a preliminary one. Subsequent studies will be carried out by combination of objective method and subjective method to further validate the rationality of the requirements of the pilots as a whole.

Compliance with Ethical Standards The study had obtained approval from the State Key Laboratory of NBC Protection for Civilian Ethics Committee.

Each pilot was briefed on the aims of the study, and his consent was obtained. All pilots were paid ¥100/hr. for their participation.

All relevant ethical safeguards had been met in relation to subject protection.

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Part V
Research on the Man–Environment Relationship

Experimental Research on the Effects of Noise on the Crew's Reliability in Information Processing

Weiping Liu, Bo Yang and Zheng Zhang

Abstract To explore the relationship between noise and the reliability of crew's work, a two-task experiment was conducted, based on the theory of Irrelevant Sound Effect (ISE), in which 40 participants (classified into three noise groups and one control group) performed representative information processing tasks in different noise environments. The time to complete tasks and the error rates of every participant in different groups were evaluated, respectively. In the experiments, the time and error rates of subjects' tasks in the three noise groups are higher than those of the control group. The result indicated that noise affected the reliability of crew' work obviously. As noise loudness increased, there was an increase in time and error rate completing tasks and they are also higher than those of the subjects' tasks in the control group, which could provide a reference for further human reliability study.

Keywords Noise · In-vehicle information terminal · Information processing · Reliability

1 Introduction

Human reliability refers to a manipulator's capability of completing given tasks in the set condition and the shortest time [1]. It is rapidly becoming essential for man–machine systems. Due to the complexity of armored vehicle system, the influencing factors of the Crew's reliability are various. Noise as one of the significant environmental factors tends to be the focus of ergonomic study.

More than a hundred studies have shown the relationship between noise and human performance; methodology in fuzzy mathematics can be used to define manipulator's annoyance of noise [2]. An ergonomic study of industrial noise

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illustrates that noise has an obvious effect on human work efficiency and memory [3]. However, there are researches differed from former studies [4, 5].

The purpose of this research was to investigate the effect of noise in armored vehicle cockpit on crew's reliability of information processing. Results from this study will provide a reference for further improving crew's reliability.

2 Method

2.1 Participants

Forty male students (age range 20–25, mean age = 21.4, S.D. = 1.9 years) were selected from a military college. All participants were right-handed and passed the physical examination. They did not have the experience of in-vehicle information terminal manipulating. Before the experiment, there was a 1-hour training to enable them to manipulate the terminal. Then, they were classified into three noise groups [namely, 70 dB(A), 80 dB(A) and 90 dB(A)] and a control group randomly and equally.

2.2 Experimental Setup and Equipment

The experiment was performed in a simulating armored vehicle cockpit where the background noise ranged from 37 dB(A) to 41 dB(A). The experimental platform was the ergonomic Experiment Platform of Armored Information System, which had the functions from subject registration to task selection to parameter setting to data storage. The equipment of noise storage and noise output were a laptop computer (ENOVO S41-70) and a headphones (EDIFIER K800). Before the experiment, noise from one type of armored vehicle was collected and stored into the laptop computer as a wav. Auto file. During the experiment, participants from three noise groups and the control group were asked to wear headphones playing either 70 dB(A) noise, 80 dB(A) noise, 90 dB(A) noise, or nothing at all.

2.3 Procedure

Prior to the experiment, subjects were trained to use the platform to perform two experimental tasks until their error rate and time to complete tasks were steady. During the experiment, the subjects in three noise groups and the control group were exposed to the 70 dB(A), 80 dB(A), 90 dB(A) noise environment and natural background condition. After the experimental parameters were set and the noise signals were adjusted already, subjects had to perform 10 times of the information entering task and 10 times of the message transmittal task, respectively. After conducted the experimental task, subjects were asked to complete a questionnaire, which included the effect of noise on the individual's information perception, attention requirements, manipulation speed, manipulation accuracy, and degree of fatigue.

2.4 Variables

Independent variables were noise loudness [70 dB(A) noise, 80 dB(A) noise, 90 dB(A) noise and a control group]. Dependent variables included the time to complete two tasks and the error rate.

2.4.1 Time to Complete Tasks

The amount of time a subject used to complete each task was collected. A task started when the subject hit the "F1" or "F2" button after he or she saw the prompting information and ended when the subject hit the "Done" button; time to complete a task can be defined as follows:

$$T = \sum_{j=1}^{n} \frac{T_j}{n}$$

In the above formula, Tj represents the mean of time the jth subject used to complete two tasks, respectively; n represents the total number of subjects.

2.4.2 Error

An error was defined as a disoperation that activated the wrong button. The error rate was calculated for each task.

$$E = \sum_{j=1}^{n} \frac{\sum_{i=1}^{m} e_{ij}}{\sum_{i=1}^{m} n_{ij}} \times 100\%$$

In the above formula, eij represents the mean of error manipulations of the ith subject that the jth subject made; n represents the total number of subjects.

3 Results

Prior to statistical analyses, data from four subjects were removed because they did not perform tasks completely. Variance analysis was used to examine the significant difference of experimental data among subjects' indifferent groups. The significance level was set at $p < 0.05$ for all statistical tests.

3.1 Time to Complete Tasks

Time to complete two tasks of subjects in three noise groups and the control group was significantly different (Table 1, Fig. 1).

Table 1 Data of time to complete two tasks of subjects in different groups (ms)

Group	Information entering task		Message transmittal task	
	M	SD	M	SD
Control group	4656.27	414.12	2548.59	279.56
Noise group 1 [70 dB(A)]	5331.39	468.58	2839.63	282.16
Noise group 2 [80 dB(A)]	5524.16	516.02	3256.68	316.25
Noise group 3 [90 dB(A)]	6458.91	689.25	3812.31	395.09

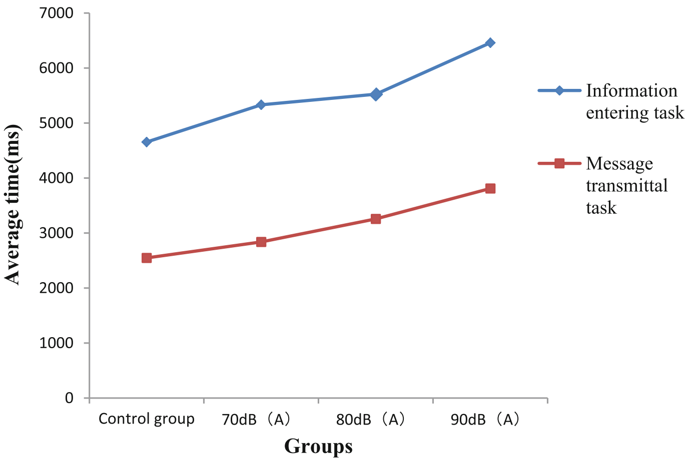

Fig. 1 Time to complete two tasks of subjects in different groups

Time to complete two tasks of subjects in three noise groups was significantly higher than that of subjects in the control group. Also subjects in noise group 1 spent less time to complete tasks compared with subjects in noise group 2 and noise group 3. The results of variance analysis indicated that time to complete tasks was significantly affected by noise loudness ($P = 0.010 < 0.05$) and task type ($P = 0.000 < 0.05$), while there was no remarkable interaction between noise loudness and task type ($P = 0.63 > 0.05$).

3.2 Error Rate

The total error rate of two tasks of subjects in three noise groups and the control group were shown in Table 2, (Fig. 2).

The error rates of two tasks of subjects in the control group were significantly higher than those of subjects in three noise groups. In addition, subjects in noise group 1 had lower error rate compared with subjects in noise group 2 and noise group 3. The results of variance analysis indicated that the error rates were

Table 2 Data of error rate of two tasks of subjects in different groups (%)

Group	Information entering task		Message transmittal task	
	M	SD	M	SD
Control group	4.57	0.39	3.20	0.29
Noise group 1 [70 dB(A)]	7.12	0.68	5.72	0.43
Noise group 2 [80 dB(A)]	9.21	0.61	9.41	0.82
Noise group 3 [90 dB(A)]	14.28	1.13	10.15	0.91

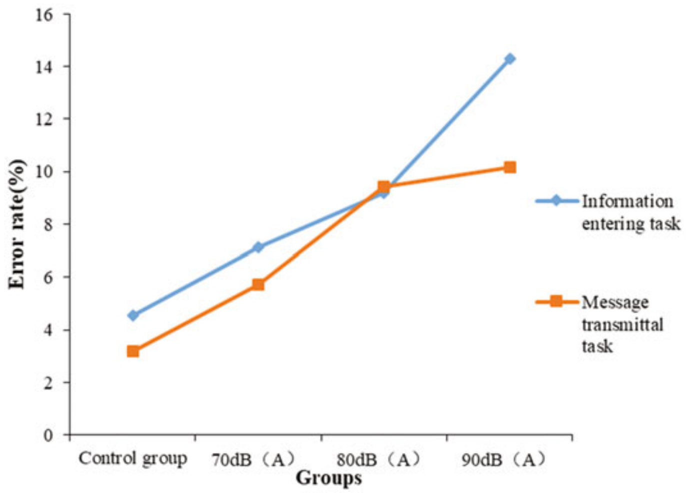

Fig. 2 Error rate of two tasks of subjects in different groups

significantly affected by noise loudness ($P = 0.000 < 0.05$) and task type ($P = 0.003 < 0.05$), while there was no remarkable interaction between noise loudness and task type ($P = 0.79 > 0.05$).

4 Discussion

The main source of noise in armored vehicle cockpit is from engines. During information processing, noise could affect the physical health of crew and cause weariness. By analyzing the feature of two representative information processing tasks, It could be concluded that both of the information entering task and message transmittal task included a series of cognitive process, which meant a large amount of attention, memory, and reaction capacity were needed. The results of objective experiment and subjective assessment indicated that subjects' ability of judgment, veracity, and speed of manipulating would decrease in noise condition, which worsened the reliability of man–machine systems. The present experimental results are consistent with Saeki's study [6].

5 Conclusion

With this experiment, we were able to show that classifying subjects into different groups and conducting representative tasks were valid methodology to explore the effects of noise on the crew's reliability. The results indicated that the error rate and time to complete tasks of subjects appeared to have an upward trend with the increase in noise loudness, which reduced crew's reliability of in In-vehicle information terminal manipulating. Thus, it is essential to focus on the improvement in armored vehicle engines and noise precaution for armored vehicle crew during information processing.

Compliance with Ethical Standards The study was approved by the Logistics Department for Civilian Ethics Committee of AAFE.

All subjects who participated in the experiment were provided with and signed an informed consent form.

All relevant ethical safeguards have been met with regard to subject protection.

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Effects of Transcranial Micro-electric Current Physiological Training on Polysonograme Under Altitude Hypoxia

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Abstract *Objective* To investigate the effects of transcranial micro-electric current physiological training (TMCPT) on polysomnograme (PSG) in order to provide technology and methods for maintaining and training cerebral function (CF) under altitude hypoxia. *Methods* Forty healthy volunteers served as subjects, who trained by TMCPT in the condition of altitude hypoxia (3700 m above sea level). Current intensity of TMCPT was limited within safety physiological band. Subjects were trained 1 times per day (before going to bed) and lasted 5 min. PSG were observed in resident phase (time lasted 3 month at least) Pittsburgh sleep quality index were investigated to evaluate the sleep quality. *Results* Compare to the results of pre-TMCPT, actual sleep time of PSG increased, sleep latency decreased, sleep efficiency improved significantly ($F = 15.43–34.75$, $P < 0.05$). $S_{2\%}$, $S_{3+4\%}$ and REM% of sleep construction in PSG increased but $S_{1\%}$ decreased ($F = 12.59–14.57$, $P < 0.05$). Subjects' sleep quality indexes had significant reduction as compared with those in pre-resident phase. *Conclusions* TMCPT can improve sleep quality under altitude hypoxia.

Keywords Altitude · Hypoxia · Cerebral function · Polysomnogram (PSG) · Pittsburgh sleep quality evaluation

1 Introduction

The adverse influence of hypoxia on the brain function was very significant, such as headache, insomnia, etc. Oxygen inhalation or taking the medicine improving the oxygen metabolic capability of brain cells could resist the influence of these adverse factors, but were proven to display the function indirectly. The transcranial micro-electric current physiological training (TMCPT) directly introduced the micro-electric current (the strength was the microampere level, μV) into the brain

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through the scalp surface electrode in the simulated brain wave way so as to physically interfere and adjust the central nervous system. The adjustment function could improve sleep [1–13]. The study observed the characteristics of the influence of TMCPT on the altitude permanent residents' EEG during sleep so as to provide technical means for guaranteeing the altitude encamping training.

2 Subject and Method

2.1 Subject

40 health volunteers who were 18–40 years old and the average age was (28.5 ± 10.4) years old. They were healthy and passed the physical examination, and didn't have the medical or drug history of the neuropsychiatry system. They worked and rested according to the army schedule, slept regularly and didn't have abnormal sleep or altitude living history.

2.2 Method

2.2.1 Equipment for Brain Function Training

The medical electronic stimulator (BT701 type, Shanghai Huayi Medical Instrument Co., Ltd) was used for TMCPT. The stimulator could output the asymmetric bidirectional pulse continuous wave, and had the simulated full-brain wave frequency. Four brain wave frequency band were included as follows: δ frequency band 1–3.8 Hz, θ frequency band 4–7.8 Hz, α frequency band 8–12.8 Hz (slow α1 frequency band 8–9.8 Hz, fast α2 frequency band 10–12.8 Hz) and β frequency band 14–30 Hz. The stimulator frequency band was 0–40 Hz, and it could be continuously adjusted [14–16].

2.2.2 EEG Monitoring

2.2.2.1 Sleep EEG monitoring assessment system [17]: the AponeScreen-type sleep EEG monitor was used for the all-night-long sleep monitoring of the volunteers after TMCPT training. Sleep progress indexes: wakefulness time, sleep latent time, actual sleep and sleep efficiency. Sleep structure indexes: sleep percentage of the first stage ($S_{1\%}$), sleep percentage of the second stage ($S_{2\%}$), sleep percentages of the third and fourth stages ($S_{3+4\%}$), and REM sleep percentage (REM%).

2.2.2.2 Assessment for sleep quality: the Pittsburgh sleep quality index (PSQI) was used for assessing the sleep quality of the altitude permanent residents after TMCPT training. It included subjective sleep quality, (SSQ), sleep latency (SL), sleep duration (SDu), sleep efficiency (SE), sleep difficulty (SDi), using of sleep medicine (USM) and disfunction in day (DD). Each item was marked as 0, 1, 2 and 3, and the total point band was 0–21 marks. The higher the score was, the lower the sleep quality was [1].

2.2.3 Training Method

Based on the principle that the brain waves were mainly in the α frequency band after the brain went into the sleep status, the simulated α frequency band was at night for training [16], and the stimulation of the micro-electronic current was extremely low (<1 mA physical safety band, the general safety requirements of medical appliance equipment was carried out [18]). The double-channel electrode (each channel included one positive electrode and one negative electrode) was used for the physical training to the frontal part (F_{p1}, F_{p2}) and occipitalia (0_1, 0_2) of the brain. The training was carried out on 22:30 every night and lasted for 5 min. The all-night-long sleep EEG monitoring was carried out at the night after training, and one time of sleep quality assessment was carried out respectively before and after the training.

3 Statistics Processing

SPSS 14.0 statistics software was used for data analysis. The test data were shown by ($x \pm s$) for the variance analysis of self-control and repeated measurement. The scheffe method was used for checking in different stages, and the statistics significance was available when $P < 0.05$ was the difference.

4 Result

4.1 EEG Monitoring of Sleep

4.1.1 Sleep Progress

Compared with the condition before TMCPT training, the volunteers' actual sleep time was prolonged ($F_{(2,39)} = 34.75$, $P = 0.002$), the sleep latent period was shortened ($F_{(2,39)} = 15.43$, $P = 0.020$), and the sleep efficiency was significantly improved ($F_{(2,39)} = 18.15$, $P = 0.012$).

4.1.2 Sleep Structure

Compared with the condition before TMCPT training, in the four sleep stages, the sleep of the first stage of the non-REM sleep was reduced, and the sleep of the second, third and fourth sleep and REM were increased, which were respectively shown by $S_{1\%}$ was significantly reduced ($F_{(2,39)} = 14.45$, $P = 0.011$), and $S_{2\%}$, $S_{3+4\%}$ and REM% were significantly increased ($F_{(2,39)} = 14.57$, $P = 0.045$, $F_{(2,39)} = 13.26$, $P = 0.030$, $F_{(2,39)} = 12.59$, $P = 0.024$), which proved the sleep was improved. Shown in Table 1.

4.2 *Subjective Evaluation of Sleep Quality*

Compared with the basic sleep and the condition before the altitude training, the indexes of the volunteers accepting TMCPT training were as follows: SSQ($F_{(2,39)} = 5.33$, $P = 0.034$), SL($F_{(2,39)} = 4.99$, $P = 0.002$), SDu($F_{(2,39)} = 3.87$, $P = 0.001$), SE ($F_{(2,39)} = 2.76$, $P = 0.008$), SDi($F_{(2,39)} = 3.79$, $P = 0.001$), DD($F_{(2,39)} = 5.46$, $P = 0.009$) and the total assessment point PSQI($F_{(2,39)} = 8.55$, $P = 0.007$) were clearly decreased, which indicated the sleep was improved. Shown in Table 2.

5 Discussion

TMCPT introduced the simulated brain waves into the brain according to the principle of the micro-electronic current stimulation technology so as to reinforce and keep the brain function, promote the sleep and improve the cognitive ability. The instrument adjusted the brain function status by simulating the brain waves of different frequencies, e.g., the brain wave frequency in the completely awakening status was >13 Hz (β frequency band) as well as 8–9.8 Hz spindle wave (slow α frequency band) or 4–7.8 Hz (θ frequency band) and 1–3.8 Hz slow wave (δ frequency band) after entering the sleep status. the EEG biological feedback training had more than 30 years of application history in the neuropsychiatric field and the neuropsychology field, and was mainly used for the EEG feedback therapy of anxiety, nervous and children attention deficit hyperactivity disorder.

5.1 *The α Frequency Band Brain Wave Feedback Training Promoted Sleep*

Indicated by the sleep medical study, when people was sleepy or felt asleep, the α frequency would be slower, and converted to the slow wave (θ frequency band 4–7.8 Hz), and after falling asleep, the slower rhymes (δ frequency band 1–3.8 Hz)

Table 1 changes of PSG of 40 volunteer during pre and post TMCPT in altitude resident phases ($x \pm s$, $n = 40$)

Stage	Index item of PSG							
	Arousal time (min)	Sleep latency (min)	Actual sleep time	Sleep efficiency (%)	S_1(%) sleep stage	S_2 (%) sleep stage	S_{3+4} (%) sleep stage	REM (%) REM sleep stage
Basic sleep phase in sea level	7.85 ± 2.72	14.55 ± 2.98	275.50 ± 8.65	92.55 ± 3.52	5.88 ± 3.73	53.64 ± 4.42	23.25 ± 2.45	22.15 ± 1.75
Pre- TMCPT in altitude	17.33 ± 3.40[a]	30.23 ± 2.15[a]	226.54 ± 8.45[a,c]	77.54 ± 3.11[a,c]	52.50 ± 5.83[a,c]	41.75 ± 5.65[a,c]	5.52 ± 2.47[a,c]	5.87 ± 1.45[a,c]
Poet- TMCPT in altitude	6.50 ± 1.78[b]	8.98 ± 2.15[a,b]	286.32 ± 7.45[b]	95.78 ± 3.01[b]	16.63 ± 3.85[a,b]	56.87 ± 3.33[b]	17.23 ± 2.46[a,b]	11.68 ± 1.61[a,b]
F	12.223	15.432	34.751	18.154	14.454	14.566	13.255	12. 587
P	0.033	0.020	0.002	0.012	0.011	0.045	0.030	0.024

Difference between stage were examined by scheffe method, comparison to the sleep in baseline level, $^aP < 0.05$; comparison to the sleep before training, $^bP < 0.05$; comparison to the sleep after training, $^cP < 0.05$

Table 2 Comparison on sleep quality of 40 volunteer between pre and post-TMCPT in altitude resident phase ($x \pm s$, $n = 40$)

Stage	Pittsburgh sleep quality index item							
	Subjective sleep quality (SSQ)	Sleep latency (SL)	Sleep duration (SDu)	Sleep efficiency (SE)	Sleep difficulty (SDi)	Using of sleep medicine (USM)	Disfunction in day (DD)	Total (PSQI)
Basic sleep phase in sea leve	1.66 ± 0.59	1.60 ± 0.55	275.50 ± 8.65	92.55 ± 3.52	5.88 ± 3.73	53.64 ± 4.42	23.25 ± 2.45	22.15 ± 1.75
TMCPT in pre-resident phase	1.57 ± 0.61	1.62 ± 0.54	$226.54 \pm 8.45^{a,c}$	$77.54 \pm 3.11^{a,c}$	$52.50 \pm 5.83^{a,c}$	$41.75 \pm 5.65^{a,c}$	$5.52 \pm 2.47^{a,c}$	$5.87 \pm 1.45^{a,c}$
TMCPT in post-resident phase	$1.38 \pm 0.58^{a,b}$	$1.12 \pm 0.57^{a,b}$	286.32 ± 7.45^{b}	95.78 ± 3.01^{b}	$16.63 \pm 3.85^{a,b}$	56.87 ± 3.33^{b}	$17.23 \pm 2.46^{a,b}$	$11.68 \pm 1.61^{a,b}$
F	5.332	4.985	3.872	2.755	3.788	2.222	5.455	8.545
P	0.034	0.002	0.001	0.008	0.001	0.055	0.009	0.007

Difference between stage were examined by scheffe method, comparison to the sleep in baseline level, $^{a}P < 0.05$; comparison to the sleep before training, $^{b}P < 0.05$; comparison to the sleep after training, $^{c}P < 0.05$

dominated. The study trained the volunteers under the training condition of the simulated α frequency and the duration of 5 min everyday, and used the TMCPT for adjusting the intracranial sleep regulating center to improve the sleep. Study indicated the low-frequency alternating electric field acted on the specific part of the brain and comprehensively adjusted the exciting and inhibition process of the cerebral cortex by influencing the bioelectricity activities of the nerve cells in the corresponding brain function area or indirectly improved the brain sleep by influencing the blood flow of the brain [12–14, 19].

Currently in general it was believed the low-frequency alternating electric field might act on the cell membrane of the organism and influence its ionic permeability to change the micro-environment of the cell and influence the metabolic activity of the cell and then the excitability of the nerve cell was changed, which indicated TMCT could also well adjust sleep and provided a study means for studying the biological effect of TMCPT on the brain function in future.

5.2 Significance of Brain Function Keeping Training for Altitude Flight to Sleep Guarantee

The altitude hypoxia environment was the main reason causing dyssomnia. Indicated by the altitude medical study, all altitude permanent residents' sleep quality was decreased. It was the clearest in the early stage, which was characterized in headache and insomnia. With the prolongation of the living time, some person's conditions might be recovered or improved because of the variation of individual adaptabilities, however the hypoxia environment always existed, the significance difference between the sleep quality and the basic sleep (in the low altitude area or plain area) didn't disappear [1]. Continuous oxygen inhalation was proven to be the effective way for improving the altitude hypoxia and improving the sleep quality, but it was not practical of supplying oxygen in 24 h, and the poor sleep quality would always exist in the altitude hypoxia environment but could not be avoided. Ensuring the high-efficiency brain function was the necessary condition for the pilot to operate the advanced and complicated electronic cabin, thus, the external intervention and training for brain function was one of the effective practical means which could be taken for improving the sleep in the altitude hypoxia condition.

Compliance with Ethical Standards The study was approved by the Logistics Department for Civilian Ethics Committee of institute of aviation medicine. All subjects who participated in the experiment were provided with and signed an informed consent form. All relevant ethical safeguards have been met with regard to subject protection.

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The Crew Seat Vibration Test and Analysis to a Special Vehicle

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Abstract This paper tested and analyzed the vibration of a special vehicle's crew seat, collected the vehicle cabin vibration signal under different road environment, and at certain speed, it studied the effect of vehicle vibration on crew, and as the basis of vehicle seat retrofit design. The analysis results show that the maximum vibration acceleration value was on the longitudinal of the driver and other crew's position, and in the later, design improvements should mainly focus on the longitudinal vibration reduction. At the same time in the process of vehicle test under different grade road crew's comfort, all performed well; this shows that design in a certain velocity of anti-vibration meets the requirements of ergonomics. This paper provides suitable personnel vibration fatigue monitoring test method for special vehicle crew; the data obtained from this method are significant and can be effectively applied to the practical test, and it has important reference value on the seat of the vehicle vibration reduction design and the crew comfort evaluation.

Keywords Special vehicle · Seat · Vibration · Collect and analyze · Comfort evaluation

1 Introduction

The safe and comfortable working environment can guarantee the special vehicle crew's work efficiency and the effective displaying of the equipment performance. As required by mission, besides working on the roads of low grade and even in the severe environment, the special vehicle also needs to do some special work [1], and cabin vibration environment generated during work severely influences the crew's work efficiency. The comfortability in the vehicle can be assessed by collecting and analyzing the cabin vibration signals. Based on the influence and assessment of the

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vibration environment of the vehicle cabin and its influence on the crew's work efficiency, basis can be provided for controlling the vibration of the vehicle cabin and the crew's individual protection, which is significant for ensuring the crew's work efficiency, increasing the crew's work ability, and displaying the technical performance of the equipment of the special vehicle [2]. The paper collects and analyzes the vibration signals of the cabin seat of a special vehicle and mainly collects the relevant information about the influence of the vehicle vibration on the crew and is significant for improving the driving environment of the vehicle.

2 Analysis of Vibration Characteristics of Vehicle Cabin

The vibration characteristics can be summarized as the direction, strength, and frequency of the vibration. The vibration of the cabin of the special vehicle is the whole-body vibration in three axial directions which are respectively in the *X*-axis (from back to chest), *Y*-axis (from right side to left side), and *Z*-axis (from foot or hip to head). The excitation of the body caused by road unevenness is the main reason causing the vibration of the cabin of the special vehicle. Most of the vibration of the vehicle cabin is the low-frequency great-amplitude vibration, and the vibration strength in the *Z* direction is commonly larger than those of *X* and *Y* and is the main factor influencing the crew's work efficiency. Also, there are test results that show the spectrum range at the driver position is wide, and many signals have the uneven energy distribution at the range of 1–80 Hz to which the human body is most sensitive, and also the low-frequency ingredients are rich while the vibration frequency range of most crew positions is relatively narrow and is mainly distributed at 20–50 Hz [3]. Because the driver position is close to the engine compartment, and also the space of the driving cabin is narrow, the driver's seat is designed to be different from the passenger's seat in structure, size, and vibration reduction, which causes the comfortability of the driver's seat not as good as the passenger's seat while the vibration strength is higher than the that of the passenger's position. Thus, the low-frequency vibration in the *Z*-axis direction of the driver is the key point for the vibration control and protection design of the special vehicle.

3 Vibration Test

3.1 Test Scheme

The test is carried out strictly according to GJB59.15 field vibration test regulations [4]. Three sampling points together are set as follows: the first sampling point is set inside the driving cabin and near the driver's seat so as to collect the vibration signals in three directions of the driver's seat, whereas in the X-axis direction, it points from back to chest; in the Y-axis direction, it points from the left side to the right side; and in the longitudinal direction of Z-axis, it points from foot to head. The influence of vehicle vibration on the driver is obtained by analyzing the 3D vibration signals at the seat of the driving cabin. The second sampling point is set at the copilot site to collect the vibration signals of the copilot site when the vehicle runs, and the influence of vehicle vibration on the copilot is obtained by analyzing the 3D vibration signals at the copilot seat of the driving cabin. The three sampling point is set at the back passenger site to collect the vibration signals of the passenger site when the vehicle runs, and the influence of vehicle vibration on the back passenger is obtained by analyzing the 3D vibration signals at the back passenger seat of the passenger cabin.

The cement road, gravel road, and rough road are used for the test, and two times of test are respectively carried out to each type of road. The speeds for each test on the cement and gravel roads are all 40 km/h, and the speed on the rough road is 30 km/h.

3.2 Test System

The test system comprises the following parts as shown in Fig. 1. The acceleration sensor, the charge amplifier, and the portable data collector form the system for collecting the vibration signals. According to the test regulations, the acceleration sensor and charge amplifier from the PCB company are used for the test. The portable data collector comprises of a signal processor and some peripheral components.

The measurement of the vibration signals at the seat position belongs to the low-frequency vibration measurement, and also the seat surface is uneven when it is used by the passenger and cannot be drilled, either; thus, the best installing way is installed in the cushion.

Because the responses of all points of the vibration structure are greatly different, the proper position for installing the sensor is very important. Generally, the sensor shall not be installed on the node or nodal line of the structure vibration but the position with high structure response signals so as to increase the signal-to-noise ratio as well as the test precision. The seat test aims to monitor the vibration source of the seat structure, and the position for installing the sensor shall be as close as to the direct transmission path of the vibration source, and the installing direction must reflect the vibration direction of the vibration source.

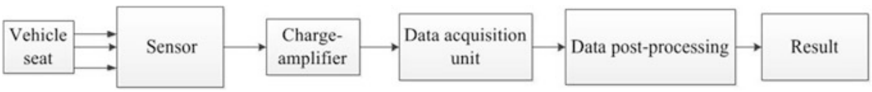

Fig. 1 Diagram of vibration test experiment system

4 Processing and Analysis of Test Data

4.1 Processing Method for Vibration Data

The key point for processing the test data is to confirm the driver's allowable exposure time according to the limit curve of work efficiency reduced by fatigue, which is given by *X*-, *Y*-, and *Z*-axis according to the regulations of the vibration test, so as to confirm the driver's safe driving hours, and also the total assessment for the driver's comfortability is qualitatively given according to ISO2631 [1]. At first, spectral value of one-third of octave of the corresponding vibration signals of each coordinate axis is calculated out at first, and then, the corresponding weighting acceleration root-mean-square (RMS) value can be confirmed according to the spectral value of one-third of octave. The formula is as follows:

$$a_{wj} = a_j \times w_j \tag{1}$$

wherein: a_j is 1/3 of the central frequency f_j and the spectral values of octave are $j = 1, 2, \ldots 20$, and w_j is the weighing factors relevant to the vibration direction and central frequencies. Then, the maximum value of a_{wj} is used for finding out the allowable exposure time according to the limit of the work efficiency reduced by fatigue in the corresponding direction in Table 2. At last, the minimum allowable exposure times in the *X*-, *Y*-, and *Z*-axis are used for confirming the driver's allowable exposure time.

4.2 Analysis of 3D Vibration Data at the Crew's Seats

The weighting acceleration root-mean-square values corresponding to each axis of each crew is calculated out as shown in Figs. 2, 3, and 4 according to Formula (1):

According to the analysis based on the calculation results, the weighing acceleration root-mean-square value in the transverse *Y* direction of the driver's position is minimum. According to Table 1 fatigue-work efficiency exposure time, it can be obtained that the allowable exposure times of the driver's position on three types of road are respectively as follows: On the cement road when the speed is 40 km/h, it is 16 h; on the gravel road when the speed is 40 km/h, it is 7.8 h; and on the rough road when the speed is 30 km/h, it is 19.6 h, and so on. The allowable exposure times of the copilot and back passenger positions under the three types of roads are shown in Table 2.

Indicated by Figs. 2, 3, and 4, the longitudinal weighing acceleration root-mean-square values of the three positions are maximum, and generate the highest influences on the crew, which will cause the crew to feel uncomfortable, wherein the uncomfortable seats play 80% influence on the crew's comfortability [5]. After comprehensively analyzing the 3D vibration test data of the seats, when

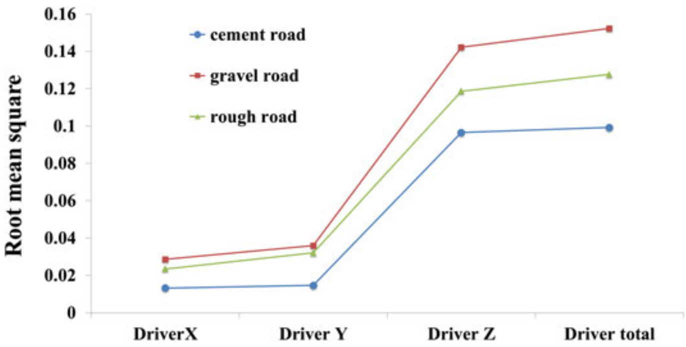

Fig. 2 The root-mean-square value of the driver's *X*, *Y*, *Z* directions and total weighted acceleration

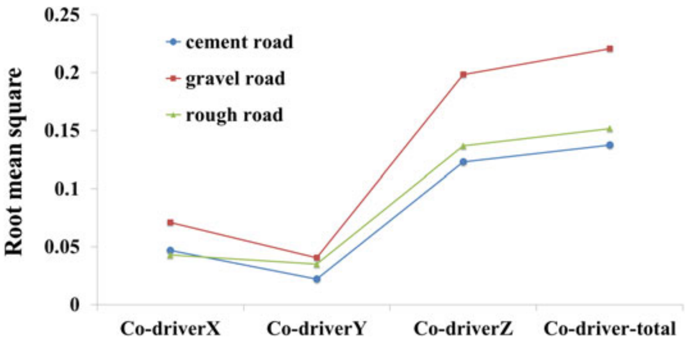

Fig. 3 The root-mean-square value of the co-driver's *X*, *Y*, *Z* directions and total weighted acceleration

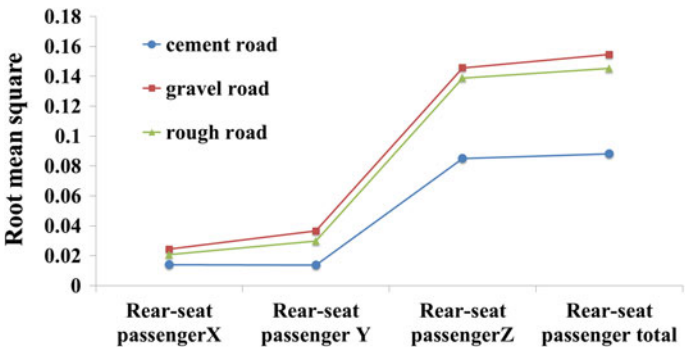

Fig. 4 The root-mean-square value of the rear-seat passenger's *X*, *Y*, *Z* directions and total weighted acceleration

Table 1 The corresponding acceleration-weighted root-mean-square value of allowed exposure time (m/s^2)

Time	24 h	16 h	8 h	4 h	2.5 h	1 h	25 min	16 min	1 min
The root-mean-square value of vertical weighted acceleration	0.14	0.212	0.32	0.53	0.7	1.18	1.8	2.12	2.8
The root-mean-square value of horizontal weighted acceleration	0.1	0.15	0.22	0.36	0.5	0.85	1.25	1.5	2

Table 2 The crew allowed exposure time (h)

The road level	Driver Y	Co-driver Y	The rear passenger Y
Cement road 40 km/h	16	15.7	24
Gravel road 40 km/h	7.8	17.7	14
Rough road 30 km/h	19.6	15.7	21.7

Table 3 The weighted acceleration value of all the crew in three kinds of road level (m/s^2)

The position	Driver	Co-driver	Rear-seat passenger
Cement road	0.09	0.14	0.09
Gravel road	0.15	0.22	0.15
Rough road	0.13	0.15	0.15

Table 4 The relationship between acceleration value and crew's subject feeling

The weighted acceleration value (m/s^2)	<0.315	0.315–0.63	0.5–1	0.8–1.6	1.25–2	>2
The evaluation of Crew's feeling	None	Little sense	Some feeling	Uncomfortable	Very uncomfortable	Terrible
	Good	Good	Good	Not good	Bad	Very bad

the vehicle runs at a certain speed on every type of the road, the comprehensive assessment of all positions of the passenger is obtained. Wherein, the weighting acceleration values of the three passengers on the three types of roads are shown in Table 3. Indicated by the relationship between the acceleration values and people's subjective feeling of Table 4, the vibration comfortability of the crew at the three positions is good.

5 Discussion and Conclusion

(1) The difference of the seat vibration system of each position after vibration reduction is mainly caused by the different structure design and layout of the whole body. The analysis of the vehicle vibration test is the important way for assessing the vehicle body vibration environment. The data obtained by measurement can be analyzed to provide data support for designing the seat and the whole vehicle vibration systems. The vibration reduction efficiency of the seat system can be improved for absorbing the vibration energy, wherein the vibration reduction material of the seat and the contact part of the seat and the vehicle body can be improved. Because the vibration conditions of different positions are different, the vibration reduction requirements on different positions cannot be satisfied if only one type of vibration reduction is used. Indicated by the test, the vibration statuses of the vehicle on different types of roads are not same, but in general, the longitudinal vibration acceleration value is the highest, and it shall focus on improving the design of the longitudinal vibration reduction. Also, it indicates the crew's comfortabilities on different types of roads in the test process are good, which means the vibration reduction design of the vehicle at a certain speed meets the requirement of work efficiency.

(2) Limited by the actual test field, the test does not cover all of the tests on all types of roads and at high speeds, and it will be supplemented and completed in future tests.

(3) The paper provides a test method applicable for the special vehicle crew's vibration fatigue monitoring. The data obtained by the method are significant, can be effectively applied to the actual field test, and play an important reference value for the vibration reduction design of the vehicle seat and the assessment of the crew's comfortability.

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Part VI
Research on the Machine–Environment Relationship

Modeling and Analyzing of Fire-Control Radar Anti-jamming Performance in the Complex Electromagnetic Circumstances

Wei Yu, Yan Sun, Xiaonian Wang, Kun Li and Jiang Luo

Abstract Purpose: To obtain an accurate and true assessment result through the research in the fire-control radar anti-jamming performance in the complex electromagnetism circumstance. Method: By consulting the correlation data, the model is applied to the anti-jamming performance evaluation of three kinds of fire-control radars in the assumptive jamming circumstances. According to the characteristic of fire-control radar, the anti-jamming evaluation model of multi-attribute decision-making is built based on synthesizing six radar attributes: resolution, power, frequency, system, anti-jamming technical measures, and photoelectricity equipment. Result: The result of model can reflect fact because of considering all kinds of attributes about anti-jamming performance. Conclusion: With a reasonable, simple calculation, the model is valuable in practice.

Keywords Complex electromagnetic circumstances · Fire-Control radar · Anti-jamming performance · Model · Assessment

1 Introduction

As an important component of air defense forces (ADF) weapon system, the fire-control radar (FCR) is employed to search, detect, intercept, and track aerial targets. The electromagnetic environment is nowadays getting more and more complex, which brings about greater and greater adverse influences upon ADF FCRs and increasing difficulties in quantitative assessment of their performances. Various standards are adopted by researchers to assess the anti-jamming performances of such complicated equipment from different angles or emphasis [1–4]; therefore, it is hard to reach a consensus in the assessment of FCR anti-jamming performances. Limited by conditions of this kind and that sort, obtaining the actual data of FCR anti-jamming performances through a number of confrontational tests is of com-

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plicated implementation, high expenses, and long-time consumption. In addition, many a jamming method exists in complex electromagnetic circumstances, whose effect shall undoubtedly be differed either with regard to one anti-jamming measure or with regard to anti-jamming measures of different kinds, resulting in the absence of a mathematical model to precisely assess the anti-jamming performances of FCRs. It is therefore an issue worthy of researching to carry out comprehensive assessment of FCR anti-jamming performances with proper methods.

2 Analysis of the Assessment Standard of FCR Anti-jamming Performances

2.1 The Standard of Information Losses

Jamming functions to suppress or destroy the FCR's capabilities to detect or obtain target information. The FCR detects aerial targets in the background of random noise and is featured by the attribute of uncertainty. According to the theory of information, ENTROPY [5] is the value to weigh the uncertainty of random variables, and it is usually adopted to evaluate the FCR anti-jamming performances and the optimum jamming wave pattern. This standard is characterized by clear conception, strict theory but complicated calculation, and is yet to be broadly applied.

2.2 The Standard of Power

It means to assess the FCR anti-jamming performances by researching the variation of the ratio between the power of signal and that of jamming, and usually adopts the FCR self-defense range and suppression coefficient as the evaluation index. This standard shows the fact that radar confrontation is the confrontation of power, reflecting the traditional thoughts of anti-jamming performance assessment, and is most widely and frequently adopted.

2.3 The Standard of Tactical Application

This standard falls into 2 categories: one is to link FCR and relevant weapons and assess the anti-jamming performances according to how much air defense operation is completed with the support of the FCR, and the overall confrontation effect is assessed with the probability of penetration and damage as the index; the other is to take the variation of such tactical parameters as FCR working range, measuring accuracy and tracking accuracy as the index while avoiding possible changes when FCR is equipped with different weapons.

2.4 The Standard of Probability

This standard is to measure the anti-jamming performance in accordance with the probability of FCR's completion of given tasks, with the probability of FCR deception jamming, false alarm, and detection as the index. It accents the FCR capability of battle space information obtaining and is of good intuition and convenience, but this standard is built upon large quantities of statistical data based on real combat or tests and is therefore difficult to obtain and compute.

2.5 The Standard of Time

In given conditions, it takes a component of a weapon system a certain period of time to complete a certain task, namely, the FCR needs time to detect, indentify, intercept, and track a target. Response time may immediately reflect the performance of a weapon, so the standard of time is an intuitional and effective standard of assessment. Detecting time ratio, tracking time ratio, and flight path starting time difference are usually adopted as the index.

2.6 The Standard of Display

It means to destroy some display features of echo waves so as to adversely influence or reduce the visibility of target signal and increase the difficulty to find the target, or even leave nothing but only the scanning line on the radar display, making it impossible to search, intercept, or track aerial targets. Such jamming may as well generate a number of dummy targets so that FCR operator cannot identify and judge aerial targets, resulting in false or lost air situation and leading to hindrance of air defense operations. Jamming strength is often adopted as the index in level I, II and III.

3 Modeling of FCR Anti-jamming Capability

In complex electromagnetic circumstances, an individual assessment standard may not be suitable to measure the FCR's overall anti-jamming capability when confronted with various jamming or passive jamming. In accordance with the FCR technical characteristics, this paper adopts a multi-attribute decision-making method which categorizes the FCR anti-jamming capability into several attributes, assesses each one with suitable standard, and integrates the results by proper means. This method may, on the one hand, deduce quantitative factors by strict theoretical calculation, and on the other hand, combine qualitative factors, experience data, and expert opinions, and it is therefore a reasonable and applicable assessment method.

3.1 To Determine the Set of Assessment Schemes

The set of assessment scheme, represented by V, refers to 3 types of FCR, namely $V = \{V_1, V_2, V_3\}$. It is required to conduct comprehensive analyses on the 6 attributes of the assessment scheme in one jamming environment in order to obtain the value of each scheme.

3.2 To Determine the Primary Attributes

3.2.1 The Attribute of Resolution

Use the factor of Resolution, E_1, to assess the comprehensive resolution [2] as follows:

$$E_1 = T_o B_s G_{\mathrm{A}} \tag{1}$$

In this equation, T_O represents the time of duration of radar signal; B_S represents the instant bandwidth of the radar system; G_{A} represents the radar antenna gain. High radar resolution may not only project more transmitting power onto target but reduce the jamming power of antenna input.

3.2.2 The Attribute of Power

Use the factor of power, E_2, to assess the influence of receiver SINR upon radar anti-jamming capability as follows:

$$E_2 = \begin{cases} 0, & P_{\mathrm{rj}}/P_{\mathrm{rs}} \geq 2K_{\mathrm{j}} \\ 1 - \frac{2}{3}\left(\frac{P_{\mathrm{rj}}/P_{\mathrm{rs}}}{K_{\mathrm{j}}} - 0.5\right), & 0.5K_{\mathrm{j}} < P_{\mathrm{rj}}/P_{\mathrm{rs}} < 2K_{\mathrm{j}} \\ 1, & P_{\mathrm{rj}}/P_{\mathrm{rs}} \leq 0.5K_{\mathrm{j}} \end{cases} \tag{2}$$

In this equation, P_{rj} represents the power of jamming signal received by radar; P_{rs} represents the power of target echo; K_{j} represents the SINR needed by radar when working normally. Greater value of E_2 stands for better radar anti-jamming capability. SINR $P_{\mathrm{rj}}/P_{\mathrm{rs}}$ may be computed as follows:

$$\frac{P_{\mathrm{rj}}}{P_{\mathrm{rs}}} = \frac{P_{\mathrm{j}}}{P_{\mathrm{s}}} \cdot \frac{4\pi R^2 G_{\mathrm{j}}}{\sigma G_{\mathrm{A}} F_{\mathrm{A}}} \tag{3}$$

In this equation, P_{j} represents the power of jammer; P_{s} represents the power of radar; R represents the distance; G_{j} represents the gain of jammer; σ represents RCS of the aircraft; F_{A} represents the equivalent loss.

3.2.3 The Attribute of Frequency

Use the factor of Frequency, E_3, to assess the matching frequency of radar and jamming. The frequency range of radar is $[f_{\mathrm{r1}}, f_{\mathrm{r2}}]$, the frequency range of jammer is $[f_{\mathrm{j1}}, f_{\mathrm{j2}}]$, and length of intersection of the two ranges is $d\{[f_{\mathrm{r1}}, f_{\mathrm{r2}}] \cap [f_{\mathrm{j1}}, f_{\mathrm{j2}}]\}$, so

$$E_3 = \begin{cases} 1 - \frac{\min(f_{\mathrm{j2}}, f_{\mathrm{r2}}) - \max(f_{\mathrm{j1}}, f_{\mathrm{r1}})}{f_{\mathrm{r2}} - f_{\mathrm{r1}}}, & d\{[f_{\mathrm{r1}}, f_{\mathrm{r2}}] \cap [f_{\mathrm{j1}}, f_{\mathrm{j2}}]\} \neq 0 \\ 1, & d\{[f_{\mathrm{r1}}, f_{\mathrm{r2}}] \cap [f_{\mathrm{j1}}, f_{\mathrm{j2}}]\} = 0 \end{cases} \tag{4}$$

3.2.4 The Attribute of Angular Tracking Mechanism

The angular tracking mechanism is the core part of an FCR, and the main part is subject to exterior jamming. Use the factor of angular tracking mechanism, E_4, to assess the anti-jamming capability against various jamming pattern. Generally, it is hard to express E_4 with a given value, and there exists no mathematical formula to obtain E_4. It is required to study the matching extent of jamming pattern and tracking mechanism and give a value between 0 and 1 as E_4. The document [2] adopts a half-qualitative half-quantitative method to estimate the probability of counter angular deception jamming of different tracking mechanism and takes the average probability of counter angular deception jamming of various tracking mechanisms as shown in Table 1.

Table 1 Anti-jamming capability of angular tracking mechanism

Angular tracking mechanism	Exposed conical scanning	Hidden conical scanning	Exposed line scanning	Hidden line scanning	Single pulse
Value	0.26	0.42	0.26	0.42	0.46

3.2.5 The Attribute of Technical Measures

According to the inherent features of FCRs, this paper lists 16 anti-jamming measures and their influence upon anti-jamming capability as shown in Table 2.

In practical use, the value of the factor of radar attribute is the sum of each anti-jamming capability.

3.2.6 The Attribute of Optoelectronic Devices

Many such optoelectronic devices have nowadays been equipped to the FCR as an important auxiliary and anti-jamming measure as optical director, remote command telescope, laser ranger finder, IR tracking system, and TV tracking system. These devices, free of microwave jamming and passive jamming, are not only able to measure angle and range independently but work together with radar to measure angle and range. Table 3 lists out the value for the anti-jamming capability of various optoelectronic devices. If more than one device is adopted, the value is the sum of all corresponding factors.

3.3 To Determine the Weight Coefficient of the Primary Attributes

Based on experts' opinions, this paper adopts the 1–9 scale AHP method to establish the comparison matrix of importance for the primary attributes as follows:

$$B = \begin{bmatrix} 1 & 1 & \frac{1}{2} & \frac{1}{5} & \frac{1}{7} & \frac{1}{5} \\ 1 & 1 & \frac{1}{2} & \frac{1}{5} & \frac{1}{7} & \frac{1}{5} \\ 2 & 2 & 1 & \frac{1}{3} & \frac{1}{4} & \frac{1}{3} \\ 5 & 5 & 3 & 1 & \frac{1}{2} & 1 \\ 7 & 7 & 4 & 2 & 1 & 2 \\ 5 & 5 & 3 & 1 & \frac{1}{2} & 1 \end{bmatrix} \tag{5}$$

This matrix is proved to be satisfactorily consistent,which adopts characteristic roots method to find the characteristic vector of the matrix. Through calculation, the weight coefficient of the primary attributes is (0.05, 0.05, 0.09, 0.22, 0.37, 0.22).

Table 2 Anti-jamming capability of technical measures

Technical measure	Multiple band	Low side lobe	Variable polarization	Decoy deception	Self-adapted frequency agility	Power burn-through	PD	Frequency agility
Value	6	6	6	6	5	5	5	4
Technical measure	Complex signal processing	MTD	MTI	Frequency management	Constant false alarm	Waveform agility	Size limit	Variable multi-pulse
Value	4	4	3	3	3	3	2	1

Table 3 Anti-jamming capability of optoelectronic equipment

Device	Remote command telescope	Optical director	TV tracker	IR tracker	Laser range finder
Value	1	2	3	3	2

3.4 To Determine the Decision-Making Model

In this paper, 6 attributes are all playing some certain role in the comprehensive assessment; therefore, it takes the linear weighing model to conduct comprehensive processing:

$$E = \sum_{i=1}^{6} E_i w_i \tag{6}$$

In this equation, E_i is normalized value of attributes; w_i stands for its weight.

4 Case Study

Take the self-defense jamming against FCR by the built-in jammer AN/ALQ-171 equipped to USAF fighters as the example, and apply the model to assess the anti-jamming capability of various types of radar. The frequency range of AN/ALQ-171 jammer is 2.0–16.0 GHz; the frequency density of its noise barrage jamming is 20–30 W/MHz and take the median in calculation; take the radar cross-sect. 2 m^2 and the slant range 50 km; radar technical and tactical performances are omitted. Normalize E_1, E_5, and E_6, set 1 as the maximum value, and the other normalized value is the actual value divided by the maximum value and obtain such results as is shown in Table 4.

Conduct comprehensive calculation with the decision-making model and obtain the anti-jamming capability value of the assessment schemes $V = \{V_1, V_2, V_3\} = \{0.66, 0.49, 0.78\}$. The anti-jamming capability of the 3 types of radar can be ranked as $V_3 > V_1 > V_2$.

Table 4 Radar anti-jamming capability assessment

Radar	E_1	E_2	E_3	E_4	E_5	E_6
V_1	0.56	0.17	0	0.46	0.81	1
V_2	0.60	0.34	0	0.42	0.56	0.63
V_3	1	0.75	0	0.46	1	1

5 Conclusions

This paper studies on the anti-jamming capability of FCR in complex electromagnetic circumstances. As various attributes, including those qualitative ones in particular, which may probably influence the anti-jamming capability, are taken into consideration, and large quantities of experience data and expert opinions are incorporated, this paper reaches a precise and true result. The assessment model is reasonable, simple, and effective, and it is of a certain practical value. Further study needs to be done in determining the weight of each attribute, as well as the dynamic confrontation between jammer and FCR so as to perfect the assessment model.

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Part VII
Research on the Overall Performance of Man–Machine–Environment System

The Layout Virtual Verification Method Based on Human Factors Engineering for Nuclear Power Control Room

Kun Yu

Abstract The layout of human–machine interface equipments in the nuclear power control room has an important influence on the efficiency of human–machine interaction and the operation safety. The layout virtual verification method based on human factors engineering was studied. The clustering method based on grey theory was established to aggregate the verification information of human–machine system. The human factors layout virtual verification platform was developed based on the simulation system, and the feasibility and visibility of the layout of control room, the work attitude and the rationality of the work space were realized with using the proposed virtual human model. The proposed virtual verification method can complete the human factors layout verification and improve the nuclear power control room design during the virtual design phase.

Keywords Nuclear power control room · Layout · Human factors engineering · Virtual verification

1 Introduction

The nuclear power control room was the monitoring and control centre for the nuclear power system both in normal operation and accident status. The nuclear power plant accidents investigation of USA, France and other 6 countries showed that the average ratio of human-related events over 60%, up to 85% [1]. The human factors had become the main influencing factors for the nuclear power system safety. The rationality of human factors engineering design of control room directly affected the efficiency and safety of nuclear power system. There were many researches on the virtual verification for nuclear power plants in foreign. Isaac José had done researches on virtual verification of human–machine system of Argonauta nuclear power plant reactor consoles [2]. Carlos had developed the virtual console

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models of nuclear power plant for the operators training, and human–machine system verification [3]. Leandro had developed the operators' human body and the virtual environment model of main control room to test the operation time of critical safety systems for nuclear power plants. The operators could perform active navigation and interaction in the virtual control room [4]. Virtual verification technology had become an important design verification method in nuclear power system. In this paper, the virtual verification of human factors layout for the nuclear power control room was studied, and the verification technique based on Delmia simulation platform was constructed. To realize the virtual verification of the layout, accessibility,visibility and comfort of human body in the nuclear power control room through study of layout method.

2 Verification Indexes for Control Room Layout

In the human engineering review program NUREG-711 of U.S. nuclear regulatory commission USNRC, verification and validation of human factors design was prescribed as an important and necessary part of a nuclear power plant design [5]. There were design requirements for main control room, remote shutdown station layout, the backup panel layout, including the large screen system, backup panels, operator stations, and so on. In the human–system interface design review guidelines NUREG-700, there were the design requirements for human–machine interface of nuclear power plant [6]. The basic requirements for human factors layout of nuclear power control room were constructed, and layout verification indexes system of nuclear power control room was established, as shown in Table 1.

3 Virtual Verification Method

3.1 Visibility Verification Method

The visibility of equipments layout in control room required that the operators could observe the human–machine interface equipments conveniently and clearly while keeping normal operating position, including the layout visual field of displays, visual angle of characters and symbols in human–machine interface. The VDU displays, large screen displays, the displays and indicators in backup panels should be arranged in the view of operators, and the frequently used or continuous monitoring or important displays should been arranged within the operators' best or comfortable vision. The height of the labels in backup panel was not less than 15 arcmin, and the best visual angle was about 20 arcmin. The height of the character in large screen display should be greater than 15 arcmin. The operator human body model was distributed to the 3D environment model of the

Table 1 The layout verification indexes for nuclear power control room

Items	Objective verification indexes	Subjective verification indexes
(a) workplace layout	1. Distance between console and obstacle 2. Sitting lateral space for operators 3. Single channel width 4. Double channel width 5. Console height 6. Console depth 7. Width of foot space 8. Height of foot space 9. Leg width in sitting position 10. Length of writing area 11. Width of writing area	1. Operators can observe all the necessary information 2. Operators can reach any workstation without obstacles 3. Workstation position should be convenient for communication 4. Workstation height does not affect operators' sight line for large screen 5. Operators can change position, leave the workstation at any time 6. Channels should be as short as possible 7. No cross operation between workstations 8. Writing area should be easy to achieve 9. Provide space for rules and documentations
(b) Character readability	1. Visual angle of single character 2. Visual angle of group characters 3. Visual angle of display text or tags 4. Visual angle of character in large screen 5. Visual angle of labels in panels	1. Use legible fonts, font should be correct, consistent lifting stroke width and the ratio of length to width 2. Distinction among characters should be clear 3. All displayed labels formats should be consistent 4. All displayed labels should be worded consistently 5. Text wording should be simple and clear 6. Use the exact words instead of words or combinations of abbreviations
(c) Displays layout	1. Horizontal layout view field of VDU screen 2. Vertical layout view field of VDU screen 3. Vertical layout view field of backup panel displays 4. Horizontal layout view field of commonly used or important displays 5. Vertical layout view field of commonly used or important displays 6. Horizontal layout view field of inactive or general displays level layout 7. Similar small displays layout length	1. Displays should be horizontal layout, rather than vertical column layout 2. When the displays were observed in a particular order should be grouped together 3. Frequently used displays should be located near the centre of the optimal visual area 4. Displays layout should ensure that the user was able to read clearly and does not produce parallax at the normal operating position 5. Displays, when used to perform specific function or the same purpose, should be grouped together 6. In different panels or the same panel, the repeat function group and single display layout should be similar

(continued)

Table 1 (continued)

Items	Objective verification indexes	Subjective verification indexes
	8. Row number of the similar displays	7. Same displays should layout in same way at all locations 8. Repeat function should not mirror layout
(d) Controllers layout	1. Layout range of computer control equipments 2. Controllers layout height of backup panel 3. Controllers layout depth of backup panel 4. Distance between adjacent controllers 5. Distance between controllers to be operated at the same time 6. Distance from backup panel front to controllers	1. Controllers layout shall not be blocked displays during operation 2. The correlation between controllers and displays should be easy to identify 3. Control channel should not be hindered by any adjacent controllers 4. Controller operation should not result in the unintentional start of the adjacent manipulator 5. Controllers in a particular operation order, should be grouped together 6. Frequently used controllers should be located near the centre of the optimal control area 7. Functionally relevant controllers should be grouped together 8. In different panels or the same panel, the repeat function group and single controller layout should be similar 9. Same controllers in all locations shall be consistent 10. Repeat function should not mirror layout

control room. In the virtual environment, the visibility of the equipments layout of control room could be visualized with combined with the ergonomics data of binocular visual field of virtual human body model. Figure 1a is the case of layout view field verification by binocular vision domain. Figure 1b is the visual angle analysis of the character and label; the visual angle is constructed by developing the spatial position relation between the binocular visual field and the upper and lower boundaries of the character. Figure 1c is the visual calculation results based on human visual field.

3.2 Accessibility Verification Method

Accessibility was the difficulty degree of operators accessing to computer control device, backup panel controllers. The layout accessibility of nuclear power system could be visualized based on the ergonomic data and visual hand function touching domain of virtual human model. The backup panel layout verification was shown as

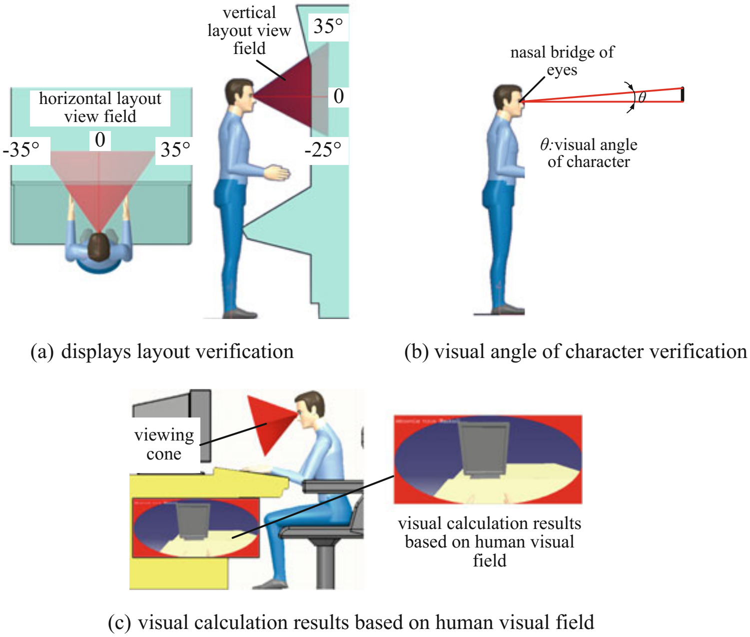

Fig. 1 Case for visibility verification method

an case. The virtual human models of fifth percentile (P5) female and a ninety-fifth percentile (P95) male were generated. The highest height of controllers layout of backup panel determined by selecting the P5 female human model can reach the highest position in the absence of extension or ladder tools. The minimum height of controllers layout determined by selecting P95 male human model can reach the minimum position in the absence of bending. The range between the highest and lowest layout height could be visually observed by visual reachability domain of hands as shown in Fig. 2.

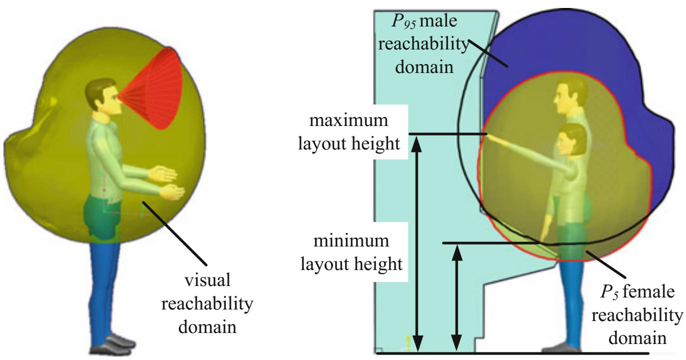

Fig. 2 Case for reachability verification method

3.3 Overall Verification Method of Layout

The general principle of working space layout was to improve the overall movement efficiency and reduce the overall movement distance, to minimize the total amount of movement of each part of body [7]. Dynamic human-machine interaction based on human body model was driven by HTS module. The HTS module had the ability to edit human actions, such as walking, crawling, placing, head rotation, body bending, rotation, to simulate dynamic task process. First, operating model of operator's human body in different position and time in control room was created and virtual human operating postures were connected in time order; then, the key frame fusion technology was used to combine and connect all the actions to achieve a coherent simulation process. Indexes of overall layout verification [8]: ① operating time: the time required to complete the tasks; ② moving distance of body gravity centre: the total distance of human body in the 3D space during tasks, it indicated whether the operators body need to move too long, or frequently move body, and the degree of match; ③ body rotation angle: body axis rotation angle of human body model during tasks, it explained whether operators need to move frequently in control room; ④ total hand moving distance: hand moving distance of human body during tasks, it reflected the rationality of the controllers layout. Figure 3 was case of the schematic diagram of operator's right-hand tracking.

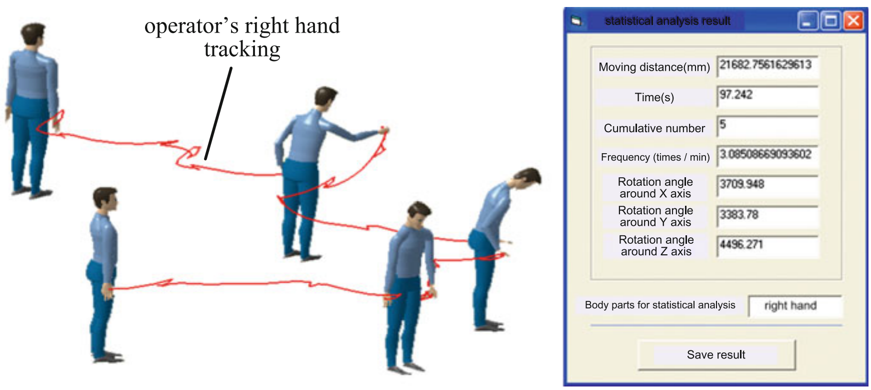

Fig. 3 Case of tracking motion path of operator's right hand

4 Verification Method Based on Grey Clustering

The grey whitening weight function theory had an advantage in solving the uncertainty information value clustering [9]. The researches showed that the Gauss distribution was feasible to construct the information cognition degree distribution function. It was universal and effective in expressing the universal distribution of linguistic value system uncertainty. While $X = [a, d]$, $a \le b \le c \le d$, constructed the whitening weight function model $f(x)$ for verification index uncertainty information cognitive degree based on the Gauss distribution. As shown in (1.1).

$$f(x) = \begin{cases} \exp\left(-\sigma_1 (x-b)^2\right), & x \in [a, b) \\ 1.0, & x \in [b, c] \\ \exp\left(-\sigma_2 (x-c)^2\right), & x \in (c, d] \end{cases} \tag{1}$$

In practical application, it was meaningful to truncate the x value range as $[a, b]$. $f(x)$ ranged from [0, 1] to $[\varepsilon, 1]$, $0 < \varepsilon < 1$. Coefficient σ determined the linear distribution amplitude: when $1/\sigma$ was smaller, the distribution was more concentrated; on the contrary, the distribution tended to disperse. The coefficient σ value was related to the length of the distribution interval and the φ of the intersection point of the adjacent whitening groups. It was determined σ by distribution interval length and ε value.

$$\sigma = -(\ln \varepsilon)/D^2, \text{ s.t. } \quad \varphi < 0.5 \tag{2}$$

In which, D was the length of the distribution interval, as $|b - a|$ or $|d - c|$, and $\varphi < 0.5$. The results of the human factors layout design of nuclear power control room were divided into 5 categories: extreme grey group (1): $f_j^1([20, 30])$; differential grey group (2): $f_j^2([30, 50])$; common grey group (3): $f_j^3([50, 70])$; good grey group (4): $f_j^4([70, 90])$; superior grey group (5): $f_j^5([90, 100])$. The 5 values of grey value interval were extended to calculate central value vector of each grey group $(0, 25, 40, 60, 85, 100, 105)$. The distribution coefficient σ_1, σ_2 was calculated according to Formula (2), $\varepsilon = 0.01$, while $\varphi = 0.3162 < 0.5$. The Gauss distribution whitening function was calculated for the centre points of 5 grey values.

$$
\begin{aligned}
f_1^1 &= \begin{cases} \exp\left(-(x-25)^2 \big/ 135.7\right), & x \in [0,\ 25) \\ 1, & x = 25 \\ \exp\left(-(x-25)^2 \big/ 48.86\right), & x \in (25,\ 40] \end{cases}, \\
f_1^2 &= \begin{cases} \exp\left(-(x-40)^2 \big/ 48.86\right), & x \in [25,\ 40) \\ 1, & x = 40 \\ \exp\left(-(x-40)^2 \big/ 135.7\right), & x \in (40,\ 65] \end{cases}, \\
f_1^3 &= \begin{cases} \exp\left(-(x-60)^2 \big/ 86.86\right), & x \in [40,\ 60) \\ 1, & x = 60 \\ \exp\left(-(x-60)^2 \big/ 135.7\right), & x \in (60,\ 85] \end{cases}, \\
f_1^4 &= \begin{cases} \exp\left(-(x-80)^2 \big/ 135.7\right), & x \in [60,\ 85) \\ 1, & x = 80 \\ \exp\left(-(x-80)^2 \big/ 48.86\right), & x \in (85,\ 100] \end{cases}, \\
f_1^5 &= \begin{cases} \exp\left(-(x-100)^2 \big/ 48.86\right), & x \in [85,\ 100) \\ 1 & x = 100 \end{cases}
\end{aligned} \tag{3}
$$

Integrated verification of human factors layout within hierarchical structure, the σ_i^k synthetic clustering coefficient of verification object i $(i = 1, 2, \ldots, n)$ about value grey groups k $(k = 1, 2, \ldots, s)$ is shown in (4).

$$
\sigma_i^k = \sum_{j=1}^{m} f_j^k(x_{ij})\eta_j \tag{4}
$$

In which, η_j was integrated clustering weight of layout verification index j. If $\max_{1 \le k \le s}\left\{\sigma_i^k\right\} = \sigma_i^{k^*}$, K was considered to belong to the grey group k^*.

The weight of verification group $\alpha = [0.119, 0.215, 0.226, 0.180, 0.130, 0.130]$, 9 indexes weight vector $\beta = [0.186, 0.126, 0.126, 0.142, 0.079, 0.103, 0.103, 0.056, 0.079]$. The subjective interval number comments were divided into 9 groups of subjective interval number $R(j)$

$$R(1) = [[65, 74], [50, 65], [68, 75], [70, 78], [65, 68], [56, 75]],$$
$$R(2) = [[75, 83], [80, 85], [81, 88], [75, 75], [75, 82], [77, 80]],$$
$$R(3) = [[45, 53], [51, 55], [53, 56], [55, 68], [50, 56], [44, 45]],$$
$$R(4) = [[0, 0], [0, 0], [0, 0], [0, 0], [0, 0], [0, 0]]^T,$$
$$R(5) = [[30, 35], [20, 30], [38, 45], [42, 50], [28, 35], [26, 35]],$$
$$R(6) = [[45, 58], [55, 62], [50, 55], [56, 60], [38, 44], [42, 52]],$$
$$R(7) = [[46, 50], [50, 55], [36, 45], [30, 42], [42, 48], [34, 40]],$$
$$R(8) = [[50, 53], [44, 56], [60, 68], [55, 67], [52, 59], [45, 55]],$$
$$R(9) = [[50, 68], [52, 74], [55, 75], [54, 69], [48, 55], [45, 53]]$$

A method based on interval number sequence of fuzzy centroid confidence factor was used to cluster the validation information [10]. According to the (3), the Gauss distribution of the 9 distribution indexed of whitening weight σ_j.

$$[\sigma_j] = \begin{bmatrix} 0 & 0 & 0 & \boxed{0.01} & 0.169 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0.083 & 0 & \boxed{0.517} & 0.209 & \boxed{0.973} & 0.064 & 0 \\ \boxed{0.796} & 0.034 & \boxed{0.725} & 0 & 0 & \boxed{0.449} & 0.020 & \boxed{0.790} & \boxed{0.989} \\ 0.062 & \boxed{0.909} & 0 & 0 & 0 & 0 & 0 & 0 & 0.016 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

The comprehensive clustering coefficient of 9 subjective indexes σ_i^k.

$$\sigma_i^k = [0.0148, 0.1766, \boxed{0.4144}, 0.1273, 0]$$

The results of cluster result of 9 indexes were as follows: [common grey group, good grey group, common grey group, extreme grey group, differential grey group, common grey group, differential grey group, common grey group, common grey group]. The result of comprehensive clustering evaluation was common grey group.

5 Conclusion

The virtual verification method of human factors layout for nuclear power control room was studied. Virtual verification system was developed based on Delmia, combining virtual human model and virtual model of human–machine interface, and the human–machine interaction system was constructed in control room. The visibility, accessibility, operation posture and overall layout verification could be verified visually. Based on the requirements of human factors engineering and NUREG standards, the human factors layout verification indexes system could contain completely the workplace layout, display equipments and control equipments. A data processing method based on grey theory for human factors layout verification, and the whitening weight function model based on Gauss distribution were established. The determination of the distribution amplitude and the method for dealing with the adjacent intersection points were proposed. The evaluation model of the comprehensive value of verification information based on central point Gauss distribution whitening weight was constructed, to gather the subjective and objective information to the comprehensive value grey group. The proposed layout virtual verification method based on human factors engineering could improve the rationality of human engineering design of nuclear power control room.

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Research on Carrying Load Test and Evaluation System and Its Application

Chenming Li, Yuhong Shen and Yichao Du

Abstract *Objective* To evaluate the efficiency of carrying load scientifically and effectively and reduce human damage through the research of carrying load test and evaluation system. At the same time, the research can guide the design and development of carrying equipment, which will improve the adaptability between the equipment and the human body. *Methods* The carrying load test and evaluation system is composed of simulation model of human, sensing and acquisition device of information, simulation platform of motion, force efficiency evaluation model of human, software platform of test, and evaluation and so on. Three kinds of outdoor backpack were tested under four different load weights to evaluate the backpack performance through the system. *Results* The force, the resultant force, and the resultant moment of the sample A are better than those of the sample B and the sample C. *Conclusions* Different carrying load conditions are reflected by the standard model of human body and precisely controllable simulation of movement state, which solves the large individual differences of real tests, long test period, and other issues. Based on the biomechanical test, the evaluation model of human body force was established. The results show that the system can effectively carry out scientific prediction and evaluation of the load carrying state through the testing of different types of backpack.

Keywords Carrying load · Sense of force · Simulation model of human · Platform of motion

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1 Introduction

Walking with weights is a situation that outdoor enthusiasts, troops, and others often encounter. In the process of carrying the load, due to the role of load gravity, the relative movement between the load and the human and the bending of the body to balance the weight will lead to fatigue, pain, and other symptoms [1, 2]. If the load is too heavy, and the walking time is too long, it may cause foot soles, back pain, even muscle strain, fracture, and other injuries [3, 4]. Scientific and effective assessment of the carrying load efficiency can improve the adaptability between equipment and human, which helps to reduce human injuries, protect the human body, improve the operational efficiency, and guide the design and development of carrying equipment [5–7].

At present, the research on the efficiency of carrying load mainly adopts the subjective inquiry and the individual physiological experiment with carrying load [8, 9]. The shortcomings of the method are its high cost and long experiment period, and the deviation of the experimental result is big due to the individual difference. This paper introduces an evaluation system of carrying load test, which uses 50% of the male manikin model, and simulates walking, running, and other sports through the movement simulation platform. Manikin and carrying equipment installed on a variety of sensors, measuring the surface force of the manikin, the force and torque of the torso, the tension equivalent of the shoulder strap, and the force of the human can be predicted to evaluate the system of carrying load.

2 Carrying Load Test and Evaluation System

The carrying load test and evaluation system are composed of simulation model of human, sensing and acquisition device of information, simulation platform of motion, force efficiency evaluation model of human, software platform of test and evaluation, and so on.

2.1 *Simulation Model of Human*

Simulation model of human meets the size of 50% of young men characteristics, and the hardness of the shoulder, waist, back, and other key force parts is similar to the young soldiers. In addition, the centroid of the internal skeleton and the segment is close to the human body.

The shape of the simulated human body is based on the analysis of the size of male young people. The body size of 12 young middle-size male soldiers is measured by three-dimensional scanner, and the collected data are analyzed statistically. The average and standard deviation of the above data determine the size of the key parts. The centroid of the model is measured by the human centroid measuring instrument through the above 12 subjects. The centroid position of each segment is calculated according to GB/T17245-2004, and the data were analyzed and processed by statistical method to determine the centroid position and mass distribution of each segment. For simulation model of human, two-component vulcanized silicone rubber is used as the base material, while silica gel as the reinforcing agent, silicon powder as filler, methyl silicone oil as diluent, and dialkyl dicarboxylic acid as catalyst. Based on the body size and skeletal CT scan data, three-dimensional CAD software is used to simulate the skeletal structure of the manikin by using the torso load simulation. The internal skeletal structure of the simulation model is developed by using CNC machine tools and 45 steel.

2.2 Sensing and Acquisition Device of Information

The signal collected by the system mainly includes the pressure signal on the back, waist, and shoulder, the tension signal of the shoulder strap, the force and torque on the spine, and the tracking of the movement waveform.

Pressure measurement selects the 9801 thin-film pressure sensor produced by the United States Tekscan. The pressure sensor is mainly located in the shoulder, waist, and back. The tension sensor is mainly used to measure the tension of the shoulder strap. SMRT-P-200 micro-tension sensor is selected, which installs in the connection of backpack and lower part of the shoulder strap. Motion signal is measured by the PATRIOT WIRELESS system produced by the United States POLHEMUS company, which uses the wireless electromagnetic tracking method for motion signal acquisition. Force and torque sensors are selected by the German GTM's MKA-1K six-dimensional force and torque sensors. The sensor is installed between the human simulation model and the motion simulation platform, and it can measure the force and torque of X, Y, and Z in three axial directions at the same time.

2.3 Simulation Platform of Motion

Simulation platform of motion is mainly used for simulation of walking, running, jumping, and other motor functions. The time-domain signal on six degrees of freedom, which is collected by the human body attitude measurement sensor, is converted into vibration displacement and vibration velocity signal by the low-pass filter and the digital signal. And the signal is the drive signal for a six-degree-of-freedom low-frequency simulation platform of man's motion to achieve the simulation of the action.

The motion simulation platform is mainly composed of upper platform, lower platform, six electric cylinders, ball hinges, universal joints, electronic control system, and control computer. The motion of the platform is realized by the coordinated movement of six electric cylinders, which is three-degree-of-freedom translation motion and rotary motion around the *X*-, *Y*-, *Z*-axis direction.

2.4 Force Efficiency Evaluation Model of Human

Conduct the experiment in the condition of different loads, different kinds of carrying equipment, and the actual walking test. Then measure the pressure of the shoulder, back, and waist and the tension of the shoulder strap, and score the sense of force according to the evaluation scale. Next, power spectrum and 1/3 octave method are used to normalize the test data. The mixed-effect regression analysis method is used to establish the evaluation model of the force for scientific evaluation of the shoulder and body force. Establish a body force model, and the formula is as shown in Formula 1:

$$\begin{aligned} \mathrm{WBRPT(t)} = {} & 0.022023 \times L^2 - 1.212125 \times L + 0.143309B + 0.001181 \\ & \times \int_{k=0}^{t} \mathrm{FshPSD}(k) + 0.175881 \\ & \times \int_{k=0}^{t} \left(\frac{\mathrm{PshPSD}(k)}{\mathrm{PshPSD}(k) + \mathrm{PbaPSD}(k) + \mathrm{PwaPSD}(k)} + 23.11685 \right) \end{aligned} \quad (1)$$

2.5 Software Platform of Test and Evaluation

The software of test and evaluation is the control center of the whole system. The main control program adopts the Labview with advanced computer bus technology and virtual instrument programming technology and MATLAB, which is a powerful data analysis and engineering computing language. The C language programming is used in the Field DSP control for its high reliability and the characteristic of easy to write. Based on the above technologies, the user-friendly, easy-to-operate, and strong-extension software is designed, which is an application software with a fast and efficient data acquisition, model operation, force prediction, and other functions.

3 Experiments

3.1 Test Information

The object is three kinds of backpack produced by Shanghai Paijian Industry and Trade Co., Ltd. (as shown in Fig. 1), and the simulation mode of the human motion (speed: 5 km/h, slope: 0°) is selected. Four load weights (25, 29, 34, and 37 kg) in each backpack were tested three times. Measure the pressure of the shoulder, waist and back of the simulation model, the tension of the shoulder strap, and the force and torque of the model spine. Then, the force of the human body will be predicted.

3.2 Test Results

The test results are shown in Table 1.

It can be seen from Fig. 1 a 2-cm-thick filler is filled at the overall position between sample A and the human back, while the filler of sample B and sample C mainly concentrated in the back of the human on both sides. At the same time, for sample A, metal bracket structure is used between the filler and the backpack. At the bottom of the metal bracket, the curved protrusions (Fig. 2) make the backpack and the human body is more closely fit, which will help rational distribution of the weight on back, shoulder, and waist, and protect the human body from carrying load. Therefore, the force, the resultant, and the resultant moment of the sample A is better than that of the other two backpacks.

The size of the shoulder strap and belt of three kinds of backpack is shown in Table 2.

As can be seen from Table 2, compared sample A and sample C, the width of the shoulder strap is close, but the shoulder strap of sample A is significantly thicker,

Fig. 1 Three tested backpacks **a** Sample A; **b** Sample B; **c** Sample C

Table 1 Test results of three backpacks

Weight (kg)	Backpack	Sense of force	Resultant (N)	Resultant moment (Nm)
25	Sample A	12.18	143.51	20.74
	Sample B	12.27	150.19	21.08
	Sample C	12.32	148.72	21.34
29	Sample A	14.01	149.91	21.50
	Sample B	14.09	154.88	22.04
	Sample C	14.21	156.46	22.40
34	Sample A	16.18	167.55	24.27
	Sample B	16.42	179.08	24.80
	Sample C	16.54	179.05	24.77
37	Sample A	17.62	176.61	24.92
	Sample B	17.71	196.83	26.61
	Sample C	17.95	192.92	26.19

Fig. 2 Metal stent of sample A

Table 2 The size of the shoulder strap and belt of three kinds of backpack

No.	Backpack	Width of the shoulder strap (cm)	Thickness of the shoulder strap (cm)	Width of the belt (cm)	Thickness of the belt (cm)
1	Sample A	7.2	2.1	14.6	3.1
2	Sample B	6.6	0.9	10.0	2.6
3	Sample C	7.4	1.6	14.4	3.3

which plays a better cushioning effect, so the shoulder force is less. Although the sample B's shoulder strap and belt are narrower and thinner than the sample C, the softness is significantly better than that of the sample C, resulting in a more uniform force across the shoulder and waist. Therefore, the sense of force has no big difference between sample B and sample C.

4 Conclusions

Carrying load test and evaluation system use the standard human simulation model, precise control of the movement state to simulate different carrying load conditions, which solves the large individual differences, long test cycle, and other issues. Based on the biomechanical test, the evaluation model of human force is established. The test of different types of backpack shows that the system can effectively predict and evaluate the load carrying state.

5 Acknowledgement

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Compliance with Ethical Standards The study was approved by the Logistics Department for Civilian Ethics Committee of Academy of Military Medical Sciences.

All subjects who participated in the experiment were provided with and signed an informed consent form.

All relevant ethical safeguards have been met with regard to subject protection.

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Changes of Workload During Simulated Long-Haul Flights at Different Time Periods

Qingjun Zhang, Hua Ge, Hua Guo, Zhigang Jiao, Feng Wu, Andong Zhao and Hao Zhan

Abstract *Objective* To investigate workload changes of subjects during simulated long-haul flights at daytime and nighttime. *Methods* Eight volunteers were completed the simulated long-haul flight experiments at the same time periods of day and night. The parameters of measurements included flight simulation performance, additional task performance, ratings of perceived exertion scale (RPE), Stanford Sleepiness Scale (SSS), and critical flicker fusion frequency (CFF). *Results* There were no significant changes of the simulated flight performance between daytime group and nighttime group. The achievement of additional task was significantly lower than that of the same time period in daytime group. RPE and SSS scores in nighttime group were increased and CFF decreased. *Conclusions* Simulated long-haul flight at nighttime could aggravate the flight workload and reduce the reserved operating capacity.

Keywords Simulated long-haul flight · Workload · Critical flicker fusion frequency

1 Introduction

With the rapid development of aviation technology, military pilots have more opportunity to perform long-haul flight missions. According to the reports, B-2 bomber of 509th bombing wing of U.S. Air Force in the war on terror operation,

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named “Operation Enduring Freedom,” came from Missouri Whiteman air base kept sustained flight up to 44 h of the longest record [1]. Because of the unpredictable working hours, long duty periods, circadian disruptions, and insufficient sleep in military flight operations, pilots’ fatigue is a significant problem in long-haul flight missions. To evaluate the workload of Air Force pilots in long-haul flight missions and develop effective health safeguard measures was an important way to improve combat capability of military pilots.

2 Methods

2.1 Subjects

Eight healthy young male volunteers, age 20.5 ± 1.2 years, self-reported no sleep disorders, were participated the experiments. Using a self-repeated measurements design, the subjects were divided for into two groups according to the experiment period of day and night: daytime group, 12:45–17:00, and nighttime group, 0:45–5:00.

2.2 Parameters and Equipment

(1) Flight performance score and additional task performance.

The flight performance score and additional task performance can be automatically generated and evaluated by simulated long-haul flight workload evaluation system. The evaluation quality standard was set to “high.” The additional task performance parameters include task quantity, accuracy rate, and reaction time (RT).

(2) Critical flicker fusion frequency

Window flicker meter (BD-II-118) was used. Yellow spot was selected, light intensity was 1/16, bright black ratio was 1:1, and the background light intensity was 1/16. According to the order of “raise, raise, cut, cut,” recording a total of four frequency values, take the arithmetic mean as the results.

(3) Standford Sleepiness Scale (SSS) and Ratings of Perceived Exertion Scale (RPE)

SSS is divided into seven grades, from “awake and alert” for 1 scores to “almost fall to sleep” for 7 scores. RPE is also divided into seven levels, from “very, very light” for 6 scores to “very, very heavy” for 19–20 scores.

2.3 Experimental Procedure

The subjects were trained for simulated flight operation for 2 weeks at least. Each scoring period was set to 1-h period, of which the simulated long-haul flight time accounts for about 45 min. The parameter measurements accounted for about 15 min. A total of scoring periods were five phase (0, 1, 2, 3, and 4 h).

2.4 Statistical Analysis

SAS statistical software was used for multivariate repeated-measures analysis of variance. The percentage data were arcsine-square-root-transformed, and non-normal distribution data were logarithmic-transformed.

3 Results

(1) **The performance of simulated flight and additional task**

As shown in Fig. 1, the quantity of additional task finished at the 3rd h and the 4th h in nighttime group was significantly lower than that of the same time period in daytime group ($p < 0.05$, $p < 0.01$), in which the quantity of additional task finished at the 4th h was even lower than that of the same flight at the 1st h period ($p < 0.01$). Compared with daytime group, the accuracy rates of additional task in nighttime group decreased significantly and the RT prolonged at the 4th h, which was even longer than that of the same flight at the 1st h ($p < 0.01$), as shown in Fig. 2.

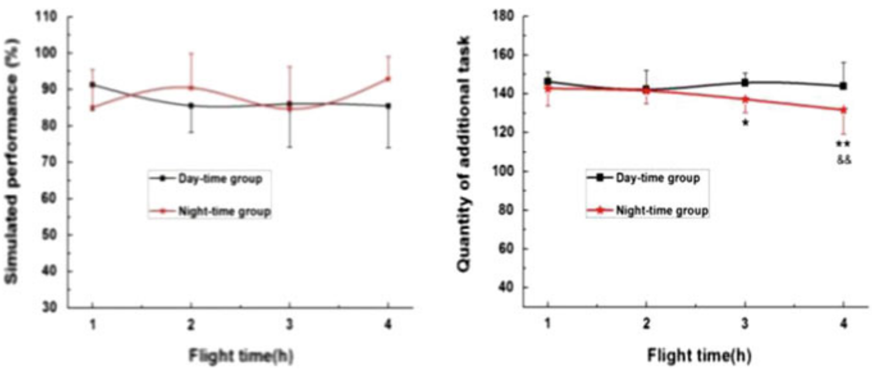

Fig. 1 Changes of flight performance and additional task quantity of the subjects in different phases during simulated long-haul flights. (*Note* $^{\&\&}p < 0.01$, compared with the same group at 1 h; $^{*}p < 0.05$, $^{**}p < 0.01$, compared with daytime groups at the same time)

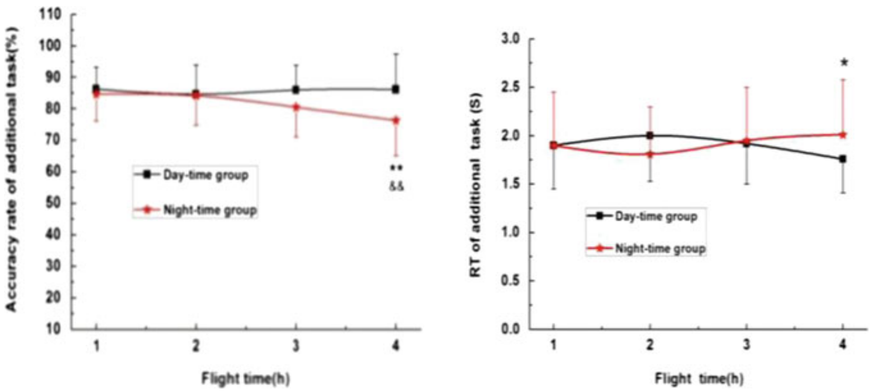

Fig. 2 Changes of additional tasks accuracy rate and RT of subjects in different phases during simulated long-haul flights. (*Note* $^{\&\&}p < 0.01$, compared with the same group at 1 h; $^{*}p < 0.05$, $^{**}p < 0.01$, compared with daytime groups at the same time)

(2) **Changes of subjective scale and CFF**

As shown in Fig. 3, RPE scores in nighttime group were increased from the 2nd h and remained high constantly ($p < 0.01$), and was higher than daytime group at the 4th h ($p < 0.01$). According to the RPE score judgment, the scores were between "lighter" (11–12) and "a little bit heavy" (13–14). SSS scores in nighttime group were increased from the 3rd h ($p < 0.05$).

As shown in Fig. 4, CFF in nighttime group decreased from the 2nd h ($p < 0.05$, $p < 0.01$), and was still lower than that at 3rd h in daytime group ($p < 0.05$).

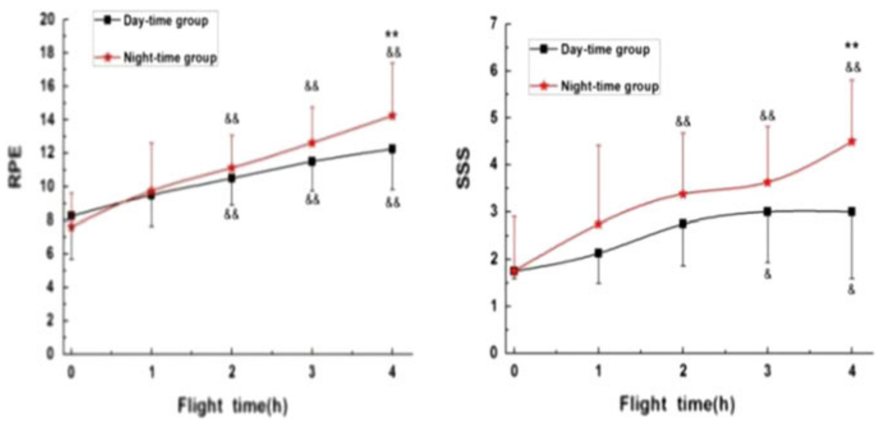

Fig. 3 Changes of RPE and SSS of subjects in different phases during simulated long-haul flights. (*Note* $^{\&}p < 0.05$, $^{\&\&}p < 0.01$, compared with the same group at 1 h; $^{**}p < 0.01$, compared with daytime groups at the same time)

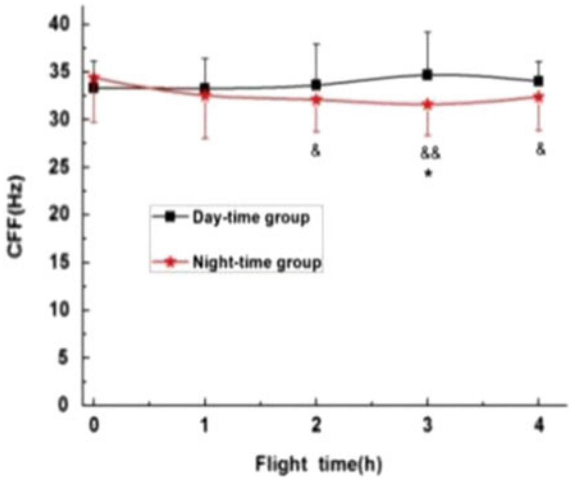

Fig. 4 Changes of CFF of subjects in different phases during simulated long-haul flights. (*Note* $^{\&}p < 0.05$, $^{\&\&}p < 0.01$, compared with the same group at 1 h; $^{*}p < 0.05$, compared with daytime groups at the same time)

4 Discussion

Workload evaluation is an important tool to improve operational efficiency, prevent fatigue, and maintain physical and mental health of workers. Due to long duty periods, circadian disruptions, insufficient sleep, acute or cumulative flight fatigue, a decline in spatial orientation ability occurs, and thus seriously affects flight safety [2]. It was found that not only sleep/awakening is associated with biological clock, but also working capability changes as the core body temperature fluctuates. For example, during the lowest core body temperature at 3:00 AM–5:00 AM, the alertness, RT, accuracy, and physical force would all be reduced [3]. Therefore, to research workload changes in different time intervals of daytime and nighttime flight is of special military significance.

Based on different aircrafts, a variety of flight simulators have been developed, such as UH-60 helicopter simulator, Boeing 737 simulator, F-117 fighter simulator, as well as F-7E simulator. The additional task performance efficiency can indirectly reflect the workload by main task. Common contents of additional tasks include memory ability, digital computing, RT, time estimation, target tracking, etc. [4]. The study results showed that the performance in simulated long-haul flight did not noticeably affected by nighttime period of the experiments. But the quantity of additional task completed by the subjects was reducing with low accuracy rates, and RT prolongation, indicating that the operational workloads in nighttime were increased and the reserved workload capacity was declined.

People have a certain self-perception on workload. Therefore, subjective scales can be used to judge subjective workload. Ratings of Perceived Exertion Scale (RPE) and Stanford Sleepiness Scale (SSS) are often used to evaluate the workload [5]. Our results showed that both daytime and nighttime simulated flights would all induce the subjects' subjective fatigue, significantly increased sleepiness, but judging from the specific scores, RPE scores were in between “lighter” and “a little bit heavy,” and SSS scores were in between “alertness and responsiveness bad” and “minds not quite awake, bad energy,” which were within the best of labor load range [6].

CFF, an indicator for assessing nervous fatigue, is often used to measure and determine the workload of nervous system. This study results showed that the CFF was decreased in the subjects in nighttime simulated long-haul flight operations, suggesting that the workload of simulated long-haul flight during night was significantly heavier than that during daytime.

5 Conclusion

In conclusion, simulated long-haul flight at nighttime could aggravate the flight workload and reduce the reserved operating capacity in subjects. Above all results, this study provides a theoretical basis for the development of targeted health safeguard strategy in future.

Compliance with Ethical Standards The study was approved by the State Key Laboratory of NBC Protection for Civilian Ethics Committee.

All subjects who participated in the experiment were signed an informed consent form and paid ¥100/h for their participation.

All relevant ethical safeguards have been met with regard to subject protection.

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Research on Design and Application of Vehicle Simulation Driving Test Platform for University Lab

Ping Zhang, Xiaomin Ding, Yi Zhang, Quan Yuan and Maoming Sun

Abstract This paper will discuss how to design and assemble a test platform for vehicle driving simulation, which is based on the university laboratory project, aimed at promoting both the quality of teaching and scientific research level in the university laboratory. Low cost and easy assembly are most outstanding characteristics of the simulation test platform for university laboratory, and it can meet ergonomics requirements in terms of vehicle driving comfort. It can play an important role in design practice for teaching. In order to help students understand the property and distribution of the parameters of the vehicle driving ergonomics, it is necessary to develop their abilities to analyze and solve problems. It can also stimulate their interests and enhance their creativity.

Keywords Automotive ergonomics · Comfort level · Simulation test platform · University laboratory

1 Introduction

Nowadays, automobile design follows some principles of user-centered, safety, comfort, and convenience. The vehicle driving simulator can simulate the state of the vehicle driving and research on the integration of the man–machine interface, to verify and optimize the automobile ergonomics design [1].

It is found that the vehicle driving test platform is mainly used in the automotive industry, and it is very hard to apply to ergonomics in universities laboratory. Those have been referred in some relevant theoretical researches. One of the researches was conducted by Yin Mengjie. She used the virtual human body model to study the interface of the car seat, control interface, and display device interface in the "Research on human machine interface design for automobile cab"; According to

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the experimental platform of biomechanics behavior of drivers, Zhang E, Hong Jun, Wu Wenwu, Liang Jian thought they can simulate and analyze people's behavior in different driving environments and discuss how to match to the interface in the paper of "Design and analysis of a test stand for biomechanics of man-machine interface in automobile driving." Yuan Dongmei, Li Yahui, Zheng Xiaomei designed a strength test platform for automobile seat in the paper of "Design on strength test bed of automobile seat," and it was little complex and could do many kinds of strength test, such as the backrest test, headrest strength test, and seat static performance test.

Currently, most of the vehicle driving simulation test platforms are complex, multifunctional, and expensive; but they are not suitable to university laboratory. Therefore, this paper will introduce the design and manufacture of a vehicle simulation test platform. The benefits are low cost, easy assembling, wide universality, which meet the needs of experimental teaching well. With the help of the ergonomic evaluation system of automobile driving, the ergonomics design of the vehicle can be verified and optimized.

2 Analyzing of Human Comfort in Automobile Driving

This paper is based on the theory of ergonomics, in order to optimize the comfort of driving. While driving in well posture, people feel tireless and energy consumption is low. So the efficiency of the equipment in the laboratory is very important for the drivers. Not only it can help the operator to take a stable posture to perform more fine motor, but also it is good to operate the pedal control devices [2]. Standard car seat driving postures are presented in Fig. 1. The position of the human body on the car seat is determined by the visual fields, and the comfort range of various parts of the human body is shown in Fig. 1. The most comfortable vertical distance from ischium to heel is 250–405 mm [3].

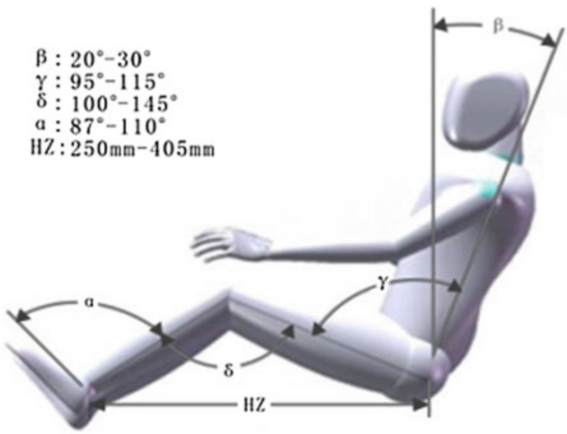

Fig. 1 Ergonomics form parameters of car seat

3 Design and Assemble of Vehicle Simulation Driving Test Platform

3.1 Design Principles of Vehicle Driving Simulator

The target user of the vehicle simulation driving test platform is the faculty in university laboratory. The main purposes are inexpensive, easy to install, and convenient to operate. By the test platform to achieve ergonomics experiments, it will improve the level of combination of theoretical teaching and practical operation. Finally, it will be helpful for students to understand relevant knowledge of vehicle driving.

Vehicle driving simulation test platform should have some parts of function structures, support structures, installation, and adjustment mechanism. First of all, the functional structure includes car seat assembly, steering wheel assembly, and driving pedal assembly. This professional independent equipment, including seat, steering wheel and pedals, are custom-made subject to manufacture requirements. Then, the supporting structure is the whole framework of the test platform, including the bearing frame of vehicle seat, the bracket of steering wheel, and the position reference of car pedal. To be ensured the reliability of the test operation, the reasonable installation methods, positions, and quantities can be set up by the stress analysis of the functional structure. The same installation forms are shared by different types of the same components, which is easy to replace during the test. Finally, the regulators should be set up on the basis of the following parameters: the height of the seat; the height, the angle, and the distance of the steering wheel; the angle and the distance of the automobile pedal.

In order to meet those requirements mentioned above, the projects of the prototype of the vehicle simulation test platform are demonstrated in Fig. 2.

3.2 The Assembly of Vehicle Simulation Driving Test Platform

1. Building the support structures
   We choose aluminum sections which label is 4040L as main elements to building the test platform. Aluminum profile has light mass and is easy to operate, which may ensure the whole structure stable, reliable, and easy to disassemble (Fig. 3). Some joint elements were chosen to fastening the structure, like the corner fittings, T bolts, and flange nuts.
2. Manufacturing the functional structures
   In fact, to functional structure, the material selecting and the production processing will affect the reliability of the experimental results. Hence, it should be developed in cooperation with professional manufacturers, aimed to achieve mass production with low cost and high generality. The test platform includes

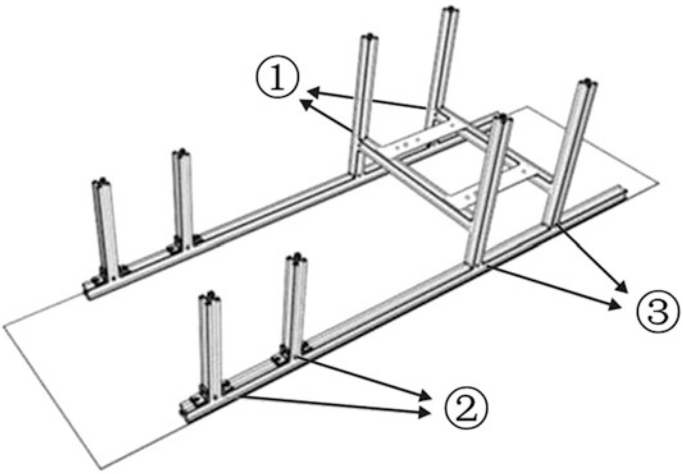

Fig. 2 Prototype of the experimental platform

several functional structures, which were chosen from different types of car seats, steering wheel assembly, and car pedals.

3. Setting up adjustment structures
   There are three kinds of adjustment mechanisms in the automobile seat test platform (Fig. 2). ① shows a high degree of adjustments, and ② and ③ show the position adjustments.
4. Setting up the installation method
   In order to ensure those different functional structures can be exchanged each other in the test platform, the same installation methods are adopted. For the test platform, the cushion assembly and the backrest assembly are fixed by bolt connection on to the supporting structure. In addition, the car seat has been set with two profiles, and each section is fixed by two bolts. The steering wheel and pedals are fixed directly on the ground by the customized pipe. Figure 4 shows the final equipment.

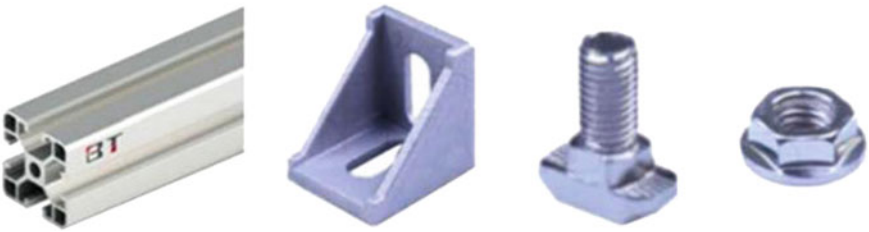

Fig. 3 Aluminum sections and joint elements

Fig. 4 Test platform and testing

4 Application of the Driving Simulation Test Platform

Due to the advantage of stimulation driving test platform, students will use ergonomic knowledge, such as human body static size, sitting physiology, and mechanics, to adjust the height, depth, scale parameters, angle position of seat back, and other operating equipment. Simultaneously, it can combine with the body pressure distribution test and SEMG testing to give evaluation to the ergonomics interaction [4]. Then, in the perspectives of convenience and comfort of operation, the test object will be created by the experimental data.

4.1 Testing of the Driver's Hand Touch Interface and Operating Comfort

1. Experimental objectives
   Both the handles and operation buttons are basically required to reduce the frequency of incorrect operation to achieve safe driving [5]. The purpose of the experiment is to test the arrangement of the control device of the driving cab according to the international standard ISO3958.
2. Experimental contents
   When testing, the drivers are told to put the right foot on the accelerator and one hand holding the steering wheel, and also, another can touch the maximum ranges (Fig. 5).
3. Experimental facilities
   Such as car seat, bend tapes, vehicle simulation driving test platform, driving simulation system.
4. Experimental process
   (1) In accordance with GB/T 17867-1999, the place which the driver can reach is divided into several areas. Therefore, the subjects should control controls in designated areas and the conductors record the comfort data;

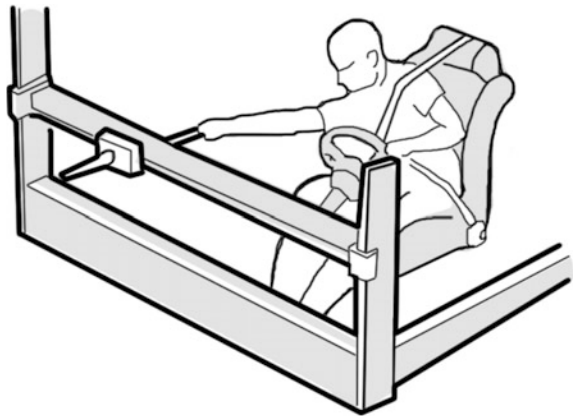

Fig. 5 Experimental process

(2) Measuring and recording the dimension parameters of the cab and relevant parts and components.

5. Analyzing the experimental results

(1) Statistics the testers' comfort changes during the process of driving;
(2) Through the measurement, reasonability of the placement should be checked based on data calculation and comparison.

Compared with the experimental data, standard parameters of automobile driving comfort can be verified and the reasonability of the components will be examined as well.

4.2 Testing of the Comfort of Driving Posture

1. Experimental objectives
   It is the key factor that whether driver's motion is comfortable in the design of human–machine interface. The aim of this experiment is to study relevant knowledge of seat comfort requirements for drivers and to understand the influencing factors about human body size for product design, so as to guide the practical design.

2. Experimental contents
   On the basis of the vehicle simulation test platform, the simulated driving space can be built up. In the stimulation status, when the sitting position of driver was close to the threshold of fatigue, the data of sitting position, the pressure distribution of sitting, and the change in the sitting posture were recorded and monitored.

3. Experimental facilities
   Such as vehicle driving simulation test platform, car seat, seat pressure test system, SEMG, bending tapes.

4. Experimental process
   (1) Adjusting the seat to accommodate the most comfortable level of the subjects;
   (2) Keeping driving for a period of time. Allowing subjects change posture freedom and keeping them perform naturally;
   (3) Recording the data of the sitting position and the pressure distribution during experiment.

5. Analyzing of experimental results
   (1) Analyzing statistically data of the sitting position and the pressure distribution;
   (2) Recording the sitting posture change;
   (3) Recording the psychological status change of the subjects;

Generally, analyzing these streams of data can get the threshold of fatigue and the distribution of pressure distribution at specific time. So we got the driving posture comfort data based on this experiment.

4.3 Testing of Comfort of Automobile Seats

1. Experimental objectives
   In the course of driving, the comfort, safety, and scientific design of car seat should be taken into considerations. The purpose of this experiment is to help students understand the structures and functions of car seat, study geometric parameters and ergonomic requirements in the design of the car seat, and evaluate the comfort of the car seat.

2. Experimental contents
   The subjects will simulate driving state during the driving process and take different types of car seat within a set period of time. After that, the body pressure data were recorded, and then factors that affect the comfort of car seats can be analyzed.

3. Experimental facilities
   Such as three kinds of automobile seat have the same filling materials and the surface cover; the body pressure distribution experiment instrument; the automobile driving simulation system and the vehicle simulation driving test platform.

4. Experimental process
   (1) Adjusting car seat cushion height and tilt angle, so that the subjects can sit more comfortable;
   (2) Keeping subjects driving for a period of time. Posture change should be allowed to keep them perform naturally;
   (3) Recording the contact area of the car seat backrest and cushion parts, average pressure, peak pressure, and other numerical changes.
5. Analyzing of experimental results
   (1) Recording the area of contact, average pressure, peak pressure, and so on;
   (2) Calculating the maximum longitudinal pressure and pressure gradient by relevant professional software, and drawing the curve of pressure and isobaric map.

Through analyzing these experimental data, the body pressure distribution of three car seats can be obtained, and the design of automobile seat will be optimized, which provides a theoretical basis of the comfort evaluation of automobile seat [6].

5 Conclusions

In this paper,the design and construction of the vehicle simulation driving test platform are for the university laboratory. In a sense, the test platform is simple and crude, but it has a lot of advantages in teaching practice. The simulation driving platform can meet the requirements of driving, so it can be used to verify the theory of the human driving engineering. The construction of the vehicle driving simulator is not only to cultivate students' practical skills and practical ability, but also to improve the teaching and scientific research of ergonomics.

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Application of Fault Tree Analysis for Safety Evaluation About Coal Dust Explosion in Coal Mine

Yan Li, Sen Yang and Jianping Jiang

Abstract The aim was to abate the casualty, wealth loss, and frequency of coal mine accident and to understand the pathogenesis, influencing factor, and the hazard of coal dust explosion, which is one of the major accidents in coal mine. Take Shen Bao surface coal mine for example. Fault tree analysis is used to make the careful analysis of the basic events leading to the accident under the production system and the hazard of the coal mine production system. On the basis of it, we put forward the classification of the coal dust explosion hazard and construct mathematical functions, and calculating the occurring probability of the top event and coal dust explosion data of minimum cut sets, minimum path sets. After all the analyses, the results show that the more the basic events, the lower the probability of their simultaneous occurrence in minimum cut sets, which means the lower possibility of coal mine accident. Also we give the safety recommendations on the basis of conclusion that the hazard is mainly on coal mine gas explosion, spontaneous combustion of coal, and high concentration of oxygen.

Keywords Safety evaluation · Coal dust explosion hazard · Fault tree analysis · Minimum cut sets · Minimum path set · Important degree of the structure

1 Introduction

The deaths of coal workers in China caused by accidents in recent years present as a downward trend, the national coal production has increased nearly 4 times from 10 million tons by 15 years, death toll caused by the coal mine accident has decreased

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from nearly 7000 people to less than a thousand people today, but there are still some major coal mine accidents.

Not only the production of coal has been restricted, but also heavy casualties and huge economic losses have been caused by the coal dust explosion. Therefore, the coal dust explosion accident is still the focus areas of accident control. Based on this, take Shen Bao surface coal mine for example; using fault tree analysis method, this paper analyzes the hazard of coal dust explosion accidents in coal mines.

There are some articles about using the fault tree analysis method to evaluate the enterprise security in the world. K. Brik investigated the fault tree analysis in theory; he believes that the fault tree analysis method provides a framework that can analysis all the accident event combination cause the occurrence of accidents deductively [1]. Ibrahim Akgün studied the application of fault tree analysis in disaster management, and he thinks that the fault tree analysis can significantly divide hazard into different levels of risk [2]. Lindhe Andreas reckons that by the results of fault tree analysis, we can compare performance goal with acceptable level of risk effectively [3].

Fault tree analysis method has gone through a great development in the theory and application level in China. Bu Quanmin thinks that the fault tree analysis method can determine the order of measures to control each basic event and can contribute to formulate a targeted and practical safety control plan [4]. Wang Houjun's study on the coal mine flood obtain that there are 35 basic events in minimum set that can prevent the coal mine flood from occurring, and put forward the best approach to eliminate coal mine flood according to the results of the analysis [5]. Xu Jiangtao combined the fault tree analysis method and qualitative analysis and quantitative analysis based on computer programming and research on application of fault tree analysis in coal mine flood prevention, and put forward effective advice about the prevention of coal mine flood [6].

Although the number of literature for colliery enterprises safety evaluation is currently large, most scholars used experimental measurement method to do research on the coal mine dust explosion. Yang Shuzhao systematically studied coal dust explosion in confined space propagation rules and accident damage characteristics by experimental testing, theoretical analysis, and numerical simulation methods [7]. Based on this, take Shen Bao surface coal mine for example, and this paper measures the probability of top event in coal dust explosion, minimum cut sets, and the minimal path sets and provides suggestions and countermeasures for coal enterprises' safety evaluation.

2 The Construction of Fault Tree

2.1 General Overview of Shen Bao Surface Coal Mine

Shen Bao Energy Co., Ltd, main mine, is located between the State Road 301 and Hailahei provincial road. The company has 23 tons of resources, and the state-approved productivity is 35 million tons per year. The company owns two sets of ground production system currently, and its coal crushing productivity is 5000 tons per hour. In terms of transport, it has 23 km private railway line.

2.2 The Construction of Fault Tree

Coal mine dust is mainly from the following several ways: (1) transport operations, (2) blasting operation, (3) mining equipment operation, (4) the process of drilling dust, and (5) dump and slope cleaning dust.

From field investigation, we can know the risk sources of Shen Bao coal mine are car dust, road dust deposition, dust generated from coal mining process, blasting dust and drilling perforating, and so on.

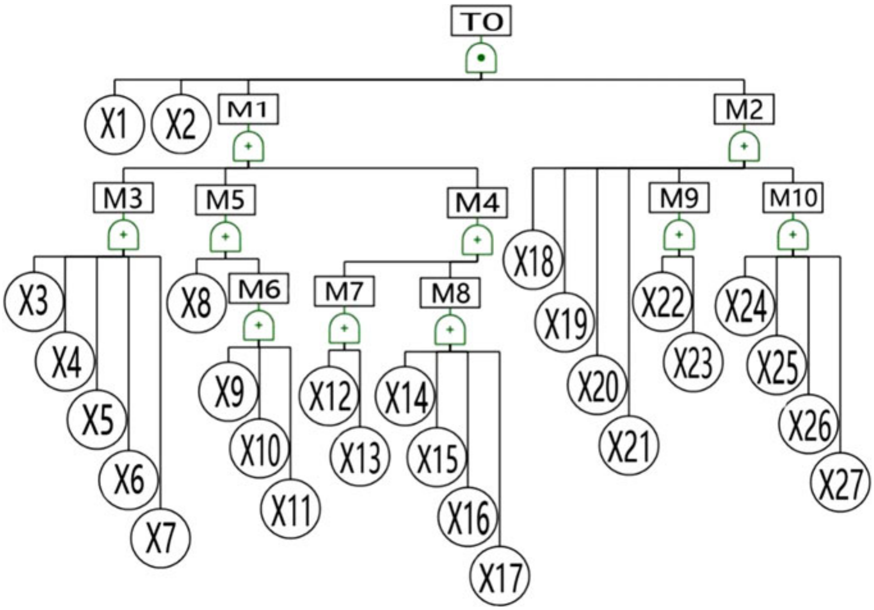

Fig. 1 Fault tree

By drawing the top event and by analyzing the underlying causes and basic events, we can obtain the fault tree, as shown in Fig. 1.

$T0$—Coal dust explosion	$M1$—Gather a certain concentration of dust
$M2$—Detonate fire source	$M3$—Too much dust in working platform
$M4$—Dust removal failure	$M5$—Coal body drying
$M6$—Coal seam water injection has no effect	$M7$—Poor ventilation
$M8$—Dust removal failure	$M9$—Flame
$M10$—Electric spark	$X1$—Coal dust is explosive
$X2$—Oxygen	$X3$—No dust removal during blasting
$X4$—No wet drilling	$X5$—Internal and external spray does not match
$X6$—Borehole without cement plugging	$X7$—Clear the coal without water
$X8$—No coal seam water injection	$X9$—Water injection hole design is not reasonable
$X10$—Insufficient water injection pressure	$X11$—Insufficient water injection time
$X12$—Excessive air flow	$X13$—Insufficient air flow
$X14$—Failing to install dustproof facilities	$X15$—Not using the dustproof facilities according to regulations
$X16$—Dustproof facilities failure	$X17$—Failing to regularly scour dust
$X18$—Gas explosion	$X19$—Blast flame
$X20$—Coal spontaneous combustion	$X21$—Friction impact spark
$X22$—smoking	X23—Underground electric welding
$X24$—Cable damaged	$X25$—Electric instrument blasting
$X26$—Live overhaul	$X27$—Electric spark of motor vehicle

3 Fault Tree Analysis

3.1 Calculation of Minimum Cut Set

A cut set is a set of events that can make a top event happen. If all of the basic events included happen, then the top event is bound to occur. The minimal cut set is defined as the set of minimum probability events that cause the occurrence of top event of the fault tree.

With a simplified fault tree, the minimum cut sets can be obtained after the fault tree structure is simplified. With a non-simplified fault tree, the Boolean algebra method is used to simplify the fault tree to obtain the structure function formula.

In this case, the minimal cut sets of the fault tree are as follows:

$$
\begin{aligned}
T0 &= X1\,X2\,M1\,M2 \\
&= X1\,X2(M3+M5+M4)[(X18+X19+X20+X21)\,M9\,M10] \\
&= X1\,X2\{(X3+X4+X5+X6+X7)+[X8+(X9+X10+X11)]+(X12+X13) \\
&\quad +(X14+X15+X16+X17)\}[(X18+X19+X20+X21) \\
&\quad +(X22+X23)+(X24+X25+X26+X27)]
\end{aligned}
$$

In FreeFta software, click on the "minimum cut set—copy all the text—save as a text file" and get the following cut set calculation results:

$$
\begin{aligned}
&K1 = \{X1, X2, X10, X18\} \\
&K2 = \{X1, X2, X10, X19\} \\
&K3 = \{X1, X2, X10, X20\} \\
&K4 = \{X1, X2, X10, X21\} \\
&\ldots \\
&K148 = \{X1, X2, X9, X25\} \\
&K149 = \{X1, X2, X9, X26\} \\
&K150 = \{X1, X2, X9, X27\}
\end{aligned}
$$

The minimum cut set group number is 150, and the equivalent fault tree expressed by the minimum cut set is shown in Fig. 2.

From the minimum cut sets, 150 cut sets represent the coal dust explosion in 150 ways and represent the probability of occurrence of the top event.

3.2 Calculation of Minimum Path Set

When the basic events in the minimum path set obtained by calculation are all in non-fault state, then the minimum path set is in non-fault state and the state of the basic events in minimum path set can directly determine the state of the minimum path set. A success tree is a fault tree consisting of all the minimum path set. As

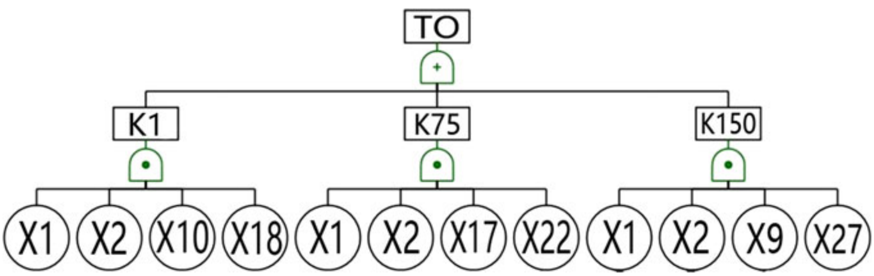

Fig. 2 Equivalent fault tree (minimum cut set expression)

long as the "AND" and "OR" logic gates in the fault tree get mutual exchanged, we can achieve the transformation of a success tree and a fault tree.

The solution of the minimum path set is as follows:

$$\begin{aligned} T0' &= X1' + X2' + M1' + M2' \\ &= X1' + X2' + (M3' \times M5' \times M4') + [(X18' \times X19' \times X20' \times X21') + M9' + M10'] \\ &= X1' + X2' \end{aligned}$$

Thus, we can obtain 2 sets of minimum path sets:

$$P1 = \{X1\}; \quad P2 = \{X2\}$$

$P1$ and $P2$ represent the basic event $X1$ and basic event $X2$ that cannot cause the occurrence of the top events in fault tree.

3.3 Structural Importance Analysis

The processing method of structural importance is varied, and the approximate judgment method is used in this paper,

The results are listed as follows:

$$\begin{aligned} I_\varphi(1) &= I_\varphi(2) > I_\varphi(18) = I_\varphi(19) = I_\varphi(20) = I_\varphi(21) = I_\varphi(22) > I_\varphi(23) = I_\varphi(24) \\ &= I_\varphi(25) = I_\varphi(26) = I_\varphi(27) > I_\varphi(8) > I_\varphi(3) = I_\varphi(4) = I_\varphi(5) = I_\varphi(6) = I_\varphi(7) \\ &= I_\varphi(8) > I_\varphi(9) = I_\varphi(10) = I_\varphi(11) = I_\varphi(12) = I_\varphi(13) = I_\varphi(14) \\ &= I_\varphi(15) = I_\varphi(16) = I_\varphi(17) \end{aligned}$$

4 Conclusion

1. From the fault tree in Fig. 1, we can see that the proportion of "OR" logic gates is more than 90%. Thus, most of the basic events will lead to a upper event. For example, insufficient water injection time ($X11$) or insufficient water injection pressure ($X10$) will lead to coal seam water injection which has no effect ($M6$). Compared with the "OR" logic gates, the proportion of "AND" logic gates is only 10%, and only occurrence of every event will lead to a upper event. From the proportion of the "AND" and "OR" gate, we can know the coal dust explosion has a great probability of occurrence.
2. From Fig. 2, under the circumstances of all events in a cut path Ki that occurs simultaneously, the dust explosion will happen. For example, in Ki, when the coal spontaneous combustion ($X20$) basic event occurs, then detonate fire source

($M2$) will happen, and when the dustproof facilities failure ($X16$) occurred, there will be dust removal failure ($M4$) event. If $X1$ (coal dust is explosive) also occurs at the same time with the above events, which is bound to happen, and with $X2$ (oxygen) basic events, then it will eventually lead to the occurrence of coal dust explosion ($T0$). In minimum cut set Ki, the more the basic events, the less the probability that they occur simultaneously, which means a lower chance to lead to a top event. In contrast, the probability of the occurrence of the top event will be greater.

3. Through the structural importance analysis, we can see that basic events $X1$, $X2$, $X18$, $X19$, $X20$, $X21$, and $X22$ have a relatively larger degree of structural importance; thus, we can obtain that the main hazard of Shen Bao coal mine is mine gas explosion, coal spontaneous combustion, and high concentration of oxygen. Therefore, effective approach to prevent coal dust explosion of Shen Bao coal mine is to reduce the sparks generated by impact friction of various machinery and equipment, use of machinery and equipment according to regulations, and avoid detonate fire source.

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Research on the Relationship Between Coal Mine Safety Expert Cooperation Network and Cooperation Performance

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Abstract In order to reduce the coal mine accidents. From the point of scientific cooperation, based on the social network theory, we explore the relationship between the mine safety expert cooperation network and the cooperation performance. Using the method of questionnaire investigation, we take the enterprise security management specialist as issue objects. SPSS19.0 software is used to make the reliability and validity .On the basis of it,we use multiple-stepwise regression analysis method to study the effect of the expert cooperation network on cooperation performance. After all the analyses, the results show that network centrality, network density, structural holes, ties trength are negatively correlated with cooperation performance. Results show that network cooperation, network centrality, network density, structural holes, and relationship strength were negatively correlated with cooperation performance.

Keywords Coal mine · Safety expert cooperation network · Social network · Cooperative performance · Multiple regression analysis

1 Introduction

The coal mine safety accident is highly dangerous and uncontrollable and has brought great difficulty to the national control and the government regulation [1]. Effective cooperation between coal mine safety experts can help solve the above coal mine safety issues [2]. Coal mine safety expert network belongs to the field of safety science and technology experts in the form of a social network [3]. Luis de-Marcos [4], using social network theory, found that social network facilitates

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communication and cooperation among students and facilitates the improvement of academic achievement. Dao Cheng-hong, Shen Liang [5] have found that applying social networks to the field of knowledge cooperation can help improve the overall performance level and maximize cooperation outcomes. Militano [6] defines the meaning of network centrality in social network structure and proposes that the degree of network centralization can improve the team's creativity.

This paper uses the social network analysis method, taking the social network as the independent variable, and the cooperation performance as the dependent variable, so as to systematically analyze and verify how the coal mine safety experts interact with each other and enhance the cooperative performance of the cooperative network.

2 Research Assumptions

2.1 Social Networks and Collaboration Performance

Li Mengnan, Jia Zhenquan (2014) think that the social network is a relatively stable contact system, which is made up of the population, also it is a kind of social capital. From the social network theory, from weak to strong connection process is the process of social capital development. Based on scholars' research on social networks, this paper divides social networks into four dimensions: network centrality, network density, structural holes, and relationship strength.

This paper uses Ganesan's view to define cooperative performance as follows: Since the establishment and continuous development of cooperative relations, experts tend to inject more costs to achieve the desired objectives and get more comprehensive benefits.

2.2 Relationship Between Social Network and Cooperative Performance

1. Network centricity and cooperative performance

The degree of network centrality represents the level of convergence or centralization of the entire network. The higher the network centricity of a network, the stronger the degree of its concentration and the more frequent the interaction between members. If more experts are in a central position in social network, it is conducive to the improvement of cooperative performance. Based on this, the following assumption is made:

H1: The degree of network centricity in the coal mine expert network has a positive effect on the cooperative performance

2. Network density and cooperative performance

Network density is used to represent the level of interconnection between nodes in the network [7]. Coal mine safety experts cooperative network can help experts connect. The more intimate the relation is, the more communication among experts, it can make more effective resources, which more likely to improve the performance. Therefore, the following assumption is made:

H2: The network density has a positive effect on the cooperative performance in the coal mine expert network

3. Structural holes and cooperative performance

The structural holes refer to a gap between two nodes in the network. The greater the number of structural holes, the less repetitive of resources. The experts in the structural holes position in the network control the flow of resources of other nodes and also help to improve the utilization of resources, and ultimately improve the performance of coal mine experts. Thus, the following assumption is made:

H3: The structural holes in the coal mine expert cooperation network has a positive effect on the cooperative performance

4. Relationship strength and cooperation performance

Relationship strength refers to the frequency of communication between experts, generally through the length of time between each other communication, network density, emotional affinity, mutual trust, and interaction dimensions. Therefore, Strong tie has reflects the characteristics of the-network to a certain extent. The experts relationship become more and more close, and at the same time, the cooperation to be strengthened day by day. Thus, the following assumption is made:

H4: The intensity of relationship in coal mine expert cooperation network has a positive effect on cooperative performance

3 Reliability and Validity Analysis of Questionnaire

This study needed to analyze the reliability and validity of the social network scale and cooperative performance scale.

3.1 Social Network Scale

The reliability of social network scale was tested. The overall reliability of the scale was 0.829. The reliability of the four dimensions network centrality, network density, structural holes, and relationship strength was 0.781, 0.747, 0.733, and 0.775, respectively, which means the social network scale has a better internal consistency of the data; and the CITC value of the items was greater than 0.4, indicating that the scale has a good reliability.

The KMO coefficient was 0.755 and the Bartlett sphere test had a p value of 0.000, which is significant to indicate that it is appropriate to do the factor analysis, in order to judge the KMO sample value and the Bartlett sphere test value. Then, principal component analysis and maximum variance rotation were used to analyze the data. The results show that the total variation is 70.361%, the network centrality, network density, structural holes, ties-trength explained 69.597%, 66.437%, 65.298% and 69.847% of the total variation [8].

3.2 Cooperative Performance Scale

The reliability of the performance scale was analyzed. The total reliability of the scale was 0.824, which was higher than 0.7, which indicates that the cooperative performance scale has a good reliability. The results of KMO and the Bartlett sphere test showed that the KMO value of the cooperative performance scale was 0.738, greater than 0.7, and the significance level of Bartlett's sphere test was 0.000, indicating that the test passed. There is a strong correlation between the data of the cooperative performance scale, so the cooperative performance scale is effective.

4 Data Analysis

4.1 Correlation Analysis of Social Network and Cooperation Performance

There is a significant positive correlation between social network and cooperative performance, which the significance level less 0.01, and the correlation coefficient was 0.621. The relative deviation greater than 0.5 and less 0.8. It shows that the level of social network has a significant impact on the cooperative performance.

The significant positive correlation between network centricity and cooperative performance, the coefficient was 0.642, so the study confirmed H1. Also the network density, structural holes, ties trength all have significant positive correlation between cooperative performance, the coefficient respectively was 0.691, 0.954, 0.611, the results supported the hypothesis H2, H3, H4 (Table 1).

Table 1 The Pearson correlation between social network and cooperative performance

	Network center degree	Network density	Structural holes	Relationship strength	Social network
Cooperation performance	0.642**	0.691**	0.954**	0.611*	0.621**

Note *$P < 0.05$, **$P < 0.01$, and ***$P < 0.001$

4.2 Regression Analysis of Social Network and Cooperative Performance

The independent variable and dependent variable were used to carry out linear regression of the network centrality. The multiple stepwise regression results are shown in Table 2.

It can be seen from Table 2 that the adjusted coefficient of determination (adjusted R^2) was 0.753, indicating that 75.3% of the explanatory variables can be explained by the model. The observed value of F test statistic is 45.271. The linear relationship between explanatory variables cooperative performance and network centrality, network density, structural holes, and relationship strength is significant. A linear model can be used to describe and reflect on the relationship between them.

It can be seen from Table 3 that (1) the explanatory variables network center degree, network density, structural holes, and relationship strength have a significant effect on the cooperative performance, which means that it has a great influence on the cooperative performance; and (2) the standardized coefficients of the four explanatory variables are 0.267, 0.361, 0.235, and 0.420, which are all positive, indicating that their influence on the cooperative performance is positive in the network centricity, network density, structural holes, and relational intensity. According to Table 3, regression equation can be established, namely:

Table 2 Multiple regression analysis of social network and cooperative performance

Model	*R*	*R*-side	Adjust the *R*-side	*F*
Cooperation performance	0.878	0.770	0.753	45.271

Table 3 Regression coefficients of the dimensions of social network and cooperative performance

	Constant	Network center degree	Network density	Structural holes	Relationship strength
Standard coefficient	−1.379	0.267	0.361	0.235	0.420
Sig.	0.001	0.000	0.000	0.001	0.000

$$\begin{aligned}\text{Cooperative Performance} = & -1.379 + 0.267 * \text{Network Center Degree} \\ & + 0.361 * \text{Network Density} + 0.235 * \text{Structural Hole} \\ & + 0.420 * \text{Relationship Strength}\end{aligned} \tag{1}$$

4.3 Results and Discussion

1. The network center degree of coal mine safety expert cooperation network has a significant positive effect on cooperative performance. This shows that in scientific collaboration, security experts have to be very high social status, they enjoy more network relations and social resource, others are willing to meet the demands of cooperation. This cooperation is also a process of network learning among experts.
2. The network density of coal mine safety expert network has a significant positive effect on cooperative performance. Frequent network connection is to the optimal allocation of resources, it promotes dissemination of information and resource flow, which can makes the relationship of experts become harmonious by communicating frequently. Fom another angle, it more conducive to cooperation efficiency.
3. The structural holes of coal mine safety expert network has a significant positive effect on cooperative performance. Coal mine safety expert has more structural holes, and the ability to absorb, utilize, share, and innovate is more stronger. Only experts in structural holes can ensure resources and information in the cooperation network; in order to ensure the healthy development of the entire cooperative network, network cooperation in the performance of experts can be improved. Therefore, increasing the number of structural holes has a significant positive effect on improving the efficiency of coal mine safety expert cooperation network.
4. The relationship strength of coal mine safety expert network has a significant positive effect on cooperative performance. This shows that the longer interaction time, the more emotional intimately. It gets more opportunities for cooperation. This relationship can help each other, it is important to enhance the efficiency of network cooperation.

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Study on the Standard of Military Training Examination

Cheng Jin, Zhibing Pang, Genhua Qi, Quanliang Yin, Shuai Mu, Runfeng Hou and Pengdong Zhang

Abstract *Objective* To establish the meaning of the evaluation standard, principle, method, and relevant requirements and matters needing attention through research and analysis in the military training, to lay a theoretical foundation for the standard of the military training evaluation, so as to increase the combat effectiveness finally. *Methods* By consulting the relevant information, summarizing for the purpose of the assessment standards the performance assessment, the followed principle, and the attention paid to matters. *Results* To summarize the basic requirements of the standards for assessment of military training and related regulations, to lay a theoretical basis for developing standards. *Conclusion* To make the military training assessment standards of the related content clear, to formulate appropriate evaluation criteria scientifically and reasonably, so as to comprehensively measure the training situation and improve the battle effectiveness.

Keywords Military training evaluation criteria · Principle · Performance evaluation · Conception

1 Introduction

In the new situation, the rapid formation of combat effectiveness of people and equipment is the most important task; it can directly affect the outcome of future war, whose role is critical. Military training is a normalized work and training effect directly affects the familiarity and ability of people and equipment, leading the speed of formation of combat effectiveness; thus, a reasonable assessment of training effectiveness is very important [1]. Assessment is an important system in the military training work. It is a very direct and effective means to evaluate the effect of the training, because it can understand the situation, check the effect, summarize the experience, and promote the training. The development of assessment standards

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helps to uniform the training standards and measure the individual and unit level to master skills comprehensively, so as to enhance the overall combat effectiveness. This paper focuses on the study of basic requirements for the development of assessment standards and the relevant provisions, to lay the theoretical basis for the development of assessment standards of specific subjects.

2 The Purpose and Basic Requirements for the Development of Assessment Standards

2.1 The Purpose

Military training assessment standards are formulated based on military training syllabus, regulations, and the relevant provisions of the tutorial, in accordance with actual combat requirements; combined with the actual development of military training, it is the basic basis of grass-roots units and institutions to assess military training performance.

The purpose of the assessment standards is to unify the army's training quality standards, to examine the degree that trainees master the subject accurately, to measure individuals and units' total score of a period of training comprehensively, to promote comprehensive training to guide the training to the good development, to enhance the ability of people and equipment, to improve the overall combat capability, and to strengthen the grass-roots units of regular construction.

2.2 Basic Requirements

Development of assessment criteria should not be blind, subjective, and should comply with certain requirements, so as to measure performance and check the effect of the effect. The basic requirements for the development of assessment standards are as follows:

First, implement the rules and regulations, orders, tutorials, and training programs' standards strictly;

Second, start from the actual combat and depend on the situation, such as combat missions and combat targets, combat missions in the region, so as to give prominence to importance;

Third, insist on the rules strictly and difficultly, make requirements reasonably, make a comprehensive consideration of the tactical, technical, and other aspects;

Fourth, seek for truth based on facts scientifically and reasonably; the standard should be able to effectively reflect the level of training and play an evaluation role.

3 Principles to Develop Assessment Standards

3.1 The Systematic Principle

Assessment standards should be able to reflect the overall assessment and evaluation of the overall level of training. From the horizontal point of view, the assessment criteria should reflect the assessment of the subject time, accuracy, proficiency, action of the normative, rapid, and security; from the vertical point of view, assessment standards should be sufficient to reflect the dynamic development of training process, Evaluation of the performance and effectiveness can not only reflect the previous training, but also be able to guide and improve the future training, so as to make the training meaningful and effective [2].

3.2 The Guiding Principle

To ensure that the assessment results are scientific and effective, the development of assessment standards should have a strong orientation role. Assessment standards should be as simple and clear as possible with a small amount of indicators and concise language summary to reflect the purpose of the assessment and enhance the orientation, making the assessment of the subject and object easy to understand and accept, to ensure that the examination standards can check the pre-training effect and guide the latter part of the training methods, to enhance the practicality of overall assessment standards.

3.3 The Theoretical Principle

The development of assessment standards should be guided by the scientific theoretical basis. For the grass-roots units of equipment training, assessment standards must be closely integrated with the characteristics of equipment, so as to study in-depth; the development should refer to the manufacturer's engineers' technical advice, combined with the unit training, combat, and other applications of tactical requirements, on this basis to develop rigorously and scientifically after the comprehensive measurement.

3.4 The Practical Principle

Assessment criteria should be based on a solid foundation for practice. The final purpose of the development of assessment standards for the grass-roots units training and institutions of teaching services, and the development of standards must be prior to the assessment of the equipment in a large number of practical applications, to conduct a large number of experiments to training data and actual training data as the basis for scientific development.

3.5 The Operational Principle

Assessment standards should be developed with a strong maneuverability as the goal. Assessment criteria should have a strong maneuverability and strive to achieve the assessment criteria to be comparable and reflect the common attributes of different assessment objects once enacted, to enhance the practical value of the standard. And resolutely put an end to the phenomenon such as that the assessment criteria lack of strong operability, defined fuzzy, and unclear expression [3].

4 Performance Evaluation in the Assessment Standards

Performance evaluation in the assessment standards takes the five-point system generally, with four levels of assessment; the overall score takes the average score, 4.5–5 points means excellent, 3.8–4.4 points means good, 3–3.7 points means passing, and below 3 points means not passing. Specific grading standards for each level should be further analysis and research due to the different assessment subjects and different job requirements.

In military training, a single examination subject generally according to time and accuracy to make a comprehensive assessment results. The criteria are as follows:

If there are three grade standards (excellent, good, pass) according to the accuracy and time, then take the average score of the two results, but the result is not allowed to be higher than the accuracy grade.

If there is only one grade standard according to the accuracy (time) and there are three grade standards according to the time (accuracy), then we evaluate performance according to time (accuracy) on the basis that the accuracy (time) is up to standard, and if the accuracy (time) is not up to standard, then the result is not passing.

If there is only one grade standard according to both the accuracy and time, then we claim it passing when both are up to standard.

If the number of not passing is more than half, then we claim it not passing in comprehensive performance.

5 Conception to Develop Assessment Criteria

In order to effectively enhance the scientific and targeted assessment criteria, an appropriate assessment system should be established, to rich assessment methods and improve the assessment results, to make plans and design for specific criteria of the assessment [4].

5.1 Establishing Assessment System, Making Records for the Examination Results Systematically

First is to inspect the effectiveness of military training comprehensively, make the assessment throughout the military training and the whole process of military training; second, we must systematically record the results of the assessment, to make a comparative analysis of the previous assessment results and assessment criteria, so as to comprehensively grasp of the situation; third, we must play a guiding role, using the examination system to urge the promotion of military training to improve combat effectiveness.

5.2 Enriching Assessment Methods, Scientifically Improving the Assessment Process

There is some specialty, complexity in some subjects in military training, which requires the use of a variety of means, comprehensive training on the comprehensive assessment. First, we must play an important role in professional assessment, and assessment for complex subjects must increase the intensity of positive assessment; second, we must play a supplementary role of periodic random assessment to see the natural training performance of trainees in the case of no preparation, to see whether there is the existence of slack off behavior, to increase the intensity of reverse assessment [5]; third, we must use assessment tools reasonably to identify obstacles to enhance the training level of deep-seated reasons, to increase technical assessment efforts, so that we can make the assessment criteria purposeful.

5.3 Make the Assessment Effective, Improve the Mechanism of the Use of Results

To make the assessment standards play its role effectively, so that the results of the assessment program can be the primary basis to adjust the training as well as the important means of measuring the effectiveness of training. First, we should expand the scope of the use of assessment results appropriately in order to better play an active role in the assessment criteria; second, the assessment results should be a feedback to the relevant departments in an appropriate form, to improve the unit and personnel awareness, make the trainees themselves have objective evaluation on their own performance and existent problems. Thus, they form a catch-up atmosphere where they promote each other and improve together to further improve the ability of people and equipment integration, so as to form combat effectiveness.

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A Study on Field Man-Machine-Environment Monitoring Cabin

Zhibing Pang, Chenhui Li, Haitao Zhao, Hong He, Honglei Li, Hongyan Ou and Yu Zou

Abstract It is on purpose to probe into the effective method for collecting the relevant data of Man, Machine, or Environment and intersystem factors in a quick, accurate, scientific, and efficient way. The paper lays the theoretical foundation for the construction of Man-Machine-Environment Cabin. By document retrieval, theoretical analysis and review of the previous Man-Machine-Environment Engineering experiment method, it puts forward the construction ideas in connection with the status quo of the monitoring technology. To specify the problems to be solved, four needs and six functions are presented concerning the construction of field Man-Machine-Environment monitoring cabin. The construction of the cabin is necessary since it adapts to the information warfare. It is feasible since it is based on the current science and technology. And it is a significant approach since it serves the promotion of the forces combat effectiveness and popularization of Man-Machine-Environment theory.

Keywords Field operations · Man-machine-environment · Cabin · Monitoring

1 Introduction

The future warfare is an informationized one as well as a confrontation between systems. Such confrontation gives not only test on weapons and equipment and combatants but also the maximization of the efficiency of the whole system involving the combat environment. First, the theoretical development needs to be proved by practice. The system engineering theory is one of the core theories to promote the system efficiency. Secondly, the development of weapons and equipment needs to be examined by practice. With the application of science and tech-

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nology in military field, the weapons and equipment develop dramatically. Whether the weapons and equipment achieve the goal or not needs practical test. Finally, the new technology, new craft, and new method should be applied in practice. The training ground and military exercise area are the optimal site for practical examination. A large amount of data pertaining man, machine, and environment should be collected to forecast every possible change in the future battlefield, which provides reliable theoretical and data support for future warfare. Therefore, the construction of field Man-Machine-Environment monitoring cabin is advanced in this paper.

2 Realistic Significance

2.1 Practical Need for Man-Machine-Environment System Engineering

Man-Machine-Environment system engineering is an engineering technology, which reveals the relationship between man, machine, and environment by use of system engineering ideas and methods and ensures an optimal combination of Man-Machine-Environment system engineering [1]. The study of Man-Machine-Environment system makes a qualitative description of the mutual effects between man, machine, and environment as well as the quantitative analysis of the exact relationship between the three. Since each one of the three has its own characteristics and assessment criteria, a portable and integrated equipment is thus needed to measure man, machine, and environment, respectively, for supporting the comprehensive assessment system. An integrated field Man-Machine-Environment cabin can be taken as an helpful approach.

2.2 Practical Need for Military Ergonomics

Military Ergonomics is the specific application of ergonomics in military. It adopts the theory of systems science and the method of system engineering to design and research the optimum combination option of Man-Machine-Environment system in consideration of interaction of man, machine, and environment in Man-Machine-Environment system. With the modernization of national defense, the weapons and equipment become more and more informationized, digitized, automated, and complicated. "Serviceman-Weaponry-Military activity environment" system turns to be more complex [2]. The construction of the integrated field Man-Machine-Environment cabin is the application of Military Ergonomics as well as its practical need.

2.3 Need for Full Service Life Study of Weaponry

The life cycle of weaponry includes the whole process of argumentation, research and development, manufacturing, experiment, employment, storage, scrapping, etc. [3]. The weaponry varies in life cycle due to their different nature, function, and complexity. Just like human life, it could be divided into the first half and the latter half of its life.

The first half of its life is given to conduct argumentation of the program, engineering research, and manufacturing. In this phase, man-oriented idea should be stressed as human property, human cognition, human training level, and skill criteria in various operating environments, that is, "machine adapting to man and environment" [4].

The latter half of his life is used for employment, support, and decommission. In this phase, machine-oriented idea should be stressed as machine's property, technical and tactical performance, configuration, and adaption to the environment, that is, "man adapting to machine and environment" [4].

In these two phases, the measurement and assessment of man, machine, and environment are the basic starting point. Furthermore, the individual weapons and equipment are located at different places during research, development, and employment. A single measuring equipment could not satisfy the requirement of the whole weapon system. To construct an integrated field, Man-Machine-Environment cabin will bring convenience for study of the two adaptations.

2.4 Need for Upgrading Combat Effectiveness

At present, the forces are required to firmly establish combat effectiveness as the sole fundamental criterion [5]. Thus, the training is oriented to the combat. The combat effectiveness is cultivated from the initial training on training ground, then the rehearsal at military exercise site, and is finally presented in the future battlefield through operations with live ammunition. From the training ground to the future battlefield, the combatants, weapon system, and combat environment undergo great change and bear close connection among them. The upgrading of the combat effectiveness depends on both hard and scientific training. The training process should be elaborated for qualitative and quantitative research and planning. The combatants, weapon system, and combat environment should be closely monitored to obtain the effects of the three factors on the combat effectiveness so as to provide strong support for effectively and comprehensively upgrading the combat effectiveness.

3 Basic Function

How to enhance the organic integration of man, machine, and environment and to fully improve the whole combat effectiveness has become the focus of military research around the world. Man-Machine-Environment monitoring cabin is mainly used to monitor and analyze the adaptation of man to equipment, of man to environment, of equipment to environment as well as degree of fatigue and combat performance during training. The monitoring cabin consists of human life data-monitoring subsystem, weaponry running data-monitoring subsystem, combat environment data-monitoring subsystem, comprehensive data processing and analyzing subsystem, information communication subsystem, auxiliary decision-making and decision-supporting subsystem.

3.1 Human Life Data-Monitoring Function

Human life data cover a wide range and their data-collecting and data-monitoring methods are diversified. Therefore, the data will be focused on pulse, heart rate, breath, body temperature, oxyhemoglobin saturation, posture, time, and geographical data according to combat conditions and requirements. These data will be collected to analyze the vital signs and current posture of servicemen and assess their vitality. The variation of spatial position of the sensors is used to analyze the labor intensity and infer the degree of fatigue and working performance. Meanwhile, the human life data are collected by contacting the measured man. The miniaturization of sensors and data remote transmission should be taken into consideration during research. In connection with microsensors and Internet of Things, all the instrument and devices to be used should be thoroughly analyzed and optimized in accordance with the operational requirement of the military forces.

3.2 Weaponry Running Data-Monitoring Function

The modern weapons and equipment are of high level of integration with perfect combat function. Yet, the complicated operation of weapons makes high demand on the adaptability of man to weapons and of weapons to environment. As a result, the forces could not bring weaponry into full play. In order to improve the utilization efficiency of weaponry, it is necessary to monitor its running data. The quantitative statistic analysis may draw scientific basis to guide forces' combat and training. The weaponry running data to be monitored involve the basic performance data of weaponry, operations data, weaponry operating data, weaponry's running data in various environment, etc. By such data collection and analysis, abstract regularity from mass data and work out the relevance index so as to serve the weaponry in combat and training.

3.3 Combat Environment Data-Monitoring Function

The complicated modern battlefield environment, esp. severe weather, and electromagnetic environment affect the informationized weaponry seriously. How to enhance the environment adaptability of weaponry as well as how to guide its employment becomes a hard nut to crack. The environment data to be monitored involve air temperature, wind speed, rain and snow, sunlight, altitude, oxygen content, salinity–alkalinity, dust, geomorphology, surface features, terrain, electromagnetic density and power, and civil considerations. By such data collection and analysis, work out topography in area of operations so that data support is provided for forces deployment and weaponry employment.

3.4 Synthetic Data Processing and Analyzing Function

Each subsystem of the cabin collects a diversified and large number of data. They may be structured data or unstructured data. In order to increase data statistical and analytical efficiency, an intelligentized data mining method has to be adopted. At the same time, synthesize data processing and analyzing function of subsystems according to requirements of modularized design. It may intensify cohesiveness on the one hand and enhance data analyzing efficiency on the other hand.

3.5 Auxiliary Decision-Making and Decision-Supporting Function

After collection, processing, and analysis of relevant data concerning man, machine, and environment, this part is used to realize dynamic presentation so as to make commanding officers easily grasp the battlefield situation in real time and acquaint with the change of man, weaponry, and combat environment. It provides strong data support for commanding officers at each echelon to make a decision in a scientific way.

3.6 Information Communicating Function

The data collected by each subsystem, after being preprocessed, are transmitted to synthetic data processing and analyzing subsystem through corresponding information transmission modules. The information communicating technology varies depending on different monitoring objects. The vital signs data of human life are transmitted by means of bluetooth or ZigBee technology, the weaponry data by means of wifi or high-speed bus, and environment data by various communication technologies according to different monitoring locations. Each monitoring sensors apply terrestrial reference and time scale to the datum collected by use of BeiDou navigation system, and then carry out data gathering by existing or military communication means. In designing information communication subsystem, electromagnetic jamming and information countermeasures should be taken into consideration. Small-power and close-range communication technology is recommended in each local area network of sensors. In implementation of distant transmission of data, the subsystem compatibility with current military communication technology has to be taken into account; especially, it could not jam the military communication system and avoid self interference and mutual interference.

4 Conclusion

In accordance with Military Ergonomics, macrolevel, intermediate level, and microlevel should be integrated [6]. In accordance with Man-Machine-Environment system engineering theory, man, machine, and environment should be integrated. Thus, a scientific and reasonable weapon system can be constructed, which meets the need of future information warfare.

The field Man-Machine-Environment monitoring cabin put forward in this paper characteristic of information integration, small size, convenience, quickness, and accuracy. It may achieve quick collection of Man-Machine-Environment data, accurate and efficient analysis, and judgment, which provide a scientific basis for commanding and decision-making. This is a brand new idea. It needs multi-disciplinary and multi-technology synthesization. It is a complicated system engineering requiring a good top-level design and engineering practice.

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The Study of the Performance Assessment in Military Training

Xu Li, Xian Shi, Hong He, Haitao Zhao, Nan Men and Chenliang Ye

Abstract As the new military reformation develops accelerately, the military urgently calls for a system which will continuously develop the performance assessment of the soldiers in military training. The study shows that how the performance assessment practices in military training. The introduction of the idea of the performance assessment can make the whole process of the military training assessment to develop from qualitative to quantitative, from experience to science. It also can provide conduction in development of standards, scientific assessment, and efficient management for the training assessment. It will make the training of the military more scientific, the assessment more objective, and the effect more significant (Dali and Fu in Principles of military training. Military Science Press, 2016 [1]). It plays a positive role in the scientific military training and the objective assessment.

Keywords The performance assessment · The military training · The military assessment

1 The Conception of the Performance Assessment

The performance assessment refers to the organization that will assess someone's capacity for work and his job performance in a scientific way regularly and irregularly, according to the standard and the procedure, which has been drawn up in advance [2]. As a kind of management thought which emerges in recent years, it has a positive effect in the military training management. The performance assessment can evaluate the soldier's service performance in a comprehensive way and provides the reference for the work allocation and the position change. It can evaluate the whole process of the specific training program, which can provide a basis for the improvement of the training quality. As far as the individual is concerned, the training process can be

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recorded in scientific way, which can help the trainee get aware of the weakness and the mistake of the operation. The record can provide the data support for the development of the accuracy and speed of the operation [3].

2 The Main Problems in the Training Assessment

As a special group, the military has used a traditional way to assess the military training for a long time. But with the arrival of new military revolution, the military has a huge change by means of the warfare operations, the military hardware, and the fighting operation, which has a new request for the purpose and ways of the assessment and challenges the traditional military training assessment.

2.1 The Difference Between the Syllabus and Objective Reality

At present, with the development of the new equipment performance, the equipment requires a higher ability of operation and the weapon system needs more and more indexes to evaluate. So the traditional index, which is relatively simple, cannot meet the selected requirement. Meanwhile, the different index has the different proportion in the weapon system. If the indexes are made equally, the assessment will lose the objectivity. For example, in the process of the operation, there is a conflict between the precision standard and the speed standard, but the syllabus does not explicitly show the judgment basis of this situation, which has troubles in judging the situation. In the view of the military reality, it is difficult to set up the proportion objectively and scientifically. The standard of the selection mostly depends on the personal experience of the interviewer, which is not judged comprehensively and objectively. And the assessment result is affected by the personal will, which has an influence on the objectivity of the assessment in some extent.

2.2 The Difference Between the Assessment Procedure and the Practice

With the development of the new equipment, the operator must meet the requirements of the different equipment and the different position. But the most syllabuses are classified into four types, such as excellent, good, pass, fail. The syllabus is classified in a careless way, which makes a difference between the four types and cannot show the final results of the assessment. When the difference reaches a level which makes peoples in a low spirit, it will weaken the motivation of the training [4].

2.3 The Difference Between the Training Methods and the Progressive Ideas

The traditional training ways came from the training and wars, which concord with the actual situation and the background in our army. As time goes, the battlefield environment has changed a lot than ever before and the military ideas have renewed constantly and require the new challenges and methods for the military training. The traditional training aimed to improve the ability of human being, and then performed the task after adjusting the environment. But so far, all kinds of the equipment are developed, especially the complex weapon system displayed, whose adaptabilities vary with all kinds of complicated environments. If the training practices in a relatively peaceful environment, the disadvantages are obviously shown and it is not good for the training. At the same time, in the process of training, the operator always considers how to improve the quality of the training and the weapons and the environments in which the weapons are practiced are neglected. The simple and necessary renovation of the weapons and the operational environments will make the training get twice the result with half the effort. Thus, in order to improve the training efficiency, the operator, the weapon equipment, and the operational environment should be taken into comprehensive consideration.

2.4 The Difference Between the Assessment Results and the Assessment Progress

At present, the results lead to the assessment of the weapon operation, and what the assessment needs is the operation meets the standard. The trainer thinks highly of the results and neglects the process, which will cause the operator to pay more attention to the results when they operate the weapon. This will make the operator pursue the speed without goals, act and operate against the procedure, which is harm to the weapons, and deviate the original purpose.

3 The Characteristic of the Performance Assessment

With the arrival of the new military revolution, the huge changes occur to the means of the military battle, the weapons, and the way of the military battle. There need to be a lot of improvement in setting up the system of the training performance assessment. So how to adapt to the various military task and to practice the efficient training of the equipment operation still need to be completed in drawing up the standard of the training assessment. According to the quality principle of the army building, it is of great practical significance to establish a scientific and reasonable evaluation system, to measure the equipment training, and to evaluate the sustainable development ability of the equipment [5].

3.1 The Standardization of the Performance Assessment

The first step is to make the assessment procedure and to introduce the operational factor. In order to assess the performance, the organizers must design a set of procedures to achieve the goals. In other words, this set of procedures is regarded as the standard of the assessment performance, so that the difference in different times can be assessed in a scientific way.

3.2 The Specification of the Assessment

The second step is to assess scientifically and to reflect the results of the task. The performance assessment is an evaluation process, which instructs whether and how to achieve a goal. The information that is from the operator's operation shows the performance assessment of the operator's. The performance assessment is used at the results of the task operation.

3.3 The Scientific Management

The last step is the quantitative management. The present performance should be managed in a scientific and quantitative way. The performance assessment need continues to test, to record, and to analyze, which are the basis for the improvement of the performance assessment and the selection of the operator. At the same time, the present data can predict the operator's operation in other situation and the results of the performance assessment.

4 The Application of the Performance Assessment

The performance assessment is used as the main idea, which is applied in the military training and can play a positive and useful role.

4.1 Improve the Methods and the Quality of the Training

Drawn up scientifically, the standard of the performance assessment is not only the performance assessment of the operation, but also the standard of the assessment, which can instruct the standard of training. And the methods of the training based on the performance assessment will come into being. The effective way to improve the quality of the training is to transfer the single subject based on the result control into the combination of the result control and the process control. In the whole process, the operator's operation and the quality of the team training can be instructed at present. The various problems can be coordinated and solved timely in the process of the training. Meanwhile, the weakness has been recorded by the video and the corresponding training will be applied, which not only quantifies the operation result, but also specifies the process of the operation. This can provide the basis for the improvement of the manipulator operation, and calculate and record the team and the operator's performance assessment. Compared horizontally and vertically, this also can show the status of the mastery of the operator. The analysis of the situation is beneficial to improve the overall standard of the operator and the military team training.

4.2 Control the Training Process and Balance the Development of the Whole

In the course of the process, the assessment promotes the training because the subject will be assessed after one subject and the team will be trained after one team. This ensures that the training quality of the single subject and the single team is in accordance with the performance standards. At the same time, the army adheres to the traction of the goal and tries the best to improve the quality of the training. The high quality standard of the soldiers and the high ambition of the soldiers can make the soldiers compare, learn, catch up with and help each other during the new equipment training to make sure that the new equipment can be able to move to a regular basis quickly and become the military hardware.

4.3 Achieve the Performance Management Select the Operator

The main idea of the performance assessment is to improve the operation standard of the operator by quantizing the training process so as to improve the performance assessment of the organization and the team. It provides a simple and standard platform for the scientific management. The various models of the operation performance assessment are studied in a scientific way, which can make the management of the operation skill scientific, timely, and accurately. This also can make the management of the military training scientific, timely, and accurately. The selection of the operator and the excellent team building depend on the results of the performance assessment.

5 Conclusion

In the process of the military assessment, the application of the performance assessment can make commander pay more attention to the purpose and the progress of the training. By tracking the training progress, the army can take advantages of the daily performance assessment timely to inspire, instruct, and help the soldiers to improve the operation procedure and develop the ability of the operation, which will contribute to improve the military battle capacity. Meanwhile, the performance assessment can provide the objective training and the assessment atmosphere, which play an important and positive role in developing the trainee's training.

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The Construction of Performance Evaluation Model for Multi-people Operating One Machine

Haitao Zhao, Qiaoyu Wang, Zhibing Pang, Pengdong Zhang, Hualiang Xu and Chuanyin Ji

Abstract *Purposes* The aim was to improve the existing performance evaluation model of multi-people operating one machine, and provide an effective way to evaluate the performance of the new weapon system team. *Methods* On the basis of the existing performance model, through the analysis of the advantages and disadvantages of the model, a new reference factor is added, and a new mathematical model is constructed. The model is also checked by the operating data of a certain type of equipment. *Results* A new factor which can fully reflect the operation level of the operation team is added in the model, which makes the performance model of multi-people operating one machine more practical. *Conclusions* The performance evaluation model is improved for the imperfection of existing model. This improvement is in line with the actual development of the troops, provides a reference basis for the selection of the operation team, and promotes the publicity of people–machine–the environment system theory.

Keywords Performance model · Multi-people operating one machine · Improvement

1 Introduction

With the rapid development of equipment science, high-tech weapons have been widely used in modern warfare. In order to comply with the trend of the times, a series of new equipment, typically characterized by a high degree of information and automation, began to gradually use in troops in a wide range of applications. Most of these new equipment apply the modular design, so that a single equipment is able to combine with many combat functions, which changes the situation that usually a single operator operating into a new situation that an operational team made of multi-people operate the equipment. How to scientifically train and assess

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such complex weapon systems is an urgent problem. Performance evaluation, as a management method, and its basic ideas can be applied to the training and assessment of the troops. It can more objectively reflect the effectiveness of the entire weapon system, including the effectiveness of the operator. Above all, building the relevant model by the use of performance ideas is the core content of the model [1].

2 Characteristics and Improvement of Existing Performance Model

The existing performance model is based on the performance model of single person operating one machine and records the actions "h" (number), the time "t" (second), and the action error rate (percentage) when the operators complete an operation, then according to the "accuracy/speed" weight given by relevant experts, and the analysis of the error actions in operation, and finally get the performance of the operation. The final performance "E" of the team is as follows [2]:

$$\mathrm{E} = P_{zm} \times P_{rj} \times \sum_{n=1}^{N} \left[W_n \frac{R(1-p_n)}{h_{n \times} t_b} \right] \tag{1}$$

The variables are as follows:

- P_{zm} In operation, if any of the operators in the team make mistake in key steps of operation and cause the operation fail, the value is 0, if not, then the value is 1;
- P_{rj} In operation, if the general errors made by operators exceed a certain degree and cause the operation fail, the value is 0, if not, the value is 1;
- N The number of involved operators in the operation;
- W_n In operation, the n-th operator occupies the weight of the entire cooperative operation;
- R The weight ratio between the operating accuracy and the operating speed;
- p_n The failure rate of the n-th operator in operation;
- h_n The time the n-th operator use to complete the operation;
- t_n The number of actions the n-th operator have made.

2.1 *Disadvantages of Existing Models*

Because the factors in the model are not comprehensive, in the process of practical application, there are more and more limitations, which are mainly shown as: The existing model records the environmental conditions that the operators live in and calculate the effects of environmental factors on the operator. The disadvantage is that it is not proper to position the environmental impact of the operation performance on the precision of operation. The reason is that the environment not only has an impact on people, but also has an impact on the equipment, so the impact of the environment should affect the overall performance of the operation [3].

2.2 The Idea of Improving the Model

In addition to increasing the environmental impact factors in the job performance model, more comprehensive consideration should be given to operator. The following will improve the model in terms of the present problems from two aspects:

The first is adding real-time monitoring to the heart rate of the operator. The original model is one-sided to reflect the environmental impact from the errors on operation. The effect of human adaptation to the environment can be used as an effect on environmental impacts. In the future battlefield, a variety of environmental factors would change dramatically, so the physiological indexes can reflect the influence of natural and social environment. Therefore, in the new model, the real-time heart rate data are added to the operator, and compared to the calm heart rate value [4], so as to get the effect of environmental factors.

The second is adding the influence of the operator's knowledge assessment. New equipment integration technology is more intensive; if the operator is just familiar with the process of operation, and know nothing about the principle of operation, then the fault possibly appeared will be difficult for him to dispose of. Meanwhile, due to the emphasis on the speed of operating, the operator may appear substandard "barbaric operating." Therefore, it will make the assessment more comprehensive to add the influence of the knowledge assessment, which includes the assessment to the operator's familiarity with the operation standard [5], the equipment structure and the monomer structure knowledge, etc.

3 The Construction of the Model for Multi-people Operating One Machine

Construct the new model for multi-people operating one machine according to the above idea of improvement.

3.1 The Assumptions for Model

The assumptions for constructing a model for multi-people operating one machine are as follows:

(1) Assuming that the operation errors of an operator cannot be remedied by another operator;
(2) Assuming that the operator's body is in good condition;
(3) Assuming that the operations performed are normative operations, and the numbers of operations as well as the actions that different operators have made keep in step;
(4) Assuming that the operator's heart rate is higher than that of the calm during the operation.

3.2 The New Variables

There are two new variables added in new model according to the idea of improvement.

3.2.1 The Effect of Environmental Influence

The effectiveness of environmental influence is mainly calculated by the change of the operator heart rate. The operator will have different physiological responses due to different operating conditions. More positive the operator mood is, more strong the body adaption to the environment is, more stable his body is, smaller the change of heart rate in the numerical value is, and higher the relative value of performance is. The method of calculation is:

$$X_H = \frac{b_c}{b_{zc}} \tag{2}$$

Among it:

X_H The effectiveness of environmental influence;
b_c The average heart rate of the operator during operation;
b_{zc} The heart rate of the operator in the normal state before operation.

3.2.2 The Familiarity with Theoretical Knowledge

Before the operation, the operator need to attend an examination of theory firstly and finish the subjects given by specialist. There are subjects (the same as the number of actions), corresponding to each action. If error occurs, the definition of the degree of familiarity with theoretical knowledge is:

$$L_T = \frac{a}{h} \tag{3}$$

3.3 The Construction of the Model

According to the characteristics of multi-people operating one machine, the value of the performance is inversely proportional to the environmental effect and is proportional to the level of theoretical knowledge. The improved performance of the model for single person operating one machine is:

$$\mathrm{E} = P_{zm} \times P_{rj} \times \sum_{n=1}^{N} \left[W_n \frac{R(1 - p_n) \times (1 - L_T)}{h_{n\times} t_b \times X_H} \right]$$

4 Model Checking

Refer to a certain weapon system, the model is checked by using the data of the ammunition loading in the firing preparation. In the course of the experiment, some parameters are collected in the actual operation, such as operating time, heart rate, wrong movements, theoretical test scores.

4.1 The Introduction of Operation

The operation has three operators A, B, C. In the process of loading ammunition, the process of operation is as follows: When operator B enters the cabin, then select the appropriate time to start the electric machine after the completion of power; operator A arranges the bullets chain and sets the sensor in the last bullet, then, with the hook, pull the top of the chain from the position 1 to the position 2; At the same

Table 1 The weight of the operation action scored by specialist

No.	Operator	Weight	No.	Action	Weight
1	The commander	0.2	1	Enter into the operation cabin	0.25
			2	Turn on the power switch	0.25
			3	Turn on the electric machine switch	0.25
			4	Start the electric machine according to the sign of operator A	0.25
2	The driver	0.4	1	Take the arranged bullet chain into the bullet cabin	0.1
			2	Set up the no-bullet sensor on the last bullet	0.2
			3	Give instructions to start the electric machine and observe the movement of the bullet chain	0.3
			4	Arrange the hook to the top of the bullet chain	0.3
			5	Pull the bullet chain to the position 1	0.1
3	The gunner	0.4	1	Lock the structure 1 on the position 1	0.3
			2	Lock the structure 2 on the position 2	0.3
			3	Adjust structure 1 when the bullet chain moves from the position of preparing to arrange to the position of preparing to move	0.4

time, the operator C timely adjusts the v and locks the structures 1 and 2 to prevent the chain from slipping.

After analyzing the specific action of three operators, the expert scores. The ratio of working accuracy and speed is 0.5, and the weight of the moves in operation is shown in Table 1.

4.2 Experimental Test

During the test, the number of actions (h), the time (t), the number of error actions of three different group of operators, and their average heart rate and the normal heart rate before operation (b_c, b_{zc}), and errors in theory knowledge test (a) were measured and recorded. The results are shown in Table 2.

According to the model, the results are shown in Table 3.

In this test, the first group and the second group of operators are the old students and new students, respectively, and the third group of operators is the professional operator. Through the calculation and analysis of the data given by the model, the final performance results show that the new model can objectively reflect the operating level differences of different operators.

Table 2 The results

	Group 1			Group 2			Group 3		
	Operator B	Operator A	Operator C	Operator B	Operator A	Operator C	Operator B	Operator A	Operator C
h	4	5	3	4	5	3	4	5	3
t	33	67	35	39	69	40	30	59	31
b_{zc}	73	71	73	72	75	71	69	71	71
b_c	80	82	88	80	84	89	71	74	75
a	0	1	1	1	2	1	0	0	0
Error actions	1	0	1	1	2	2	0	1	0
Error number	1		1	1	1.5	1.3		2	

Table 3 The results of calculation

	The final performance
Group 1	3.165×10^{-3}
Group 2	2.801×10^{-3}
Group 3	3.536×10^{-3}

5 Conclusion

Based on the performance model of the original multi-people operating one machine, the paper analyzes the problems in the practical work, ensembles the related theory of performance, and constructs the performance evaluation model for multi-people operating one machine which can fully reflect the operating level of different operation teams. And the model is checked by further practical examinations for its practicality. It also provides the basis for the evaluation of the team operation and facilitates for the selection of the operator.

Due to the limitation of the experimental conditions, the model is not tested in the verification, and the practicality of the model needs further examination and improvement. There are still some subjective effects on some of the methods in the model, which is the direction of next step to research.

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Research on Man–Machine Integration Method of Weapons and Equipments

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Abstract *Purpose* To research on the man–machine integration method of weaponry and equipment. *Method* To analyze and study the method of man–machine integration of weaponry and equipment via consulting documents, investigating data, and experimenting on equipments. *Result* Through research, it is found that such man–machine integration methods as scientific selection of operators, optimized training of operator, effective examination of operators, will rapidly increase the capabilities of weapons and equipments after their deployment. *Conclusion* In view of the inherent characteristics of weapons and equipments, formulate man–machine integration standard, operators in a scientific way, optimize operating procedure and examine effectively, to improve efficiency, enhance reliability, and to achieve best performance of the system.

Keywords Weapons and equipments · Man–machine integration · Method

1 Introduction

Man–machine integration throughout the life cycle of weapons and equipments means adaptation in two facets: in the process of access, research, development, manufacturing, and experimenting, to insist on human-oriented principal, with consideration on basic human characteristics, cognition, and proficiency, and consideration on standard for the representation of skill in different operating situation, which simply means machine adapts itself to human; while after weapons and equipments were deployed to units for training, employment, maintenance, sustainment, repair, and retirement, to insist on machine-oriented principal, with consideration on the basic characteristics, tactic and technical features, layout and structure of the machine, which simply means human adapts itself to machine [1].

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This paper explores how to exploit and maintain the capability of weapons and equipments when they are deployed to unit, or in their latter half of life, and as operators or maintainers how to realize human adaption to machine with well-directed effort.

2 The Significance of Man–Machine Integration Method Research

2.1 Enable Weapons and Equipments with Operational Capability Rapidly

Research on method of man–machine integration adopted systematic engineering philosophy, with overall thinking and coordinated development, will fully exploit the man–machine system capability and will facilitate the perfect integration of the system, to enable weapons and equipments with operational capability rapidly.

2.2 Improve Reliability of Weapons and Equipments

Reliability requires no or few malfunctioning occurred in the employment of equipment, and with long operational time [2]. Research on method of man–machine integration will help achieve best effectiveness of both man and machine factors, to decrease the failure rate of weapon system, increase operational time, and fully enhance reliability of the system.

2.3 Decrease the Expense on Weapons and Equipments Throughout Their Lifecycle

Lifecycle expense refers to the overall cost on the whole process including access, research, development, manufacture, employment, maintenance, and retirement of equipment. Research on man–machine integration method will reduce the cost on the process of equipment employment and maintenance, which results in reduce on its life cycle expense.

2.4 Enhance Operational Capability of Military Forces

With man–machine integration method, misoperation accident can be reduced, and personnel can be allocated properly as modern hi-tech warfare requires.

3 Specific Methods Adopted in Research

3.1 Select Operators in a Scientific Way

The employment and maintenance of equipment requires qualified operators, and selection of operators is a prerequisite for training them to be highly qualified. With excellent crewmen of appropriate capacity as different equipment post requires for further training, multifold effects will be achieved with half the effort.

3.1.1 Clarify the Connotation of Operator Selection

Different types of equipment, and different posts of same equipment, require that different operation action and embody different operation characteristics, and their requirements on operator's physical and mental status are differentiated [3]. The connotation of operator selection is two-way selection, which means select the most qualified personnel as operator, and assign operator the post that best for them, to make full use of personnel and their capacity.

3.1.2 Construct a Mathematical Model for Operator Selection

Once the weapon design was approved, as different posts embody pertinency requirements, it is necessary to establish mathematical model for operator selection as per post characteristics and requirements. To construct the model, factor set, weighted criteria set, and evaluation set need to be established as per post characteristics require crewmen of their physical, mental, and intellectual status, and change it from qualitative to quantitative, to facilitate the selection effort with more operability.

3.1.3 Organize the Selection in a Scientific Way

The effort to select operators in a scientific way is to measure and evaluate the physical and mental strength of the candidates and obtain the specific condition of the testers via appropriative device and appropriative scientific theory, and to select qualified operators as per different requirements from equipments. With scientific operator selection, perfect man–machine integration can be achieved, the system's efficiency and reliability can be increased, and the system's best performance can be expected.

3.2 Optimized Training of Operator

Optimized training of operator means optimizing the man–machine operating procedure of the weapon system. To optimize the man–machine integration operating, multiple principals should be followed such as paralleled operating, economization of activity amount, simplification of steps, comfortable posture of action, best efficiency of whole operating action; gradually progress the effort in such facets as subject activity analysis, action analysis, and timing; optimize operating method, shorten operating time, and improve operating efficiency; formulate a scientific and practical operating procedure for the weapon system [4].

3.2.1 Principal Line of Effort Analysis

The first objective is to clarify those items as operation content, phases, connection among phases, starting, ending, sequence, and principal line of effort. First, in view of the content and purpose of the operating, analyze the operating procedure of the vehicle units of the a new type of weapon system in its deployment phase to determine the sequence of operating; second, differentiate the temporal and spatial phases of the weapon system's operating procedure, clarify the starting and ending of phases, and create condition for the determination of the principal line of effort in the whole process; third, in view of the system efficiency, choose the principal vehicle unit deployment operation as the principal line of effort in the operating process, and simply the operating procedure accordingly, to obtain the preliminary outlook of the optimizing; fourth, based on the operator's actions and their connections, eliminate unnecessary connections with analysis, and prioritize the principal line of effort for operators, preparing for the action analysis.

3.2.2 Action Analysis

Usually, with principal line of effort analysis to be conducted, on purpose of saving time and manpower and safety in operating, action analysis is to find out the right operating actions, to eliminate inappropriate and unnecessary actions as per machine structure and function, and human action characteristics. First, based on the operating procedure of the principal vehicle unit crewmen of a new type of weapon system, observe and record in detail, with the effort to coordinate operators' timeline, and combine them together as a man–machine operating analysis chart [5]. Second, according to principals in optimizing man–machine operating, the possibility to improve the procedure depends on such three facets as follows: paralleled operating of all operators; elimination of unnecessary running actions; simplification of command actions. Third, draft a improvement plan, illustrate the plan with a man–machine analysis chart for comparative analysis, and formulate the optimized plan with a optimized flowchart.

3.2.3 Timing

Usually, timing will be conducted after operating sequence has been verified, and operating method has been standardized. Timing without standardized operating and action units will be invalid. The appropriateness, effectiveness, and reliability of the operating procedure are the foundation of timing. Testers in timing usually are operators of medium proficiency scale, to ensure timing results are practical [6]. Human mentality and operating performance are not be affected by experimental factors if possible.

Overall, to optimize weapons and equipments man–machine integrated operating, to coordinate human and machine, and to achieve appropriate cooperation among crewmen, it is necessary to put assorted factors, which affect the optimizing of man–machine operating, optimize operating procedure, improve operating method, shorten operating time, increase operating efficiency, and formulate scientific and practical operating procedure of weapons and equipments.

3.3 Effective Examination of the Trainee

Effective examination of the trainee means formulating scientific test standard and conducting accurate examination.

3.3.1 Formulate Scientific Standard

Training standard should be scientifically formulated in accordance with Military Training and Examination Syllabus, and the standard should be conformed to the training level of different trainees in different training stages. Unpractical standard provides positive results for training—excessively high standard results in lack of confidence in training, while excessively low standard constrains the training to stay at a low level. Hence, as the training principal of approaching step by step requires, training standard is dynamically formulated in different training stages to keep a spiral rise, and eventually rise up to the standard required by Military Training and Examination Syllabus.

3.3.2 Conducting Accurate Examination

The accurate training examination provides principal gauge of armed forces training status and an effective mean to spot weaknesses in military training. Therefore, conducting accurate examination is not only to require the comprehensiveness of examination content, and the authenticity of examination result, but also the accuracy of examination occasion, in order to exploit the evaluation effect of examination, and exploit the encouraging and reforming effect, improving the evaluation, training and reforming.

4 Points to Emphasize in Weapons and Equipments Man–Machine Integration Method Research

4.1 Improve Human Characteristics Research

Improving human characteristics research is to explore the anatomical, physical, and psychological features of military personnel, to understand the activity capacity and limit of military personnel, and to improve research on how to conform weapons and equipments function to human physical function.

4.2 Improve Machine Characteristics Research

Improving machine characteristics research is to research into the technical function and operating characteristics of weapons and equipments. According to characteristics in man–machine integration, via questionnaire, consulting experts analyze the capacity requirements for operators from weapon system, and the weaknesses in weapon system that affects man–machine integration.

5 Conclusions

Weapons and equipments man–machine integration research is to study and test in physical and mental aspects; in view of the inherent characteristics of weapons and equipments, to formulate man–machine integration standard, operators in a scientific way, optimize operating procedure and examine effectively; and to improve operating efficiency, enhance reliability, and achieve best performance of the system.

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Analysis on the Effect of Culture Constructional Factors in Military Academies

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Abstract For military academies, to draft and employ the cultural construction and management strategies, it is fundamental to locate the cultural factors embedded in the academies' management practices, and meanwhile to reveal the relationship and influence between cultural and constructional factors. On the basis of mass data, this thesis uses factor analysis and SEM to build the factor model for military academies' cultural construction. Cultural and constructional factors are extracted, the relationship and influence between the two are analyzed, and the constructional factors which have significant influence on military culture are found. This research provides important suggestions for the cultural construction in military academies.

Keywords Culture I military academies · Cultural construction · Cultural management · Factor analysis · Structural equation modeling

Cultural management is the fundamental choice to advance the innovative management in armies [1]. The basic methods include developing advanced culture, creating a fine atmosphere, then influencing the ideology and values of officers and soldiers, and further regulating their behaviors [2]. At present, most researches on culture in military academies are qualitative researches. They have gained certain

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theoretical achievements in discussing the contents, factors, and construction methods of culture, yet they lack scientific quantitative studies. Based on SEM, this thesis constructs the structural equation model for military academies' culture construction by combining qualitative and quantitative researches. This thesis also analyzes the relationship and influence between cultural and constructional factors, and provides scientific guidelines for cultural construction in military academies.

1 A Brief Introduction on SEM

SEM (structural equation modeling) is a statistical method based on covariance matrix to analyze the relationship between variables. SEM combines factor analysis and path analysis, and tests the relationship between observable variable, latent variable, disturbance or error variable in the model, and then receives the influence of independent variable on the dependent variable.

SEM basically includes two types of variables, observable variable and latent variable; two models, measuring model and structural model; and two paths, the path between observable and latent variables and the path within latent variables. SEM analysis examines the variance and covariance structures of variables or the correlation between them [3].

2 Obtaining Research Data

2.1 Designing Questionnaire

When designing the questionnaire, we considered both theoretical researches and practices in military academies and distinguished the constituent and influential elements in military culture. We consulted experts in military academy management through symposia, online surveys, and questionnaires, and raised 95 questions on military academy's culture. After further classification and consolidation, we finally picked 75 questions. The questionnaire contained two parts. Part I had 32 questions about fundamental elements of military academy's culture and measured its internal constituent factors; part II had 43 questions about the driving elements in cultural construction and measured the external influential factors.

2.2 The Process of Questionnaire Survey

In this study, three surveys were conducted during May to June in 2015; 768 respondents were selected from three different types of academies, including an intermediate commanders' academy, a junior commanding academy, and a comprehensive military academy. Respondents contained officials, cadres, teachers, graduate students, and serving cadre students. Twenty-eight invalid questionnaires were removed, and thus, 740 valid questionnaires were obtained.

2.3 Analysis on the Reliability and Validity of Questionnaire

Reliability refers to the consistency of measurement, reflecting the consistency or stability of the result got by test tool. It indicates the fidelity of the measured characteristics of an object. Validity evaluates whether the test tool can measure an object accurately. It reflects how the result reflects the measure goal. Using SPSS15.0, we found that the reliability coefficients of the two parts of our questionnaire were both higher than 0.90, showing that the internal reliability of the questionnaire was high. A questionnaire's high reliability does not necessarily lead to high validity, yet high validity is always related to high reliability. Using the KMO statistics and Bartlett's test of SPSS 15.0 to measure the structural validity of our questionnaire, we found that the KMO statistic values of both parts of our questionnaire were higher than 0.90, showing that the questionnaire's validity in analysis was good. The result of Bartlett's test reached a significant level, and shared information existed between different variables, indicating that the questionnaire had good structural validity [4].

3 Extracting Culture Constructional Factors in Military Academies

We used SPSS 15.0 to do factor analysis. Through principal components analysis (PCA) and varimax orthogonal rotation, we listed the factors by their contribution rates and loading values, and extracted the factors whose eigenvalues were higher than 1. These were the internal constituent and external influential factors of cultural construction in military academies.

3.1 Extracting Internal Constituent Factors

Through factor analysis, we received the independent dimensions of the internal constituent factors based on our 740 samples. According to the result, the eigenvalues of 6 principal components were higher than 1, and their accumulative contribution rate reached 71.434%. We named the 6 factors as core spirit (S1),

Table 1 Eigenvalues and contribution rates

Factor	Initial eigenvalue			Accumulative variation contribution rate after rotation		
	Sum	Variance contribution rate %	Accumulative variance contribution rate %	Variation contribution	Variation contribution rate %	Accumulative variation contribution rate %
S1	12.374	48.931	48.931	5.148	26.087	26.348
S2	2.141	6.691	55.622	4.434	13.856	40.240
S3	1.571	4.910	60.532	3.274	10.230	50.434
S4	1.365	4.265	64.797	2.467	7.710	58.144
S5	1.160	3.626	68.423	2.205	6.889	65.033
S6	1.033	3.011	71.434	2.048	6.401	71.434

educational and teaching concept (S2), rules and regulations (S3), facility conditions (S4), organization behavior (S5), and personnel behavior (S6) [5]. See Table 1.

3.2 Extracting External Influential Factors

Through factor analysis, we received the independent dimensions of the external influential factors based on our 740 samples. According to the result, the eigenvalues of 8 principal components were higher than 1, and their accumulative contribution rate reached 72.983%. We named the 8 factors as historical tradition (S7), initiative of the academy president (S8), request of the superiors (S9), organ's working style (S10), model units and people (S11), personnel practice (S12), general custom and tendency (S13), and social influence (S14) [5]. See Table 2.

Table 2 Eigenvalues and contribution rates

Factor	Initial eigenvalue			Accumulative variation contribution rate after rotation		
	Sum	Variance contribution rate %	Accumulative variance contribution rate %	Variation contribution	Variation contribution rate %	Accumulative variation contribution rate %
S7	15.419	48.857	48.857	5.968	13.878	24.930
S8	3.179	7.392	56.249	4.052	9.423	34.353
S9	1.352	3.145	59.394	3.534	8.219	42.572
S10	1.254	2.916	62.310	3.208	7.460	50.032
S11	1.242	2.889	65.199	3.018	7.018	57.492
S12	1.161	2.700	67.899	2.369	5.510	64.510
S13	1.153	2.682	70.581	1.929	4.486	68.996
S14	1.033	2.402	72.983	1.715	3.987	72.983

4 Quantitative Analysis on the Effect of Culture Constructional Factors

To draw the order of the effects of different culture constructional factors, we used SEM to build a model for the 6 internal constituent factors and 8 external influential factors and then analyzed the effect of the latter on the former.

4.1 Analysis on the Model Fitness Rate

We built the structural equation model for cultural construction in military academies with our related theories and experiences. We then used AMOS 7.0 to test the fitness rate of the model. See Table 3 for the result. According to the result, the fitness rate was good, which meant the model fitted for practical data, and thus, our model was satisfactory for following analysis.

4.2 Analysis on the Effect of Culture Constructional Factors

We used AMOS 7.0 to carry out the parameter estimation for our model, and we got the effect of internal constituent factors on external influential factors through path analysis. See Table 4.

Table 3 Result of model fitness rate test

Test statistics	Fitness standard or critical value	Model fitness index
Absolute fit measures		
X^2/df	$x^2/df \leq 3$	1.987
RMSEA	<0.08 (good), <0.05 (excellent)	0.063
Incremental fit measures		
IFI	>0.90 and over	0.948
TLI	>0.90 and over	0.951
CFI	>0.90 and over	0.935
Parsimony fit measures		
PNFI	>0.50 and over	0.872
PCFI	>0.50 and over	0.713

Notes X^2/df degrees of freedom for chi-square test; *RMSEA* root-mean-square error of approximation; *IFI* incremental fit index; *TLI* Tucker–Lewis index; *CFI* comparative fit index; *PNFI* parsimony normed fit index; *PCFI* parsimony comparative fit index

Table 4 Effect of internal constituent factors (S7–S14) on external influential factors (S1–S6)

	S7	S9	S13	S8	S14	S12	S11	S10
S4	0.577	0.434	0.009	0.260	0.001	0.121	0.012	0.002
S6	0.286	0.215	0.829	0.418	0.426	0.240	0.329	0.252
S5	0.198	0.072	0.438	0.573	0.084	0.682	0.391	0.019
S3	0.720	0.196	0.326	0.241	0.039	0.232	0.170	0.147
S1	0.899	0.067	0.234	0.737	0.065	0.538	0.252	0.521
S2	0.347	0.205	0.012	0.802	0.097	0.158	0.005	0.002

From Table 4, we could receive the following conclusions:

(1) The factors influencing core spirit (S1) were historical tradition (S7), initiative of the academy president (S8), personnel practice (S12), and organ's working style (S10). S7 had the greatest influence.
(2) The factors influencing educational and teaching concept (S2) were initiative of the academy president (S8), historical tradition (S7), request of the superiors (S9), and organ's working style (S10). S8 had the greatest influence.
(3) The factors influencing rules and regulations (S3) were historical tradition (S7), general custom and tendency (S13), and initiative of the academy president (S8). S7 had the greatest influence.
(4) The factors influencing facility conditions (S4) were historical tradition (S7), request of the superiors (S9), and initiative of the academy president (S8). S7 had the greatest influence.
(5) The factors influencing organization behavior (S5) were personnel practice (S12), initiative of the academy president (S8), and general custom and tendency (S13). S12 had the greatest influence.
(6) The factors influencing personnel behavior (S6) were general custom and tendency (S13), social influence (S14), and initiative of the academy president (S8). S13 had the greatest influence.

5 Conclusions and Suggestions

Based on factor analysis and SEM, the thesis takes the 740 valid questionnaires on cultural construction in military academies as initial data and extracts 6 cultural factors and 8 constructional actors through statistical software. The cultural factors include core spirit, educational and teaching concept, rules and regulations, facility conditions, organization behavior, personnel behavior, etc. The constructional factors include historical tradition, initiative of the academy president, request of the superiors, organ's working style, model units and people, personnel practice, general custom and tendency, social influence, etc. We also analyzed the influence of constructional factors on cultural factors. The result shows that historical tradition, initiative of the academy president, personnel practice, and general custom and tendency have significant influence on military academy's culture. This provides a clear direction for cultural construction in military academies.

To strengthen the cultural construction, we not only need to construct comprehensively, but also need to construct with highlights. In this way, our cultural construction will be more targeted and effective. We have four specific strategies. Firstly, we should attach great importance to the historical and cultural heritage of academies, maintaining our fine customs and selecting cultural essentials. Secondly, academy presidents should proactively call for development in academy culture. They need to use their own influences and devote to this undertaking. Thirdly, we must strive to create a good atmosphere in the academy. Organizations can unite together to promote good customs and tendencies. Finally, all the staff should contribute to the academy culture. We must work jointly for the full implementation of cultural construction [5].

Compliance with Ethical Standards The study was approved by the Logistics Department for Civilian Ethics Committee of Air Defense Forces Academy. All subjects who participated in the experiment were provided with and signed an informed consent form. All relevant ethical safeguards have been met with regard to subject protection.

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Analysis on Risk Identification of Railway Transportation in Air Defense Force's Trans-regional Training

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Abstract Railway transportation has the advantages of large carrying capacity, strong continuous ability, high speed, and efficiency and is rarely influenced by weather conditions. It now becomes the main mean of transport for armies to carry out long-distance troop delivery and plays an important role in trans-regional training and performing emergency tasks. In recent years, when air defense forces organize trans-regional trainings, many troops are involved, the maneuvering distance is long, and lots of equipment is required. All these increase the security threats in training. In this way, it is of great importance to carry out risk identification of railway transportation in trans-regional training and strengthen our security management. Based on risk management theory and according to the characteristics of railway transportation in training, this thesis concludes risk causes, summarizes risk identification methods, and then analyzes the implementation of risk identification. The findings provide basic guidance and methods for air defense forces in their future risk identifications and management.

Keywords Air defense forces · Trans-regional training · Railway transportation · Security risks · Risk identification

Railway transportation has the advantages of large carrying capacity, strong continuous ability, high speed, and efficiency and is rarely influenced by weather conditions. It now becomes the main mean of transport for armies to carry out long-distance troop delivery and plays an important role in trans-regional training [1]. The security of railway transportation determines whether our troop delivery is successful and whether our training plan can be completed. For this reason, we need to strengthen the risk identification of railway transportation in trans-regional

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training, find risk causes, summarize risk identification methods, and analyze the measures to implement risk identification. Our efforts can offer a solid foundation for risk control and contribute to the success of military training.

1 Risk Causes

According to the characteristics and occurrence mechanism of risks in railway transportation in trans-regional training, we can sum up the basic causes into four aspects: personnel, equipment vehicles, transportation environment, and organization and management [2].

1.1 Personnel Factor

Personnel risk mainly refers to the risk caused by drivers, vehicle guides, and passengers. Among them, drivers are the main source of risks, and they are generally affected by their driving ages, driving skills, driving experiences, and safety awareness. Vehicle guides often cause risks when loading and unloading the equipment vehicles and are affected by guidance skills, experiences, sense of responsibility, and safety awareness. Passengers may also cause risks, and they are affected by their concepts of organization disciplines, safety awareness, safety education, etc.

1.2 Equipment Vehicle Factor

Equipment vehicle risk mainly refers to the risk caused by military passenger cars, tractors, equipment vehicles, and other equipment. Among them, vehicles of different types are the major cause. They are affected by their models, service life, vehicle condition, active safety, and passive safety. Active safety includes a vehicle's power, braking, handling stability, and tire performance; passive safety includes a vehicle's safety design, fire prevention measures, and restraint devices.

1.3 Transportation Environment Factor

Transportation environment risk mainly refers to the risk caused by train's flatcars, railways, and natural factors. Flatcars are limited by their lengths and widths and may have imperfect reinforcement facilities, and thus they can cause risks. Railway risks are caused by electrical equipment and the speeding up and down of trains.

Natural risk is caused by bad weather conditions (such as snow and ice, wind and rain, heavy fog, burning sun) and natural disasters (such as landslides, tsunamis, debris flow).

1.4 Organization and Management Factor

Organization and management risk refers to the risk caused by unscientific plans, imprecise organization, and careless checking. These risks include personnel management risk, equipment management risk, and activity organization risk. Personnel management risk is caused by careless personnel management, and thus people may fall down, get electric shocks, be squeezed, or get lost. Equipment management risk is caused by imperfect reinforcement facilities and delayed checking, and thus equipment may get loosened, collapsed, be collided, and fall down. Activity organization risk is the risk caused by ill-considered plans, unscientific commands, and careless supervision.

2 Risk Identification Methods

The main risk identification methods for railway transportation include risk checklist, expert evaluation, and field survey.

2.1 Risk Checklist

Risk checklist method is the basic method for risk identification of railway transportation. In this method, we need to first design a questionnaire or chart to list all the possible risks in railway transportation in detail. Then, staff will hold this checklist and investigate the parts involved, and gradually get the identification results, which is also called the risk framework.

The main forms of risk checklist include loss checklist, responsibility checklist, and problem checklist, and corresponding analyzing methods include loss checklist method, systematic risk analysis questionnaire method, and list checking method [3].

2.2 Expert Evaluation

Expert evaluation method is a common method in risk identification. In this method, we need to invite relevant staff and experienced safety experts in railway transportation field to meet and discuss in symposia. In the end, they will have a consensus, which is the result of risk identification [4].

2.3 Field Survey

Field survey method is very important in risk identification, and it often acts as the supplement of other methods. When we fail to fully and clearly identify the risks through the other methods, we need to send some staff to take investigation and accumulate evidences on the spot. Staff should try to find the risk condition and underlying problems of different parts and finally identify the risks. This method requires us to design a field survey questionnaire and invite relevant technicians to assist us.

When identifying the risks in railway transportation in air defense force's trans-regional training, we often use these methods comprehensively to ensure our work is scientific and covers all aspects.

3 The Implementation of Risk Identification

To implement the risk identification, we need to comprehensively use various methods, analyze the risk factors and links in railway transportation, and find the potential risks.

We take Army A's trans-regional training in 2016 as an example and analyze the single- and multi-factor risks in this activity.

3.1 Identifying the Single-Factor Risks

Personnel, equipment vehicles, transportation environment, and organization and management are all independent risk causes. They have different features, manifestations, and influences, yet if we consider them separately, they all belong to single-factor risks. We usually take field survey and expert evaluation methods to identify them. According to the characteristics and conditions of risk factors, we analyze potential risks and their influences and then get the identification results. Since the manifestations of single-factor risks in railway transportation are quite complicated, we need the support from organizations of all levels and the active participation of officers and soldiers, so as to get precise data.

The identification results of single-factor risks are shown in Table 1.

Table 1 Results of single-factor risk identification of railway transportation in Army A's trans-regional training in 2016

Source	Cause	Influence
Personnel	1. Lack of standby drivers	Fatigue driving
	2. Some driver's driving ages are short and driving skills are poor	Improper disposal of unexpected situations
	3. The guidance of vehicle guides are not standardized, and their gestures are not clear enough	Wrong operations of drivers
	4. Some officers and soldiers have poor sense of discipline	Passengers fail to get back to the vehicles after break
	5. People violate operation regulations, directly or indirectly touching high-voltage, electrical facilities	People get electric shocks and facilities are damaged
Equipment vehicles	1. Some artilleries and radar tractors are old and cannot meet standards	Cannot meet the requirements of driving on long-distance and complex roads
	2. Some brakes are damaged and are not repaired in time	Brakes are locked and lead to accidents
	3. The restraint facilities of some antiaircraft artilleries are damaged	Equipment may spin and artilleries may damage railway facilities
	4. Some safety equipment is not fully equipped, e.g., extinguishers	Increasing danger in unexpected situations
Railway environment	1. Flatcars are aging and not strong enough	Vehicles and equipment are seized up
	2. Differential gas pressure between adjacent trains appears when trains are speeding up	Wild shift of trains and danger for nearby people
	3. The height of railway overhead contact net is too low	People get electric shocks and facilities are damaged
Organization and management	1. Having many vehicles and the transportation team is long. Present communication devices can only be used within short distances and are not well tamper-proof. Lack of standby devices, communication cannot be guaranteed	The whole team is disordered
	2. Careless safety checks for vehicles and equipment	Carriages get loose and lead to safety problems
	3. Little safety education for passengers	Passengers are lack of safety awareness
	4. No specific rules for railway transportation	Affect prejudgment

Table 2 Results of multi-factor risk identification of railway transportation in Army A's trans-regional training in 2016

Potential accident	Cause	Possible loss
Rollover of vehicles and equipment	Poor driving skills of drivers, unstandardized gesture of vehicle guides	Injuries and deaths of people; vehicles and equipment are damaged
Wild shift of vehicles and equipment	Reinforcement and restraint facilities are damaged	Vehicles have to be scrapped and railway facilities are damaged
Injuries occur and vehicles are damaged when determining the flatcar's positions	Unclear command, irresponsible vehicles guides and commanders	People are hurt or dead; vehicles and equipment are damaged
People get electric shocks	People touch the high-voltage, electrical facilities during transportation	Injuries and deaths of people; vehicles and equipment are damaged
Injuries and deaths occur when trains are having stopovers	People are lack of safety awareness and violate regulations	Injuries and deaths of people
Injuries occur when carrying equipment	Unclear command, people are lack of safety awareness	Injuries and deaths of people

3.2 *Identifying Multi-factor Risks*

The accidents in railway transportation are often caused by many factors, which mean they are comprehensive and dynamic. We need to carry out multi-factor risk identification on the basis of single-factor risk identification to find out the risk links and points [5]. To identify multi-factor risks, we can divide the railway transportation process into several stages: loading, running, stopover, and unloading. We analyze these stages one by one, and then make a risk checklist, carry out expert evaluation, and implement field investigation to find out underlying accidents, their causes and possible losses, and finally get the risk identification results.

The identification results of multi-factor risks are shown in Table 2.

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Design Evaluation Method to HHIPS Based on Ergonomics Analysis

Min Gao, Zhen Liu and Renhe Zhou

Abstract Hand-held industrial products (HHIPS) can reduce human labour intensity and physiological burden. These kinds of products are very important part of product design field. This paper introduces the characteristics and different ways for classification of HHIPS. It also parses the ergonomics analysis method and some points in the process of design evaluation based on the ergonomics. The instance of hand-held electric sharpener is listed. To design more HHIPS accorded with the physiological and psychological needs for reducing the use of fatigue and enhancing use of comfort HHIPS, the man–machine-engineering-related knowledge is needed in the process of design for HHIPS to achieve the goal of optimization through the actual operation of measurement data analysis evaluation.

Keywords HHIPS · Man–machine · Hand-held · Physiology · Psychology

1 Introduction

Physiological load refers to the combination of external physical or information burden (pressure) to have function on a living organism in the body. The function is to maintain body's internal stability or affect the outside of body. A human is under a lot of physiological load in his daily life. The physiological load can lead to discomfort and fatigue [1]. The generation of ergonomics is based on the aim of

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solving such problems. By the study of the factors such as anatomy, physiology, psychology in a work environment and human–machine, environment interaction, fatigue and physiological, psychological burden of the body are reduced. An important problem with ergonomic product design is to determine the cause of comfort and discomfort factors. Hands are the parts of a human body used in high frequency [2]. Human actions like mobility and manipulation make the use of hand diverse [3]. Some operations even need the human body to use the hand to the extreme state [4]. Ergonomics designed HHIPS reduces the human labour intensity and physiological burden. It also reduces the negative effect of the hand tools on the human body [5]. So it becomes one of the hottest design propositions today because of its close nature with human's daily life.

2 The Characteristics and Classification of HHIPS

Hand-held products should be designed in different shape, size, weight and structure according to different purposes and functions to make the hand-held industrial products be used more convenient. The applied ergonomics principle of HHIPS can be found in some data and literature. Some basic principles for hand-held products are listed.

1. Avoid static muscle load. Static muscle load of the lifting arm can be reduced when the HHIPS design makes the operating position of arms in natural prolapse.
2. Keep the operation state of the wrist in straight status. So the wrist is relaxed in the middle position, operating fatigue is reduced and comfort is enhanced.
3. Avoid high pressure to the palm of hand through product design.
4. Pay attention to measurement of the handgrip strength.

Development and progress of science and technology make the structure and the operating interface of HHIPS more and more humanized and easy to use. It is also more and more accurate, reliable and safe. The ergonomics design to HHIPS can make it more suitable for operation and make the product to be the extension of human body. The man–machine engineering characteristics of hand-held product design mainly include the following items.

1. Reduce the fatigue and improve use comfort of operator with HHIPS.
2. Increase the service efficiency of HHIPS.
3. Apply psychological theory in HHIPS design as modelling and colour design to get the best effect of human–computer interaction.
4. Reduce the mis-operation possibility.
5. Improve safe and reliable performance when using HHIPS.
6. Make it easier to repair and maintain.
7. Make the product easy to recognize.

The main research methods associated with human factors' research include anthropometry, biomechanics, human psychology, product modelling theory, cognitive science. According to the power source, HHIPS can be divided into two kinds as power hand-held products and non-power hand-held products. Referring to the contact position of the hand and product, HHIPS can be divided into two kinds as finger-held products and palm-held products.

3 Ergonomics Analysis Method of HHIPS

Hand-held products are closely linked with the hands. The analysis of the structure of skeletal muscle to hand, arm, sometimes including shoulder part of human being can be used in the field of hand-held products' design and research. The skeletal muscle of hand includes thumb from the roots of skeletal muscle (CMC), hand–finger joint (MCP), internode joints between fingers (IP), internode joint of proximal finger (PIP), internode joint of distant finger (DIP).

Kinetics of hand analyses the strength, operating time and torque to finger and muscle tendon. Thus, it can apply physical science theory instruction to HHIPS design study. The instance of analysis research with the reliability of hand-held products shows that composite reliability of HHIPS depends on the result that reliability of human body multiplies by reliability of HHIPS. Human reliability can be improved by according guidance to operator. The improvement of product reliability needs reasonable and effective design.

Repeated use of hand-held products which is not in conformity with the ergonomics design for a long time may cause the cumulative damage or other syndrome to the operator. The design can be optimized through the analysis of hand muscle. Such optimization is made as some modified model lines in the hand-held products. Changing the linear type to streamlining type can increase grasp power for hand-held products, so as to achieve the design target of reducing the control force and the operating fatigue.

In design for HHIPS, psychology and physiology both provide theoretical basis for research related to hand-held products. Psychology is the science to study psychological activity and behaviour of human and animal. In the early nineteenth century, the German philosopher and education expert, J.F. Herbart, first proposed psychology is a science. Model and colour should accord to the operating environment and operating requirements in HHIPS design. More emphasis should be put to the effects on the person's psychology. The modelling aesthetic rule should be carried on the corresponding design. Then, the product can reach a certain visual effect from the perspective of scale, symmetrical balance, stability and lightness.

4 Design Evaluation Based on Ergonomics to HHIPS

4.1 Establishment and Evaluation of the Model

Through the simulation, modelling and entity model make feedback and design integrate closely in the process of development. Static two-dimensional plane figure, three-dimensional digital model and physical model can help the user to get design preview and timely evaluation. The cost evaluation is lowed, and design optimization is achieved before the final testing.

4.2 Example of Hand-held Electric Sharpener Design

Product introduction: The development of sharpener began in foreign countries, and the history of sharpener research in our country only lasted a decade or so. The current brands include Zhongshan Ditai, Zhejiang Wantong. Electric sharpener generally has a build-in small direct current or alternating current motor. The motor isinstalled around knife material named knife head to make the internal rotation. According to the different requirements of knife, electric sharpener can also be divided into one knife head design and many sections' knife head design. Many sections' knife head design often include two parts with coarse grinding and fine grinding. The service life of electric sharpener mainly depends on the quality of the motor and the abrasive resistance of the knife head.

Performance program: Turn on the power of the electric sharpener and switch. Knife head begins to spin. Put the knife head into the knife mouth. Let the head contact with knife tablets. Pull along the curve back to the knife blade angle with uniform velocity and constant efforts about 3–8 s (ordinary steel knife 3–6 s, ceramic knife 4–8 s). Achieve the goal of grinding knife sharp through repeated pressure and before and after movement (Fig. 1).

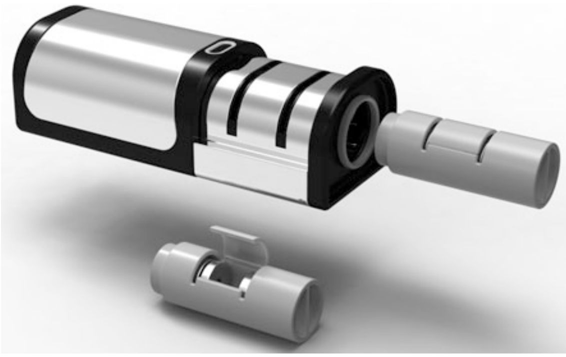

Fig. 1 The graphical representation to internal knife head of handheld electric sharpener

Design points are as follows:

1. Sharpener design should comply with the hand-held product design characteristics. Fully man–machine analysis must be conducted before design, especially reducing the use fatigue of the operator and improving the use of comfort. The analysis makes the product conform to the operation habit of most consumers and improves the use safety.
2. The design breaks the traditional model of straight line machinery and applies more rounded edge model. This makes the product create the visual effect of easy communication. At the respect of colour, it is designed to be in harmony with the use of environment. The style is defined as concise and modern to reflect science and technology feeling.

Design evaluation: This design is made into the mould production with plank through rapid prototyping technology. The subjects operate the electric knife sharpener plank with hand and the usage of data of hands and arms is measured. Then, the data is compared with the data of similar products on the market. Man–machine parameter is extracted by surface muscle testing machine. It measures physiological reaction signals to the product. The information of operation comfort can be obtained by the analysis equipment of grasping movement from psychological stress data. Detailed analysis is carried on for the design requirement. Eventually it is proved by human–machine experiments that the new design can meet the requirements of the operator's hand operation, reduce the fatigue of operators and improve comfort experience. Model sense design and technical sense color satisfy the psychological needs of users.

5 Conclusions

Hands no doubt play an important role in the human's daily life to change the world. Hand-held product is just the product type closely related to the operator's hand. In order to reduce the user's physiological and psychological fatigue, achieve the ultimate goal of comfort usage, design for HHIPS should have different structure and model to conform to the requirements of the man–machine engineering according to the function and the environment. Even though the sort of HHIPS is diverse and the function of it is various in life and work, there are some common principles and basic theories in the aspect of man–machine and environment to assist the related design research.

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The Profile of Common Physical Tasks Determination in Foreign Armies and Its Enlightenment on Formulation of Military Physical Training Plans

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Abstract The foreign army researchers analyzed all working classification of hundreds of combat missions and carried out assessments on the traditional physical test standards to determine the abilities such as "lifting and handling, digging, walking and running," as common tasks. Based on the above research from several countries, common military tasks were identified that provided the preference physical fitness in general goals set of the training program. The enlightenment to our army's military training scheme is as follows: (1) Should follow the military training policy and directives; (2) Should be combined with the platform for development and reform, and the requirements of military physical training program; (3) Post the actual analysis of physical quality of common needs, develop optimal military physical training plans. In particular grassroots units, units engaged in combat missions for physical task analysis are relatively easy to operate, can fully demonstrate the common physical tasks, according to the physical needs, take the appropriate military physical education courses as a means of training, so as to improve the fitness level for army, and meet the needs to carry out combat missions.

Keywords Common physical tasks · Military physical training plans · Physical fitness standard

1 Foreword

In the army investigation, when we asked how military physical training plan was developed, we usually heard three answering. Answer 1 is "do not know how to draw up training plan but according to the previous plan", answer 2 is "don't understand, according to supervisor training program, we have slightly refined"; answer 3 is "in accordance with the program, combined with military training

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organization of work, issued by the superior military physical training plan prepared on the basis of the unit plan." Clearly, answer 3 is more accurate, but only a few units can correctly formulate military physical training program.

2 Profile of Common Physical Tasks Determination in Foreign Armies

Through the literature reports of foreign military forces [1], determination of the basic military joint physical tasks in foreign armies is as follows.

2.1 Canada

As early as 1983, Canadian army began to study for the arms (null, San Diego, sea, and land) setting minimum physical fitness standard. In 1985, the research confirms ability to dig foxholes, overland escape capability, and low/CoGi creeping ability to escape, carrying sandbags, and the land is all soldiers must master common military tasks to deal with any emergency situation. In 1996, Canadian army undertook argumentation about the relevant documents on military and military exercises of the cold war. Table 1 describes the common military tasks required to perform urgent tasks. Results show that initially established five common military tasks are representative of the beginning in the late 1990 of the twentieth to twenty-first century basic military skills. Also found oil drum (weight) is also a major joint military task, and ultimately this skill was also included in a standard.

2.2 Netherlands

In 2004, researchers performed six tasks based on units (including peacekeeping operations and various other tasks), listed the specific skills required for the forces: observation posts, checkpoints and patrols were the most common tasks. Four experts of the Netherlands with 5 different types of combat troops (airmobile Brigade, and commando armored) described the most common skills were needed, regardless of offense or defense requires these skills. And weight-bearing walk is part of the most important. In addition, the "shooting and moving", alternately kneeling, digging, lifting and handling were identified as abilities that combat troops must-have.

Table 1 Common CF emergency tasks by operation

Operation	Sea evacuation	Land evacuation	Low/high crawl	Entrenchment dig	Sandbag carry	Lifting
Manitoba flood: domestic operation		×		×	×	×
Saguenay flood: domestic operation		×			×	×
Eastern Ontario ice storm: domestic operation		×			×	×
Peacekeeping: international operations		×	×	×		×
Humanitarian operations: international				×		×
Gulf war			×			×

Adapted from Ref. [6]

2.3 British

The Royal Navy has re evaluated traditional body testing standards and identified "broadside firing, wounded delivery, and fleeing ships in various ways" as their common task. The typical common task of naval fire fighting skills are "fire circle condensation cooling, rolling drums, carrying fire extinguishers, carrying hose running, climbing ladder". In 2003, the British army confirmed the contents of the 14 core combat tasks and formulated the corresponding physical fitness standards. The skills of "digging or shoveling, lifting and carrying" are identified as a common task of air force enforcement. In order to meet the minimum requirements in the physical quality level of combat missions, fighting quality evaluation system revised by the British Royal Air Force in 2005 also identified four common representative tasks. they are "Lifting the ammo box continuously, carrying 2–20 water tanks continuously, lift and carrying the ammunition box repeatedly within 10 meters, and Marching for 12.8 kilometers". It meets the basic physique requirements of the air force's 14 core operations.

In 2004, researchers perform six tasks based on units (including peacekeeping operations and various other tasks) and list the specific skills required for the forces: observation posts, and checkpoints, and patrols were team to perform the most.

2.4 American

As early as 1984, experts analyzed all working classification of 1999 combat missions. Table 2 describes the most common order of skills.

As early as 1984, the US military Ordinance 611–201 contained six of the most important categories: lifting and carrying, lifting aloft, lowering, climbing, digging, walking, marching and running, pushing and pulling”. These were carefully selected by US military experts after analyzing the 1999 operational tasks required by all categories of military work in the United States. Among them, lifting and conveying are recognized as the most versatile skills, representing 232 tasks for 172 types of professionals. The second is “high and low”, which represents the 92 tasks of the 75 types of professionals; Excavation represents 18 tasks for 18 types of professionals; Walking, marching, and running represent 22 tasks for 18 types of professionals. Whether it’s a long walk, a long march or a long run. Long marches are considered to be especially important for combat units.

Based on the above research from several countries, common military tasks were identified that provided the preference physical fitness in general goals set of the training program.

Table 2 Rank order of the most frequent physical tasks in the U.S. Army

Physical tasks	Total (%)	Very heavy MOS (%)	Heavy MOS (%)	Moderately heavy MOS (%)
Lift/lower	41	40	43	40
Carry/load bear	30	31	30	28
Pull/torque	6	8	6	7
Push	5	5	5	7
Climb/descend	4	4	5	3
Reach	2	2	2	1
Stoop	2	2	2	2
Dig	1	1	1	2
Crawl	1	1	1	<1
Kneel	1	1	1	1
Crouch	1	1	1	1
Hammer/pound	1	1	1	1
Stand	<1	0	0	<1
Recline	<1	<1	1	<1
Handle/finger	<1	<1	1	<1
Throw	<1	<1	0	0
Walk/March	<1	0	<1	<1
Rush/run	<1	<1	0	0
Swim/dive	<1	<1	0	<1
Sit	0	0	0	0

3 The Enlightenment to Our Army's Military Training Scheme

3.1 *Should Follow the Military Training Policy and Directives*

"The military physical education" pointed out: "the military sports training plan is purposeful, organized, step by step, the scientific arrangement of military sports training and guidance documents successfully completed the indispensable military physical training tasks [1]." Military physical training plan is an important part of military training program, "the military physical training" proposed military training plan refers to the organization, implementation, coordination, monitoring and protection of military sports training schedule [2] 61". On the basis of the "Forewarned is forearmed." In the theory of military sports, it is considered that the military sports training program is the pre arrangement for organizing and implementing military sports activities, and is the basic basis for clear goals and unified action [3] 248. On how to develop training programs, military sports theory points out "We should carefully understand the purpose and guiding ideology of our army's military physical training, as well as the content, time, requirements and assessment standards prescribed by the higher authorities for military sports training. According to the characteristics of services and arms, for the troops of soldiers in different tasks, the specific circumstances and geographical environment and other objective conditions, formulate feasible plan of military training." Military expert Li Zhiwen believes that the formulation of military sports training plan should be based on the military training program, higher training instructions, the head of the intention, the actual situation of the army, the principles of military sports training and other factors [3] 250. In formulating military sports training programs, grass-roots units are in accordance with the plan of the higher authorities and in accordance with the actual situation of this department. Starting from the grass-roots level and platoon training programmes, the source will be traced back. In the end, it will naturally be the headquarters, and the final basis for the training plan of the organs at all levels must be the training program formulated by the headquarters.

3.2 *On Military Physical Training Should Be Combined with the Platform for Development and Reform, and the Requirements of Military Physical Training Program*

On December 31, 2014, the four General Headquarters/departments jointly issued a circular on military physical training development and reform platform, portrays the grand blueprint for military sports training, 2015 the military physical training program introduced for comment. Due to tight schedule the task for various reasons, such as, military physical training program is not as good as foreign armies, in the wide range of positions in army common tasks of data collection and research, and use other methods to determine all the arms of military physical training based on common projects. The height and width of the outline from the army, on the arms of military training and evaluation for the specification, in order to prevent the army exam training, also adds a large number of training courses and quizzes. In the development of military physical training plans, must be closely combined with the platform and the syllabus requirements and guarantees stipulated in the outline curricula train first, taking care to avoid the simplistic idea of what training, and strive to combine jobs the job actually, targeted training positions physical tasks require physical fitness, to ensure "training for war."

3.3 Post the Actual Analysis of Physical Quality of Common Needs, Develop Optimal Military Physical Training Plans

In view of the actual physical fitness of the common requirements, the Canadian military's military sports training program implements this principle. That is, all soldiers must master the joint military task to deal with any emergency. The Holland army has worked out specific tasks for the specific tasks of the detachment, including observation posts, checkpoints, patrols, and weight-bearing walking, shooting and moving, alternately standing, kneeling, digging, lifting and carrying. When the British Army formulated the corresponding standard of physical fitness for the implementation of the combat mission, 14 core joint fighting tasks were identified. US military experts screened out 6 of the 1999 missions. Therefore, our army should learn from foreign experience in the development of military sports training plan. Especially at the grassroots level, developing military physical training plan is according to the actual demand analysis of common physical quality, taking the corresponding military sports training courses, in order to meet the need to carry out a specific task. The means used in class training process should really improve the pertinence in fulfilling their tasks.

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Information Security Impacts Future Traffic Safety of Intelligent Vehicle

Quan Yuan, Haojie Yang and Yang Liu

Abstract As the development of intelligent vehicle technology, the road traffic system will become more complex, and the degree of internet application will be higher. These result in that information security problems are also changing to be more prominent. So it is necessary to keep abreast of the future development of transport system and the possible risks. This paper analyzes the mechanism of some new technologies (such as cloud storage and cloud computing) used in the future traffic system and summarizes the potential risks of future traffic system, especially the risks of information security. The related issues include the possible fault in the information processing system, hacker attack, the risk of information disclosure in the cloud storage center, and the physical damage to the future traffic system itself. Furthermore, this paper tries to provide a preliminary and effective solution, as far as possible to enhance the stability of the future traffic system. By using physical isolation and other effective methods, related agencies can avoid hacker intrusion and protect the information security of the system users so as to ensure the future traffic safety.

Keywords Intelligent vehicle · Information security · Risk · Fault tolerance · Cloud computing

1 Introduction

Due to the rapid development of intelligent vehicle technologies, especially self-driving and Internet of vehicles, the existing transport system is undergoing an unprecedented change, and the blueprint for the future road traffic system has appeared. However, when the traffic becomes more and more intelligent, we should perform in-depth study to explore if the traffic system can keep drivers and

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passengers safe throughout. From the initial traffic accidents involving intelligent vehicles, we can get a glimpse of the risks of future traffic systems. But it is undeniable that this transform will not stop because of these temporary problems. What we can do is to promote this transform, pay attention to the risks and prepare related solutions.

The type of vehicle is becoming increasingly innovative, while the road traffic system is becoming more and more complex. It is impossible to summarize all possible patterns and features of traffic accidents. In this paper, through investigating possible situation and trends of the future traffic system, and analyzing emergency incidents caused by intelligent vehicles, we suppose several possible forms of traffic accidents and suggest some preliminary solutions.

2 Background

2.1 Current Situation of Self-driving Vehicles

If a driver wants to control a normal vehicle safely, he should receive outside information first, then process information by the brain and make a decision, finally give an order from the brain to body to carry out the order. Therefore, there are several aspects to design self-driving vehicle at present.

First of all, it is necessary to liberate the sensory organs including eyes, ears, skin from driving. And various sensors are used to receive complex information from outside instead of the driver. At present, most of the sensors are radar including laser, microwave and sound waves, and vision including single vision, double visions, and night vision.

Then liberating the brain of the driver is also important. In the self-driving vehicle, the chips with powerful computing power have replaced the brain of mankind. As present situation, server-level processing chip is sufficient for this function.

Finally, since the CPU of computer system can give an instruction to the vehicle directly, current mechanical control system should be adjusted in order to adapt the self-driving situation.

The above aspects are all the requirement of self-driving vehicles. Considering the possible system failure and other risks, it is necessary to reserve normal driving system in self-driving vehicle to prevent possible emergency incidents.

2.2 Outlook of Future Traffic System

At present, many companies and institutions which develop self-driving vehicle have completed the above aspects. And several kinds of self-driving vehicles which are tested have been able to travel on the road. However, only self-driving vehicle is not enough. People can not only design intelligent and self-driving vehicles, but also put all self-driving vehicle as well as the traffic environment into a common network which is called vehicle networking.

Vehicle networking can also be called intelligent traffic system, which is a real-time, accurate, efficient transportation management system acting on wide range and all directions. The system integrates information technology, data communication technology, electronic sensing technology, control technology, computer technology, and other advanced technologies. In the vehicle networking, there are not only exchange between human and vehicle, vehicle and traffic environment, but also between vehicle and vehicle, vehicle and database. Because of this, the Bluetooth, CAN bus of vehicle, and GPS which are installed in normal vehicle can be connected with vehicle networking.

In the vehicle networking, self-driving system collects information from the surroundings to control the vehicles. At the same time, the system can communicate with other vehicles directly, and receive environmental information from other vehicles. As a result, the system can get more useful information to make a better decision to control the vehicles safely by the CPU.

Above all vehicles that access the network, there is a database, or a cloud storage-computing center. All of the information collected by the vehicles will be uploaded to the cloud storage-computing center (CSCC). In normal conditions, the vehicle's own CPU can process the information by itself. But when the information is too complex to be processed independently by the CPU, the CSCC can help the vehicles process the information, and feed back the results to the vehicles in order to improve the operation efficiency of vehicles.

In addition, the CSCC can collect environmental information from all vehicles in the world. Therefore, one vehicle's decisions don't need to be confined in 10 m. According to the plan that vehicles upload, and the information 10 km or further around the vehicle, the CSCC can help the vehicle make the best decision. For example, if a road is crowded now, or there is a traffic accident, the center can feed back to the vehicle in advance. Then, the vehicle can choose other routes to save driver's time, and improve traffic efficiency.

3 Risks of Future Traffic System

3.1 Hacking Attack

As mentioned earlier, GPS, Bluetooth, CAN bus will still appear in the automatic driving system in the next period of time because of their own characteristics. But these technologies are currently or will be attacked by the hacker [1]. It can be seen that self-driving vehicles face the same threat of hacking in the future.

On the afternoon of March 30th, well-known bug reporting platform “WooYun” exposes a serious bug in BYD intelligent vehicle, which maybe lead to a complete control of the vehicle by the hacker. This bug is related to cloud service, which can help the hacker write program to get any drivers’ information (name, license plate number, vehicle frame number, ID number, contact name, mobile phone number, and so on) and the control code to get the control of the vehicle and the owner’s privacy. Thus, in the future, when the vehicle has been highly electronic and become the center of information exchange, to prevent the invasion from hackers, this risk must be taken seriously. If a vehicle can exchange information by the network, it must face the threat of hacking. And once the hackers intrude, they will completely control the vehicle. At that time, the harm to vehicle owner is self-evident.

3.2 Risks of Cloud Mode

In the future, all autopilot, unmanned, and intelligent traffic need traffic information’s real-time collection and analysis, and they also need a system to predict the traffic dynamics. Facing of such a huge amount of traffic information, that we only rely on the car terminal to collect and analyze the information is far from enough. Relying on cloud storage and cloud computing collection and analysis the information is more likely [2].

At present, Ford company is providing information services based on cloud storage [3], and Ford can update its automotive infotainment systems by using Microsoft’s Azure’s cloud services [4]. But some of the recent cases about leakage of information show some drawbacks of cloud storage. As reported, in the case of stealing and selling citizen’s information that was cracked by Ministry of Public Security, 5 billion pieces of citizen’s information were leaked. Someone familiar with the matter said the information belongs to some users from Internet companies. The information uploaded to these companies’ cloud storage was stolen by the administrators. That shows cloud storage’s shortcomings (information access permissions may be out of control, so there is the risk of information leakage. The stored data from the vehicle interior are placed outside of the vehicle, so the security of data is questionable. It is difficult to restore the information that is attacked seriously, and it is difficult to compare the excellent algorithm for the processing system because of the suddenness of the unexpected situation.). Even these shortcomings of cloud storage mean that there will be serious risks in the future traffic system.

In addition, the cloud model itself also has the possibility of going wrong. On March 15, 2017, Microsoft disclosed that the storage tier from its Azure public cloud is facing issues in data center regions across the globe. Out of 28 data center regions, 26 were having storage issues, according to the status page [5]. And the cloud model needs to set up a permission to update the traffic information, coordinate the traffic flow, and shut down itself when it goes wrong. Then when there is the abuse of authority, the drivers' information of residential, work place, and driving routes will be leaked out, even the system will be shut down and countless unmanned and automatic cars may lose control.

3.3 Fault Tolerance

Fault tolerance is the property that enables a system to continue operating properly in the event that some of its components go wrong (or one or more faults within). Because autopilot, unmanned, and intelligent transportation systems are also concerned with the safety of passengers and must not be interrupted; strong fault tolerance is very necessary for these systems to deal with their huge flow of information. However, taking into the processing system's mode of all-weather working and that traffic information changes happen in the moment and unexpected, such strong fault tolerance maybe also not enough. How to solve the problem of the handling system's reliability will be the key of the health of traffic system in the future.

3.4 Physical Damage

The physical damage to the traffic system is also a serious issue. Whether it is GPS satellite, cloud storage, cloud computing center, or information relay-stations will probably cause the breakdown of intelligent traffic, and automatic car will be out of control due to natural physical damage. The paralysis of a traffic system with hundreds of millions of people is extremely destructive, and the most possible enforcers are the terrorists.

4 Discussion

As the stability of the traffic handling system is linked to its fault tolerant, we need to enhance its fault-tolerant performance to improve the stability of the system according to the formed and perfect computer system. At present, the fault-tolerant technologies used in computer are structural redundancy, information redundancy, time redundancy (it takes a long time), spatial redundancy, and redundant additional technology which is required for space redundancy (it is suitable for improving the future traffic system where time's requirements are extremely strict). In addition, lockstep can also improve fault tolerance by running the same set of operations at the same time in parallel [6]. The redundancy allows error detection and error correction: the output from lockstep operations can be compared to determine if there has been a fault when there are at least two systems (dual modular redundancy). This technology requires the system to run its memory doubled that will be bound to lead to increasing costs for cloud storage and cloud computing. It is worth for the huge staff of the transport system.

At present, government and society mainly concern about the network's information security, and many countries have issued some guidelines about it. China issued a "Opinions of the National Informatization Leading Group on strengthening the work of information security" called as "No. 27" containing information security level protection (ISLP) and building network trust system based on the password-based information protection on August 26, 2003. It can be seen that its main strategy is to encrypt the key information for information security. Taking into account, the amount of information that the future traffic system needs to collect and encrypt information is time-consuming. This shows that encryption is not suitable for this system. How about network firewall? Theoretically that any network firewall is not absolutely safe, only the real physical isolation can maximize the protection of information security. Figure 1 shows a new concept design for traffic safety system in the future to ensure the information security of the system. There is currently a scheme of internal and external network isolation which can achieve this physical isolation where only the credit terminal (e.g., the smart car) can access the processing system [7].

As shown in Fig. 1, the firewall isolates the cloud system from the outside world,and only traffic information can pass through the firewall. The public terminal includes the mechanical operating system and the various ports. The safety terminal is the intelligent driving brain connected with the cloud system. The safety terminal transmits the data to the public terminal to manipulate the vehicle.

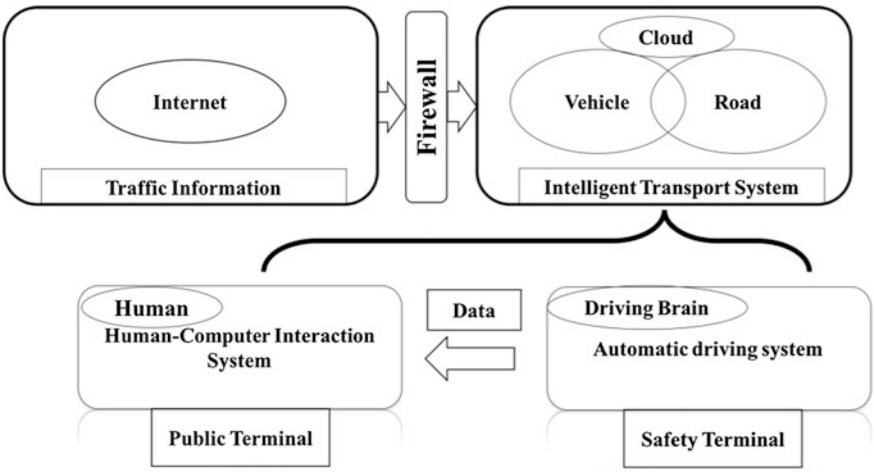

Fig. 1 New concept design of information security for automatic vehicle

This new design can isolate the traffic processing system and the illegal terminal. In addition, in order to prevent hackers from using the trusted terminal to attack the processing system, we can build a system which is similar to the physical isolation system with single hard disk. The system can be divided into two virtual mobile terminals (security terminals and public terminals) to achieve the physical isolation and to create a one-way security channel where data can only be transferred from the public terminal to the security terminal so as to prevent hackers from using the trusted terminal (their cars) to attack the traffic processing system [8].

5 Conclusion

Considering the existing issues of traffic system, this article examines several possible risks of future traffic systems including intelligent vehicles, such as hacking attack, risks of cloud mode, fault tolerance, and physical damage of system. And some related solutions are discussed. In order to protect the transmission of information flowing to be secure in the cloud mode, this paper designs an internal and external network system which can achieve the physical isolation to prevent hacker from attacking the system and stealing information. However, the vital problem is how to establish and protect that big firewall between Internet and intelligent transport system.

Concerning the high-speed development of relevant technologies, there will be more new applications in the future traffic system. And there will be some other potential risks outside of this paper. Therefore, the researchers still need actively explore the risks and offer the solution to avoid them.

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Research on the Evaluation Model of Party Construction in Higher Vocational Colleges Based on Analytic Hierarchy Process

Haiwei Peng, Xiaohui Peng and Xiaogao Wang

Abstract This article takes the evaluation of Party building work in higher vocational colleges as the research purpose. Through the access to information, the establishment of mathematical models and other research methods,firstly, it introduces the status quo of the Party building in higher vocational colleges and the importance and necessity of the evaluation of the Party building work. Secondly, it constructs the index system which influences the evaluation of the Party building work in higher vocational colleges and establishes the evaluation model of the Party building work in higher vocational colleges based on the analytic hierarchy process. Finally, the feasibility of the model is verified by taking the grassroots Party organization of a vocational college as an example. The results show that the comprehensive weight of the indicators is basically consistent with the actual situation. The evaluation results have certain reference function for the managers to formulate the Party building measures and the scientific development of the grassroots Party organizations.

Keywords AHP · Higher vocational colleges · Party building work

1 Introduction

The Eighteenth National Congress of the Communist Party of China proposed to build a learning, service, and innovative Marxist ruling Party. Party building in higher vocational colleges is an important part of the construction of the new great project of the Party, and it is an important content to consolidate the ruling foundation of the higher vocational colleges. In recent years, the colleges and universities have attached great importance to Party building work and take effective

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measures to strengthen student Party building work, but also achieved certain results. However, there are many problems, such as the emphasis on process management, ignoring the results management, and evaluation management [1].

With the transition from scale to quality, the Party building in higher vocational colleges is developing from extensive to fine. To explore the evaluation of vocational college students' Party building work model, can promote the scientific and advanced building work, conducive to innovation and development of grassroots Party organization in higher vocational colleges, to urge all Party cadres to work hard, wholehearted devotion to public duty, construction, and management of cadre team of our Party is more scientific, fair, and transparent [2].

2 Construction of Evaluation Index System of Party Building in Higher Vocational Colleges

The factors that affect the quality of students' Party building work are multi-faceted and multi-level. As shown in Fig. 1, based on the principle of orientation, comprehensiveness and feasibility, four factors, such as the construction mechanism of the Party building, the performance of the Party building, the quality and function of the Party members, and the masses evaluation, are selected as the first-level indicators of the evaluation of Party building work in higher vocational colleges [3].

In order to increase the measurement of the index and the accuracy of the evaluation, the first-level index is divided into many more specific two indicators, as shown in Table 1.

Party building work mechanism: refers to the work of the Party system and plans to complete the work. This paper mainly studies four aspects: development mechanism, learning mechanism, activity mechanism, and supervision mechanism.

The performance of the Party building work: refers to the main tasks of the Party organizations at the basic level and the achievements obtained. This paper mainly

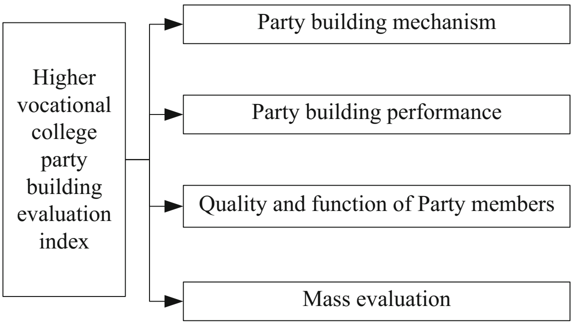

Fig. 1 Higher vocational college Party building evaluation index

Table 1 Evaluation index system of Party construction in higher vocational colleges

Level-1 index	Level-2 index
Party building mechanism A	Development mechanism A_1,Learning mechanism A_2, Activity mechanism A_3, Supervision mechanism A_5
Party building performance B	Be commended B_1, Typical extension B_2, Mission accomplished B_3, Party development B_4
Quality and function of Party members C	Political thought C_1, work ability C_2, demonstration function C_3
Mass evaluation D	Organization evaluation D_1, personal evaluation D_2

studies four aspects: recognition, typical promotion, task completion, and the development of Party members.

The quality and effect of the Party member: Party member quality refers to the intrinsic quality reflected a Party member or Party members in nature from other people, other organizations, the role of Party members refers to Party members through their subject status, influence, and lead the masses around the utility generated. This paper mainly studies three aspects: political thought, work ability, and demonstration function.

Mass evaluation: refers to the teachers and students of the basic organization of the students of the system of normative, scientific decision-making, management transparency, the method of reasonable content, and recognition. This paper mainly studies two aspects, which are organization evaluation and individual evaluation.

3 Establishment and Solution of the Evaluation Model of Party Construction in Higher Vocational Colleges Based on Analytic Hierarchy Process

At present, the evaluation of Party building work in higher vocational colleges mainly from the perspective of qualitative analysis, lack of quantitative methods, and the evaluation model of the operability is not strong, AHP is a combination of qualitative and quantitative analysis method, and it has the advantage of systematic, hierarchical, etc. [4].

3.1 Coefficient of Determination

The determination of the weight coefficient is the key to the quantitative research on the quality of student Party construction. Whether the setting of the weight coefficient is reasonable and accurate will directly affect the scientific, reliability, and accuracy of the evaluation results. The main steps are as follows:

Step1 Establish the pairwise comparison matrix M. Using the classic 1–9 scale method, the factors of the same level of indicators are compared. The pairwise comparison matrix of the target layer to the target layer, and the pairwise comparison matrix of the sub-index to the index layer are [5]:

$$M_{A-D} = \begin{pmatrix} 1 & 3 & 2 & 3 \\ 1/3 & 1 & 2 & 1 \\ 1/2 & 1/2 & 1 & 2 \\ 1/3 & 1 & 1/2 & 1 \end{pmatrix}, \quad M_{A_1-A_4} = \begin{pmatrix} 1 & 2 & 3 & 2 \\ 1/2 & 1 & 1 & 1/2 \\ 1/3 & 1 & 1 & 2 \\ 1/2 & 2 & 1/2 & 1 \end{pmatrix}$$

$$M_{B_1-B_4} = \begin{pmatrix} 1 & 2 & 1/2 & 1/2 \\ 2 & 2 & 1 & 1 \\ 2 & 1 & 1 & 1 \\ 1/3 & 1 & 1/2 & 1 \end{pmatrix}, \quad M_{C_1-C_3} = \begin{pmatrix} 1 & 2 & 3 \\ 1/2 & 1 & 1/2 \\ 1/3 & 2 & 1 \end{pmatrix},$$

$$M_{D_1-D_2} = \begin{pmatrix} 1 & 2 \\ 1/2 & 1 \end{pmatrix}$$

Step2 Find the weight coefficient ω of each factor. Taking the pairwise comparison matrix as an example, the matrix after normalizing the column vector is:

$$M_{A-D} = \begin{pmatrix} 0.545 & 0.545 & 0.364 & 0.429 \\ 0.181 & 0.181 & 0.364 & 0.143 \\ 0.273 & 0.273 & 0.182 & 0.286 \\ 0.181 & 0.181 & 0.091 & 0.143 \end{pmatrix}$$

According to the line to get $\omega = (1.883, 0.869, 1.014, 0.596)^{\mathrm{T}}$, normalized to get $\bar{\omega}_0 = (0.43, 0.20, 0.23, 0.14)^{\mathrm{T}}$, $\bar{\omega}_0$ is the corresponding indicators of the various factors of the weight coefficient. Similarly, the weight coefficient of the sub-index layer to the index layer is: $\bar{\omega}_1 = (0.39, 0.14, 0.17, 0.30)^{\mathrm{T}}$, $\bar{\omega}_2 = (0.15, 0.22, 0.43, 0.20)^{\mathrm{T}}$, $\bar{\omega}_3 = (0.42, 0.28, 0.30)^{\mathrm{T}}$, $\bar{\omega}_4 = (0.67, 0.33)^{\mathrm{T}}$. Among them, the uniformity ratio of all weights is less than 1, both through the consistency test.

Step3 Seek the comprehensive weight $\bar{\omega}_{综}$ of the secondary index.

$$\bar{\omega}_{综} = \omega_0^{\mathrm{T}} \bullet (\omega_1, \omega_2, \omega_3, \omega_4) \tag{1}$$

The result was caculated by formula (1):

Table 2 Evaluation table of basic level Party organizations in higher vocational colleges

Level-2 index	A_1	A_2	A_3	A_5	B_1	B_2	B_3
Scoring	84	95	90	78	82	70	90
Level-2 index	B_4	C_1	C_2	C_3	D_1	D_2	
Scoring	88	90	85	75	80	86	

$$\bar{\omega}_{综} = (0.156, 0.060, 0.073, 0.129, 0.030, 0.044, 0.086, 0.040, 0.097, 0.046, 0.087, 0.095, 0.046)^{\mathrm{T}}$$

3.2 Model Building

Using the method of assessment score, score G of each secondary index can be obtained. Then the Party building a comprehensive score Y is:

$$Y = \sum_{i=1}^{n} \omega_{综}(i) \bullet G(i) \tag{2}$$

3.3 Case Analysis

Taking the construction of the basic level Party organizations in a higher vocational college as an example, the 13 items of grade two were scored, respectively, as shown in Table 2.

The above data into the formula (2), the comprehensive score of 79.72, can be seen from Table 2, three indicators of the grassroots Party organization supervision mechanism, typical promotion, and exemplary role of the lower scores, learning mechanism, mechanism, task and political thought of four indicators score higher, indicating that the grassroots Party the organization construction of basic requirements, but because of the comprehensive scoring low, there is still much room for improvement.

4 Conclusions

The evaluation of Party construction in higher vocational colleges is complex system engineering, it is difficult to use a simple deterministic analysis tools to quantify. In this paper, the evaluation index system of Party building in higher vocational colleges is established, and the evaluation model based on AHP is established. The results show that the comprehensive weight of the index is consistent with the actual situation, and the evaluation results have a certain reference value for the evaluation of the grassroots Party building work in higher vocational colleges.

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Integrated Usability Evaluation Method for Cockpit of Civil Aircraft

Hongjun Xue, Tao Li, Xiaoyan Zhang and Rong Wang

Abstract Cockpit of civil aircraft is the only most important cabin that pilots executing tasks. The usability of a cockpit has been identified broadly as associating with the pilot–cockpit interaction efficiency and flight safety. However, usability has been paid limited attention by researchers from aviation industry. The current evaluation method may not be consummate enough, and the indicators are less targeted for cockpit. Therefore, the paper aimed to put forward an evaluation method taken into consideration comprehensive factors. The integrated usability evaluation model built included product attribute, performance attribute and impression attribute. The three attributes were then further developed as seven indicators such as error, satisfaction. The second problem solved in this paper was to calculate usability evaluation result accurately. The calculation method integrated grey statistical evaluation method and DEA method to solve the multi-objects decision. The method considers different groups which would lead to the evaluation difference. The integrated usability method proposed in this paper has practical implications for improving flight safety.

Keywords Cockpit · Pilot · Usability · Grey statistical evaluation method

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1 Introduction

As a complicated system, cockpit's ergonomics design is essential for flight efficiency and safety [1–3]. According to the statistical summary of commercial jet airplane accidents reported by Boeing, nearly 90% aviation accidents could be attributed to human errors [4]. Improper ergonomic design may be the primary factor that has direct effects on human error. Thus, ergonomic design and evaluation in aviation become important for safe flight. Flight efficiency, crew workload and comfort evaluation have been focused on recently [5–7]. However, the indicators mentioned above are targeted, and the ergonomic evaluation should be executed comprehensively. The single indicator is not adequate enough to evaluate the ergonomics design. Therefore, the paper aimed to introduce usability evaluation to solve this problem. Usability has been broadly used to evaluate the users' experience in web page, mobile phone, and so on. Usability in aviation has been used to evaluate the human–machine interface such as communication system, monitoring system, and GPS, multi-function control display unit (MCDU) [8–18]. While, as for cockpit, the whole complicated system, the interface evaluation is not enough and could induce the evaluation results one-sided. In order to better evaluate cockpit usability, there is a need to propose an effective usability evaluation model to evaluate the whole cockpit usability effectively and accurately. Therefore, the objective of the present study was to establish an integrated usability evaluation model to give the cockpit a comprehensive and reasonable usability evaluation.

2 Integrated Usability Evaluation Method for Cockpit

2.1 The Integrated Usability Evaluation Model

Usability was introduced first by Shackel [19], and the four indicators included in the usability model have been broadly used. Nielsen is another researcher putting forward a usability model from sociology. The two models have some characters in common such as error and learnability. Although the two general models are broadly used, as for cockpit, the task executed there is always time and physical consuming and highly attentive; thus, the indicators in the model are inadequate. To conclude the cockpit's particular product performance and the pilots' experience, the model built has three attributes, that is, product performance, impression performance and pilot performance. The architecture has been further developed as seven indicators, that is, operation quality, learnability, and error, cognition workload, satisfaction of the human–machine interface, and operation comfortable, inner microenvironment comfortable. The seven indicators are capable of evaluating the cockpit usability and can avoid duplication of too many indicators. The integrated usability evaluation model of cockpit is shown in Fig. 1.

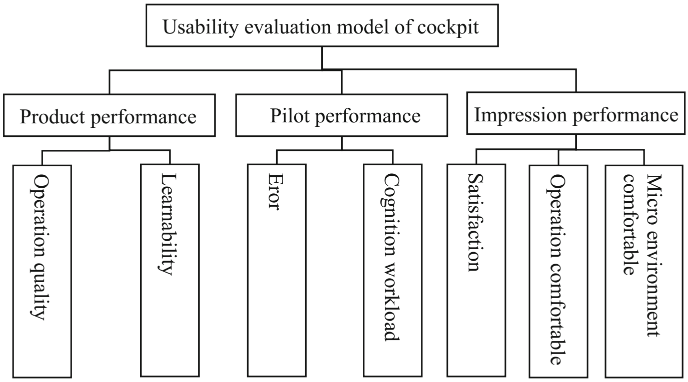

Fig. 1 The architecture of integrated usability evaluation model

2.2 Evaluators

The traditional methods always singled out experts to evaluate the objects. The experts do have more experience, but the users may conclude novice pilots. The designers to the good of better design should also be considered, so is the flight cadets. Therefore, the method recommends five groups participants concluding designers, evaluators, and experienced pilots, novice pilots and flight cadets. In the model, the five groups are represented by I–V, and the number of five groups is represented by N_1, N_2, N_3, N_4, N_5. The average score for an indicator of specified group serves as the score of the group for this indicator.

2.3 Calculation Method of Weight Coefficient Matrix

2.3.1 The Method to Calculate Weight Coefficient Matrix Based on Grey Statistical Method

The weight coefficient matrix was calculated by grey statistical method. Whitening function was used to process the evaluation coefficient of different indicators from multi-groups. In the model, we hypothesise that there are five evaluation ranks, that is, excellent, good and general, bad, too bad, respectively. Evaluation ranks are five evaluation grey groups. We assign the serial number of the five grey groups as k (k = 1, 2, 3, 4, 5). The score of evaluation result is represented by matrix D, and the element d_{ij} means the score of indicator i from group j. The whitening coefficient function of number k evaluation grey group is defined as $f_k\left(d_{ij}\right)$.

For "excellent" grey group, grey value d belongs to [80, 100], and the whitening coefficient function $f_1(d)$ is represented in Eq. (1).

$$f_1(d) = \begin{cases} 1 & d \in [80, 100] \\ (d - 60)/20 & d \in [60, 80) \\ 0 & d \in [0, 60) \end{cases} \tag{1}$$

For "good" grey group, grey value d belongs to [60, 80), and the whitening coefficient function $f_2(d)$ is represented in Eq. (2).

$$f_2(d) = \begin{cases} (100 - d)/20 & d \in [80, 100] \\ 1 & d \in [60, 80) \\ (d - 40)/20 & d \in [40, 60) \\ 0 & d \in [0, 40) \end{cases} \tag{2}$$

For "general" grey group, grey value d belongs to [40, 60), and the whitening coefficient function $f_3(d)$ is represented in Eq. (3).

$$f_3(d) = \begin{cases} 0 & d \in [80, 100] \\ (80 - d)/20 & d \in [60, 80) \\ 1 & d \in [40, 60) \\ (d - 20)/20 & d \in [20, 40) \\ 0 & d \in [0, 20) \end{cases} \tag{3}$$

For "bad" grey group, grey value d belongs to [20, 40), and the whitening coefficient function $f_4(d)$ is represented in Eq. (4).

$$f_4(d) = \begin{cases} 0 & d \in [60, 100] \\ (60 - d)/20 & d \in [40, 60) \\ 1 & d \in [20, 40) \\ d/20 & d \in [0, 20) \end{cases} \tag{4}$$

For "too bad" grey group, grey value d belongs to [0, 20), and the whitening coefficient function $f_5(d)$ is represented in Eq. (5).

$$f_5(d) = \begin{cases} 0 & d \in [40, 100] \\ (40 - d)/20 & d \in [20, 40) \\ 1 & d \in [0, 20) \end{cases} \tag{5}$$

Based on the Eq. (1–5), the grey rank of different indicator can be confirmed. For indicator i, the total grey evaluation matrix can be calculated according to Eq. (6).

$$n_i = \sum_{k=1}^{5} \sum_{j=1}^{5} f_1\left(d_{ij}\right) N_j \tag{6}$$

And then the coefficient of different grey rank k is defined as:

$$\sigma_{ik} = n_{ik} / n_i \tag{7}$$

2.3.2 The Method to Normalise the Evaluation Result Based on Data Envelopment Analysis (DEA)

The input vectors in the model are three grey ranks, that is, "general", "bad" and "too bad", while the output vectors are "excellent" and "good".

Then, the DEA-C^{2}WH evaluation model is built as follows:

$$\begin{cases} \max\ \mu_1 Y_{11} + \mu_2 Y_{12} = V_p \\ \text{s.t.} \\ \qquad \omega_1 X_{11} + \omega_2 X_{12} + \omega_3 X_{13} - \mu_1 Y_{11} - \mu_2 Y_{12} \geq 0 \\ \qquad \omega_1 X_{21} + \omega_2 X_{22} + \omega_3 X_{23} - \mu_1 Y_{21} - \mu_2 Y_{22} \geq 0 \\ \qquad \omega_1 X_{31} + \omega_2 X_{32} + \omega_3 X_{33} - \mu_1 Y_{31} - \mu_2 Y_{32} \geq 0 \\ \qquad \omega_1 X_{41} + \omega_2 X_{42} + \omega_3 X_{43} - \mu_1 Y_{41} - \mu_2 Y_{42} \geq 0 \\ \qquad \omega_1 X_{51} + \omega_2 X_{52} + \omega_3 X_{53} - \mu_1 Y_{51} - \mu_2 Y_{52} \geq 0 \\ \qquad \omega_1 X_{61} + \omega_2 X_{62} + \omega_3 X_{63} - \mu_1 Y_{61} - \mu_2 Y_{62} \geq 0 \\ \qquad \omega_1 X_{71} + \omega_2 X_{72} + \omega_3 X_{73} - \mu_1 Y_{71} - \mu_2 Y_{72} \geq 0 \\ \qquad\qquad \omega_1 X_{11} + \omega_2 X_{12} + \omega_3 X_{13} = 1 \\ \qquad\qquad\quad \omega_1, \omega_2, \omega_3 \mu_1, \mu_2 \geq 0 \end{cases} \tag{8}$$

Where, X and Y are the input matrix and output matrix of decision-making unit. As for the cockpit usability evaluation, the input matrix is the evaluation score of "general", "bad" and "too bad" grey rank, respectively, and the output matrix is the score of "excellent" and "good" grey rank. ω, μ are the weight coefficient of input vector and output vector, respectively. In the model built here, ω represents σ_{i3}, σ_{i4} and σ_{i5}, and ω represents σ_{i1} and σ_{i2}. Vp is the cockpit usability evaluation result as expected.

3 Example Validation

This study picked three different commercial cockpits and evaluated their usability design by the integrated method proposed in this paper. In the experiment, the ratio of different participants N_1: N_2: N_3: N_4: N_5 is 1: 2: 3: 3: 2. For example 1, the statistical grey value is calculated and shown in Table 1.

Table 1 Statistical grey value of example 1

Indicator (i)	Grey rank (k)	n_{ik}	n_i	σ_{ik}
i = 1	k = 1	3.15	20.65	0.153
	k = 2	7.70		0.373
	k = 3	7.85		0.380
	k = 4	1.95		0.094
	k = 5	0.00		0.000
i = 2	k = 1	7.10	20.75	0.342
	k = 2	7.55		0.364
	k = 3	2.50		0.120
	k = 4	2.20		0.106
	k = 5	1.40		0.067
i = 3	k = 1	5.50	21.90	0.251
	k = 2	7.90		0.361
	k = 3	4.45		0.203
	k = 4	3.00		0.137
	k = 5	1.05		0.048
i = 4	k = 1	3.00	20.45	0.147
	k = 2	6.05		0.296
	k = 3	5.70		0.279
	k = 4	3.40		0.166
	k = 5	2.30		0.112
i = 5	k = 1	6.15	22.00	0.280
	k = 2	9.80		0.445
	k = 3	4.85		0.220
	k = 4	1.20		0.055
	k = 5	0.00		0.000
i = 6	k = 1	5.25	19.90	0.264
	k = 2	8.75		0.440
	k = 3	5.75		0.289
	k = 4	0.15		0.008
	k = 5	0.00		0.000

(continued)

Table 1 (continued)

Indicator (i)	Grey rank (k)	n_{ik}	n_i	σ_{ik}
$i = 7$	$k = 1$	4.80	21.70	0.221
	$k = 2$	7.40		0.341
	$k = 3$	3.20		0.147
	$k = 4$	3.30		0.152
	$k = 5$	3.00		0.138

Table 2 Vp of the three cockpits

Vectors		Example1	Example2	Example3
Weight coefficients of input vectors	ω_1	6.781	4.435	13.533
	ω_2	0.000	0.000	0.000
	ω_3	0.000	0.000	0.000
Weight coefficients of output vectors	μ_1	0.000	1.410	0.000
	μ_2	2.245	0.088	2.307
V_p		0.837	0.598	0.950

From Table 1, the grey evaluation matrix is calculated as follows:

$$\sigma_1 = \begin{bmatrix} 0.153 & 0.373 & 0.380 & 0.094 & 0.000 \\ 0.342 & 0.364 & 0.120 & 0.106 & 0.067 \\ 0.251 & 0.361 & 0.203 & 0.137 & 0.048 \\ 0.147 & 0.296 & 0.279 & 0.166 & 0.112 \\ 0.280 & 0.445 & 0.220 & 0.055 & 0.000 \\ 0.264 & 0.440 & 0.289 & 0.008 & 0.000 \\ 0.221 & 0.341 & 0.147 & 0.152 & 0.138 \end{bmatrix} \tag{9}$$

The integrated usability evaluation result of example 1 based on DEA-C^2WH model is shown in Table 2.

From the calculation of three different cockpits' usability, the integrated evaluation method of cockpit is validated. The method is effective and can avoid the evaluators' subjectivity.

4 Conclusions

The paper put forward an evaluation method taken into consideration comprehensive factors including product attribute, performance attribute and impression attribute. And to avoid the subjectivity, the calculation method integrated grey statistical evaluation method and DEA method. The method has been validated by the evaluation of three different cockpits. The integrated usability method proposed in this paper has practical implications for improving flight safety.

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The Man-Machine-Environment Comprehensive Evaluation Method of Military Equipment

Heping Wang, Yuping Luo and Zhongren Xia

Abstract The man–machine environment of military equipment has a serious influence on the efficiency of the operator, and it is necessary to evaluate the objective influence on the personnel. According to the different influence of microenvironment characteristics of parameters, the evaluation system of microenvironment in compartment is constructed and the evaluation parameters are quantified according to the characteristics of the parameters. The Delphi algorithm is optimized, and the weight coefficient of the impact of various parameters are determined. The whole environment is evaluated synthetically. A basis for the evaluation and optimization design of military equipment is provided, and the problem of objective and quantitative evaluation of military equipment environment is solved.

Keywords Military equipment · Man–machine environment · Quantitative indices · Comprehensive evaluation

1 Preface

The inside environment of military equipment and the pavement make the working microenvironment of operators very bad. The strong vibration, impact, deafening noise, high, and low temperature result in serious physical and mental influence on the operators, which will drop the continuous combat capability and efficiency of operators. Therefore, comprehensive evaluation is necessary to the influence of military equipment microenvironment on the operators with research on the man–machine adaptability. In the aspect of comprehensive evaluation on the military equipment microenvironment, since the characteristic and physical quantity of the indices are not accordant, it is difficult for unified quantitative evaluation, and such parameters mostly deal with fuzzy measure, and then evaluation is made with the

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fuzzy mathematics, grey system or level analysis method. However, the above methods are difficult to directly link these parameters with the working efficiency of operators for objective and scientific quantitative evaluation. This paper has made research on the microenvironment parameters of the military equipment which influence the operators, established the military equipment cabin environment indices system, taken different single index quantitative method according to the attribute of parameters, and evaluated the comprehensive environment.

2 Research on the Establishment of Military Equipment Cabin Environment Evaluation System

It is shown from the analysis on the typical equipment working task profile and features of military equipment, the microenvironment in the vehicle is bad caused by vehicle vibration, impact, noise, high and low temperature, high humidity, noise, dust, and harmful gas, which are the factors with relatively high influence on the human–machine task performance of the military equipment [1].

The vibrations tested and evaluated in military equipment include the sitting posture vibration of operators, hand and foot vibration, and prone position vibration [2]. The noises main compose of the steady state noise in the vehicle when the vehicle is driving and pulse noise produced during artillery firing. The test and evaluation of steady state noise focus on the *A* weighed 1/3 octave noise level, and the test and evaluation of pulse noise focus on the decibel level of sound pressure and the duration of pulse peak. The test and evaluation factors of microclimate environment in the vehicle main compose of the temperature, humidity, and wind speed near the operators. The evaluation method shall combine the task performance of operators and temperature and humidity limit such as isothermal degradation. The harmful gases in the military equipment main compose of inorganic harmful gas and organics such as carbon dioxide, carbon monoxide, and oxynitride. When testing in the vehicle, special attention should be paid to the indices of the main instrument such as luminance, uniformity, and brightness. The evaluation index of dust in the vehicle is main the dust concentration.

As a summary, the cabin environment parameters indices system which is shown as below is established. The vibration, noise, microclimate, harmful gas, dust, and illumination are selected as the environment influencing Level-1 indices, where, vibration includes hand and foot vibration, prone position vibration, sitting posture vibration are three Level-3 indices; impact includes two Level-3 indices such as prone position impact, sitting posture impact; noise includes two Level-3 indices such as steady state noise and pulse noise; microclimate includes Level-3 indices such as temperature, humidity, and ventilation. Harmful gas includes four Level-3 indices such as carbon monoxide, ammonia, sulfureted hydrogen, and oxynitride; intensity of illumination includes three Level-3 indices such as luminance, brightness, and contrast [3]. Please see Table 1 for the specific indices level.

Table 1 Environmental index system of military equipment cabin

Primary index	Secondary index	Third index
Environmental index system of military equipment cabin	Vibration	Sitting vibration
		Prone position vibration
		Hand and foot vibration
	Noise	Steady noise
		Impulse noise
	Microclimate	Temperature
		Humidity
		Ventilation
	Noxious gas	CO
		H_2S
		NO
		NH_3
	Lighting	Illumination
		Luminance
		Evenness
	Dust	–

3 Equipment Cabin Single Factor Environment Parameters Evaluation

3.1 Basic Model of Environment Parameters Single Factor Evaluation

It is found after analyzing the environment parameters evaluation standard of the military equipment that the evaluation of environment parameters main has two basic types. The first one is the parameters adopting limit evaluation, for example, the environment parameters such as impact, noise, electromagnetic radiation, ventilation, dust, and harmful gas; the second one is the non-limit evaluation parameters, for example, environment parameters such as vibration, temperature, humidity, and illumination; the following two categories of single factor evaluation models are proposed basing on the above analysis. Category 1: environment parameters evaluation model based on limit evaluation.

When evaluating this kind of parameters, first, limit inspection shall be conducted: if it is lower than the limit, then quantitative analysis shall be taken for the measured value according to the demands of evaluation; then, the weight coefficient is given for comprehensive evaluation. The flow is shown in Fig. 1. What should be described is that not all limit evaluation parameters, after exceeding the limit, will immediate threat to life safety. This kind of parameter shall be directly given the

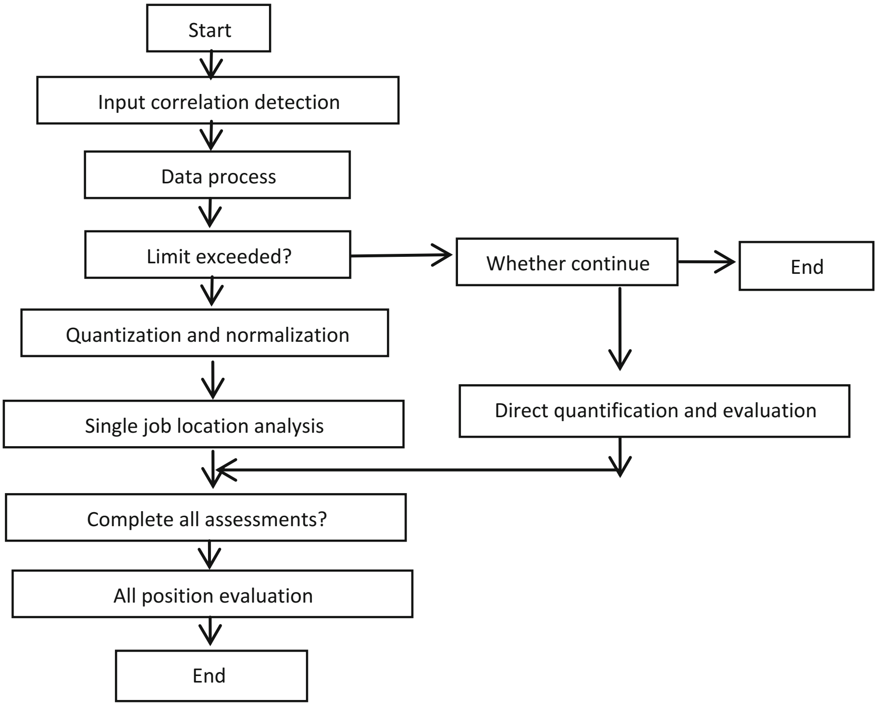

Fig. 1 Evaluation process of environmental parameters based on limited value evaluation

worst evaluation results when it exceeds the limit, and then the comprehensive evaluation of other parameters and cabin environment shall be continued.

Category 2: Environment parameters evaluation model based on non-limit evaluation.

When evaluating this kind of parameters, quantitative analysis and normalization are conducted directly according to the demands of evaluation, the key is the quantitative method; then, the weight coefficient shall be given for comprehensive evaluation. The flow is shown in Fig. 2.

3.2 Confirmation of Weight Coefficient of Single Factor Comprehensive Evaluation of Environment Parameters

The subjective weighting method is adopted for the single parameter comprehensive evaluation of the whole vehicle. Both the level analysis method and the optimum order method are applicable. Two methods differentiate the weight through multiple comparison, but the level analysis method is used for multi-level analysis with obvious advantage, however, the calculation quantity of it is relatively

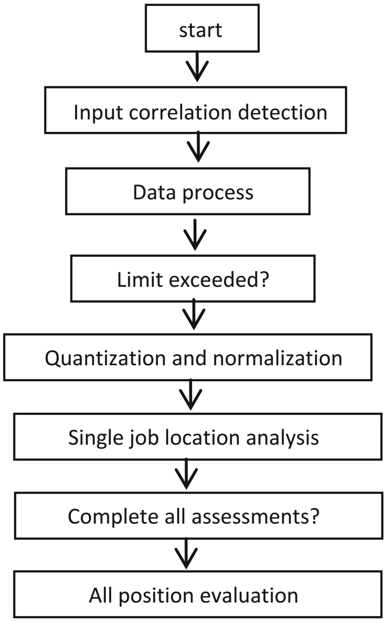

Fig. 2 Evaluation process of environmental parameters based on non-limited value evaluation

big. Optimum order method has relatively less calculation quantity and is applicable to the distribution of multidimensional weight of the same level. Since the single factor evaluation of whole vehicle has less level, with consideration on the actual operation, it is suggested to distribute the weight with optimum order method.

Multiple comparison is adopted for n factors, if index i is important than index K, then index i is 1, equal importance is 0.5, otherwise, it shall be 0, the score is α_{ik} shown as below, λ_i means the weight of index i. Then λ_i is calculated with the formula below

$$\lambda_i = \frac{\sum_{k=1}^{n} \alpha_{ik}}{n(n-1)/2 + 0.5n}$$

3.3 *Quantitative and Normalization of Single Factor Evaluation of Environment Parameters*

3.3.1 Normalization Method of Non-limited Indices

The quantitative and normalization of environment parameters must abide by the consistency principle of comprehensive evaluation, and the environment parameters are main subject to the evaluation indices provided in the relevant evaluation method and standard, and quantitative normalization is adopted with the mathematic methods such as linear interpolation and exponential curve fitting. For example, the normalization method for steady state noise index is shown as below:

Normalization is conducted for steady state noise basing on continuous working time. Since nonlinear relation exists for the allowed sound level and allowed exposure time of steady state noise, least square exponential curve fitting method is adopted for processing [4]. The formula is shown as below:

$$T(A) = ca^{bA},$$

$$R = \sum_{i=1}^{n} (\Phi(A_i) - T_i)^2 = \sum_{i=1}^{n} (ca^{bA1} + ca^{bA2} + \cdots + ca^{bAn} - A_i)^2,$$

where

A allowed sound level;
T allowed exposure time;

a, b, and c are undetermined constants. Please refer to the least square method principle to get the undetermined constants.

The steady state noise quantitative index <90 dB is recorded as 1, and the noise quantitative index >113 dB is recorded as 0, the steady state noise quantitative index L basing on 8 h benchmark continuous working time is

$$L = \begin{cases} 1 & A < 90 \\ \mathrm{L} = ca^{bx}/8 & 90 \le A \le 113 \\ 0 & A > 113 \end{cases},$$

where

A steady state noise A weighted sound level, dB

Constant $c = 8.59 \times 109$, $a = 2.72$, $b = -0.23$.

3.3.2 Quantitative Normalization of Limit Indices

Limit indices compose of pulse noise, CO concentration of shooting conditions, electromagnetic radiation, impact, ventilation, and so on. The quantitative normalization of limit indices is conducted under the condition without exceeding the limit. The quantitative normalization formula is shown as below:

$$y_{ij} = 1 - \frac{\underset{1 \le i \le m}{P(x_{ij})} - x_{ij}}{\underset{1 \le i \le m}{P(x_{ij})}},$$

where

m	limit indices;
j	working conditions;
x_{ij}	measured value;
$P(x_{ij})$	index limit.

4 Comprehensive Quantitative Evaluation Research on Equipment Cabin Environment Parameters

4.1 Confirmation of Weight Coefficient of Comprehensive Evaluation Indices Basing on Delphi Optimization Algorithm

Due to the importance of weight coefficient, the method of confirming weight coefficient has earned high emphasis from people. The common methods for confirming weight main include Delphi method, expert investigation method, and judgment matrix analysis method. Delphi algorithm is optimized in this research. The optimized Delphi algorithm calculation steps are shown as below: the evaluation of the investigated personnel on the factor u_i is used as evaluation matrix. The evaluation score of digit k given by the investigated personnel on factor u_i is recorded as S_{i-k}, (i-factor u_i, i = 1, 2, …, m; k-investigated personnel of digit k; S—score), and S_i value evaluation table of each investigated personnel is listed out. On the assumption that there're n investigated personnel, the investigation results of all investigated personnel are combined to form one evaluation matrix with n lines and m rows (Table 2).

The above-mentioned evaluation matrix is calculated as below:

if $S_{i-k} > S_{j-k}$, $P_{ij-k} = S_{i-k} - S_{j-k}$; otherwise, $P_{ij-k} = 0$. P_{ij-k} means the relatively important score of evaluation factor u_i to evaluation factor u_j in the opinion of digit k investigated personnel, which is named as the priority score of evaluation factor u_i compared with evaluation factor u_j. All P_{ij-k} values are added to produce:

$$P_{ij} = \sum_{k=1}^{n} P_{ij-k},\; i = 1, 2, \ldots, m;\; j = 1, 2, \ldots, m. \tag{5}$$

It is the priority scores plus of all the investigated personnel on evaluation factor u_i compared with evaluation factor u_j. The evaluation scores of the evaluation

Table 2 Evaluation of the Si Value of the First k Crew

Factor number	u_1	u_2	…	u_m
Crew scoring	S_{1k}	S_{2k}	…	S_{mk}

factors are processed one by one according to the above-mentioned algorithm, it produces $m \times m$ P_{ij} values, the priority score matrix formed is shown in Table 3.

P_{ij} calculates weight coefficient, accumulate the P_{ij} values in all lines of Table 3 to produce:

$$P_i = \sum_{i=1}^{m} P_{ij}, j = 1, 2, \ldots, m. \tag{6}$$

P_i characterizes the total priority score of factor u_i compared with other evaluation factors, it makes

$$P = \sum_{i=1}^{m} P_i. \tag{7}$$

Set $a_i = P_i/P$, then a_i can characterize the influence degree of factor u_i to the evaluation. It is known from the calculation method, $\sum_{i=1}^{m} a_i = 1$; normalization is not necessary for the calculation results.

4.2 Comprehensive Weighed Evaluation of Equipment Cabin Microenvironment

After Level-3 indices evaluation for single factor parameter, dimensionless value and weight coefficient of Level-2 indices of vibration, noise, harmful gas, temperature, and humidity is produced, then processing according to weighted average to produce the comprehensive evaluation result. The calculation formula is:

$$I = \frac{\sum_{i=1}^{n} z_i w_i}{\sum_{i=1}^{n} w_i} \tag{8}$$

where $0 \le w_i \le 1, \sum_{i=1}^{n} w_i = 1,$

w_i—weight coefficient, z_i—dimensionless value of environment parameter, n—quantity of environment parameter.

Table 3 Improved priority scoring matrix

Factor number	u_1 u_2 …… u_m
u_1	0 P_{12} … P_{1m}
u_2	P_{21} 0 … P_{2m}
……	… … 0 …
u_m	P_{1m} P_{2m} … 0

5 Conclusion

This paper has made research on the human–machine environment of military equipment cabin, established the Level-3 evaluation indices system of man–machine environment, and proposed the quantitative method of limit indices and non-limit indices and Level-3 indices evaluation method according to the characteristics of different evaluation parameters. On this basis, this paper has optimized the Delphi algorithm to get the weight coefficient of Level-2 and Level-3 evaluation indices of the evaluation indicators, and conducted the quantitative comprehensive evaluation of the whole cabin environment to get the comprehensive quantitative indices of the man–machine environment, which provided the references for the objective evaluation and optimization design of the equipment human–machine environment.

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The Comparison Study of Usability Test Methodology Based on Eye-Tracking Technology

Zengyao Yang, Yu Zhang, Meng Li and Tianning Chen

Abstract Eye-tracking technology, as an objective-recording method of user's eye movement data, has widely been applied in human–computer interface usability test. The quantitative analysis of eye movement data is good at comparing different UI designs; however, it can hardly probe the influential factors of usability issues from a UCD perspective. This research aimed at improving the validity of usability test, and tried to fill in the gap of merely applying eye movement data in usability test. In this paper, we compared the characteristics and differences of concurrent and retrospective think-aloud on UI usability evaluation, which were combined with eye-tracking system. We found that concurrent think-aloud would interfere users during the tests, thus increased their mental stress and cognitive workload, which suits assessing simple-operation and low-cognitive-workload tasks; the retrospective think-aloud enables user to operate more naturally, thus is proper for more complex task chain testing. Moreover, the retrospective think-aloud is more efficient for analyzing the cognitive factors of usability issues in-depth.

Keywords Eye tracing · Usability test · Think-aloud · Cognitive workload

1 Introduction

In the assessment of the human–computer interface design, generally, the traditional usability test methods for the user interface are that the participants operate the interfaces, and the main testers record the user's operation behaviors and analyze the user's operation characteristics, etc. These methods can provide suggestions and help for improving the human–computer interface design in different degrees, but the traditional usability test methods have some problems in practical application,

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such as the operation of participants may be influenced by the main tester's speech and acts, the record of the result data is influenced by the main tester's preference and not very objective, the analysis of the test data mainly depends the main testers' knowledge and experience and is too subjective, etc. The eye-tracking technology can accurately record the objective eye movement information when users operate so as to improve the validity of the usability test. Goldberg and Wichansky discussed the application fields of the eye-tracking technology [1], and the product usability test is one of them. Goldberg believed the eye-tracking technology has been successfully applied to the usability test and can provide design guidance [2], e.g., when the user gazes at the interface element for an overlong time, it means the user has a cognitive difficulty, while the user's cognitive change can be extracted by scanning data.

In the usability test combining with the eye-tracking technology, the eye movement data themselves recorded by the eye movement system cannot disclose the user's operation, motivation, intention, understood meanings, etc. Thus, the user data recorded by the eye-tracking technology shall be explained further by the user [3]. In the usability test, the explanatory information of the data is mainly obtained by the think-aloud method [4–6]. The think-aloud can be classified as concurrency think-aloud and retrospective think-aloud according to different test methods, wherein the concurrency think-aloud requires the user to continuously express his/her thinking, expectation, decision, etc., during test, therefor it influences the user's actual operation; while the retrospective think-aloud requires the user to recall his/her operation process after a silent operation, and when recalling, the user will add or delete some information, which decreases the data accuracy. Pointed out by Guan et al., using the video playing with the eye movement gazing path for stimulating the retrospective think-aloud is effective and reliable, and using the video playing with the eye movement gazing path for stimulating the retrospective report is helpful for retrieving the information from the longtime memory [7]. But he doesn't compare the characteristics of the two test methods and the influences on the user's psychological properties. Found out by Bowers and Snyder, when the common screen recording is used for stimulating the user's think-aloud, the word quantities generated by the user during the concurrency think-aloud and the retrospective think-aloud are different, and also the contents expressed by the users are differed [8]. In the usability test, the user's operation flow can be observed directly during the test process while the user's cognitive data has to be obtained by think-aloud. The paper proposes to study and compare the difference of the user's output language types between the two test methods, and compare the influences of the test methods on the usability problem analysis.

From a perspective of the improvement of the usability assessment validity, the paper combines the eye-tracking technology with the think-aloud test and applies the theories of design psychology, the human–computer interface, and user model, to establish the user-centered usability test method and process based on the eye-tracking system, to build the experiment platform, to compare the user's subjective data and physical data during the concurrency think-aloud and the retrospective think-aloud by experiments, to point out the characteristics and difference of the influences of the two test methods on the user's psychology and cognition of the two test methods, and to propose the applicability suggestions of the two methods.

2 Construction of Test Platform and Implementation of the Experiment

According to the user-centered usability test method, the authors designed and constructed the think-aloud test experiment platform equipped with SMI RED 250 eye-tracking system; we set a CTA (Concurrency Think-Aloud for short) control group and a RTA (Retrospective Think-Aloud for short) experiment group according to the two think-aloud modes, and analyzed the difference and characteristics of the two test methods.

2.1 Construction of the Experiment Test Platform

The test object was the Word from Microsoft Office which is widely used in daily work. During the experiment, the tester asked the user to complete ten typical tasks with difficulty gradient, such as amplifying the font size as "small one," text format *combining two rows as one*, and quoting caption in a crossway.

The experiment equipment used by the test is the RED remote desktop eye-tracking system from SMI Ltd. The experiment platform was built in the Experiment Center software system, and comprised of one calibration, one validation, 11 pictorial stimulations (used for showing the user's goal task), 11 screen recording stimulations (used for recording the user's operating process), and 24 text stimulations, and there are 45 trials together. The experiment also uses the Affectiva Q Sensor 2.0 emotion measurer which was wore by the user on the forearm wrist during the test for collecting the tested user' EDA variation during the operation tasks.

The test was conducted in the human factors human engineering lab, Mechanical Engineering School, Xi'an Jiaotong University. The unified light source is set in the laboratory so as to avoid the interference to the test results caused by visual fatigue and illumination difference.

2.2 Experiment Process and Data Collection

Two test groups are set in the experiment, i.e., RTA as experiment group and CTA as control group. During the experiment, the CTA group uses the concurrency think-aloud to complete the operation content, and the users are required to operate and describe the operation process and thinking process while operating the tasks, and the users are encouraged to TALK more. The RTA group applies the retrospective think-aloud to complete the experiment content, and the users are required to be silent during operation (the user is allowed to speak to himself/herself). After the two groups complete the operation, the video with the eye movement gazing paths is displayed for stimulation and letting the users to recall their thinking and operating processes. During the pretest phrase, the participants wear the Affectiva Q Sensor 2.0, get familiar with the laboratory environment, and receive basic training and psychological instruction for at least 30 min. Each test lasts for about 70–80 min in total. There are 20 users from 19 to 27 years old who have attended the experiment. These users are the average users of the Office software. During the test, the 20 persons are randomly allocated to the CTA group or the RTA group, and the ratio of male to female in every group is 1:1.

During the test, four types of data are collected: (1) the conventional usability problem data recorded by the main tester; (2) the user's think-aloud vocal recording data; (3) the EDA data collected by the Q Sensor wore by the users; and (4) the objective users' eye movement data collected by the SMI RED 250.

3 Experiment Data Analysis and Discussion

3.1 Influence of the Two Test Methods on the User's Psychological Tension

During the experiment, the Affectiva Q Sensor 2.0 is used for collecting the user's EDA data of which the unit is microsiemens (μS). When the user feels nervous, anxious, or excited during the experimental operation, the EDA level will increase, and when the user feels relaxed and calms down, the EDA level will decrease. Three users are, respectively, extracted from the two groups for comparing the user' EDA level variation tendency during the test, as shown in Fig. 1. At the same time, indicated by the EDA mean value and standard deviation of the two groups (as shown in Table 1), in the operation phrase, the user's EDA data deviation is clear, and the mean values are, respectively, 0.88 and 0.25 μS. The deviation in the retrospective stage is not clear. It proves the user's psychological tension in the concurrency think-aloud stage is higher than that of the silent operation which is more helpful for the user to relax.

In the concurrency think-aloud, the user is required to complete the operation mission and describe their behavior and psychological states at the same time, which clearly increases the user's mental tension, and thus, when completing the test mission, the EDA level of the CTA group is clearly higher. RTA group is not required to operate and talk at the same time when implementing the test tasks; thus, their mental status is relaxed, so the EDA level is relatively lower. During the

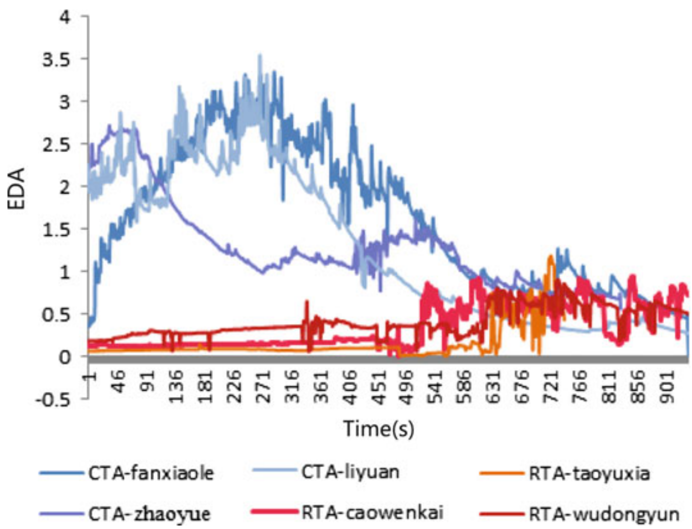


Fig. 1 EDA variation trends of two groups in testing

Table 1 Difference of EDA level of two groups in operation and retrospection

Group	Operation stage (μS)		Retrospective stage (μS)	
	Mean	Standard deviation	Mean	Standard deviation
CTA	0.8765	0.15265	0.5301	0.35982
RTA	0.2476	0.86613	0.4486	0.48509

retrospective stage, both of the CTA group and the RTA group are required to recall their operation processes, and at this time, their EDA data is not significantly differed.

3.2 Comparison of the User's Cognitive Workload Under the Two Test Methods

The cognitive workload is defined as the total amount of the human cognitive sources required for the information processing during task completion. The user's time spent for the cognitive activity can be approximately observed by the duration of gazing at the screen when the user is operating a computer, and then his/her cognitive workload during computer operation can be approximately estimated. It is equal to the ratio of the think time (the duration of eye gazing or pausing) to the total operation time [9]. The paper adopts the direct objective measurement method to estimate the user's cognitive workload.

The formula for estimating the user's cognitive workload is as follows:

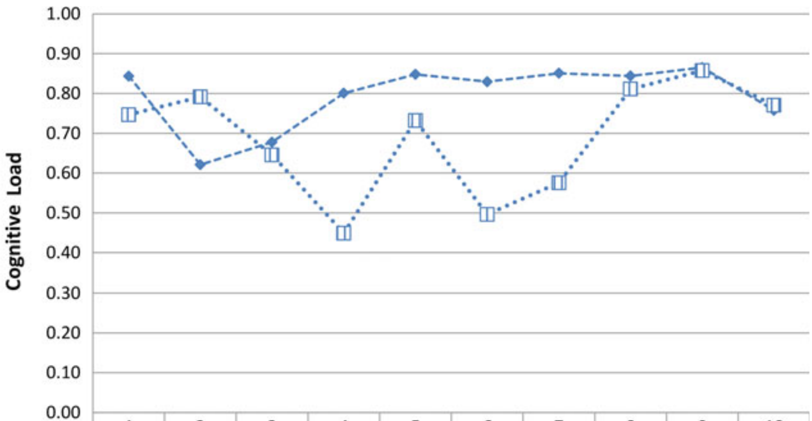
$$C = T_1/T_2 \tag{1}$$

where

C cognitive workload;
T_1 total eye gazing time (ms);
T_2 total operation time (ms)

The total gazing time of the eye and the total operation time are both recorded by the SMI eye tracker, and after the data is exported, the mean values of the users' cognitive workload of the two groups for completing the ten tasks are calculated according to the formula (1). The average value of the users' cognitive workload in the CTA group is 0.79, which is higher than 0.69 of the RTA group. Indicated by the data of Fig. 2, under the condition of completing the same task, generally the CTA group is higher than the RTA group, wherein the biggest one is from task 4 of which the difference is 0.35, and to task 2 and task 10, the users' cognitive workload of the CTA group is smaller than that of the RTA group.

The longer the gazing lasting time is, the more difficult the user will be to extract the information and then the higher the cognitive workload will be. Because the test methods of the two groups are different, compared with the operation of RTA, the user's processing quantity is increased for the CTA group during task completion, namely the brain needs the additional cognitive processing for TALK; thus, the user's cognitive workload is increased.



	1	2	3	4	5	6	7	8	9	10
Group CTA	0.84	0.62	0.68	0.80	0.85	0.83	0.85	0.84	0.87	0.76
Group RTA	0.75	0.79	0.65	0.45	0.73	0.50	0.58	0.81	0.86	0.77

Fig. 2 Average cognitive workload of CTA and RTA on different tasks

3.3 Comparison of Language Types of the Two Think-Aloud Methods

The analytical key point of the think-aloud is the user's subjective language description. Hansen proposes the three types of retrospective language marks for the eye movement records [10] as follows: manipulative operation, visual operation, and cognitive operation. However, the cognitive operation framework proposed by Hansen is oversimplified. In fact, the cognition relevant to the user's action psychology includes five dimensions, i.e., intention, understanding, expectation, judgment, and memory. Moreover, Hansen only compares the user language data under the two types of RTA modes (playing back the video with the eye movement path and the common video).

During the experiment, by comparing the language data types of the CTA stage of Group CTA, the RTA stage of Group CTA, and the RTA stage of Group RTA, the extended language type framework is to compare three main factors—manipulative operation, visual operation, and cognition operation—and the secondary frame under the cognition operation comprises of intention, understanding, expectation, judgment, and memory.

The experiment collects the vocal recording samples about 11 h, and on the basis of counting the data types of the samples, the user's think-aloud language data types under three modes are compared, and then we find out the user's language types in the CTA group in the CTA stage and the RTA stage have significant differences: The ratio of manipulative operation in the CTA stage is 53.4 and 35.9% of the cognition operation, while the ratio of manipulative operation in the RTA stage is 16.8 and 72.7% of the cognition operation. The total language amount described in the RTA stage of the RTA group is higher than the one of the CTA group in the CTA stage. The differences of the three language ratios in the manipulative operation, visual operation, and cognitive operation of the CTA group and the RTA group in the RTA stage are small. The ratios of the visual operation data under the three modes is slightly differed and are, respectively, 10.7, 10.5, and 9.6%. The statistic ratios of the language types are shown in Fig. 3.

In general, in the CTA stage, the users describe their manipulative operation most, which is relevant to human thinking characteristic, i.e., the human thinking speed is far more higher than human speaking speed. When the users operate and describe at the same time, the users' key thinking point is for how to OPERATE; thus, the language description is generated with the manipulative action. In the RTA stage, the users describe their cognition most, and at the same time, the users watch the screen recording playback video with the gazing path and do not need the manipulative operation but only WATCH and THINK; thus, the users pay more attention on describing their cognition operation.

Among the cognition operation data, the users' language amount of the intention, understanding, expectation, judgment, and memory in the three modes are counted, and then, we get the total quantity of the cognition languages in the CTA stage are 127, which is far more less than that of the RTA stage. Among the users'

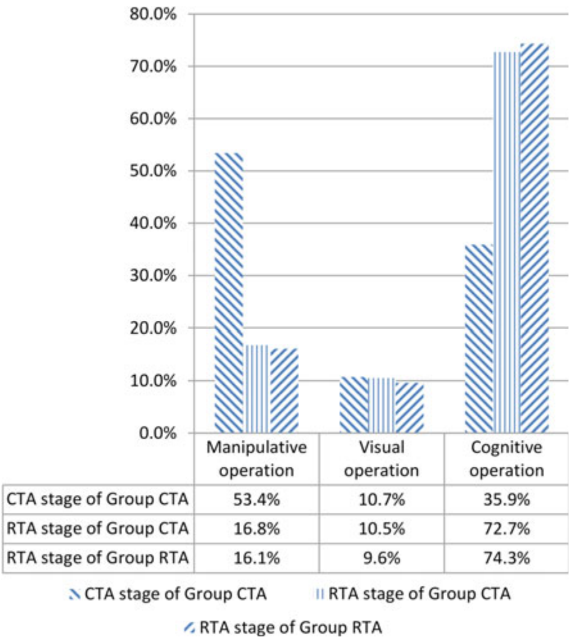


Fig. 3 Comparison of language data types in think-aloud in three modes

mean ratio of the cognition operation, the memory is 7.9%, which is the lowest, and the judgment is 27.6, which is the highest. The intention, understanding, and expectation are basically the same. The ratios of the users' cognition data in the three modes are shown in Table 2.

Among the data collected via the UI usability test, the users' manipulative data can be directly observed and judged during the users' operation. The users' eye movement data can be recorded by the eye-tracking system. The users' cognition data can help significantly to probe the cognition usability problem. In the retrospective think-aloud test, the quantity of the users' cognition operation languages is

Table 2 Ratios of user's cognitive operation expression in three modes

	The total number of cognitive language	Cognitive operation				
		Intention (%)	Understand (%)	Expectation (%)	Judgment (%)	Memory (%)
CTA stage of group CTA	127	20.5	17.3	22.8	36.2	3.1
RTA stage of group CTA	311	24.4	20.3	24.4	20.9	10.0
RTA stage of group RTA	370	22.2	23.2	16.5	30.3	7.8
Average proportion		22.8	21.2	20.5	27.6	7.9

much higher than that of the concurrency think-aloud; thus, the retrospective think-aloud is more effective for analyzing and assessing the cognition usability problem.

4 Conclusion

The study of the paper finds out that when the eye-tracking equipment is used for the usability test, the concurrency think-aloud test method increases the users' psychological tension and cognitive workload, then influences the accuracy of the test result, so it is suite to the simple tasks. The retrospective think-aloud is closer to the user's operation in a natural status and is better for the complex tasks or the task chain test. The language description types of the concurrency think-aloud and the retrospective think-aloud are differed in a certain degree, i.e., the CTA users pay more attention to describing their manipulative action while the RTA users pay more attention to describing their cognition. The ratios of three types of language for the two groups in the retrospective stage are not significantly differed. Among the mean ratios of the cognition operation language, the memory is the lowest (7.9%), and the judgment is the highest (27.6). In brief, the RTA is more effective for intensively evaluating the usability problem of the cognition.

The study of the paper can provide a theoretical and methodology reference for the studies on the similar topic, e.g., conducting a study of eye movement of reading or visual searching state, in the psychological study field; studying the consumer's visual psychology to evaluate the design and effects of advertisements in the commercial field; analyzing the driver's driving psychology in the traffic field so as to provide theoretical benchmarks for designing the control panel and the cabin environment; assessing the pilot's flight cognition test in the aviation field; and analyzing people's motivation, intention in social science. In the above fields, if the think-aloud can be applied in study, richer test data can be generated by the participants, and the validity of the eye movement study can be improved.

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Construction of Backup System and Operating Mechanism for Military Archives

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Abstract The military archives are a valuable cultural asset of the CPC, the country and the army, and also very important information resources. Once the archives are damaged, irreparable damage will be caused. Therefore, the establishment of military archive security system is the fundamental guarantee of military archives work. Information security is both the first task of the archives administrator and the lifeline and bottom line of archival work. Based on the actual needs and development of the military archives, we should use innovative means and technology and focus on the military archive backup system and operational mechanism. The only purpose of this paper is to scientifically build up a backup system and a flexible and reliable operating mechanism archive with the characteristics of the PLA and provide a strong service guarantee for winning the wars.

Keywords Military archives · Archive backup system · Operating mechanism

1 Introduction

Archival data security is a key component of archival security architecture. At the national level, archival data security has been incorporated into the "three systems" (i.e., archives resource system, archival use system and archival security system), which also show the importance of archival security system. At the military level, with the in-depth development of information-based archives management, the archives-related departments in the PLA has started the primary study on the off-site heterogeneous studies of archives step by step since the second five-year plan

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period but at a pace slower than local relevant authorities, not to mention overseas relevant authorities. Anyway, no matter for local relevant authorities or for military relevant departments, systematic and in-depth study on archive backup system construction and operating mechanism is still needed. Presently it is difficult to ensure the safety of archival data or "win" the wars.

Especially in today's information technology conditions, it is imminent to scientifically construct military archives backup system and operational mechanism. Combined with the military system reform, it is time to design this work from upper level in a long run.

2 Security Threats to Archival Data

The archives department, like other departments, may also face various emergencies and unexpected events such as earthquakes, floods, fires, and mass incidents. A considerable proportion of the archive departments have no prospective contingency plans, or their contingency plans do not meet the actual work so that these departments cannot play an effective role. As a consequence, before unexpected events, they have no idea to do something useful, resulting in loss or damage of a large number of archive data and e irreparable huge losses to the archival undertaking of the CPC, the country and the army.

Especially in the information conditions, the security of archival data is even more important. Whether there is threat of natural disasters, or the subjective factor of the disaster, once the preserved archived data are destroyed, tampered or lost, the consequences will be disastrous.

The factors that threaten the security of archive data generally include the following:

(1) Natural factors: fire, earthquake, hurricane, lightning, flood, strong convective extreme weather, industrial accidents, etc.;
(2) Human factors: reselling, deliberate destruction, theft, computer viruses, operation error for violation of procedures or lack of experience, accidental deletion and modification caused by pressure and panic, etc.;
(3) Hardware failure: damage of media and hard disk, server downtime, equipment power failure, memory failure, etc.;
(4) Software failure: database design flaws, application software failure, operating system failure, etc.;
(5) Network failure: failure of network connection, failure of network card and driver, etc. and
(6) Wars and conflicts;
So, it is urgent and vital to effectively deal with the above-mentioned accidents, to ensure the security of archival data and truly prospective scientific build an archive backup system and its operating mechanism.

3 Main Links and Contents Involved in Archive Backup System

To meet the integration requirements of the armed forces, ensure the permanent security of military archives and scientifically construct military archives backup system and its operating mechanism, following major links and contents are important [1].

(1) To complete information works (including paper archives, photo archives, audio and video archives, physical archives and special carrier archives, etc.) of archives on all kinds of carriers in the PLA in accordance with the unified requirements of the PLA;
(2) To research and develop new storage technologies, including advanced large-capacity storage media and storage technology overseas, focus the study on advantages of cloud storage technology application and fully discuss large data in the context of storage technology while objectively analyzing the risks of cloud storage technology to archives heterogeneous backup and finding effective preventive measures;
(3) To study archive data remote heterogeneous backup, including selection of off-site heterogeneous backup environment, off-site heterogeneous backup, off-site heterogeneous backup media, location of off –site heterogeneous backup (center), etc. [2];
(4) To study archival data backup technology and focusing the advantages and disadvantages of several common backup technologies and the backup technology meeting the intelligent demand of user at the time of service [3];
(5) To study archival data disaster recovery technology, including the construction of archival data recovery system and linkage mechanism, focusing on the absolute security of data sources;
(6) To build up archival data backup mode and system, focusing on the combination of characteristics of archival data and user orientation and make study and deployment for the PLA as a whole [4];
(7) To study the operating mechanism of archive data backup system,, unify standards combined with the actual needs of the army and use stable linkage mechanism from the actual situation of the combination of peace and war to ensure that the archive data backup system is in normal operation free of risk [5];
(8) To study and explore the relevant laws and regulation on the construction and operating mechanism of archive backup system and establish the relevant system in the form of legislation. To solve out the problem that different authorities handle current archive backup works in different ways for absence of relevant regulations institutionally by revising the "Archives Law", "Measures of Implementation of Archives Law" and "Regulations for Archives of Chinese People's Liberation Army", study the relevant business standards and management measures and deal with the issues like ownership, standard and duty of archive backup works by law to ensure that the archive backup works are conducted in order in a scientific backup mechanism by laws and rules [6].

4 Basic Conditions and Significance of Construction of an Archive Backup System

Combined with the characteristics of archive works of the PLA, status of archives management and construction of archives laws and regulations, starting from the technical and basic guarantee of archive backup and other relevant works, we should organizationally plan and scientifically build up an archive backup system and an operational mechanism of the PLA.

4.1 Existing Conditions

With the promulgation of National Archives Bureau's "Guide to Prevention and Control of Disasters in Archives", there are existing guiding principles for relevant archive backup studies. At present, the archive backup studies mainly discuss from aspects of strategy, principle, method and backup of digital archive carriers. The study results have laid a theoretical foundation for the construction of the archives backup system in the PLA [7].

At the same time, the archives administrations of some provinces and municipalities have deployed and implemented off-site heterogeneous archives background in accordance with the requirements of "Guide to Prevention and Control of Disasters in Archives". In the process of building up an archives backup system in the PLA, the practical results of these archives backup can be used as references of practical experience of the archives backup work in the PLA and the optimal scheme for military archives backup may be summarized from the practices.

Considering from the existing conditions of the archives of the PLA, it is proved that the archives backup work of the PLA has certain substantial basis and facility and equipment conditions and fully equipped with the practical basis for this job. For example, each archives department of the PLA has built important place keeping archives in 1950s. When we talk these archive backup problems once again today, these resources can be re-planned into the archive backup system with new mission and role of the time [8].

4.2 Foreseeable Guiding Role

The archives backup work of the PLA is not an item of works of a local archives department. It is a major subject to resist the sudden natural disasters, war and human factors and to protect the military archives information resources. Therefore the further promotion and application of archive backup work are impossible without the deployment and study of the archive backup system starting from the archive works of the whole PLA.

The military archives backup system should be discussed from the overall and local aspects of the archives backup work of the PLA, which includes not only the macro environment, technical condition and legal protection of the archives backup system of the PLA, but also the design of specific implementation plan of the archives backup work and making the military archive backup study more overall, normative, coordinated and unified theoretically and practically in combination with characteristics of archives of each military region and each service for future implementation and mobilization of archive backup work in the future.

In the time of digitalization, information security is facing more threats from the carrier, equipment, technology and personnel management and other aspects so as to make the archive backup work more complex and uncertain. With the knowledge of applications of keeping and backup of digital archives home and abroad, we should standardize and study the best common format and path for the military digital archive backup to provide a more standardized way of keeping the backup and ensure the long-term preservation of digital archive information [9].

To sum up, the scientific construction of the army archive backup system and operating mechanism is guided by basic principles of archives work of the PLA, which may be used as a theoretic and practical reference in developing the military archive backup standards and unifying military archive backup strategies and plans in the future.

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Construction of the Virtual Maintenance Human Action Library Based on Motion Capture System

Xue Shi, Pinwang Zhao, Jinlong Zhao, Yue Liu, Shulin Liu, Qun Wang and Ruqiang Li

Abstract The paper selects the maintenance personnel of an engineering vehicle as the tested object. Using the motion capture system, we can collect and handle the various data of the maintenance. Finally, it makes up the dedicated motion library and is easy to use. This avoids the handling and correcting problems, raising the work efficiency significantly. And, we extract the body appearance and the anthropometric measures and record the basic postures of the maintenance personnel. Finally, it makes up the dedicated virtual human body. On this basis, the action library was integrated into the DELMIA software, simulated analysis and evaluated the visual ability, reachability and human body comfort with the DELMIA.

Keywords Virtual reality · Motion capture system · Virtual maintenance

1 Introduction

In recent years, with the rapid development of the VR technology, the research institutes at home and abroad make a great amount of exploration and application for the important application of the virtual maintenance in the maintenance field of the VR technology. In the military equipment field, the virtual maintenance technology is applied to the Lockheed Martin tactics plane system and the F-35 plane. The virtual maintenance training system is also constructed in the M1A1 tank and M1A2 military vehicles of US army. The study of the virtual maintenance in China is mainly concentrated on a few colleges and research institutes. Just as the other emerging technologies, the virtual maintenance is also the product of the multidisciplinary cross and integration and is mainly characterized in the following four parts:

(1) Full digitalization of model: The virtual maintenance belongs to the emulation technology and depends on the model, such as the product geometric model,

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assemblage model, reliability and maintenance model, and maintenance resource model.

(2) Information integration of model: Solving the maintenance runs through the whole service life of the product and relates to many subjects and professional fields, which makes its dependent models various. The description models include the maintenance process model, the activity model, and the resource model. The reasonable integration among models is the significant base for the successful virtual maintenance.

(3) High fidelity of maintenance emulation: The high fidelity owns two types of meanings: One is the high reliability of the emulation result, and the other is the high natural degree of the interaction between human and the virtual maintenance environment.

(4) Naturalization of human–machine interaction: The product maintenance relates to various mutual actions of human–product–tool. The virtual maintenance emulation can only accurately master the essence of the maintenance process by naturally and realistically displaying these interactions so as to accurately find out the problem.

2 Virtual Maintenance

The virtual maintenance is the natural realization of the actual maintenance process in the computer. It adopts the computer emulation and VR technologies and realizes the natural processes of the product maintenance such as the design analysis of product maintenance, planning and verification of the maintenance process, maintenance operation training and maintenance support, and management and control of various levels of maintenance organizations, through the mode of collaborative work so as to reinforce the decision and control abilities of all stages of the service life and all levels of the whole system.

The virtual maintenance is a new maintenance technology. It is supported by information technology, emulation technology, and VR technology and enables people to feel the product performance relevant to maintenance and the reasonability of the maintenance process of the product in future before the product design or maintenance guarantee system is physically realized; thus, the prospective decision and optimized implementation scheme can be made [1].

3 Motion Capture System

With the fast development of the computer software and hardware technology and the emulation technology, the motion capture system in the developed countries has been in the practical stage. With the VR technology becoming more and more mature day by day, the researchers pay more and more attention to the fidelity and natural interaction of the emulation process. The motion capture system can restore the human behavior and physical characteristics in maximum; thus, more and more scientific research colleges have purchased the motion capture system which is used for simulating the high-fidelity emulation of the maintenance process.

The motion capture system of the paper is used for collecting the maintenance personnel's various maintenance gestures, motions, time, and other data in the maintenance work environment.

3.1 Xsens MVN Inertia Motion Capture System

The Xsens MVN is a portable whole-body motion capture solution which can capture the human motions without a camera and will not limit any motion of the tested personnel, is characterized in high flexibility, and can be used indoor or outdoor. The Xsens MVN avoids the problems of signal blockage or marker loss and saves the time spent for the captured data cleaning work. The Xsens MVN adopts the advanced micro-type inertia sensor and the biomechanics model as well as the sensor fusion algorithm. The collected data are recorded by MVN Studio professional software and can be seamlessly integrated with the Autodesk MotionBuilder plug-in unit [2].

3.2 Vicon Optical Motion Capture System

The Vicon optical motion capture system is the capture system based on reflection and needs to attach delicate reflection balls (hereinafter referred to as the marker) on all parts of the passenger. When the red light (or visual light or visual red light) generated by the LED around the optical camera is shot on the surface of the maker point, the marker point reflects the red light of the same wavelength to the optical camera so as to confirm the 2D coordinate of each marker point, and then after being processed by the analysis software of the Vicon capture system, the 3D coordinate of each marker point can be obtained. The human rigid body model can be generated after recording the motion tracks of all marker points [3].

3.3 Software Environment

The Autodesk MotionBuilder is an important 3D motion software of the AUTODESK company and can be combined with the motion capture system to record the live actor's motion. The Autodesk MotionBuilder is the world leading 3D role animation software which is used for making games, films, radio and television, and multimedia. It uses the real-time and role-centered tool integration to capture all missions in the edition range from the traditional insertion of key frames to motion. The software provides technology instructors and artists with the function for processing the hardest and high-capacity animation. The whole paper uses the MotionBuilder software for the post-processing of the capture data [4].

4 Construction of the Maintenance Personnel's Virtual Human Body Data

In the study field of virtual maintenance, generally the virtual human body is used for maintenance training, assistant maintenance analysis, maintenance regulation check, etc.; thus, the maintenance personnel's human body model invented by the computer is required to have the actual maintenance personnel's physical features, motion codes, behavior codes, behavior feature, and intelligence.

4.1 Collection of Virtual Human Body Data

In the virtual maintenance emulation, the virtual human body is used for replacing the actual maintenance personnel for emulating the maintenance process. The paper carries out the appearance feature extraction, collection of human body size, and image photographing of basic gestures to the maintenance personnel in the specific maintenance work. The collection of human body size data is shown in Table 1, and the standard gesture collection images are shown in Table 2.

Table 1 Human body measurement parameters

Human body measurement parameters (cm)					
Height	170	Body	Head length	24	Head
Brachium	70		Neck length	8	
Shoulder	38		Neck circumference	37	
Hand length	18.5	Hand	Hip height	97	Leg
Middle finger	10		Knee height	51	
Index finger	9		Foot length	30	
Thumb	6.5		Foot width	11.5	
Hand to fingertip	45		Sitting height	43	Sitting posture
Waistline 1	75	Waist	Knee height	53	
Waistline 2	90		Top of the head	127	

Table 2 Human body appearance feature and the picture of basic postures

View	Picture	View	Picture	View	Picture
The front view of standing		The front view of stretching arms		The front view of sitting	
The side view of standing		The back view of standing		The side view of sitting	
The front view of the head		The side view of the head		The top view of the head	
The back view of the head		The palm of the hand		The back of the hand	

4.2 Geometric Model of Virtual Human Body

MAYA modeling software is used for constructing the 3D model of the human body, the surface map, and bone bonding. Based on the human body appearance and according to the actual measured data, the maintenance personnel's virtual human body model applicable to the study is formed as shown in Table 3.

5 Maintenance Motion Model

The maintenance motion is the motion used by the maintenance personnel in the maintenance work, such as screwing out the bolt or opening the lid. According to the characteristics of the maintenance motion, we divide the maintenance motion

Table 3 Real human body and the virtual human body

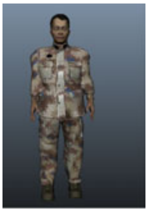
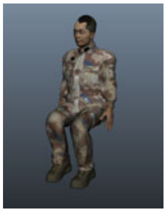
Standing/real body	Standing/virtual body	Sitting/real body	Sitting/virtual body
			

Table 4 Tools of maintenance operation

No.	Type	Method	Description
1	Screws	Prying	With a circular arc movement of pry
		Screwing	Around the longitudinal axis and rotation screwdriver itself
2	Pliers	Griping	Around the link point of plier and clamping
3	Hammers	Thumping	Swing
4	Spanners	Screwing	The circumference of a circle or arc centered on bolt midpoint
		Knocking	Swing
5	Punches	Punching	The circumference of a circle or arc centered on bolt midpoint
6	Pries	Prying	Around the link point of plier and clamping

into the mobile type and operation type, wherein the mobile type motion includes the maintenance operation personnel's position movement and gesture change and adjustment in the maintenance process and the operation type motion includes the maintenance personnel's operation motions for the object. Most of the maintenance operation works use tools. Table 4 lists the main tool types and the methods used for the maintenance work.

5.1 Motion Analysis in the Maintenance Work

Based on the man–machine engineering theory, analysis of the human maintenance motion in the maintenance work process aims to analyze and study the human part motions in the maintenance work. The complex maintenance steps are decomposed into a series of basic work units and the corresponding human motions are mapped by analyzing the detailed maintenance work of a component, and also the redundant

Table 5 List of maintenance motion

No.	Maintenance motion
1	Using the spanner, unscrewing the track shoe
2	Using the socket spanner, unscrewing the locknut
3	Using the pry and ball-peen hammer, thumping the track link pin off
4	Changing the old track shoe
5	Connecting the new track shoe to the track
6	Together the tracks by the track connector and aligned
7	Using the ball-peen hammer and thumping the guide pin into the earhole
8	Putting the gasket into the earhole
9	Thumping the track pin into the earhole
10	Using the socket spanner, screwing the locknut
11	Using the tension tools, tensioning the tracks

Table 6 List of maintenance tools

No.	Tools
1	Tension tools
2	Perch
3	Socket spanner
4	Punch
5	Octagonal hammer
6	Ball-peen hammer
7	Track connector
8	Guide pin

motions are removed, and the necessary motions are combined into the standard motion sequence. Now we take the maintenance work of replacing the crawler board of an engineering work vehicle as the example for analysis, and the lists are shown in Tables 5 and 6.

6 Capture and Collection

The MVN inertia motion capture equipment is used for collecting the human body motion data of the typical maintenance mission. The process for capturing the motion actually is more like shooting a film, because it is closely relevant to the time sequence and needs the site condition, mission division, actors, director, script holder, cameraman, and the other relevant personnel. According to the characteristic, we carry out division of work of the personnel for the collection mission. Besides the test personnel and the undertaking of the prototype of the human body, we also set one person for supporting the motion capture equipment, one person for computer terminal monitoring, one person for adjusting and wearing the motion capture clothes of the tested personnel, a cameraman for recording the tested personnel's motion process, and a director and script holder for the quality control of the whole maintenance process script.

Although we prepare well, a plurality of problems occur in the actual collection process, which lead to repeating the collection of every motion sometimes. The weather also greatly influences the tested personnel, the test is carried out in the laboratory without any heating equipment in winter, and the motion capture clothes are also required to be worn in the way of being close to the body, and then, the capturing can be more accurate; thus, the tested personnel cannot wear the heavy padded coat, and at last, the tested personnel show unnatural and inflexible motions.

7 Data Processing

When the MVN inertia capture equipment is used for capturing and collecting the motions when the human body's feet are above the ground or the human body crawls in a kneeling position, the drift or dislocation of the position inertia sensor sometimes is generated, and then, the motion capturing is distorted. To this problem, we use the MotionBuilder software for the post-stage processing. During the test, we especially videoed the motions of the whole maintenance process. When processing the post-stage distorted model, we refer to the videoed actual motion gestures and then modify the human body's joints frame by frame, which is shown in Fig. 1 in which the deformation of the ankle joints is corrected [5].

After adjusting the role's joint curves, and correcting the motion and gestures by referring to the video, the post-stage processing of the ankle curve is shown in Fig. 2.

In the post-stage processing, we also correct some parts of the virtual people's finger motions and then divide the motion data into relatively independent small

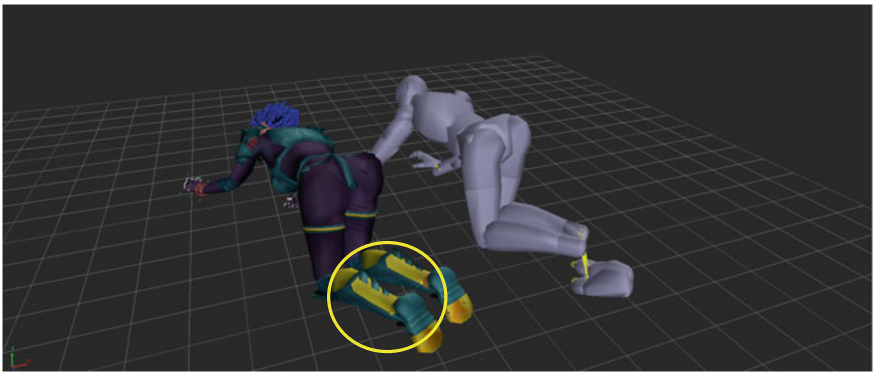


Fig. 1 Correction of the joint

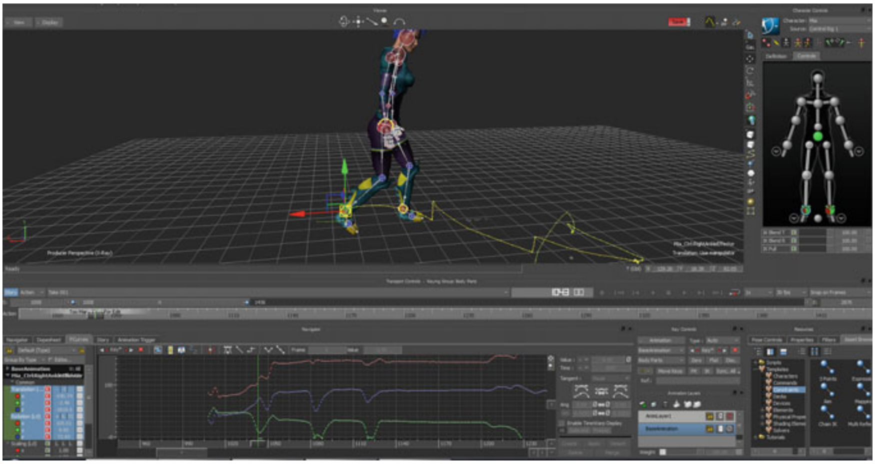


Fig. 2 Correction of the motion curve

section motions, and then correspondingly organize the big maintenance mission and a series of small maintenance work procedures into a tree-shaped structure for storage. At last, we respectively introduce the divided motions into the DELMIA platform for test.

After the work, we find out some problems which can be avoided in next motion capturing so as to reduce the work amount and time for the subsequence post-stage processing.

8 Conclusion

After capturing the maintenance personnel's maintenance motion and maintenance gesture, on the one hand, the design personnel can directly observe the maintenance personnel's status during work, and on the other hand, the design personnel can use the emulation software to objectively analyze and assess the maintenance personnel's maintenance visibility, accessibility, and human body comfortability on the basis of the actual collected data. Based on the above, the data statistics can be carried out to the maintenance work time through the emulation of the virtual maintenance process, and then, it will be used as the design input of the maintenance design to be fed back to the design personnel. Then, the maintenance availability of the product can be optimized by design, emulation, improvement, and verification.

Compliance with Ethical Standards The study was approved by the Logistics Department for Civilian Ethics Committee of China North Vehicle Research Institute, Beijing, China.

All subjects who participated in the experiment were provided with and signed an informed consent form.

All relevant ethical safeguards have been met with regard to subject protection.

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Decomposition and Classification of Flight Operation Tasks of Civil Aircraft

Xueli He, Lin Ding, Chongchong Miao and Lijing Wang

Abstract After referring to the analysis method applicable to the workload of the military aircraft and the flight operation manuals of the civil aircraft A320 and B737, the paper proposes the task decomposition steps applicable to the flight operation procedures of the civil aircraft, and then takes the pilot's normal operation procedures of A320 as the example to carry out the task decomposition on the basis of the flight operation task decomposition method and steps proposed by the paper, and classifies on the basis of the obtained analysis of the human and machine attributes. Combining with the classification of the cockpit human–machine interfaces of the civil aircraft and the development of the displaying and control interfaces, the paper determines the flight operation task type applicable to the civil aircraft. After talking with the expert pilots of different aircraft models, the task classification is consistently approved, and the expert pilots believe the classification table is reasonable and completed. For the results of the face-to-face talks of the expert pilots of different aircraft models are consistent, the classification at present is believed to be universal to the classification of the flight operation tasks of the civil aircraft.

Keywords Task decomposition · Task classification · Task analysis · Display and control interface · Flight operation

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1 Introduction

The analysis and verification of the pilot's workload are crucial to the design of the aircraft. The air worthiness regulations at home and abroad show relevant requirements on the work responsibilities of the staff and if the crew's workload is over high of the civil aircraft (such as the air worthiness regulations AC25.1523 [1] and CCAR25.1523 [2]). The common design cycle of the civil aircraft is five to fifty years. In the sample aircraft with a pilot, only the workload prediction model established by the task analysis method can be used for the analysis and assessment of the crew's workload. Since 1980s, there are many researchers begin to use the task analysis method for predicting the crew's load in the early design period of the aircraft, and it mainly targets to the military aircraft [3, 4]. The task analysis can be defined as the study of the operator's action or cognition process for completing the task target. The task analysis generally comprises of the following contents: decompose the tasks into the sub-tasks and simple task steps; all tasks are distributed to different persons, and where communication is required shall be explained; describe the correlation and connection between the sub-task or task steps; classify the task type (or the task step type); and identify the cue and feedback that supports the task steps.

Now there are many task analysis methods that can be used, and all of these methods decompose one task into a plurality of steps and sub-steps and describe the personnel' s behaviors according to the body activities or thinking activities (such as diagnosis and decision) relevant to the system. In the article written by Kirwan and Ainsworth [5] in 1992, the writers listed more than 20 task analysis technologies. Some mature analyses include the hierarchical task analysis method and the table task analysis method, wherein the hierarchical task analysis method is carried out according to the logics from top to bottom, the first is the main target of the task, then all branch tasks and sub-tasks, then the necessary conditions for executing these tasks, and the final target is the operation which shall be carried out for completing the task target or the hierarchical structure comprising of motions. And the table task analysis method can be used for special tasks or scenarios, checks every motion (the most bottom layer) identified by HTA (hierarchical task analysis) or other method, and it differs from the hierarchical task analysis in the addition of cues and feedback analysis. Although these methods can decompose the motion at last, all of these methods end at the motions obtained by final decomposition but not analyze any personnel participating the tasks or determine their roles; thus, these methods cannot be applied to the decomposition of the pilot operation procedures which take people as the target.

At present, a refined task analysis method applied for the flight operation of the military aircraft of the methodology version defines the method as the task analysis/workload methodology (TAWL) [6]. The early work of the method includes the construction of a complex task scenario, and then decomposes the task scenario into the task step, function, and operation tasks from top to bottom; then decomposes every operation tasks into the sub-tasks of the auditory sense, motion, visual sense, cognition, and spiritual motion. Kun Yang et al. [7] carried out the task decomposition of the manipulation process of the takeoff stage of A380, and decomposed the tasks into the six primary targets such as period before thrust or startup, operation of startup and after startup of the engine, sliding, and decomposed the sub-operation. Xu et al. [8] decomposed the complex combat tasks in the coordinative air battle and decomposed the complex tasks into the periodical tactical sub-tasks of the single aircraft on the basis of the task characteristic elements.

With the aircraft models are being differed, the design of the cockpit is also differed, which causes different operation tasks, thus, to apply the established decomposition methods and classification of the flight operation tasks of the civil aircraft into the continuously changed design of aircraft models, the most bottom task decomposition, and classification shall be based on different models for study. Thus, the paper proposes the task analysis method applied to the flight operation procedures of the civil aircraft, including the detailed task decomposition steps, which are applicable to the classification of the flight operation tasks of the civil aircraft.

2 Decomposition of Operation Tasks

2.1 Decomposition Steps of Flight Operation Tasks of Civil Aircraft

After referring to the TAWL applicable to the military aircraft and the flight operation manuals of the civil aircraft A320 [9] and B737, the paper proposes the task decomposition steps applicable to the flight operation procedures of the civil aircraft, as shown in Fig. 1. The following introduces and explains in detail from the specific contents of every step of work of task decomposition.

(1) Design the scenario of the flight tasks

Designing the comprehensive task scenario is the first step for the task decomposition of the civil aircraft, in which the flight tasks, cockpit environments, and outside environment shall be confirmed. The flight tasks mean the content which is anticipated to be completed by the system, such as flying from place A to place B in normal takeoff and landing flight. The cockpit environment means the aircraft model, crew members, and the human–machine interface of the cockpit. The outside environment means various types of factors or limitation conditions during task execution, including day/night, various weather conditions, and various landforms. The description of the task scenario shall include weather, flight environment, and aircraft notices.

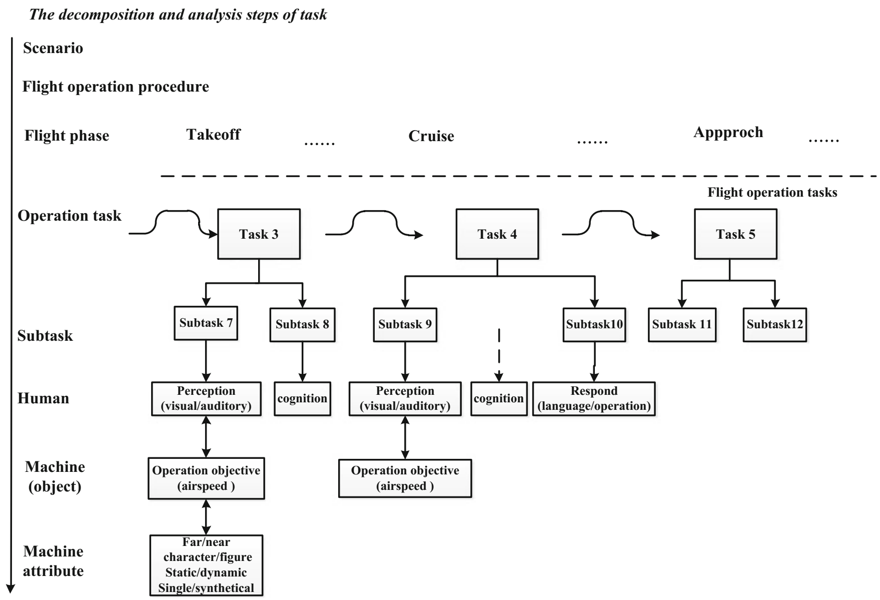

Fig. 1 The task decomposition steps of flight operation procedures of civil aircraft

(2) Confirm the flight operation procedures

After looking up the flight operation procedures of the civil aircraft and the face-to-face talk of the pilot experts, the flight operation procedures under the designed task scenario are confirmed.

(3) Decompose the flight operation procedures into the flight stages

After the flight operation procedures are confirmed, the operation procedures are decomposed into the time dispersed, continuous, and unrepeated parts, i.e., task stages, for example, the initial cockpit preparation, cockpit preparation, before thrust or startup, startup of engine, after startup of engine, sliding, before takeoff, takeoff, after takeoff, climb, cruise, preparation for descending, descending, ILS approach (or the other approach ways), landing, after landing, stop, safety check after leaving the aircraft, and flight again.

(4) Identify the functions from the flight stages (flight operation tasks)

Next step is confirming the flight operation task corresponding to each flight stage. The function is defined as the motion collection of all single logic function activity executed by the crew. The same function can be executed in different stages. The functions can be executed at the same time in the task stage or in order. The function aspects include the following: check the dashboard, communicate the autopilot, rapidly move the throttle rod to the CL position, and select the flap. To the flight operation procedures of the civil aircraft, the flight operation tasks listed on the operation manual are the functions and classified to the task layer.

(5) Confirm the crew members corresponding to the flight operation tasks

Analyze is the captain or co-pilot is the operation personnel corresponding to each flight operation. After clearly confirming the operators of all operation tasks, the operation task sequence time line of every crew member can be, respectively, established.

(6) Confirm the operation sub-tasks corresponding to each function (sub-task layer)

The sub-task operation (sub-task layer) is the activity which needs to be continuously developed by the crew for completing the function tasks. The operation tasks can be carried out at the same time or in order. The operation tasks comprise of the crew's operation motion and the objects acted by the motion, such as the operation motion comprises of check, setting, positioning, monitoring, and the objects comprise of switches, rotary knobs, helmets, maps. After being combined, some common operation sub-tasks comprise of switch check, check of rotary knob, monitoring of map, etc.

(7) Corresponding analysis of operation task channel

Based on the multi-source and information processing model of Wickens [10–12], each operation sub-tasks is correspondingly classified and analyzed according to the five task units including visual perception (v), audio perception (a), cognition (c), kinetic output (k), and speech output (s).

(8) Analysis of operation object

Clearly specify the object of the cockpit human–machine interface of each task unit, such as the altimeter, driving stick, and throttle lever.

(9) Analysis of the attributes of the operation object

Based on the human–machine interface design of the cockpit, the attribute analysis is carried out to each operation object such as far/close distance, number/symbol, static/dynamic, and single information/comprehensive information.

2.2 *Demonstration of Operation Task Decomposition of Flight*

To the military aircraft, the flight task scenario of the civil aircraft is simple without the special task demand but only the two requirements on safe takeoff and safe landing. The flight procedures of the civil aircraft comprise of the normal procedures, abnormal operation procedures, and emergency procedures. The chapter takes the normal operation procedures of the A320 pilot as the example and carries out the task decomposition on the basis of the flight operation task decomposition method and steps of the civil aircraft proposed by the paper.

(1) Design the scenario of flight tasks

Fly A320 in single crew from place A in a sunny day, there is not any abnormal operation condition or emergency operation condition, approach in ILS, and finally the aircraft lands safely in place B.

(2) Confirm the flight operation procedures

Look up the A320 flight operation manual and confirm the flight operation procedure in the standard takeoff and landing.

(3) Decompose the flight operation procedures into flight stages

The standard flight procedures of A320 can be decomposed into 18 flight stages such as initial cockpit preparation, cockpit preparation, before thrust or startup, startup of engine, after startup of engine, sliding, before takeoff, takeoff, after takeoff, climb, cruise, preparation for descending, descending, ILS approach, landing, after landing, stop, and safety check after leaving the aircraft.

(4) Identify the function tasks in the operation tasks (task layer)

In the study, the designed task scenario is under the normal condition; thus, there is the normal operation procedures in the flight operation manual, and the task operation function can be obtained from the flight operation procedures. The tasks and functions are identified by taking the ILS approach as the example, just as shown in Table 1. Initial cockpit preparation (35 tasks), cockpit preparation (43 tasks), before thrust or startup (12 tasks), startup of engine (7 tasks), after startup of engine (11 tasks), sliding (22 tasks), before takeoff (7 tasks), takeoff (27 tasks), after takeoff (6 tasks), climb (8 tasks), cruise (7 tasks), preparation for descending (16 tasks), descending (14 tasks), ILS approach (42 tasks), landing (10 tasks), flight again (11 tasks), after landing (9 tasks), stop (17 tasks), safety check after leaving the aircraft (11 tasks), i.e., 321 tasks together.

(5) Confirm the operation task of each function (sub-task layer)

Based on the task and its function, the operation motion and operation content of each task is confirmed to be completed. Take ILS approach as the example, the motion of each operation task is identified.

(6) Correspond each operation task to the people channel

Analyze the motion of the people operation task and correspond it to the channel. Take some tasks in the ILS approach as the example, the operation task *control by throttle to IDLE* can be decomposed as the sub-tasks that *the monitor the speedometer to be 25 knots (sense the input task)* and *operate the throttle lever (response to the output task).*

Table 1 The figure of flight operation tasks corresponding to the task type

	Human attribute	Tasks attribute	Typical tasks example
Perception tasks	Visual, scan	Far	Check the position status of the switch button on head panel
	Visual, scan	Near	Check the position status of the switch button on instrument panel
	Visual, fix on	Continuous, data	Monitor the altimeter or airspeed to special data
	Visual, fix on	Continuous, picture	Monitor the attitude indicator
	Visual, fix on	Discrete, data, static	
	Visual, fix on	Discrete, data, dynamic, single	Check the multi-gear selector position status
	Visual, fix on	Discrete, data, dynamic, synthetical	Check the single dynamic data information
	Visual, fix on	Discrete, picture, dynamic, single	
	Visual, fix on	Discrete, picture, dynamic, synthetical	Check the dynamic synthetical information of integrated instrument
	Auditory, signal	Attention tone	Attention tone of voice broadcast
	Auditory, signal	Warning tone	Distinguish different feature of warning tone
	Auditory, signal	Computer speech	Understand the sound pattern and content
	Auditory, language	Conversation	Understand the sentence content
	Auditory, language	Command	Pay attention to and understand the sentence content
	Auditory, language	Report	Confirm sound feedback
Cognition tasks	Automatic conversation		
	conversation		
	Spatial, signal identification		
	Spatial, automatic		
	Spatial, conversion, guess		
	Spatial, conversion, recall		
	Spatial, conversion,		
	Spatial, conversion, selection		

(continued)

Table 1 (continued)

	Human attribute	Tasks attribute	Typical tasks example
Respond tasks	Conversation, talk		Conversation with air traffic controller
	Conversation, command (report)		Command co-pilot control
	Rough operation, hand	Button, far	Button on instrument panel operation
	Rough operation, hand	Button, near	Button on head panel operation
	Rough operation, hand	Knob	Single-gear knob operation
	Rough operation, hand	Switch knob	Switch control of landing gear
	Rough operation, foot		Brake control
	Precise continuous operation, adjust		Navigation accuracy adjustment
	Precise continuous operation, control		Throttle
	Precise discrete operation, adjust		Multi-gear selection
	Precise discrete operation, control	Single	Single information input
	Precise discrete operation, control	Sequence	Continuous keyboard input

The people's information processing stages include sensing, cognition, and operation; thus, the sensing, cognition, and operation tasks are analyzed on the basis of people reaction. On the basis of the sub-tasks that *the monitor the speedometer to be 25 knots (sense the input task)* and *operate the throttle lever (response to the output task)*, the channels corresponding to people include the people' sensing of the task is visual input and gazing information; compare and judge the cognition task characteristics of the task; and manual operation is the operation task characteristic of the task.

(7) Confirm the attribute of the operation object

The operation object of the tasks in the above task analysis is the altimeter of which the attributes are static information and data information. The operation task is characterized in the lever. The following classification in Table 1 is obtained by the task decomposition of the whole stage of the normal takeoff and landing flight of A320 and the classification on the basis of the obtained analysis of human and machine attributes.

3 Classification of Flight Operation Tasks of Civil Aircraft

Observed from the classification of the human–machine interface and the development of the dashboard, the aircraft cockpit has been updated for years, the displaying interface of the cockpit of the civil aircraft has been significantly changed, but some traditional displaying ways still exist. The instrument development in the cockpit has been gradually converted into the graphics information displaying way from the former completed digital displaying way (indicator type), and some single information displaying way for the displayed information is changed into the comprehensive information displaying way. It is also found by the development of the cockpit that under the condition without the touch screen, the operation equipment of the cockpit mainly comprise of the driving handle (steering wheel), the throttle lever, the pedal, buttons, rotary knobs, switch knobs, etc.

Thus, combining with the task decomposition results of A320, the development analysis of the aviation instruments and the analysis of the operation equipment of the cockpit, in the cockpit without the touch screen, the classification of the flight operation tasks applicable to the civil aircraft is shown in Table 2. After the classification table of the flight operation tasks of the civil aircraft is completed, discussion is made with the pilots of various aircraft models in the face-to-face way for checking whether the classification table is reasonable, completed, or universal. The pilots drive A320, B737, Cessna 172, DA40D, and C90. The face-to-face talk results show 80% pilots approve the classification table, and all believe the classification table is reasonable and completed. Because the face-to-face talk results of the pilots of different aircraft models are consistent, it is believed the classification table at present is universal to the classification of the flight operation tasks of the civil aircraft.

4 Discussion

(1) Task decomposition

It is found only TAWL establishes and introduces the method and steps applicable to the task decomposition of the model in detail in the available data: At first, the task scenario is designed, and the task is sequentially decomposed into stages, sections, functions, and operation tasks; confirm the crew members corresponding to each operation task; and confirm the human–machine interface sub-system corresponding to each operation task. The model is applied to the military helicopter; thus, after being decomposed to the flight stage, the task is decomposed to the task section, and to the civil aircraft, compared with the helicopter, the operation procedures are simpler and more standard. The operation task can be confirmed after the task is decomposed into the flight stage. The task decomposition steps

Table 2 The tasks unit classification of flight operations of civil aircraft

Human attribute			Tasks attribute			Tab Num.
Perception	Visual sense	Scan	Far			V1
			Near	Location status information		V2
				Color status information		V3
		Monitor	Character			V4
			Picture			V5
		Achieve information	Character	Static state		V6
				Dynamic state	Single information	V7
					Synthetical information	V8
			Picture	Static state		V9
				Dynamic state	Single information	V10
					Synthetical information	V11
	Auditory sense	Signal	Attention tone			A1
			Warning tone			A2
			Computer speech			A3
		Communication	Conversation			A4
			Command			A5
			Report			A6
Cognition	Simple related					C1
	Selection					C2
	Signal distinguish					C3
	Estimate judgment					C4
	Prediction					C5
	Calculation					C6
Respond	Language	Conversation				S1
		Command/report				S2
	Operation	Simple operation	Button/knob/switch knob			K1
			pedal			K2
		Precise operation	Continuation	Adjust		K3
				Manipulate throttle		K4
				Manipulate (control Stick/hand wheel)		K5
			Keyboard	Solo import		K6
				Continuation import		K7

where *V* represents visual sense tasks, *A* represents auditory sense tasks, *C* represents cognition tasks, *S* represents language respond tasks, *K* represents operation respond tasks proposed by TAWL cannot be directly used for the decomposition of the flight operation procedures of the civil aircraft, and the decomposition steps shall be modified to save the unnecessary work steps. Also, although at last the assessment of the load of the operation task is carried out from the channels of vision (naked-eye/night vision goggles), cognition, spiritual activity, and muscle motion, the operation task in the model is not decomposed to the corresponding channel step. To clearly specify the corresponding relationship between the operation task and the human information processing channel as well as provide basis for task classification, the paper will add the human channel analysis and the attribute analysis of the human–machine interface system of operation under the condition that the task is decomposed to operation tasks. Thus, the paper will establish the task decomposition method and steps applicable to the flight operation procedures of the civil aircraft on the basis of TAWL task decomposition.

(2) Task classification

Not all workload prediction models have the content of task classification; e.g., W/INDEX directly assigns a value to the load of the task unit obtained by decomposition. The task classification is also greatly differed because the study objects are different. Task classification it carried out to the UH-60 functions of all tasks according to vision (naked eyes), vision (night vision), auditory sense, cognition, spiritual activity, and muscle motion. In the task classification of MH-47E and AH-64A, the night vision is not singly emphasized. The task is classified into five types, and the classification is same without any assistant vision (naked eye), cognition, spiritual activity, or muscle motion. The man-machine integration design and analysis system (MIDAS) and tasks loading model (TLM) established by US NASA and headquarter of air line of US army in 1994 classify the pilot tasks from vision, auditory sense, cognition, and motion. Although all MH-47Es are helicopters, but their applications are different, the task operation classification types are different. The division of the task types is differed by relativity. According to the human information processing mode, TLM classification is divided into vision, auditory sense, cognition, and response.

TAWL classifies according to operation angles and the relativity of task types, and the repeated classification may easily occur, such as the vision check of the static information status under the vision task and the check of the button position status under the muscle motion; however, the information processing mode division adopted by TLM can avoid the problem. But the TLM classification is more complex, and its classification is designed for the complex algorithm. The task attribute under each task type is divided from the attribute of the interface information. Thus, the paper classified by combining with the consideration of TAWL for operation and the consideration of TLM for task attributes so as to integrate the human channel attributes and task attributes and then classify the flight operation tasks of the civil aircraft.

5 Conclusion

Based on the long-term work of task decomposition and analysis, the paper proposes the process applicable to the decomposition of the flight operation task of the civil aircraft: (1) design the flight task scenario; (2) confirm the flight operation procedures; (3) decompose the task scenario into flight stages; (4) identify the function tasks from the task stages (flight operation task); (5) confirm the crew members corresponding to the flight operation task; (6) confirm the operation sub-task of each function (sub-task layer); (7) corresponding analysis of operation task channel; (8) analyze the operation object; and (9) analyze the attributes of the operation object.

Also, the task decomposition is carried out on the basis of the proposed decomposition flow by taking the normal flight operation procedures under the whole flight stage of A320 from takeoff preparation to landing. In addition, combining with the analysis of the human–machine interface of the cockpit of the civil aircraft, the task unit classification applicable to the flight operation of the civil aircraft is obtained. The sensing, cognition, and operation task unit classification obtained by study can provide basis for establishing the post-stage flight load prediction model so as to reduce the measurement work amount of the experiment and measure the load of the basic task of the flight operation on the basis of minimum workload.

Based on the study of the prediction analysis of the pilot work load of the flight operation procedures, it firstly needs to decompose and classify the flight operation procedures. The paper introduces the detailed process and steps for task decomposition and classification, establishes the operation task classification and the classification standards thereof which are applicable to the flight operation procedures of the civil aircraft, and can provide classification basis and reference for the task analysis.

Compliance with Ethical Standards The study was approved by the Logistics Department for Civilian Ethics Committee of the AVIC China Aero-polytechnology Establishment.

All subjects who participated in the experiment were provided with and signed an informed consent form.

All relevant individual information of subjects has been met with regard to subject protection.

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Optimization Design and Efficacy Evaluation of Crew Cabin Layout

Fang Xie, Qun Wang, Sijuan Zheng, Li Li, Liang Ling, Zhongliang Wei, Xiaoru Wanyan and Xu Wu

Abstract The optimization design of special vehicle cabin layout is a non-deterministic Polynomial problem. The design experience of the past has not been able to meet the design requirements of the layout of modern special vehicle compartments. Through a number of typical compartments of the layout of the comparative analysis, we can see that there are many existing layout options to be optimized. Therefore, this paper proposes an optimization design method based on genetic algorithm. By setting the objective function and the constraint condition, an improved cabin layout scheme is obtained. And the operation domain and visual field of the operator were analyzed by three-dimensional human body simulation software, and the ergonomic evaluation of the cabin layout was carried out. The results of the study can provide some technical basis for the design of special vehicle compartments.

Keywords Layout optimization · Genetic algorithm · 3D human model · Ergonomics evaluation

1 Preface

The special vehicle forms the one typical complicated human–machine environment system due to its characteristics, and the vehicle, personnel, and the environment interact on, affect, and restrict each other. As the development and research of special vehicle equipment, the problem of human–machine efficacy has attached more and more emphasis, and the military standards have published the GJB 1835-1993 [1], GJB 2873-1997 [2], and relevant vibration and noise standard, which provide the guidance rules for the human–machine environment system

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design of special vehicle. With consideration on the great influence of the bad environment factors in this system to the operator, vibration, a series of adverse environment conditions such as noise, harmful gas, and closed space have caused serious influence on the crews in the vehicle; therefore, the requirement on the rational design of compartment layout has become urgent.

The compartment layout optimization design [3] is the layout issue in the combination optimization. Analyzing the compartment layout design and optimization from the angle of layout issue, first, the systematic and overall realization should be obtained for the layout issue. After the simulation modeling on the crew cabin layout, this paper has created the preliminary design model for crew cabin layout, promoted the optimization calculation of crew cabin layout on this basis, and proposed the optimization design plan of crew cabin layout; at last, the efficacy evaluation software is adopted to complete the efficacy evaluation of crew cabin layout, and the suggestion on efficacy evaluation of crew cabin layout is formed.

2 Comparison and Analysis on the Crew Cabin Design Plan

2.1 Crew Cabin Layout Planning

The target vehicle is planned with four seats, including driver seat, co-pilot seat, crew A seat, and crew B seat, where the driver is responsible for observing landform and driving vehicle; the operating equipment includes instrumentation operation station, brake, and acceleration pedal; the display equipment includes road conditions display screen, observation mirror, vehicle control, and navigation display screen and reversing screen; co-pilot is responsible for road conditions observing and necessary control tasks; the display equipment includes observing and control zone; crew A is responsible for special reconnaissance equipment route planning, course planning, and auxiliary control; crew B is responsible for system information processing, confirming, and correcting. Additionally, six crew seats are set for the vehicle.

2.2 Crew Cabin Design Plan

According to the research vehicle prepositional power transmission layout design, three plans on crew cabin layout design are proposed. Plan 1: Three crews are side by side, one crew is at the second row; Plan 2: Two crews are side by side, two crews are at the second row; Plan 3: Three crews are side by side, one crew is at the rear side.

2.3 Comparison and Analysis on Different Plans

According to the comparison and analysis on the working space and crew working comfort of above-mentioned three plans on crew cabin layout design, the following analysis conclusions are produced: (1) Requirements on the working space: the working space width of Plan 1 is obviously inadequate, three crews are side by side, which causes inadequate per capita space width. However, the working space depth of Plan 2 and Plan 3 has obvious advantage. (2) Requirements on the position of cabin door: Three crews are side by side in Plan 1, which dropped the personnel active channel, the front and rear row design of Plan 3 causes that the middle row personnel is not convenient to use the cabin door. By comparison, the double-people and double-row design of Plan 2, it perfectly solves the problem of using the passage. (3) Requirements on seat adjustment: The double-people and double-row design of Plan 2 increases the difficulty of adjusting the seat; however, one seat of Plan 1 and Plan 3 can be moderately adjusted. (4) Requirements on the display device: In Plan 1, crews are side by side, which is convenient for sharing the display resources. Additionally, the blind area of driver in Plan 3 is also perfectly controlled, which meets the design requirements. Comparing with Plan 2, the installation position is relatively ideal, but blind area is relatively big. (5) Requirements on the manipulate device: Plan 2 provides relatively big adjustable range for the driver, and the accessibility is relatively good; Plan 1 has narrow operation panel position, three crews are side by side with low flexibility; the installation position of Plan 3 is relatively good, and the accessibility also meets the requirements. (6) Requirements on the rear resting area space: The double-people and double-row design of Plan 2 provides relatively ideal resting area space, but one side resting area of Plan 1 and Plan 3 is relatively crowded.

3 Crew Cabin Layout Optimization Design and Calculation Based on Genetic Algorithm

3.1 Mathematical Modeling of Layout Optimization [4]

The purpose of layout design is to confirm the reasonable positions of varied devices in the compartment. Therefore, design variable is the position parameter of device $x_i(i = 1, 2, \ldots n)$, which is

$$X = \{X_1, X_2, \ldots X_n\} = \{(x_1, y_1), ((x_2, y_2), \ldots((x_n, y_n)\} \quad (1)$$

In Formula (1), x_n, y_n means the *n, x, and y* coordinates of fittings, respectively; n means the quantity of fittings.

According to the above-mentioned crew cabin physical dimension, when establishing the constraint condition of layout optimization, mainly the following seven constraints are taken into consideration. (1) Working space dimension constraint: The physical dimension constraint of crew cabin is as follows: Length is 1600 mm; width is 1900 mm; and height is 1150 mm, which is the physical dimension constraint condition of the layout container. (2) Active channel dimension constraint: The physical dimension constraint of the dynamic passage is as follows: Width is 400 mm, and height is 800 mm, which is the interference distance constraint condition of layout fittings. (3) Cabin door position constraint: The physical dimension constraint of cabin door is as follows: Width is 580 mm, and length is 450 mm, which is the cabin door position constraint condition of layout fittings. (4) Crew seat dimension constraint: The physical dimension constraint of crew seat is as follows: Common seat width is 400 mm; length is 450 mm; driver seat width is 450–500 mm; length is 400–500 mm; the regulated quantity in front of and behind the seat is 150 mm; the up- and down-regulated quantity is 200–300 mm, which is the physical dimension constraint condition of crew seat. (5) Display and control device dimension constraint: The physical dimension constraint of display and control board is as follows: Width is 740 mm, and length is 150 mm, which is the physical dimension constraint condition of display and control. (6) Repair space dimension constraint: The geometric constraint of repair dimension is as follows: width is 500 mm, and length is 425 mm, which is the physical dimension constraint condition of repair space. (7) Seat and display and control board space constraint: The geometric constraint of seat and display and control board space is as follows: Control board display interface is set annularly in the zone 400–500 mm to the eyes of crews, which is the position constraint condition of seat and display and control board space.

For the problem of multiple objective optimizations, it is unavailable to weaken the functions of at least one other objective when improving the functions of any objective, and the below-mentioned objective functions are taken into consideration in this paper. Since it is required that interference should be avoided between different fittings in the compartment, this paper adopts objective function $F_1(x, y)$ to describe the interference distance, the better the bigger the distance is. In Formula (2), X_i *and* X_j are the position parameters of fittings, which have requirements on interference distance, m is the quantity.

$$F_1(x,y) = \left\{\max \sum\sum D\left(\left(X_{ij}\right)\right) \middle| D\left(X_{ij}\right) = \left(x_i - x_j\right)^2 + \left(y_i - y_j\right)^2, ij \in [1,m], i \neq j\right\} \tag{2}$$

Under the conditions of compartment dimension, fittings quantity, and certain specification, the occupied area of equipment is fixed; the remaining area is also fixed, to maximize the area of this equipment; and this paper adopts $F_2(x)$ to describe this active channel distance. In Formula (3), ω_i is the importance weight coefficient of corresponding zones for fittings in the compartment, and $\sum_{i=1}^{n} \omega_i = 1$, but X_a is the position of the center of occupied zone.

$$F_2(x, y) = \left\{ \max\left(\sum \omega_i D_a(X_i) \right) \middle| D_a(X_i) = (x_i - x_a)^2 + (y_i - y_a)^2, i \in [1, m], \omega_i \in [0, 1] \right\} \tag{3}$$

3.2 Layout Optimization Calculation Based on Genetic Algorithm

According to the established mathematic model, it is solved with improved genetic algorithm NSGA-II [5], and the optimal solution set is produced. In the Isight platform, with the formula calculator and Matlab programming, the genetic algorithm in the optimal toolbox is adopted, the population size is set at 12, genetic algebra is set at 200, crossover and mutation probability is 0.9, the NSGA-II algorithm with elitist strategy is selected, the calculation process stops after 241 times of iteration, and then, result is

$$X = \{X_1, X_2, \ldots X_{10}\} = \left\{ \begin{matrix} (678, 1335) & (1140, 303) & (1243, 76) \\ (1545, 88) & (685, 76) & (1141, 76) \\ (356, 1245) & (576, 1333) & (244, 330) \\ & (796, 1168) & \end{matrix} \right\} \tag{4}$$

Such layout mode is similar to the layout in the original Plan 2; the optimization calculation result has dropped the space of resting area on both sides; and the distance between the front display and control board is maximized; and a certain channel area is kept in the middle of the compartment, which is convenient for the activity and evacuation of operator (Fig. 1).

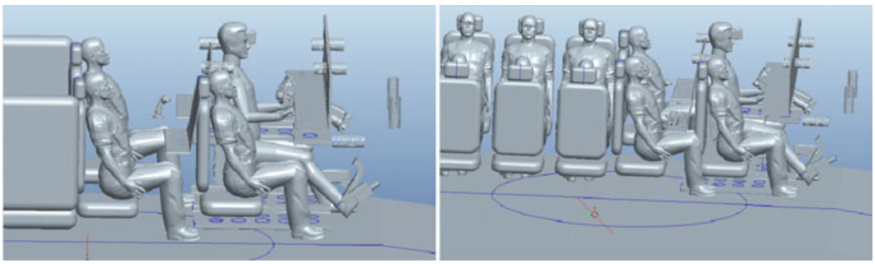


Fig. 1 Comparison of cabin layout before and after optimization design

4 Crew Cabin Layout Optimization Design and Evaluation Based on Virtual Simulation

4.1 Optimization Design of Compartment Layout

Corresponding human body model [6] is established with reference on the 50th percentile human body dimension data listed in the GJB 2873-1997 "Code for the design of Human-Machine Engineering of Military Equipment and Facilities," which regulated the dimension data of Chinese men, and is applicable to the design of space and dimension such as compartment, seat, passage, working station, and compartment layout related to the Chinese men dimension data. The established human body model is shown in Fig. 2, and this human body dimension model is adopted as the object of crew cabin layout efficacy evaluation in research.

After analyzing, the problems of crew cabin layout prototype include the following: the driver seat is too close to the steering wheel, which strengthens the fatigue of the driver under normal sitting posture, and is not good for the driver to smoothly operate the steering wheel. The co-pilot keeps at the normal sitting posture based on keyboard operation task; both hands of the co-pilot will keep below the instrument board, which will cause fatigue since the hands must raise high. Additionally, the middle display screen is not right in the middle co-pilot. Through simulation analysis based on efficacy analysis software, it is found when this co-pilot is reading the contents listed in the middle instrument; the angle for rotating the eyeball leftwards is 15°; and the range of visibility is 31.1 cm, which may easily cause visual fatigue. Therefore, the following corresponding improvement measures should be taken: moving the driver seat afterward for a certain distance; moderately lifting the seat of co-pilot, then both hands of the crew may keep above the instrumentation operation station at normal operation keyboard posture; moving the seat of co-pilot afterward for a certain distance; under the precondition without influence on the driver operation; moving the seat of the middle co-pilot for a certain distance.

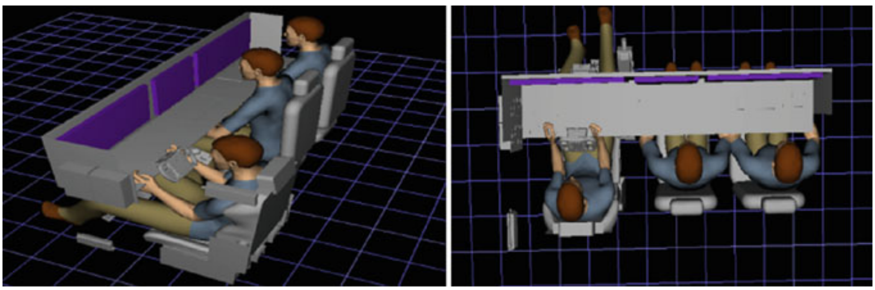


Fig. 2 Axis and top view of human–machine combination

4.2 Operating Regime Evaluation of Compartment Layout

It is shown from the operating regime analysis on crew cabin layout, after optimization design, the driver can contact the steering wheel at normal driving posture, which can drop the load of hands and increase the operation accuracy. The instrument keyboard area is at the accessible area of two co-pilots, and the co-pilots can conveniently touch the buttons. It is found through measurement that the co-pilot is 40.2 cm to the instrument, which basically meets the requirement on the distance for personnel to normally observing the computer display screen. The operating regime verification is adopted for the compartment layout plan after optimization, shown in Figs. 3, 4, and 5.

4.3 Visible Range Evaluation of Compartment Layout

Since the sensitive area of human vision is from standard line of sight to 10° range, in the 10°–20° range, the information can be correctly identified; in the 20°–30° range, human vision is sensitive to dynamic information; therefore, the driver can easily get the information displayed in the screen, shown in Fig. 6. When looking directly, co-pilot 1 can see right side two-thirds area of the middle display screen; when viewing leftward at 9.5°, co-pilot 1 can completely see the screen, shown in Fig. 7. Therefore, the important information can be displayed at the right side of the screen, and the secondary information can be displayed at the left side of the screen, which may reach best visual requirement. When looking directly, co-pilot 2 can see over half area of the screen; when the heat keeps still, co-pilot 2 can see the whole screen when the eyeball rotates for 20°, shown in Fig. 8. Therefore, it is suggested to set the information related to the battlefield situation at the right part of the screen, and the secondary information at the left side. Then, the operators can easily operate the instruments without turning the head. To observe the left side secondary information, it is comfortable to turn the head and the eyeball.

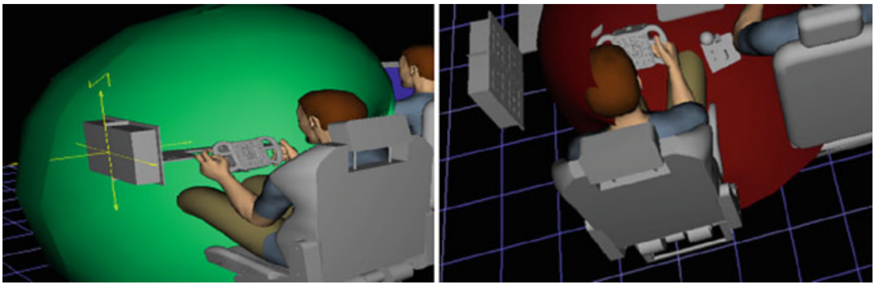


Fig. 3 The driver's hands reach the field

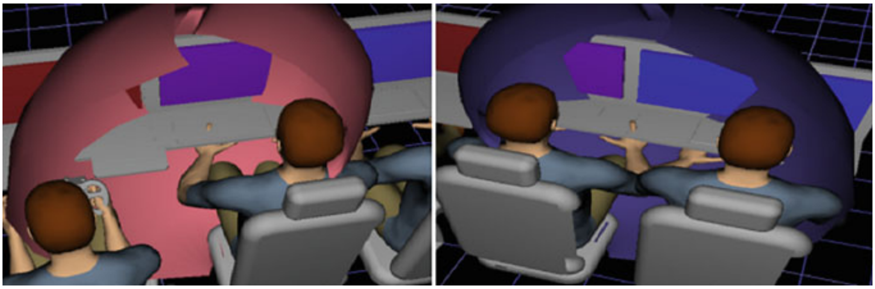


Fig. 4 Co-pilot 1 hands reach the field

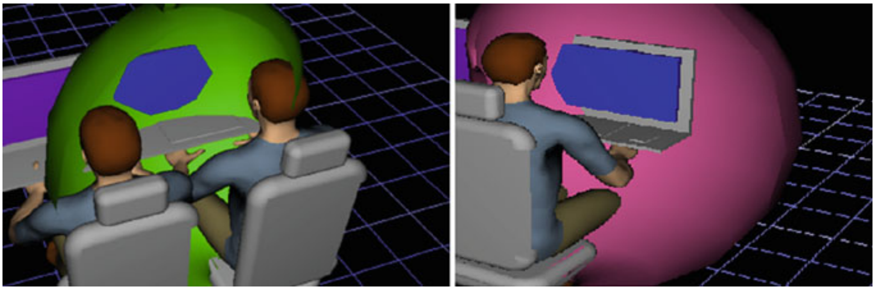
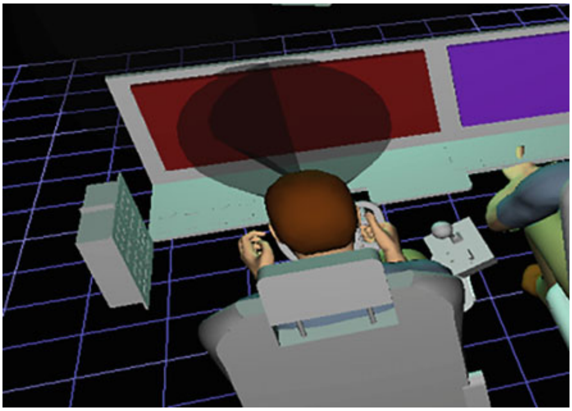


Fig. 5 Co-pilot 2 hands reach the field

Fig. 6 The driver direct view of the cone



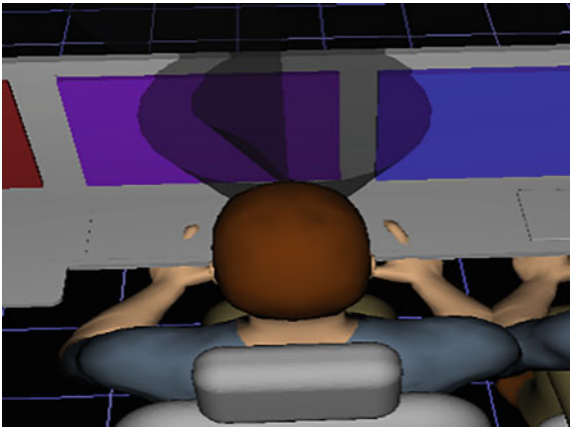


Fig. 7 Co-pilot 1 direct view of the cone

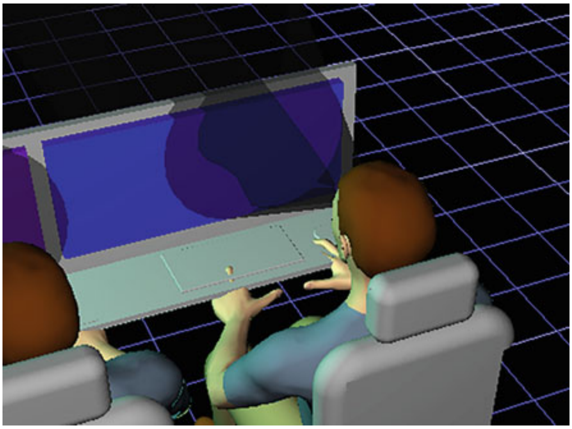


Fig. 8 Co-pilot 2 direct view of the cone

4.4 Comfort Evaluation of Compartment Layout [7]

Through simulation analysis, when the driver keeps at normal operation, the lumbar force is 292 N, which is much lower than the ultimate value of 3400 N, and keeps in the green and comfortable area. When the driver works at normal posture, the stress of all parts is in the yellow zone range, some in the best range of the green zone, and the degree of comfort reaches the best state, shown in Fig. 9. The same, when co-pilot 1 keeps normal operation, lumbar force is 303 N, which is much lower than the ultimate value of 3400 N, and keeps in the green and comfortable area. When co-pilot 2 works at normal posture, the stress of all parts keeps in the green the best range, and the degree of comfort reaches the best state.

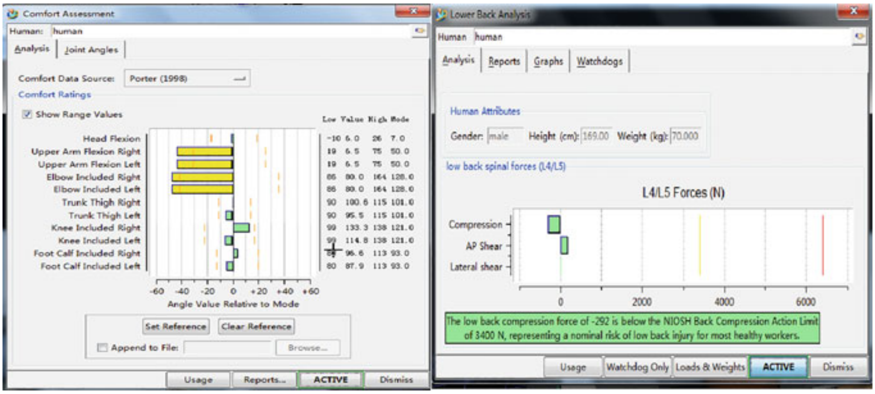


Fig. 9 Driver comfort and lumbar force analysis

5 Conclusion

According to the problem of optimization design and algorithm of typical crew cabin layout, this paper completed the digitalization of crew cabin with the computer simulation method and confirmed the constraint condition and objective function of layout optimization through obtaining the key influence factors of layout optimization, and established the layout optimization mathematic model. On this basis, the suggestions on the original compartment layout design optimization are formed via comparison and analysis. In addition, this paper conducted the ergonomics integrated evaluation for the typical crew cabin layout design, established the crew human body model with the virtual simulation method based on efficacy analysis software, and completed the further optimization of compartment layout plan combining the crew working visible range and comfort evaluation method. This paper is capable of providing ergonomics reference for the compartment layout optimization design and evaluation of special vehicle.

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Part VIII
Theory and Application Research

Analysis on Realization of Man–Machine–Environment System Targets in Macroeconomic Regulation

Yinying Huang

Abstract This paper was to analyze how the governmental planner established and implied macroeconomic policies, with the objective of economic growth through the study framework of MMESE. The main study viewpoints are as follows: Firstly, the governmental planner's macroeconomic regulation is defined as a generalized man–machine–environment system; then, with vector autoregression (VAR) and impulse response analysis methods, this paper discussed the characteristics of "machine" (economic policy) and found that policies have time lag, last for long time and have widespread and profound influences; finally, combined with policy features, to realize the basic systematic "objectives" which are "safety, efficiency, and economy," new requirements of the system are requested: to strengthen financial supervision and macromonitoring; to guide people effectively before the implementation of the policy (forward-looking guidance); and to advocate "fine-tuning" to achieve the policy objectives with minimal policy costs.

Keywords Man–machine–environment system engineering · Governmental planner · Macroeconomic regulation · Monetary policy · Fiscal policy · Interest rate policy

1 Introduction

The paper defines the macroregulation by the governmental planner with economic policy as a generalized man–machine–environment system, tries to discuss the macroeconomic regulation by modern governmental planner with the research route and method of man–machine–environment system engineering, and analyzes how the governmental planner makes and implements the economic policy to further realize the macroregulation objectives taking economic growth as the core. Through focusing on features of "machine" and analysis on system objectives, the paper

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discusses how "man" (governmental planner) adapts to and reconstructs the machine (economic environment) to realize policy's objectives and system's basic objectives—security, efficiency, and economy.

2 Man–Machine–Environment System in Macroeconomic Policy Study

2.1 Definition of the Three Elements in Economic Policy Study

In the macroeconomic policy study, we can deem economic policy decision-maker —governmental planner, as the system's "man," such as the central bank and the Ministry of Finance. The "machine" in the system can be defined as economic policy, including monetary policy, fiscal policy, and exchange rate policy, which are the policy tools adopted by governmental planner ("people") to achieve macroeconomic policy objectives. "Domestic and international economic environment" (environment) is not only the background for the governmental planner to implement the economic policy, but also the basis of macroeconomic regulation, with significant influence on economic policy formulation and implementation. Therefore, the paper considers the domestic and international "economic environment" as the most important environment factors influencing economic policies.

2.2 "Man–Machine–Environment System" in Economic Policy Study

"Man–machine relationship" refers to the relationship between "man" (governmental planner) and "machine" (economic policy), that is, how governmental planner develops an economic policy, and at the same time, how a "man" (governmental planner) to better adapt to the "machine" (economic policy) to let it play the greatest effect"; "man–environment relationship" refers to the relationship between "man" (governmental planner) and "environment" (domestic and international economic environment), i.e., how the governmental planner adopts to the change of economic environment home and abroad, how the economic policy tools influence the economic environment home and abroad, and how the environment influences the implementation effect of the tools. The "man–machine–environment system" in the study of economic policy is the organic system formed by mutual influence and interaction among governmental planner, economic policies, and domestic and international economic environment (Fig. 1) [1].

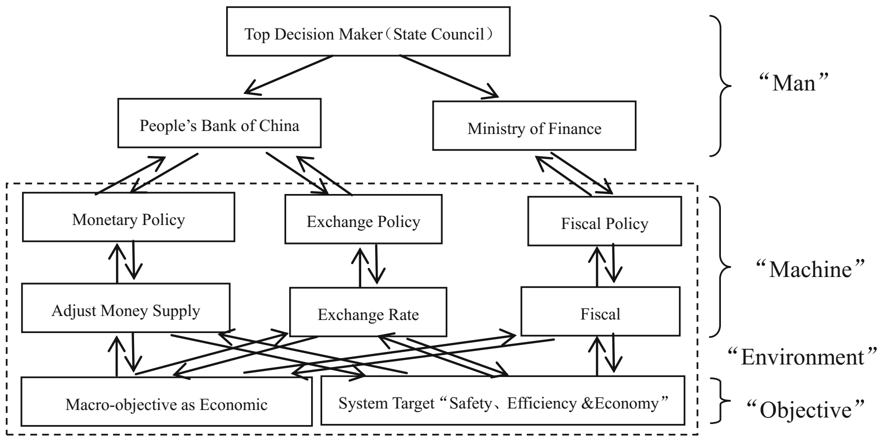

Fig. 1 Man–machine–environment system in macroeconomic regulation

3 "Characteristics of Machine" and "Target Characteristics"—Economic Policies and Output Characteristics

This section uses the annual statistical data published by some institutions including National Bureau of Statistics, the Ministry of Finance, and the People's Bank of China and uses data analysis software Eviews, mainly to analyze the data of fiscal expenditure (representing fiscal policy tools), money supply (representing monetary policy instruments), exchange (representing the exchange rate policy tool), and the output (representing the macroeconomic regulation objectives), and discusses the characteristic s of "machine" (economic policy) and its influence on the realization of objectives of economic growth (GDP).

3.1 Descriptive Statistics and Hodrick–Prescott Filter Analysis

First of all, the paper makes descriptive statistics and analysis on actual data and unifies a range of values of each variable: annual data since 1991–2016. The paper conducts descriptive statistics and analysis with software Eviews. Among them, Jarque–Bera verification is a way to test whether the overall distribution shows the normality. Test results show that the Jarque–Bera value of any of exchange rate, fiscal expenditure, and GDP is lower, while the Jarque–Bera value of money supply is higher with smaller associated probability, unable to prove that the sample is subject to normal distribution.

Secondly, the paper makes Hodrick–Prescott filter analysis for economic variables g. As a commonly used decomposition method for economic variable trend analysis, the Hodrick–Prescott filter analysis (H-P filter method) separates the long-term growth trends and short-term fluctuation range from the economic variable sequence, as shown in Fig. 2. In the figure, the solid line (blue) represents the raw data of each economic indicator. The curve of the dotted line (red) represents the trend (Trend), and the curve with the solid dot (green) represents the fluctuation item (Cycle). The abscissa represents the year, and the ordinate represents the volatility.

Since 1991 until 2016, the above economic indicators were showing an upward trend. Fiscal expenditure, gross national product, and money supply grew faster and faster. When observing the green curve of the variables representing the variables, in the international financial crisis of 2008, the money supply was significantly deviated from the downward trend of the Trend, while after Chinese government launched the investment plans for RMB four trillion in the end of 2008, the government financial expenditure economic indicators showed substantial positive impact in 2008. In terms of exchange rates, the exchange rate of Renminbi to US dollar had dropped to 8.62 once before the exchange rate reform in 1994. In 2005, a managed floating exchange rate system based on market supply and demand was introduced. By the beginning of 2014, the exchange rate of Renminbi to US dollar continued to rise and then dropped slightly [2].

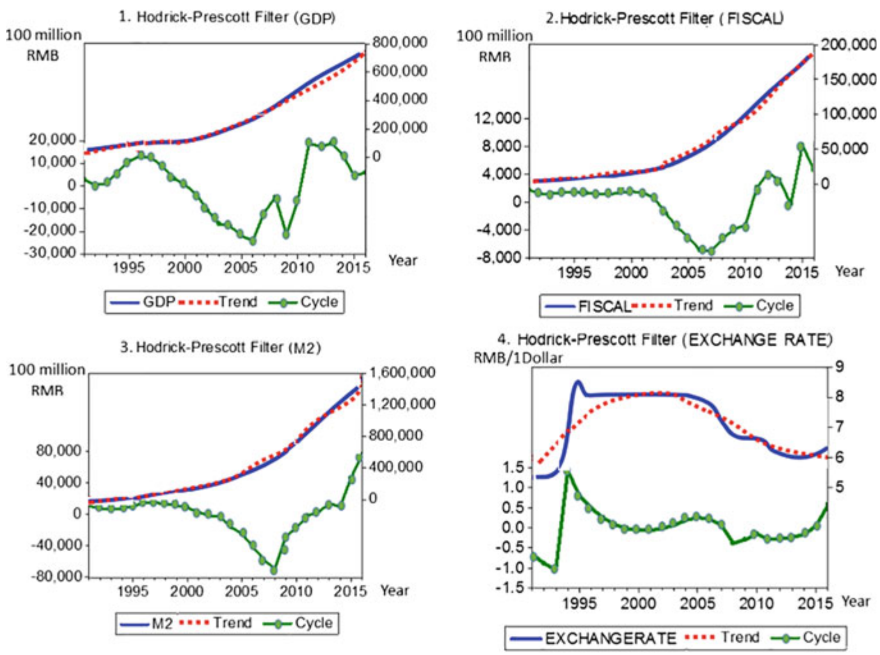

Fig. 2 Hodrick–Prescott filter analysis

3.2 VAR Analysis of Actual Data and VAR Analysis of Fluctuation Items

Vector autoregression (VAR) is one of the most commonly used models for analyzing economic variables. Here, statistical analysis of actual economic data is made with vector autoregressive model (VAR).

First of all, the software Eviews is used to establish an unconstrained vector autoregressive model. The fiscal expenditure, the money supply, the exchange rate, and the output are taken as the endogenous variables, the system default constant c is the exogenous variable, and the lag order is taken as 2. Then, the author studies the hysteresis structure of VAR model and finds that the vector regression model is not stable. Now the author should consider the economic growth rate g. In the following, the author considers only the distance of economic fluctuation and steady state. VAR analysis of each variable fluctuation separated by H-P filter analysis is verified. The VAR model is stable and can be analyzed effectively.

3.3 Impulse Response Analysis of Wave Items

Now the pulse response analysis is carried out by analyzing the fluctuation values from H-P filter analysis. The impulse response graph between each two economic

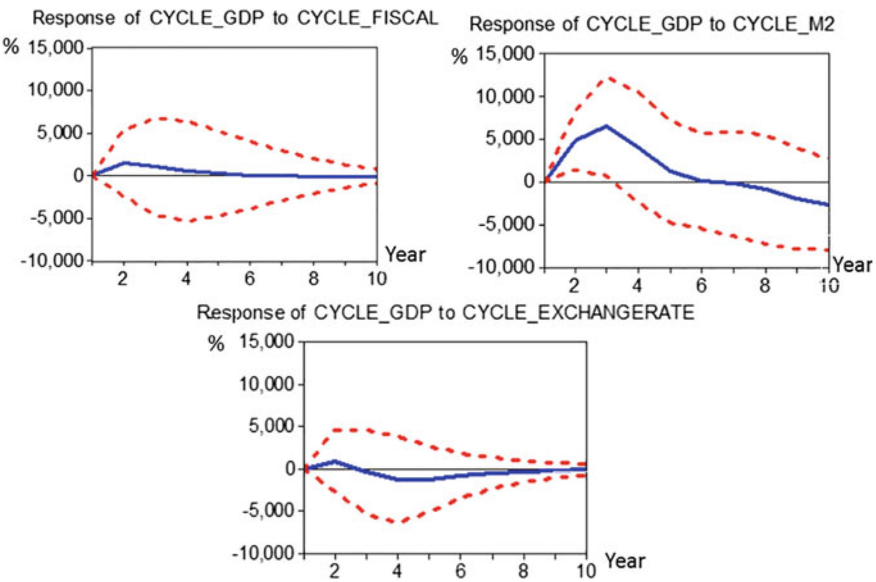

Fig. 3 Impulse response analysis

indicators is shown in Fig. 3. The abscissa in the graph represents the time (year), and the ordinate represents the percentage of the impulse response.

(1) Impulse response of GDP to fiscal expenditure, (2) response of GDP to broad money supply M2, and (3) response of GDP to exchange rate.

The impulse response analysis can be used to explain the response of impact of an endogenous variable on the error term, i.e., the positive (negative) impact (the upper/lower dashed line) of the standard deviation generated in the random error term, the degree of the impact on the current and future values of the endogenous variations. From the above pulse reaction diagram, we have the following findings:

First of all, the scale of fiscal expenditure has a positive correlation with the scale of output. The response of the output to the scale of fiscal expenditure reaches the peak in the second period, and then gradually decreases with the extension of the period until it is reduced to zero.

Secondly, the money supply is positively correlated with the output, and the correlation coefficient is relatively high. The response of the output to the impact of the money supply will increase sharply with the increase of the number of periods, reaching the peak in the third period. And then, it will be quickly weakened, even after the number of periods is increased to a certain number; after the sixth period, correlation coefficient becomes negative and may have negative impact on the output.

Thirdly, the relationship between exchange rate and output has a positive correlation in the first two periods; that is, the devaluation of the Renminbi can increase output by promoting exports. But after the second period, there is a negative correlation, when the devaluation of the Renminbi lasts for a relatively long time, which reflects that when a country's purchasing power continues to decline, the output scale becomes gradually narrowed.

4 Objectives of Optimal Combination of System

4.1 Basic Objectives of Optimal Combination of System—"Security, Efficiency, and Economy"

In economic policy study, simply speaking, "machine" is to achieve "economic growth" to make GDP growth rate achieving the desired objectives. But at the same time, basic objectives of optimal combination of system—"security, efficiency, and economy"—should be achieved. "Safety" means no damage to human and avoidance of all accidents. In the economic policy study, "security" means ensuring the security of the entire economic system, controlling the systemic risk, and avoiding the economic crisis or financial crisis. "Efficiency" means that the whole system has the best performance or the highest efficiency. In economic policy study, "efficiency" means reducing the time for policy to take effect and enabling economic policy to play its role in a timely manner. "Economy" is the most economical cost of system construction on the premise of meeting the technical requirements of the system. That is, the policy cost is minimized in the economic policy formulation and implementation process.

It is difficult to achieve three goals, in general, to meet the "security, efficiency, and economy," and sometimes among the three objectives, there are contradictions [3]. In order to combine these three performance indicators into a comprehensive performance index, we can define a comprehensive rating as Q, i.e., $Q = W1$ * security + $W2$ * efficiency + $W3$ * economy, where $W1$, $W2$, and $W3$ are the weighting coefficients for each index, respectively, and $W1 + W2 + W3 = 1$ [4]. The main factors that determine the three weighting factors are as follows: first, a country's technical level and economic strength. Taking USA and China as examples, both of them are the current world economic superpowers with striking economic strength with relatively low value $W3$. Secondly, according to the type of man–machine–environment system, the requirement of the macroeconomic regulation for the system security, or the stability of the economic system, is higher, so a higher value may be taken for $W1$; thirdly, according to the working status of the man–machine–environment system and the characteristics of fluctuations in the economic cycle, the requirement of macroeconomic regulation for system efficiency is higher, so the value of $W2$ is relatively high.

4.2 New "Man–Machine–Environment System"—Based on the Characteristics of "Machine" and the Objectives of the System

Corresponding to the characteristics of the "machine" (economic policy) in the above policy study system, the effectiveness of a policy shows time lag and lasts longer, so the influence is high. Accordingly, considering the weighted characteristics of the three major objectives of the optimal combination of system, the weights of security $W1$ and efficiency $W2$ are relatively high, bring new requirements for the macroeconomic regulation:

First of all, security. Because the "machine" (economic policy) has a wide range of effects and long term of influence, sometimes the reverse cycle of policy may be adjusted to positive cycle so as to trigger economic crisis. Therefore, it is necessary to strengthen financial supervision and macromonitoring. For example, after the financial crisis of 2008, the central banks of all countries have strengthened financial supervision and the People's Bank of China has implemented macro-prudential assessment (MPA) these years to resist the economic crisis.

Secondly, efficiency. The effectiveness of "machine" (economic policy) shows time lag and may affect the efficiency of the overall system. Therefore, it is necessary to conduct effective guidance before the policy comes into force, i.e., "forward guidance." Since the outbreak of the financial crisis, central banks of all countries have paid more attention to the importance of forward guidance. In 2017, China's monetary policy remained stable and neutral and the People's Bank effectively guided by means such as instructions for financial institutions and public announcements.

Thirdly, economy. Considering "machine" (economic policy) has greater impact, in order to ensure that the governmental planner can maintain the system's "economy" in the macroeconomic regulations, it is important to increase the frequency of policy and reduce policy efforts, i.e., encouraging policy "fine-tuning" to achieve policy objectives with the lowest cost.

5 Conclusion

Through the analysis on the characteristics of "machine" (economic policy) in the policy study system, it is concluded that the effectiveness of a policy shows time lag and lasts longer, so the influence is high. Therefore, considering the basic objectives of the optimal combination of the system, the author brings new requirements on the system: first of all, ensuring the security of the system. We should enhance the financial regulations and macroeconomic monitoring to avoid turning reverse cycle of policy into positive cycle so as to trigger economic crisis. Secondly, we should conduct effective guidance before the policy comes into force, i.e., "forward guidance," to keep the system "efficient" and avoid the time lag of "machine" (economic policy) affecting system efficiency [5]. Thirdly, we should advocate policy "fine-tuning" to achieve policy objectives with the lowest cost and maintain the system's "economy." The influence of the solution to "machine" (economic policy) is relatively high in macroeconomic regulations for the governmental planner.

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Application of Man–Machine–Environment System Engineering in Design of Public Bicycle

Canqun He, Chenchen Miao and Yuling Jia

Abstract In recent years, the rapid economic development of China accelerates the progress of urbanization. That makes the city's public transportation face greater challenges. As people value environmental protection and low-carbon travel much more than early years, public bicycle demand will be increasing. However, the ergonomics size of existing public bicycle has many problems. This paper bases on surveying, statistics and ergonomic principles to offer a correction model. The correction model provides relevant recommendations for the correction of size of city public bicycle design and manufacture. Allowing users to ride more comfortable and safer makes the city's public bicycle industry develop more vigorously.

Keywords Man–machine–environment system · Public bicycle · Body size · Correction model

1 Introduction

In recent years, with the speeding up of urbanization process, more and more urban resource waste problems need to be solved. To settle these problems, the government advocates low-carbon behavior. Thus, people's environmental protection consciousness gradually becomes stronger and riding public bicycle becomes a kind of good low-carbon way to travel. Therefore, people's demand for urban public bicycle is growing rapidly.

Public bicycle should be universal, applicable and safe, comfortable and so on [1]. There are three interfaces between public bicycle system and human: hand and handlebar, buttock and saddle, and feet and foot pedal. For the size of public bike,

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there are many notable factors such as the length and angle of the handlebar, the length and width of pedal, and the length of the crank. Among these, the most important factor is the seat height. Its size should be consistent with the correct riding posture required distance, which makes people stretch the leg muscles without hurting knee. Reasonable bicycle saddle height can make people be comfortable when they are riding, and make them achieve the best mechanical mechanics and biomechanics of optimal state. At the same time, it can avoid the sports limitations and injury which are made by unreasonable design for contact part [2].

This study focuses on the adjustable height of the public bicycle saddle and provides a model for the calculation of the saddle height. In addition, it establishes a fluctuant correction model according to 1988 national standard data to better match the current human's body size.

2 Analyzing Limits of Adjustable Saddle Height, Comfort of Saddle and Handlebar

2.1 The Necessity of Keeping the Correct Posture When We Ride

A correct posture can improve the efficiency of cycling, and make cycling more comfortable and ease. Besides, it also reduce the risk of accidents [3]. The saddle height is crucial when people are cycling. If saddle is too high, it can make knee excessive tensile damage, but a low saddle will make muscles not extend, which leads to lactic acid accumulation. Therefore, we should adopt proper cycling posture and adjust the saddle height to appropriate place.

2.2 Establishing Calculated Model of Saddle Height Limit

The relevant size of human body and bicycle can constitute a simulated triangle, as shown in Fig. 1.

a crotch height minus tibial height (dressed);
b tibial height plus sole height;
x the maximum distance from pedal to saddle flat;
θ the angle between the thigh and the calf of right position when people ride.

Limit design principle should be used to establish the model, because the model must meet most people's right riding posture needs. Then, the model uses the 5th and 95th percentile GB human's body size data, combined with range of 'θ' (the

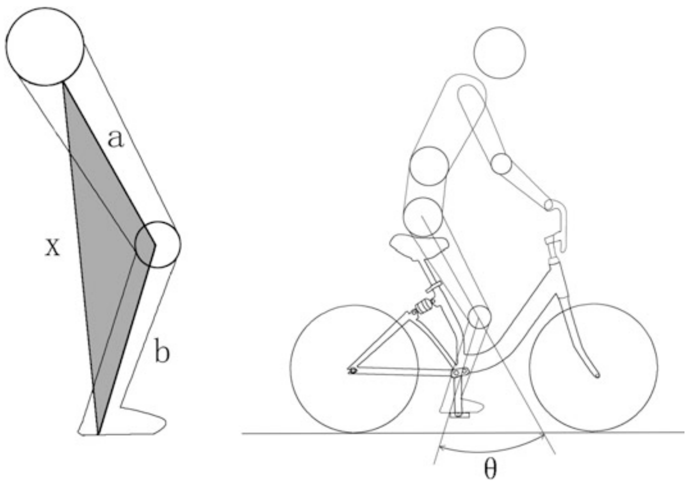

Fig. 1 Simulated triangle of saddle, pedal and knee when we ride

most suitable angel of θ is from 30° to 50°) through the cosine theorem to calculate the upper and lower limits. Next, bicycle-related dimensions and saddle adjustable height limit can be figured out through the '*x*.'

2.3 Analyzing the Comfort of Saddle

There is a close relationship between hip force and hip structure when riding. Pelvis connects the trunk and lower limb. Contact with the saddle is the lower edge of the pelvis of the tuberosity and the perineal region. At the top of the tuberosity, there is a bursa, which can secrete liquid to reduce the friction and compression between the tissues. The sciatic tuberosity is the main compression area. The perineal area is rich in blood vessels and nerves, not suitable for pressure. There is a great relationship between the force of the hip and the riding posture. Riding posture is generally divided into two kinds, that is, the athlete's professional riding posture and our general leisure posture. The majority of users use leisure posture more when using a public bicycle, so we mainly analyze the posture of the hip force.

When people use leisure riding posture, the angle between the body and the horizontal surface is 60°–90°, which is a more comfortable angle. Because at this time the human trunk is basically upright, the support point in the trunk is below. That is, most of the weight of the upper limb and trunk is supported by the sciatic tuberosity, and the oppression of the perineum area is reduced to avoid the discomfort of riding.

When riding in addition to the sciatic tuberosity, perineal area is inevitable to bear some of the weight of the upper limb, but the structure of the human body determines that the perineal area is not appropriate to bear the weight. The size of the saddle does not reduce or avoid the oppression of the perineal tissue and fat. Prolonged riding can cause numbness and ischemia in the perineal area. A lot of people have a wrong understanding that the more spacious and soft saddle is the more comfortable it is. In fact, the soft saddle cannot support the oppression of perineum, and too wide saddle makes thigh friction intensified in the process of riding, causing discomfort. The width of the saddle should be reasonable and proper and can be used to properly support the tuberosity.

On the other hand, the saddle has the same surface texture, no special parts in the design of anti-skid parts. In normal cycling, ischial tuberosity mainly bears the pressure. However, on the bumpy road, the hips will inevitably slide forward, which makes the ischial tuberosity in vain, and coccyx takes the place of ischial tuberosity to bear the pressure.

2.4 Human Factor Analysis of Handlebar

In view of the anatomical structure of the hand, the muscles of the palm are least. In contrast, the ball muscles of finger and thenar muscles are the most abundant. They are the natural shock absorber of the hand. There are many nerve endings in interphalangeal interosseus muscle and finger muscle [4].

In addition, from the anatomical structure of the wrist, the wrist is in the middle of the relaxed state when the wrist is operated in a straight line. When the wrist is away from the center position in palmar flexion, it will cause pain because of flexion, dorsiflexion and ulnar deviation. We can relieve pain by stretching tendon of wrist. That will cause discomfort to the users.

This requires a handlebar and saddle for relative position. On the other hand, the suitable angle of the brake can make the wrist and hand be in a straight line. Especially, the brake handle angle is very important for safe riding. The right angle can make the muscles of the hand in the most comfortable state, and the most rapid force and response. As shown in Fig. 2, the first one is correct, and the latter is wrong.

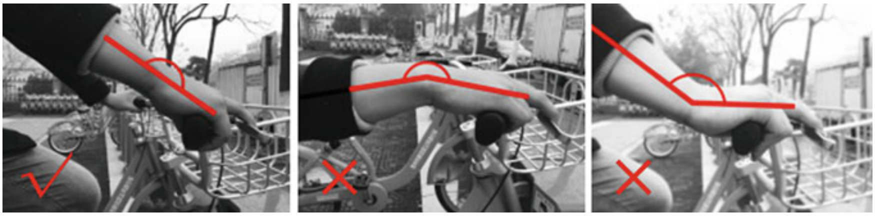

Fig. 2 Three conditions of brake handle angle

2.5 Human–Machine Improvement

When the saddle has a groove, the equivalent stress of the human body is much smaller than that of the non-groove, and the force of the perineal area is greatly reduced [5]. Taking into account the reduction of pressure on the perineum area, it is recommended that the saddle is hollow and has a groove.

In addition, the saddle filling should be solid flat. The surface coating of the saddle is suggested to be treated with anti-slip in the rear to avoid the displacement of the ischial tuberosity.

For handlebar, its size should be consistent with the data of hand. The brake angle can be designed to be adjustable. Besides, we can add a suitable support on the lateral handlebar, as shown in Fig. 3. Handlebar shape should be designed to have adequate clearance between the hold position and the palm and interphalangeal muscles. In order to reduce the pressure and friction between the muscle and the palm phalanx, that palm has good blood circulation, and nerve is not under a strong compression [6].

3 Correcting the Old National Standard

3.1 Establishing Calculated Model of Saddle Height Limit

Among the three interfaces between human and bicycle, the most important is the one between bicycle saddle and people's buttocks, because it can decide whether the legs can stretch and have a great impact on riding comfort. So the height of bicycle saddle should be calculated carefully in our design. Next, the basic model for calculating the limit height of bicycle saddle is tried to be established.

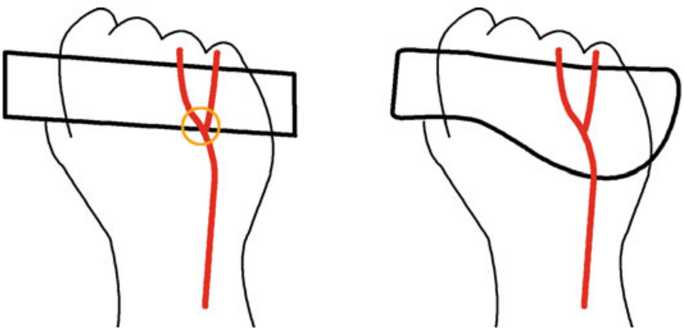

Fig. 3 Diagrammatic sketch for handlebar after adding support on the lateral part

3.2 Establishing the National Standard Size Correction Base Model

The size of the human body is extremely complex and affected by many factors so as to cause the obvious difference between individuals. Nevertheless, there is a certain mathematical relationship between the various parts of the body and height [7]. In general, the proportion of adult human body size basically unchanged within a long time.

Therefore, we measure the body size data of users widely and analyze the data. Then, we can get an approximate fluctuate value of size by comparing the data with the old one. Finally, we can use the fluctuated value to correct the design parameters of the original. We may not get the perfect parameters, but the parameters after correction must be better. So we can make user more comfortable.

The basic model is:

$$P = (M - N)/N \tag{1}$$

In this formula,

P is the fluctuated value;
M is the date of random sample for people now;
N is the date of old national standard GB1000-88.

$$T = S * (1 + P) \tag{2}$$

In this formula,

T is the parameter after correction;
S is the parameter calculated from old national standard GB1000-88.

4 The Application Methods of Public Bicycle Man–Machine–Environment System Design

In the process of design and manufacture, the man–machine–environment system for public bicycle has many size requirements. However, due to cost considerations, we can mainly consider the adjustable limits of saddle height. We can apply two basic models established in this paper in order to offer help for design of public bicycle.

Adjustable height of saddle can be figured out by the following three processes:

1. According to the calculated model of saddle height limit, we can use the data from the national standard (GB1000-88) to calculate the initial value.

2. Measuring the human body size data for bicycle users widely and analyzing the data by statistical methods and then using the national standard size correction base model to get correction factor.
3. Correcting the initial value in process 1 by correction factor in process 2, we can get final data which are a practical reference guide.

5 Conclusion

At present, more and more people like to use public bicycle because it is a kind of low-carbon way to travel. Because of the complexity of the bicycle sharing system, the basic model established in this paper may not be very accurate. However, it is enlightening for the human–machine system improvement of public bicycle.

Application and research of ergonomics have been placed on a vital position. The human–machine system of public bicycle must be improved in the future. However, there are some limitations in this study due to the reasons that the national standard data are outdated. So we hope that database for human's body size measurement can be improved as soon as possible.

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A Design Model of Guide System Based on Environment-Human-Object-Technology and Its Application

Yueqin Wu

Abstract In order to improve the effectiveness of information presenting and conveying, apply the four-dimensional system of Information Interaction Design—"environment–human–object–technology" into the Guidance System Design by decomposing the various factors and extracting useful information from complex data to understand the structure and interaction relation. Taking Pingle Ancient Town as an example, collecting and choosing data from the four-dimensional system is a design basis for guide spots, carriers, and information interaction to make the information receivers more efficient to get information with better experience.

Keywords Information interaction design · Human–machine environment · System theory · Guidance system design · Information communication

The goal of industrial design is to design some products through proper way to balance the relation between human–machine–environment system, which can satisfy the need of customers and be fit to market tendency. When the industrial society evolves into information society, industrial design has to adjust some methods to design some products and pay more attention to information interaction and user experience.v

1 Guide System

Sign has many meanings, such as signal, LOGO, instruction, indicator, trace [1]. The design of guide system not only needs to visualize the textual information and abstract graphic symbols in the space, but also makes the elements such as shape,

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color, and material integrated into the whole environment and keeps harmonization with them. Guide design is a simple, easy-to-understand visual form in public places, so that people can master the guidance of spatial information effectively [2]. The traditional "human–machine–environment" system is adjusted into "environment–human–object–technology" according to the user-centered design (UCD) and the elements and their attributions in guide system: Environment–human–object–technology (EHOT), in which the human and the environment are exteriorly defined elements of the guide design and the objects and technologies are the internal components of the guide design.

Information is a form of cognition about the state of objective things. It is the third needed resource to maintain human society and economic activities, and it is the experience, knowledge, and wisdom needed for decision-making, planning, and action [3]. From the point of design, an information activity is to convert all kinds of data into valuable information combined with specific context, which will be easily understanding and applicable for users. In terms of design of guidance system, the information activity starts from data collection and ends at information presentation.

2 Design Content and Principles of Guidance System

Design content of guidance system generally includes spot layout, carrier, and information transmission, and its design principles have certain similarities in presentation and communication of information.

2.1 Guide Spot Layout and Design

It is necessary to balance the overall style of scenic spots in an area, the distribution of scenic spots, the tour route, and other basic elements such as firefighting, ventilation, strong electricity, weak electricity, basic decoration, and the application of VI. Different types of guide information carrier should be placed in the appropriate three-dimensional space to ensure that users get access to relevant information, the design of guide spots with the specific space environment, tour routes, flow of visitors, and psychology/behavior of users' pathfinding which are closely related to general need to follow scientific principles and levels of guiding.

2.2 Design of Guide Information Carrier

Guide information carrier is an intermediary between information and audience, which is important for guide information. Generally, design of carrier belongs to the category of product design. Design of guide carrier refers to the integrated use of shape, color, material, and fit to the environment with regional cultural characteristics. The design principles of carrier are environmental coordination, durable, reliable, easy to use, easy maintenance, easy to identify, display accurately, cultural and visual unity, information recognition, and weather ability [4].

2.3 Design of Information Communication

Designer usually uses graphic, symbol, text, color, sound, etc. to convey clearly and orderly effective information to the audiences and users. The information transmission needs to be correct and fast, and seek the individuality and change in unity. According to different functions, information communication design is generally divided into five types: the identification of guidance, guided guidance, spatial guide, information guide, and management-type guide [5]. Generally, the design principles are information identification, visual unification, orientation hierarchy, cultural unity, interactive novelty, and environmental coordination.

3 Design Model of Guidance System Based on the "Environment–Human–Object–Technology"

With the development of Internet of Things and the construction of Intelligent City, the guidance system shows a scientific, intelligent, interactive design trends. The interaction between the four elements (environment–human–object–technology) includes six levels of interaction: (1) environment–human, the relationship and emotional communication between environment, users, and information transporter; (2) environment–object, including time, spot, and location of guide information carrier and information transmission; (3) environment–technology, the interaction between social environment, cultural environment, and technology; (4) human–object, the effectiveness of information communication and the interaction between users and objects; (5) human–technology, the interaction experience and emotional communication between human and technology; (6) object–technology, the mutual influence and effect between objects, output information products, and technology.

In the design of guidance system, there are some main points including how to collect the key data and how to extract effective information, so as to optimize the relationship between environment, users (human), products (object), and technology. Then, the output of information product will balance the three aspects, spot layout, carriers, and information, to satisfy the requirement of users during their path finding, both mentality and behavior [6].

4 Design Application of Guidance System Based on "Environment–Human–Object–Technology"

Pingle is a historical and cultural town in Chengdu, "the top ten charm towns," which has its beautiful natural environment, rich tourism resources, and a long history and culture to attract endless visitors. In 2015, Chengdu Municipal Government and Scenic Area Management Committee began to upgrade and transform the ancient town, to create the national 5A scenic area [7], so redesigning the guide system is one project of this important program.

4.1 *Arrangement and Design of Guide Spots*

The external qualifying factors, "environment" and "human," are the key of arrangement and design of guide spots. The main methods of data acquisition are field survey, county records, scenic area management committee, and observation of the flow of people in some intensive areas, combined with the survey results of random sampling of user to select data. Because of the complexity of the obtained data and the limited space, this paper presents only some key data and information in Fig. 1. Design researchers proposed the design of guide spots after understanding and refining the data and information with social environment.

Through the inspection of county records and the field investigation of "environment" factor, the obtained data include the following: the first town of Silk Road in south of China, a total of 33 streets, a total of 54 scenic spots, one exhibition of intangible cultural heritage, ancient architecture of dynasty Ming and Qing. Through interviews to investigate "human" factors, the obtained data include the following: 65% vacation, 27% weekend; 1-day visit accounted for 49%, 2-day tour 43%, more than 3-day visit 8%; 92% of the tourists to visit the attractions not more than 12, the first day of the tour accounted for 27%. Almost every fresh visitor will visit the Baimo River, the Millennium banyan, Le Shan Bridge. Then, the design researchers get some valid information for design with the data of "environment"

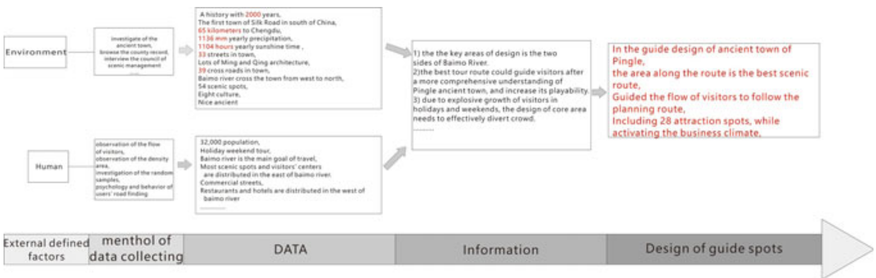

Fig. 1 Design model of guide spots in Pingle

factor and "human" factor: the key areas of design, the best tour route, and the diversion of crowd in the core area.

4.2 Design Basis and Program of Guide Information Carrier

The guide information carrier is presented in the form of "object," which involves three factors: "environment–human–technology." (1) "Object–environment," is the relationship between the carrier and the ancient town of Pingle. The design of guide information carrier also needs to consider the carrier itself, shape, color, material, and environment coordination to reflect the local humanistic spirit, the natural environment. (2) "Object–human," is the relationship between the guide carrier and the tourists, such as whether visitors can accurately find the guide carrier and obtain valid information with a pleasant experience. The data of "human" which influence the design of carrier include the composition of tourist flow, the esthetic of tourists, their psychology of road-finding, human–machine data, and so on. (3) "Object–technology" refers to the relationship between guide carrier and its implementation technology. The relevant data of "technology" include transportation of material, processing production, surface treatment, installation and maintenance, energy consumption, and so on.

Fig. 2 can show the process of designer's thinking and work, the opposite narration of the paragraph can help reader think how to form the design result. According to the design of guide spots in Pingle, the guide carrier and its information will be represented in upper, middle, and lower three-level space. The shape, color, and texture of guide carrier should be coordinated with the environment showing the 2000-year-old culture. The massive data of "environment–human–technology" will effect together on the three aspects: "shape–color–wood". Light gray, dark gray, wood grain, black, and red are the main colors of guide carriers, depending on the position and the color recognition of tourists. The materials in the guide carrier are mainly natural, such as stone, solid wood, supplemented with aluminum, copper, and other durable metal materials.

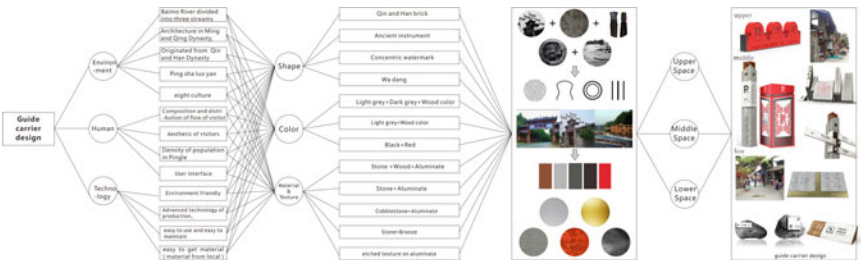

Fig. 2 Design of guide carrier under the influence of factors "environment–human–technology"

4.3 Design Basis of Guide Information Communication

The design of guiding information communication is mainly based on the visual elements, which belongs to the scope of "object" and is influenced by three factors "environment–human–technology." In this program, guide information has certain normative requirements to fit the relative standards and regulations, due to the limitation of "environment".

Design of guide information communication needs to consider the characteristics of human visual system. According to some data of ergonomics on human head rotation and characteristics of human eye area, design of guide carrier has some scientific basic to enable visitors to quickly obtain the required information. According to the measurement of distance between visitors and guide carrier, when the distance is 25 m, the height of Chinese font on sign board is less than 90 mm so 35% of users cannot effectively read the information [8]. The color of information based on visual communication depends on the function of guide carrier, emphasizing visual contrast in design. Information communication based on hearing and interactive experience is an auxiliary means. In the cultural blocks and eight sub-cultural heritage sites, some interactive area of multimedia are set up, then visitors can receive more guide information of Pingle to enhance the overall tourist experience.

5 Conclusion

The essence of guidance system design is effective information communication. By using the four-dimensional system of information interaction design, we can easily and clearly carry out investigation and research on each factor and realize the collection, collation, and research of information data, the choice of guide spots, the design of information content, and the carriers in the right exhibition; designer should pay attention to the effectiveness of information conveyed.

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Study of Man–Machine–Environment System Engineering on University Library Under Internet Condition

Kunzhu Zhang and Quan Yuan

Abstract The library plays an important role in the education and research of higher education. An effective man–machine–environment system (MMES) can guarantee the full and efficient use of the library information resources by the teachers and students. Based on the ergonomics theory, this paper investigates the composition factors of the MMES of the university library and its interrelations, analyzes the typical man–machine interface and the main humanistic function of the library in current Internet conditions, and discusses the optimization method of the MMES. The results show that in the network environment, the man–machine–environment system of university library contains many virtual man–machine interfaces and the man–machine interaction factors. Internet-based applications are the characteristics of the current university library, and the university library in the network environment should pay attention to man–machine interaction interface construction and humanized self-service function promotion. The conclusions may provide some implications for network-based and human-oriented improvement of the university library.

Keywords University library · Man–machine–environment system · Man–machine interface · Internet condition

1 Introduction

The role of the library in the working life of people is self-evident, where the majority of users can get a wealth of reading resources and comfortable learning conditions. The new type of libraries in the Internet era features big data,

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intellectualization, and humanity. People usually use computers, mobile phones, and handheld computers and other media information to query, read, and access the data; therefore, in the library's man–machine–environment system, there are more virtual system man–machine interfaces and human–computer interactions. Although the traditional paper reading has not been replaced electronically, the electronic means has been extensively used as a convenient tool for readers to obtain information and enhance the human-oriented effectiveness of the library from multiple media.

At present, the applications of ergonomics theory and technology become extensive day by day in various industries. However, there are few studies on the application of ergonomics in the library [1–7], the development of overseas libraries is faster with the complete facilities [8], and the relevant studies is still visible [9–11], but not as a hot topic. Moreover, these studies are made only starting from the reading [3], attendance, circulation, and other basic man–machine system functions, such as the local studies on reading room design [3], bookshelf construction [4], furniture [5, 6], lighting environment optimization [2], learning space management [7], security [11], and others without a unified analysis from the view of human–machine–environment system and special attention and focus on the libraries in universities.

In order to investigate the humanistic development of the university libraries in the Internet era, this paper analyzes the man–machine–environment system of the library from the angle of ergonomics, discusses the main connotations and contents of man–machine interaction, and analyzes the corresponding man nature function and features of the time so as to promote the construction of new man–machine interactive interface and the enhancement of the humanized self-service function in the library.

2 Man–Machine–Environment System of Library

The man–machine–environment system of library is composed of people and machine in the library's environment. Its composition is shown in Fig. 1, including the various types of people involved in the use of the system, machinery, and equipment and a variety of environments.

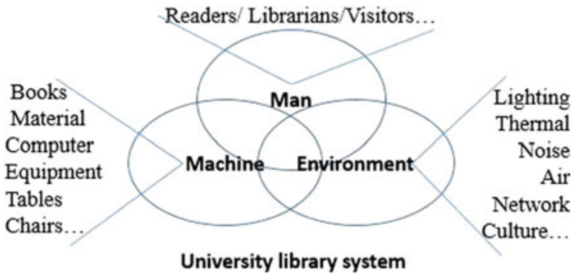

Fig. 1 Man–machine–environment system of university library

The "man" in the system mainly includes all kinds of users (teachers, student, and researchers), librarians, and related service personnel, as well as temporary visitors. Among them, teachers and students are the main objects of the university library and librarians are the main staff. All of them coexist in the system.

"Machine" first includes various and massive books and information, in paper, electronic, multi-source media and other forms. There are also shelves and computer interfaces for carrying information, tables and chairs for use, equipment systems, and service facilities such as automatic borrowing equipment, information inquiry systems, document scanning and printing systems, and elevators in drinking systems, water dispenser, vending machines, etc. available for users.

"Environment" includes the internal and external environment of the library, which is divided into light environment, thermal environment, sound environment, air environment, network environment, and other environments, similar with the environments of general classroom, office, and other public places. The impact of the environment on the man–machine system is significant. For the library, as a place to read, the light, color, sound environments and temperature requirements are very high and the designer has to consider a lot of related factors [2]. Comfortable environment can improve learning and work efficiency; on the contrary, the uncomfortable environment may reduce the efficiency, increase the error rate, and affect the health. Real-time network use is the requirement of humanization. In the Internet conditions, the use of the library shows higher timeliness, which is also a main characteristic of information access of library in this time of Internet.

Above man–machine–environment factors are intertwined with each other, constituting a complex man–machine–environment system of library. Three factors are interacted with each other; the machine and environment should meet various physiological and psychological needs of people to allow people to easily access a variety of resources, and then read and learn pleasantly.

3 Man–Machine Interface of Library

Man–machine interface refers to the area of communication and interaction between people and machine. In the library system, there are a variety of different types of man–machine interfaces. See Table 1.

The commonly seen human–machine interfaces in the library mainly include people–desk/chair interface, people–bookshelf interface, and human–computer interface.

Man-desk/chair interface in the library is similar to the relevantinterface in the office or classroom, which ensures that peoplehave stable and healthy sitting postures, comfortable visualconditions, and allow the body to have a rest and become relaxed. No doubt such traditional interface is still the longest and the most important interface between man and machine and the basic interface for all activities in this time of Internet.

Table 1 Classification of typical man–machine interface

Classification	Function	Type	Example
Common interface	Read/view	Direct	Man–desk
Computer interface	Search	System	Man–computer
Display interface	Information	Display	Man–screen
Service facility	Self-service	Combined	Man–system
Special interface	Help disabled	Special	Multimedia

Man–machine interface of the computer system means that user borrows books, enquires about information, and makes relevant searches via relevant network or linkage of the library in a computer. On the one hand, the network design should meet various humanized demand and be easy to learn and use to improve the efficiency of search and query; on the other hand, relevant hardware conditions, including the screen, mouse, and keyboard, etc., should be able to make readers comfortable and convenient during the operation.

Man–machine interface for the information display includes various information displays in the library, such as the new book notice, the event notice, the information prompts, and various videos, which are usually arranged in the passages, corridors, publicity boards, and other eye-catching places to allow users to see and acquire information and feel pleasure.

Man–machine interface of service facility refers to that, when using the library, by means of self-service service system, readers can borrow and return books or use scanner or copying machines for relevant operations, which are important service functions of the library. A good interface can make readers easily and efficiently and help study and learning. The ubiquitous Internet makes it easier for reader to access and store information.

Special man–machine interfaces refer to the special man–machine interfaces provided for the old, weak, or disabled readers or the reader using different language, such as the interface for the convenience of the visually impaired or the blind reader, the interface for network inquiry, and the interface for the accessible navigation instructions, sound prompt, etc.

Figure 2 shows the typical man–machine interface of the library based on the man body model. Taking the new library of Tsinghua University as an example, the two types of man–machine interface—reading and computer interaction—are selected, including the sitting and standing postures of human body template so that researcher can further analyze the comfort of corresponding function of human body. In addition, taking book from the shelf, borrowing book by self-service machine, copying book by self-service machine, using cell phone in free time, and some other scenarios are typical man–machine interface and man–machine interaction scenarios. In the conditions of Internet, the virtual displays of the man–machine interface and human–computer interaction scenarios are distributed all over the library as major feature of modern society. In addition to the traditional keyboard and mouse operations, direct touch screens are gradually increased, allowing the use in a more intuitive, convenient, and nature way.

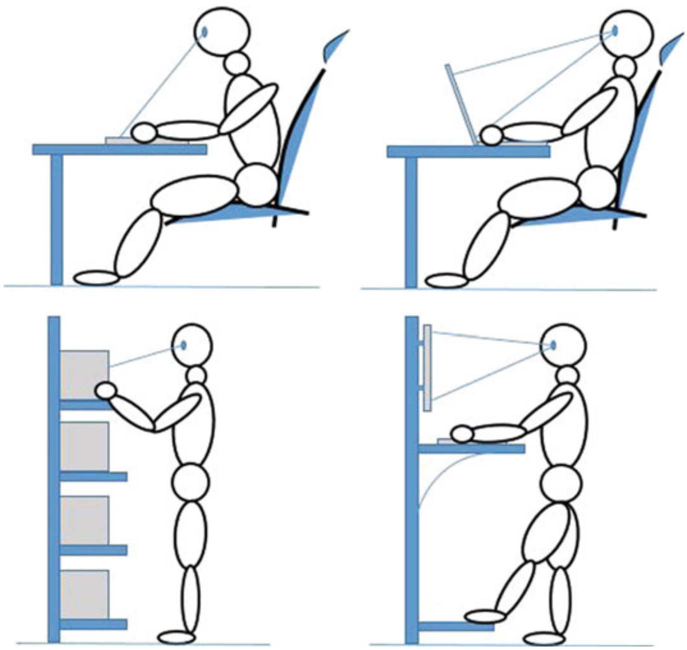

Fig. 2 Typical man–machine interface of library

4 Humanized Function of Library

Based on the above various typical man–machine interfaces, the library provides rich humanized functions for the readers. By means of the quick and convenient wireless network conditions, the reader can enjoy a variety of user-friendly features via Internet.

(1) Query and browsing function

Readers come to the library for finding the books and information needed, so the query is the primary function. Through the network-based and user-friendly menu function, readers can quickly find the required materials and then read them to get relevant information and knowledge. By the query, comparison, and screening, the reader will ultimately find appropriate bibliography. Therefore, the query and reading are the library's most basic humanized function.

(2) Borrowing and return function

In addition to sitting and reading in the library, borrowing and returning books are also the most basic functions of the library. At present, the library provides users with self-help and manual modes to borrow books. Outside the working hours, readers may return books via the return box. Through network personal borrowing system or mobile phone APP, WeChat and other functions, the reader can also keep an eye on the information like new books and popular books.

The new virtual reality experience area provides readers with virtual touch screen man–machine interfaces. On the interfaces, a variety of bibliographic cover pictures rolls on the big screen and the readers can select with a finger and then use the phone's WeChat to scan the associated picture so that he can use the borrowing function, which is more intuitive and convenient.

(3) Information acquisition function

In addition to borrowing and reading books, the library also provides readers with a variety of information access functions, including retrieval and access functions for a variety of network databases, databases, reference books, and ancient books, and audio and other multi-source information so that the reader has access or use these functions with the help of a librarian.

(4) Self-service function

Generally, reader needs to extract and record the materials found, so scanning, printing, copying, reproducing, and some other functions are practical and usual demands. Library should provide relevant equipment and system anywhere to allow readers to enjoy self-service from time to time. Taking the advantage of Internet, each equipment and system should have user-friendly man–machine interface and quick operations to meet users' demands in the saving and using data via Internet.

(5) Discussion and communication function

A variety of types and sizes of study rooms is a emerging new function these years. Besides reading, readers also need to conduct brief communication and discussion with their classmates, teachers, or peers. Library should have similar closed places for such activities.

(6) Leisure function

After reading, readers need a place to have a rest or do some simple activities. In the library, long sofas, rest corners, green plants, drinking water, and other humanized rest areas are also required. The external environment of the library should be skillfully combined with natural environment. Currently to cope with the thick smog outside, any library should have a high-performance fresh air system to provide readers with healthier atmospheric quality.

(7) Vulnerable group service function

To facilitate the use of the library by the elderly and the disabled, the library should provide the corresponding humanized function, such as navigation and reading and query functions and relevant assistances for amblyopia and blind readers to allow more readers to benefit.

Furthermore, it also includes personnel access management, escape routes, security, and other humanized features.

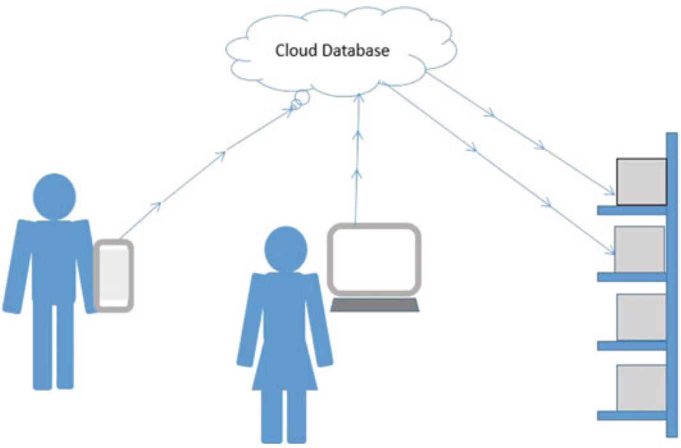

Fig. 3 Library use based on cloud database and mobile phone

Above humanized functions are the characteristics of new university library. Inclusion of above aspects will make the new library's MMES very humanized. As shown in Fig. 3, based on the query and borrowing management of library materials of cloud big data, with a cell phone or a computer only, readers can conduct relevant information processing, connect massive big data in the world, and realize the interconnection and sharing in an internationalized way, that is, the peak of man–machine engineering technology of library in this era of Internet.

5 Discussion

Nowadays, the new MMES of university library can meet the needs of teachers and students, providing comfortable, convenient, pleasant reading, learning, and working environment and a variety of self-service functions and reach a high performance as a whole. Among all functions, networking, electronization, and humanization are main features of such system.

In current network environment, the university library should pay attention to the improvement of the man–machine interaction and the promotion of the humanized self-service function. For instance, the man–machine interaction function of various interfaces of networks and equipment system shall be further improved in a humanized way; the self-service function shall also make all groups convenient, reduce difficulty of the use, enhance efficiency, and minimize the error.

In the future, designers shall make further improvement in the service for special groups and subject directions. For instance, the special devices and places may be increased for special attentions and assistance for vulnerable groups; assistance in different languages shall be provided for foreign users to facilitate the internationalized communication and use; the system shall also follow the frontier of some typical subjects, enrich contents, and introduce advanced book resources to provide researchers with more practical and targeted quality service.

In addition, to cope with harsh weather conditions, such as thick smog, heavy rain, and other extreme weathers, there should be some measures to ensure the functions involving the fresh air, good lighting, and noise reduction and other aspects to create a comfortable environment for learning.

Today, there are few studies on the MMES of library. The library as a special building environment needs to be studied from the angle of ergonomics. This paper makes primary discussions from the view of man–machine interface only. In the future, we should make further study on the details of library's MMES, such as comfortable environment design evaluation for optimization of computer interfaces, R&D of more advanced humanized interfaces, improvement of health of readers, and enhancement of effective utilization of the library.

6 Conclusion

Based on the idea and method of ergonomics, this paper analyzes the constituent factors of MMES of university library and its interrelations, investigates in the typical man–machine interface and humanized function of library under the current network conditions and discusses the optimization method of MMES. The results show that under the Internet environment, the MMES of the university library contains more man–machine interfaces and man–machine interaction factors of virtual systems. The Internet-based application is the characteristic of the current university library, and the university library under the network environment should pay attention to the construction of man–machine interaction interface and the enhancement of intelligent and humanized self-service functions. In addition, the system should be improved when considering special groups, vulnerable groups, adverse weather, and subject-oriented service. To sum up, the contents and details of the library's MMES need to be further discussed and developed.

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