The Influence of Gender on Human's Cognitive Ability and the Correlation Research of Different Cognitive Dimensions

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Abstract. Human's ability and characteristic are important content in ergonomics research. Only when machine and environment adapt to person's ability and characteristic, can human work safely, healthily, comfortably and efficiently. Four cognitive characteristic indexes were studied in this experiment which they are: visual response speed, attention span, spatial location memory span and short-time memory span. The aim was to study the influence of gender on four indicators and the correlation between them. Thirty-one postgraduates of Beihang University took part in the experiment. The subjects included 17 female and 14 male who aged from 22 to 25 years old, with an average age of 23. They were healthy and their vision or corrected vision were 1.5 or above. The results showed that there were no significant differences in the reaction time, attention span, short term memory span and spatial location memory span between males and females ($P > 0.05$). According to the comparison of the comprehensive value of cognitive ability, the comprehensive value of comprehensive ability of girls and boys was about 0.49 and 0.48 respectively, and the cognitive ability of girls was slightly higher than boys. The results of independent T-test showed that the $P > 0.05$, so there was no significant difference in cognitive ability between boys and girls. In terms of the correlation of four indicators in different cognitive dimensions, the Pearson correlation coefficient of the short-time memory span value and the attention span value was 0.445, and the significance level was 0.05. There was a certain correlation between the two indicators, while there was no obvious correlation among other indicators. This research can provide reference for information product design and some job recruitment.

Keywords: Ergonomics · Cognition · Gender · Correlation · Attention · Memory

1 Introduction

Human's ability and characteristics are an important part of ergonomics research, machines and environment must adapt to human abilities and characteristics, can human

D. Harris and W.-C. Li (Eds.): HCII 2021, LNAI 12767, pp. 185–196, 2021.
https://doi.org/10.1007/978-3-030-77932-0_16

beings work safely, healthy, comfortable and efficiently. Man is a complex system with all aspects of ability and characteristics that must be taken into account when designing a machine, such as the size of the human body, the size of the human force, the visual, auditory, human attention, memory, learning, reaction speed and other psychophysical and cognitive characteristics. This study used experiments to explore the effects of gender differences on people's cognitive abilities and the correlation between different cognitive dimensions. People have many cognitive dimensions, and this experiment only focused on four of them: human response speed or the reaction time (RT), attention breadth (AB), spatial location memory breadth (SLMB), and short-term memory breadth (STMB).

The speed of human response refers to the ability of a person to respond quickly to various external stimuli, reflecting the coordination and rapid response ability of the nerve and muscle system. Reaction speed is an important part of the evaluation index of physical fitness, which reflects the efficiency of muscle work and the function of human motor system. The faster the reaction speed, the faster the body's response to stimulation, with the increase of exercise fatigue, the reaction speed shows a downward trend, therefore, the reaction speed is also an indicator of fatigue level. In the field of psychology, the reaction time is considered to be a reliable psychological indicator, which can measure the level of excitability and inhibition of the brain and analyze various psychological activities such as human perception, feeling, attention, thinking, creation and learning [1]. It is concluded that there are two basic cause variables in the reaction time experiment, namely speed and accuracy. One of the prominent problems in the reaction time experiment is to tradeoff the relationship between the two. When subjects join a sport, they will consider the law of speed accuracy trade-offs: if the action is the faster, it will be less accurate; on the contrary, the action is the accurater, the speed will be slower. In recent years, the relevant research on reaction time has become more and more in-depth. Many scholars have studied the reaction time from different angles, such as psychology, medicine and physical education, and have made some important findings. Zhao Runshuan et al. found that the body fat rate was related to the reaction rate, and concluded that the reaction time increased by 0.0014s and 0.0015s when the body fat rate of men and women exceeded 1%. Excess body fat rate can lead to a decrease in physical fitness [2]. Zhang Liwei et al. made a analysis on the research of reaction time, and he put forward that the reaction of the short-distance speed project was better than that of the long-distance speed project, and the reaction time of the adversary open sports project was better than that of the non-confrontational and closed sports [3].

Attention breadth refers to the pointing and concentration of psychological activities or consciousness to a certain object, that is, people point to and concentrate their own perception, memory, thinking and other activities on the selected object. Attention has the function of selection, maintenance, integration and adjustment, the input of information to make choices, thus ensuring a clearer understanding of things and more accurate response, therefore, it is an important psychological quality for people to acquire knowledge, master skills, complete various intelligence operations and practical operations, and it is also the basis of information processing and other psychological activities [4]. There has been studies on the effects of emotional induction on attention breadth in humans themselves [5]. The earliest studies have shown that things with emotions have the advantage of gaining access to and focusing on attention resources compared to

emotionless things. Rowe et al. looked at the effects of positive emotions on attention breadth. It was found that positive emotions did increase the breadth of visual attention compared to negative and neutral emotions, resulting in a more significant flanker effect [6].

Spatial location memory breadth refers to an individual's ability to identify, encode, store, characterize, decompose/combine and abstract/summarize objects or spatial graphics in the mind, including spatial observation, spatial memory, spatial imagination and spatial thinking. Researchers have carried out some analysis from the perspective of individual sex and age. There were great differences in the size, importance and development process of gender differences in visual spatial ability and interpretation theory, some studies have found that girls lag behind in tasks with spatial factors, and the differences between boys and girls increased with age; another study conducted a visual test on college students, and found that there was no gender difference, while many previous studies have found that visual ability was the biggest gender difference in cognitive field. There are relatively few studies on the age difference of visual spatial ability, but the results were more consistent: young people have a greater advantage in spatial ability. In addition to gender and age factors, the researchers also studied the visual spatial abilities of different types of subjects. For example, Chinese scholar Zou Jinli discussed the cognitive characteristics of Chinese children's visual space at different literacy levels. Zhao Wei conducted experimental research on the speech consciousness and visual spatial cognition of Chinese students with difficulty reading. The research on the visual spatial ability of different groups of people in China is still limited to one aspect of spatial ability, which lacks the whole discussion of spatial ability, and the selection range of the subject groups is also narrow [7].

The task of short-term memory breadth is an important index to evaluate short-term memory ability. It has been found that the memory breadth of different materials varies greatly, for example, the breadth of numbers is generally greater than the breadth of words. Another short-term memory task, the Sternberg recognition task, had similar characteristics. Sternberg recognition task presented a string of numbers to the subjects, called reaction set, for the subjects to remember, followed by a test stimulus that asked the subjects to determine whether they were part of the reaction set. With the increase of reaction set items, the time for the subjects to do the correct reaction increased linearly. According to Sternberg, this reflected the fact that searching for items in short-term memory was a series of end-of-life scans. The search speed (that is, the scan time for each item) could be estimated by the slope of the linear regression equation for reaction time and reaction set size [8]. Many studies have shown that materials with a wide memory have shorter scanning times. Cavanagh collected literature on the memory breadth and search speed of seven different types of stimulus materials and found an inverse relationship between the two indicators of short-term memory [9]. There are many factors that affect the breadth of short-term memory. The size, complexity, and familiarity of the blocks all affect the capacity of short-term memories. Studies such as Yu Bolin and Zhang Wutian showed that the short-term memory capacity of two-tone synthesized words and four-word idioms was not as large as that of single-tone words, while four-word idioms were not as many as two-tone words; with the increase of block complexity, short-term memory capacity tends to decrease gradually; high-frequency

words had more short-term memory capacity than low-frequency words. Zhang Wutian et al. found that the stroke complexity of Chinese characters had a significant effect on short-term memory hold, and the recognition time of words with different stroke complexity had a significant negative correlation with their memory hold [10].

2 Method

2.1 Subjects

Thirty-one postgraduate students from Beihang University took part in the experiment, aged between 22 and 25, with an average age of 23. They were in good health, had no specific disease, and had naked or corrected visual acuity of 1.0 or above.

2.2 Experiment Content

Reaction Time Measurement. The time between the presentation of the stimulus and the response is called the response time. Response time measurements include visual response time measurements and auditory response time measurements. This experiment measured visual response time. The visual stimulus was a green circle (Fig. 1). All the subjects reacted by pressing the green key. The test was performed for 30 times, and the stimulation was presented at an interval of 2 s after each preparation. If there was preemptive action in the preparation stage, the result was invalid, and the computer would reject the subject and warned him. In addition, 2S of blank detection stimulus was randomly added in a group every 5 times. If any subject was forestall at pressing key, he would be warned, and this group of experiments would be re-conducted. Finally, the mean of the effective result was taken as the reaction time.

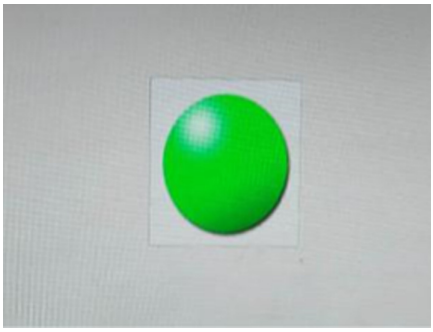

Fig. 1. Experimental stimulation for reactions time

Attention Span Measurement. Attention span usually refers to the scope of visual attention, that is, the number of objects perceived at the same time. In this experiment, the attention span of the subjects with different number of red dots arranged randomly was calculated by psychophysical method.

During the experiment, the number of red dots randomly presented on the computer screen (As shown in Fig. 2) ranged from 5 to 12, 10 of each type, 80 in total. Each display time was 0.25 s. The subject was asked to press the corresponding number key to type the answer (or click the input box with the mouse and then enter the answer through the selection menu). The percentage of correct responses to different dots was counted. Starting from five dots, the number of dots with the first 50% correct responses was calculated by linear interpolation method as the attention span value.

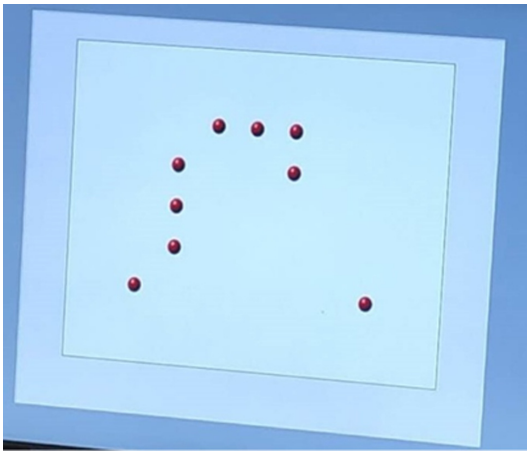

Fig. 2. Experimental stimulation of attention span

Short Term Memory Span Measurement. Memory span refers to the length of a series of stimuli that can be reproduced immediately after a sequence of stimuli is presented in a fixed order. The intervals between the stimuli presented must be equal, and the results reproduced must correspond to the order in which they were presented. Similar to the concept of sensory threshold, the so-called "just able to reappear immediately" means that 50% of the times can be reappeared immediately.

Digital memory span is a simple and easy method to measure short-term memory ability. The stimulus presented in this experiment was a series of numbers (Fig. 3).

The subjects read the instructions carefully, figuring out how to remember and how to enter the answers. When entering the answer, there should be no Spaces between the numbers. If there was any error, the subject could press Back Space to delete and re-enter. After typing, pressed enter to confirm. The interval between the numbers was 750 ms, each number presented 250 ms, starting with 3 digits, then 4, 5, 6… Until the same number series was wrong three times or up to 12 digits.

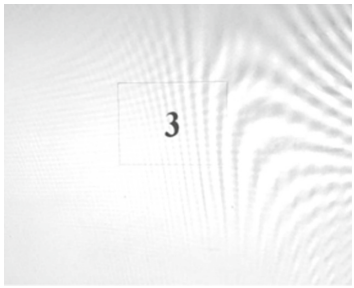

Fig. 3. Experimental stimulation of short-term memory span

The method of calculating memory span was as follows:

If each series is presented three times in a row, the longest series that can pass the three times is taken as the cardinal number, and then the length of other stimulation series that can pass is added to the cardinal number by 1/3 or 2/3, and the sum of the two is counted as memory span. This method was used to measure and calculate the digit memory span in this experiment. For example, if the longest series that could pass three times was 7 digits, the base number was 7. If the 8-digit series passed twice, the 9-digit series passed once, and the 10 digit series failed once, the memory span was $7 + 2/3 + 1/3 = 8$.

Spatial Location Memory Span Measurement. Spatial location memory span refers to the length of the spatial location series that the subject can reproduce immediately after presenting a series of positions in a fixed order. Participants must reproduce the order in which they were originally presented.

During the experiment, a 5×3 green table (Fig. 4) was presented on the computer screen, and the bright pink dots were randomly presented in some of the 15 grids (starting with 3 consecutive grids at a time). The subjects were asked to try their best to remember the location and order of the dots. After the dots appeared, the subjects were asked to click the table in the order in which the dots appeared just now, and then input by clicking the "OK" button with the mouse. After a span has been done three times, if it is not all wrong, the span is multiplied by 1 and continues until a span has been wrong three times in a row or has completed 12 tasks. Each time the participant entered an answer, if there were any errors, he or she could click on the last table to modify.

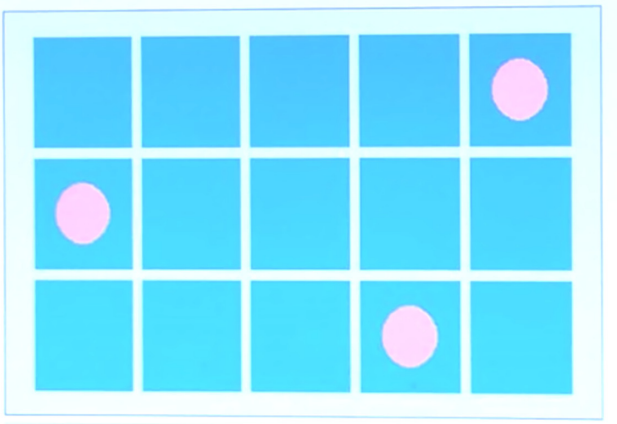

Fig. 4. Experimental stimulation of spatial location memory span (Color figure online)

2.3 Experimental Process

In this experiment, the reaction time, attention span, short-term memory span and spatial location memory span were measured in the order. The subjects first practiced the experiment by themselves until they were proficient, and then they carried out the formal measurement experiment. In the process of the experiment, they needed to rest and relax for five minutes to complete an index, and then they carried out the experimental measurement of the next index. The experimental scene was shown in Fig. 5.

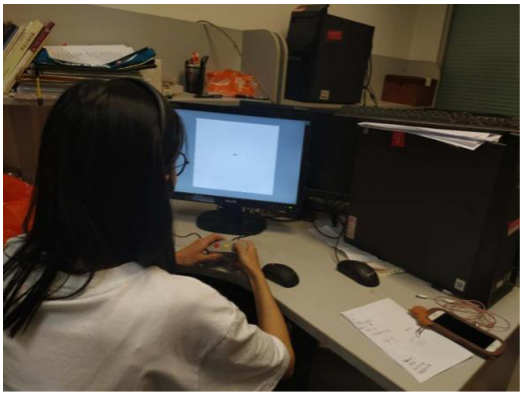

Fig. 5. Experiment scene

3 Results

3.1 Verification and Elimination of Abnormal Data

Box-plot, also known as box-whisker plot, box-plot or boxplot, is a statistical graph showing the dispersion of a group of data. It gets its name from the shape of a box, as shown in Fig. 6. The standard of box-plot to determine outliers is based on quartiles and quartile distance. Quartiles have a certain resistance, and up to 25% of the data can become arbitrary and far away without greatly disturbing the quartiles. Therefore, outliers cannot affect this standard, and the results of box-plot to identify outliers are more objective. There is a box in the middle of the box line diagram, that is, the pink part. There are lines on the left, middle and right of the box. The left is the lower quartile (Q1), the right is the upper quartile (Q3), and the middle is the median. The difference between the upper and lower quartiles is the interquartile range (IQR). Q1–1.5IQR is used to get the lower edge (minimum) and Q3+1.5IQR is used to get the upper edge (maximum). The data outside the upper edge is the maximum outlier, and the data outside the lower edge is the minimum outlier. In short, the data outside the upper and lower edge is the outlier.

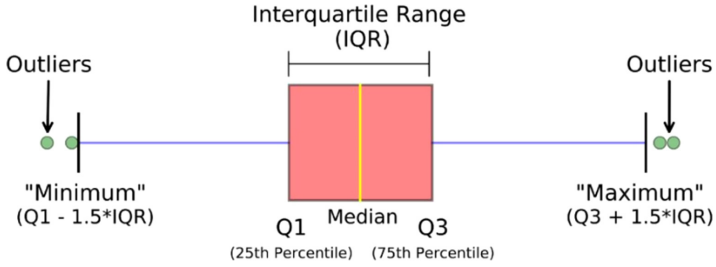

Fig.6. Box line diagram

According to the results of boxplot, in the memory span value of spatial position, data No. 15 was small and was an outlier, which can be eliminated. In the value of short-term memory span, data No. 30 was a small outlier, which can be eliminated. There was no outlier in the span of attention value. In the simple reaction time, there were 23, 30, 24, 29 which were outliers, which could be removed. Since the data corresponding to the experiment number was the experimental result of the same person, based on this, if there was a certain data deviation, it might be caused by the status of the subject or other factors. In order to ensure the reliability of the experimental data, the data obtained by the subject will be excluded here. In conclusion, for the collected data, data No. 15, 23, 24, 29 and 30 were excluded here for further statistical analysis of the remaining data.

3.2 The Influence of Gender on Cognitive Ability

The Influence of Gender on Different Dimensions of Indicators. Independent T test was used to determine whether there were significant gender differences in the four indicators. The results were shown in Table 1:

Table 1. Statistical results of the effect of gender on cognition

Cognitive indicators	Gender	Mean	F	t	Sig.(P)
SLMB	M	6.1	0.49	1.271	0.216
	F	5.8			
STMB	M	7.7	1.029	−0.966	0.344
	F	8.2			
AB	M	8.3	0.306	−1.357	0.187
	F	9.2			
RT /ms	M	643	0.368	0.963	0.345
	F	551			

The results showed that: the average value of spatial location memory span of boys was 6.132, which was slightly higher than that of girls' 5.770. The average value of short-term memory span of boys was 7.666, and that of girls was 8.166, which was slightly higher than that of boys' data. The average value of attention span of boys was 8.308, and that of girls is 9.176. The average value of simple reaction time of boys is 643.40, the average value of girls is 551.438. It could be seen that there was a slight difference in the average value of men and women of the four indicators. The independent T test results showed that there were no significant gender differences($P > 0.05$) response time, attention span, short term memory span and spatial location memory span.

The Influence of Gender on Comprehensive Cognitive Ability. Does gender have any effect on the combined value of the four indicators? The weighted calculation method could be used to carry out mathematical calculation of the four indexes to get the comprehensive value. Since the dimension of each index was different, each index needed to be normalized. The normalization algorithm was shown in Eq. (1).

$$Y = \frac{X - MIN}{MAX - MIN} \tag{1}$$

Where: Y represented the normalized value. X represented the experimental results before normalization. MIN represented the minimum value in the experimental results. MAX represented the maximum value of the experimental result.

The four indexes were calculated according to the weight to get a comprehensive value. Weight distribution method: the weight of simple reaction was 1.9; the other three indicators were 2.7 each. The weight sum of the four indexes was 1. The comprehensive value of cognitive ability was calculated according to Eq. (2).

$$Y = 1.9 * X_1 + 2.7 * (X_2 + X_3 + X_4) \tag{2}$$

In formula (2), X1, X2, X3 and X4 represented the normalized simple reaction time, attention span, short-term memory span and spatial location memory span respectively; Y represented the comprehensive value of cognitive ability.

Table 2. The influence of gender on comprehensive cognitive ability

Gender	Mean	F	t	Sig.(P)
M	0.481	0.358	−0.239	0.813
F	0.493			

Independent T-test was conducted on the comprehensive value of cognitive ability, and the results were shown in Table 2:

The average comprehensive value of boys was about 0.481, and that of girls was about 0.493. The comprehensive value of boys was slightly lower than that of girls. The results of independent t-test showed that $P > 0.05$, so there was no significant gender difference in the comprehensive value of cognitive ability.

3.3 Correlation of Different Cognitive Dimensions

The calculation formula of Pearson correlation coefficient ρ_{xy} of two n-dimensional vectors X and Y is shown in Eq. (3):

$$\rho_{xy} = \frac{\sum_{i=1}^{n}\left[(X_i - \overline{X})(Y_i - \overline{Y})\right]}{\left(\sqrt{\sum_{i=1}^{n}(X_i - \overline{X})^2}\right)\left(\sqrt{\sum_{i=1}^{n}(Y_i - \overline{Y})^2}\right)} \tag{3}$$

Where: X_i and Y_i represent the ith element value of n-dimensional vector X and Y; $\overline{X}$ and $\overline{Y}$ represent the average value of the n elements of the n-dimensional vectors X and Y.

The correlation coefficient between 4 indicators were shown in Table 3:

Table 3. The correlation results among 4 cognitive indicators

Cognitive indicators	SLMB	STMB	AB	RT /ms
SLMB	\	−0.133	−0.247	−0.039
STMB	\	\	.445*	−0.09
AB	\	\	\	0.078
RT /ms	\	\	\	\

*At the 0.05 level (double tails), the correlation was significant.

The results showed that the Pearson correlation coefficient of attention span and short-term memory span was 0.445, and there was a certain correlation at the significance level of 0.05. There was no significant correlation between other indexes.

4 Discussion

There are significant physical differences between women and men, but are there also significant psychological differences between them? Especially in terms of cognitive ability. Some occupations require higher comprehensive cognitive ability, such as fighter pilots. Understanding the cognitive differences between different genders will be of practical significance for the selection and training of some professional personnel. The researchers thought there were no significant differences between men and women in psychological traits overall, but there were differences in some areas, such as women's ability to imagine, think visually and speak, and their emotional nature. There are many studies that show that women have better willpower, endurance, adaptability and sense of responsibility [10, 11].

On gender differences, many studies have inconsistent results. Zhou Zhen et al. studied the gender differences in the development of middle school students' spatial figure folding, expansion, rotation and figure reasoning ability. The results showed that there was a significant difference in male dominance under certain conditions. However, in which age group male students were significantly better than female students in which spatial indicators, further research is needed [12]. Liu Kehui, Yan Xiaojun et al. [13] obtained memory span data of 160 college students in the study of memory span experiment based on regression analysis. The feasibility of regression analysis of the data was verified, which showed that it was statistically significant. The linear equation between short-term presentation time and memory span of numbers and letters was established. Combined with mapping analysis, it was found that there was no significant gender difference in memory span. In the study of college students' digital short-term memory span and processing strategy by Liu Wanlun [14], the research results showed that there was no gender difference in college students' digital short term memory span, which was consistent with this study. Wang Jiatong et al. Explored the differences between male and female flight cadets in basic flight cognitive ability by using four indexes: number retrieval, character recognition, hidden figure and word matching. The results showed that female flight cadets were better than male flight cadets in perceptual discrimination, short-term memory and initiative and agility of thinking exploration. There was no significant difference between male and female students in other cognitive abilities, and there was no significant difference in the comprehensive scores of the four cognitive indexes. There are some similarities and differences with this study [15].

However, it must be realized that in addition to the gender difference, even if the individual difference of the same gender is very large, so in the selection and training of career should not be targeted at gender, but should be more targeted at the measurement of individual cognitive ability.

5 Conclusion

After excluding the outliers of the data of each indicator, independent T test was conducted for each indicator, and the results showed that there was no significant gender difference in the simple response time, attention span, short term memory span, and spatial location memory span. The mean spatial location memory span of male students

is slightly higher than that of female students, while the mean short-term memory span and attention span of female students are slightly higher than that of male students. The mean value of boys is slightly higher than girls in simple reaction. Among the four cognitive dimensions, only short-term memory span and attention span are correlated, and they are closely correlated, while other cognitive dimensions are not correlated.

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