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ORIGINAL ARTICLE

Influence of cognitive ability on task performance of dynamic decision making in military vehicles under different task complexity

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Abstract

With the increment of demands on task performance in military vehicles, reasons for task performance difference in dynamic decision making have received considerable attention. The aim of this study was to explore the reasons for performance difference of dynamic decision making in military vehicles. The different influences of cognitive ability on task performance were investigated between low and high task complexity. Task performance was assessed with task completion time and error rate. Task complexity was manipulated by altering three forms of load factor, consisting of number of alternatives, information load and interruption duration. Four types of cognitive abilities were measured, including reaction ability, memory ability, sustained attention ability and attention allocation ability. The results indicated that cognitive abilities were effective predictors of task performance. High task complexity was more detrimental to individuals with low cognitive ability in terms of operation speed, and to individuals with high cognitive ability in terms of operation accuracy. High memory ability became increasingly demanded in high complexity. The key points of enhancing task performance lay in crew selection based on cognitive ability test and pertinence training on balancing operation speed and accuracy. This study provides insights into performance difference of military vehicle crew in dynamic decision making, which has remarkable significance in current crew selection, training and task assignment.

Keywords Cognitive ability · Task complexity · Task performance · Dynamic decision making · Military vehicle

1 Introduction

Military vehicles include land combat and transportation vehicles, in which crew complete missions of monitoring and operating through in-vehicle display and control system. This mission completion can be regarded as a process of dynamic decision making. Dynamic decision-making tasks involve real-time decisions that are interdependent and particularly restrained by the decision-making condition (Edwards 1962). With the advancement of in-vehicle display and control system in military vehicles, high performance of crew has been increasingly demanded in dynamic decision-making tasks. Because of complex operations conducted continuously and much information interacted randomly in military vehicle operation, the crew is strictly required to perform correctly and promptly as much as possible. However, not all the individuals are capable of meeting this high demand on account of the individual difference of cognitive ability. Moreover, the increasing levels of task complexity make missions more challenging, especially when more alternatives, higher memory load and longer interruption duration are involved in crew operating. Therefore, under the high demand in operation speed and accuracy, the effects of cognitive ability and task complexity on task performance in military vehicles have become a central research topic.

Studies have shown that cognitive abilities are related to human performance (Schmidt 2002; Gopher et al. 1994; Ball et al. 1993; Jipp 2016a) and have significant correlations with dynamic decision-making performance (Rigas et al. 2002; Nicholson and O'Hare 2014). In recent research, it was found that high memory ability and sustained attention ability can enhance the reaction speed in monitoring task (Jipp 2016b). Attention span had a remarkable influence on task completion time, and attention allocation ability had important effects on the number of errors in spaceflight emergency operation (Pan et al. 2016). Reaction time was

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used to investigate the control performance of automatic train operation (Brandenburger and Jipp 2017). Brake reaction time was also commonly employed to evaluate driving performance (Kaber et al. 2016; Rodseth et al. 2017; Teh et al. 2018). Furthermore, in personnel selection, cognitive ability tests were proved to be valid predictors of performance (Schmidt and Hunter 1981; Burkolter et al. 2009). When predicting human performance, utilizing specific ability tests was believed to be more effective than using a holistic test (Borman et al. 1997). Thus it is critical to identify the specific ability tests in the actual field. Reaction time was identified to be one of the predictors in aircraft pilot selection (Hunter and Burke 1994). Kaber et al. (2016) regarded memory ability as a primary cognitive factor for driving performance. Working memory and attention control can be treated as valid predictors for common multitasking performance (Redick et al. 2016).

Task complexity has been recognized as another factor influencing human performance in decision-making tasks, such as monitoring (Kerstholt et al. 1996; Bailey and Scerbo 2007) and operating (Horberry et al. 2006; Xu et al. 2008; Han and Patterson 2017). This impact was usually embodied in performance metrics of task completion time and error rate (Gold et al. 2016; Kim and Yang 2017; Lu et al. 2017; Abich et al. 2017). Task complexity can be manipulated by many factors. Payne et al. (1992) suggested that changes in the number of alternatives available may be the most well-established manipulation of task complexity. Hick's law explained the impact of the number of alternatives on task complexity by describing the relationship between the number of alternatives and operation time (Hick 1952; Hyman 1953). Zhang et al. (2009) also viewed the number of alternatives as an important factor of measuring operation complexity. Task complexity can also be measured from the amount of information or information load (Park et al. 2001). Liu and Li (2012) proposed ten dimensions of task complexity including the amount of information. Lai et al. (2014) manipulated task complexity by altering information load to study the effects of task complexity on working memory performance. In addition, interruption during complex tasks can induce cognitive distraction, which has disruptive effects on task performance (Monk et al. 2004). Altmann and Trafton (2002) presented a model of goal activation and suggested that the duration of interruption had an impact on task completion time in terms of resumption efficiency. Similarly, Monk et al. (2008) found that interruption duration had effects on resumption time and error rate. These findings about interruption had practical significance for complex tasks which were frequently interleaved.

Task complexity can be regarded as demands on cognitive resource. In higher complexity, more cognitive resource is needed for task performance (Liu and Li 2012). That is, task performance is associated with both cognitive resources and task complexity. Moreover, the influence of cognitive ability on task performance can vary with task conditions. Verbal ability and quantitative ability showed better predicting effects on task performance in high complexity compared to low complexity (Hunter and Hunter 1984). The cognitive ability to avoid accidents was found to be different from that of driving (Kim and Bishu 2004). The high workload was observed to have a larger effect on individuals with low cognitive ability than individuals with high cognitive ability (Gonzalez 2005). Although considerable work has shown that human performance can be affected by cognitive ability or task complexity, limited attention has been paid to the relationship between these two factors or to the different influences of cognitive ability on task performance with the increment of task complexity, especially for dynamic decision-making tasks in military vehicles.

People tend to believe that the primary task in vehicle operation is driving. In military vehicles, however, the main operation form of dynamic decision making resembles that of pilots in aircraft or operators of unmanned system (Morgan et al. 2013; Liu et al. 2016; Funke et al. 2016). Based on in-vehicle information system, dynamic decision-making tasks in military vehicles incorporate tasks of target identification, target pinpointing, target tracking, and communication, which can be summarized as monitoring and operating. Crew is required to monitor the target, environment and in-vehicle information constantly and to operate by typing and selecting information through the in-vehicle information system. One of the most typical tasks of dynamic decision making in military vehicles is information inputting. After receiving a message, the crew is first required to identify target property by selecting, and then to input the target information of type, position, number, and velocity by typing and selecting. The crew's role is to report the target information accurately and promptly as much as possible. Since real-time information and consequent decisions are interdependent particularly in emergencies, operation accuracy is supposed to be comprehensively considered prior to operation speed. Meanwhile, the increment of task complexity can hinder crew's performance. Number of alternatives, information load and interruption duration are three common forms of load factor of information inputting task. Although previous studies have evaluated the effects of cognitive ability and these three forms of load factor on human performance, the reasons for task performance difference under different task complexity in military vehicles remain an open question. The answer of this question would provide valuable reference for crew selection, pertinence training and the rationalization of task assignment.

In this study, the different influences of cognitive ability on task performance in military vehicles were investigated between low and high task complexity. To be specific, task performance was assessed with task completion time and error rate. Task complexity was manipulated by altering three forms of load factor, namely number of alternatives, information load and interruption duration. Four types of cognitive abilities were measured, including reaction ability, memory ability, sustained attention ability and attention allocation ability. The aim of this study was to explore the reasons for performance difference in dynamic decision-making tasks and to provide methods of improving task performance in military vehicle operation.

2 Materials and methods

2.1 Participants

31 male students with a mean age of 20.7 (range 19–23 years) from the Army Academy of Armored Forces (AAAF) were recruited to participate in the study. The students recruited as participants were crew candidates that were educated and trained to be real crew after graduating. They had already accomplished the same trainings as the real crew did and their operation experience was similar to each other. All participants were right handed, without prior experience in cognitive research and history of sensorimotor deficits. Given the actual situation that crew candidates recruited men only, as well as to avoid the effect of gender difference on cognitive ability (Der and Deary 2006; Barel and Tzischinsky 2018; Gagnon et al. 2018) and task performance (Bylund and Burstrom 2006; Plummer et al. 2017; Wang et al. 2017), only men were included. Participants were offered extra credit in a course in exchange for their participation. All the participants were informed about study aims and procedures prior to the experiment, and were given a written informed consent statement before being included in the study.

2.2 Apparatus

This study was conducted on an in-vehicle ergonomic test system of simulated task (Liu et al. 2015). The test system included a computer and a simulated display and control terminal. A touchscreen was utilized as the simulated display and control terminal, and its dimensions and interface layout were designed in accordance with a real one in military vehicles. The system generated simulated task situations randomly with different combinations of task information. Information was displayed and processed through the touchscreen. In addition, the system automatically recorded parameters in real time, such as task completion time, operation times, and error times. Figure 1 shows the sketch of the simulated task interface.

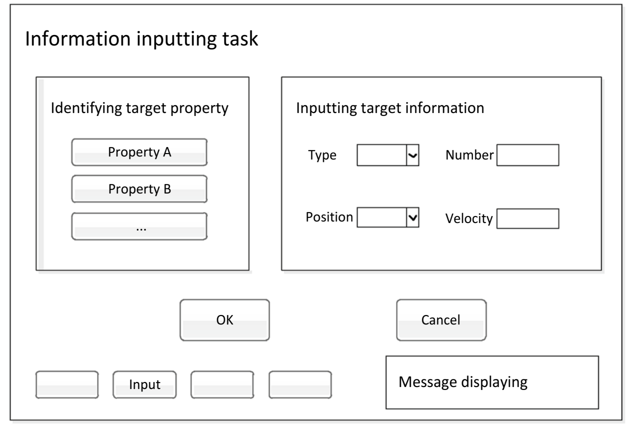

Fig. 1 Illustration of the simulated task interface. Because of confidential consideration, a real picture of simulated task interface is not allowed to be presented here

2.3 Design

2.3.1 Information inputting task

Participant's task was to input target information into blanks with a fixed format as quickly and accurately as possible. The system simulated task situations randomly with different combinations of target information of property, type, position, number and velocity. The target information was displayed at the bottom right of the touchscreen for at most 3000 ms until participants proceeded with pressing the button "input". Participants were required to understand and memorize target information within limited time. After the target information disappeared, participants were required to reproduce the target information by means of menu selecting and typing in the corresponding blanks. Each trial ended up with button "OK" pressed. After an interruption of break, the next trial began, with a total of 10 trials. The participant's task performance would be assessed with task error rate (percentage of error input) and the mean task completion time (the time between information displayed and "OK" button pressed) of 10 trials.

All the participants were required to perform in low and high complexity. As stated above, complexity condition can be determined by the number of alternatives, information load and interruption duration (Payne et al. 1992; Park et al. 2001; Monk et al. 2004). Difference between two complexity conditions of information inputting task is shown in Table 1.

2.3.2 Cognitive abilities

Cognitive ability tests are shown as Fig. 2. Reaction ability was assessed with choice reaction time (Welford 1980; Wong et al. 2015). Either of three colors of visual stimulus might appeared. Participant was required to

Table 1 Difference between two complexity conditions

Load factors	Complexity conditions	
	Low complexity	High complexity
Number of alternatives	Target property with 3 alternatives Target type with 6 alternatives Target position with 4 alternatives	Target property with 4 alternatives Target type with 10 alternatives Target position with 8 alternatives
Information load	1 piece of information	2 pieces of information
Interruption duration (ms)	1000	2000

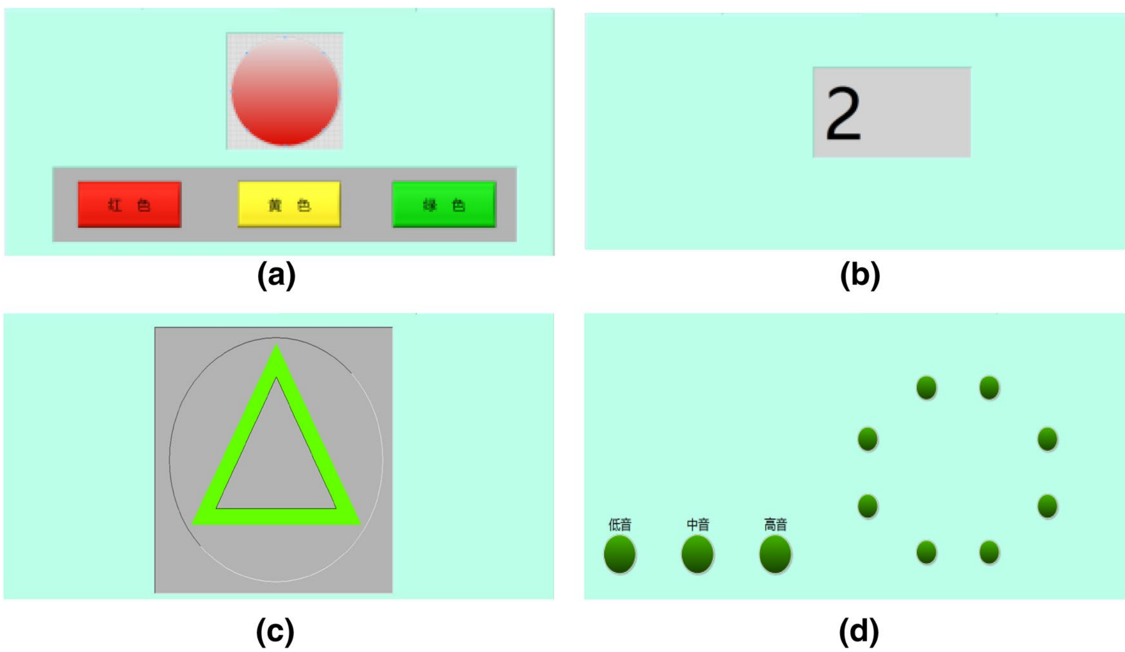

Fig. 2 Cognitive ability tests: **a** reaction ability test, **b** memory ability test, **c** sustained attention ability, **d** attention span ability

press the corresponding color button as quickly as possible. Choice reaction time was recorded as the time that elapsed between the presentation of visual stimulus and participant's response by pressing buttons. After a break of 1000 ms, the next trial began, for a total of 20 trials and false responses were not counted in. Participant's choice reaction time would be defined as the mean choice reaction time of 20 trials.

Memory ability was assessed with digit span (Jones and Macken 2015). Random digits were presented separately in sequence without any digit appearing twice in a row. Each digit was displayed for 1000 ms and was followed by an interval for 300 ms. The test began with a sequence of 5 digits for three times, increasing every three times until participant commits errors three times in a row. At the end of the sequence, the participant was required to reproduce the sequence of digits in its original order. Participant's digit span would be defined as the sum of the longest number of sequential digits that could be accurately recalled all its three times and the following number's correct times divided by three.

Sustained attention ability was assessed with attention span (Pan et al. 2016). A triangle target was presented and rotated anticlockwise with a uniform speed of 50 r/min. The participant was required to keep a test stick tracking the rotating triangle target as much as possible within 1 min. Participant's attention span would be defined as the total time that test stick was kept tracking the rotating triangle target successfully.

Attention allocation ability was assessed with attention allocation score (Yang 1989). Three buttons representing different pitch of sound stimulus were displayed in a line, and eight buttons with light stimulus were displayed symmetrically. Both sound and light stimulus appeared with equal probability. Participant's left index finger rested above three buttons at left to response to the sound stimulus, and right index finger rested above eight buttons at right to response to the light stimulus. Participant was required to press the corresponding button as quickly as possible within 1 min. Participant's attention allocation score would be defined as the geometric mean percentages of correct responses for sound and light stimulus.

2.3.3 Procedure

Once the participant signed the informed consent statement, a 20-min training and practicing session was conducted for each participant to get familiar with the in-vehicle ergonomic test system of simulated task. Then participants were required to conduct cognitive ability tests. After a break of 20 min, all the participants performed the information inputting task. The order of two complexity conditions was randomized to counterbalance learning effect. A break of 20 min was arranged between two conditions of task.

2.4 Data analysis

Bivariate correlation analysis was utilized to evaluate the possible correlations between cognitive abilities and task performance. Analysis of variance (ANOVA) was conducted to examine the effects of cognitive abilities and complexity condition on task performance. Stepwise multiple regression analysis was used to further investigate the predictive ability of cognitive abilities on task performance.

Table 2 Descriptive statistics of task performance and cognitive abilities

	N	Mean	SD	Min	Max
Task performance					
Completion time (ms)					
Low complexity	31	19735.1	3540.4	13494.5	30217.8
High complexity	31	27160.6	5791.9	15753.5	36562.7
Error rate (%)					
Low complexity	31	7.7	13.3	0	60
High complexity	31	34.8	20.5	0	80
Cognitive ability					
Reaction ability (ms)	31	686.0	75.1	555.2	899.2
Memory ability	31	8.6	1.4	6	11.3
Sustained attention ability (ms)	31	39672.9	5609.1	28930.1	48029.9
Attention allocation ability	31	0.795	0.059	0.657	0.907

3 Results

3.1 Correlations between cognitive abilities and task performance

Descriptive statistics of task performance and cognitive ability is shown in Table 2.

To investigate whether there was correlation between cognitive abilities, Pearson correlation was used to perform bivariate correlation analysis. As shown in Table 3, no correlation was found between reaction ability and memory ability ($r = -0.223$, $p = 0.227$), as well as attention allocation ability and other cognitive abilities ($r = -0.244$, $p = 0.186$; $r = 0.122$, $p = 0.513$; $r = 0.124$, $p = 0.505$). Only sustained attention ability was found correlated with reaction ability ($r = -0.416$, $p = 0.020$) and memory ability ($r = 0.429$, $p = 0.016$). The significant correlation involved with sustained attention ability can be explained that a better performance in choice reaction and digit span test also demands a better sustain attention ability. These results implied that cognitive abilities may be analogous, but different parts.

Bivariate correlation analysis was conducted to evaluate the possible correlations between cognitive abilities and task performance. As shown in Table 4, reaction ability ($r = 0.607$, $p = 0.000$), memory ability ($r = -0.569$, $p = 0.001$) and sustained attention ability ($r = -0.617$, $p = 0.000$) were significantly correlated with completion time. Meanwhile, only memory ability ($r = -0.683$.

Table 3 Correlations between cognitive abilities

	Memory ability	Sustained attention ability	Attention allocation ability
Reaction ability	−0.223	−0.416*	−0.244
Memory ability	1	0.429*	0.122
Sustained attention ability	–	1	0.124
Attention allocation ability	–	–	1

*$p < 0.05$

Table 4 Correlations between cognitive abilities and task performance

	Completion time	Error rate
Reaction ability	0.607*	0.153
Memory ability	−0.569*	−0.683*
Sustained attention ability	−0.617*	−0.660*
Attention allocation ability	−0.238	−0.084

*$p < 0.05$

$p = 0.000$) and sustained attention ability ($r = -0.660$, $p = 0.000$) were significantly correlated with error rate. There was no significant correlation observed between reaction ability and error rate ($r = 0.153$, $p = 0.412$), as well as attention allocation ability and task performance ($r = -0.238$, $p = 0.197$; $r = -0.084$, $p = 0.651$). This result revealed that reaction ability, memory ability and sustained attention ability were considered as performance predictors of information inputting task, and attention allocation ability was not included.

3.2 Effects of cognitive abilities and task complexity on task performance

Covariance analysis was conducted using complexity condition as a within-subject factor and cognitive abilities as covariates to investigate the effects of cognitive abilities and task complexity on task performance. As shown in Table 5, both complexity condition and cognitive abilities had significant effects on task performance except for reaction ability on task error rate [F (1, 59) = 0.994, $p = 0.323$].

To further demonstrate the influence of cognitive ability, participants were classified according to their mean choice reaction time (digit span or attention span) as individuals with high or low reaction ability (memory ability or sustained attention ability). Two-way ANOVAs was conducted to examine the effects of cognitive ability and complexity condition on task performance. Table 6 shows the Two-way ANOVAs results and Figs. 3, 4 and 5 show the task performance of individuals with high and low cognitive ability in different complexity conditions.

Both reaction ability [F (1, 58) = 4.373, $p = 0.041$] and complexity condition [F (1, 58) = 37.729, $p = 0.000$] had main effects on completion time. No interaction of reaction ability × complexity condition [F (1, 58) = 0.145, $p = 0.705$] on completion time was observed. With the increment of task complexity, completion time of individuals with high reaction ability increased by 7063.8 ms from

Table 5 Covariance analysis results of cognitive abilities and task complexity for task performance

	Completion time				Error rate			
	DF	F	p	Partial Eta^2	DF	F	p	Partial Eta^2
RA	1, 59	26.527	0.000*	0.310	1, 59	0.994	0.323*	0.017
CC (RA)	1, 59	54.454	0.000*	0.480	1, 59	38.109	0.000*	0.392
MA	1, 59	22.091	0.000*	0.272	1, 59	29.111	0.000*	0.330
CC (MA)	1, 59	51.630	0.000*	0.467	1, 59	55.970	0.000*	0.487
SAA	1, 59	27.852	0.000*	0.321	1, 59	26.404	0.000*	0.309
CC (SSA)	1, 59	55.298	0.000*	0.484	1, 59	54.250	0.000*	0.479

RA reaction ability, *CC* (*RA*) complexity condition in reaction ability analysis, *MA* memory ability, *CC* (*MA*) complexity condition in memory ability analysis, *SAA* sustained attention ability, *CC* (*SSA*) complexity condition in sustained attention ability analysis

*$p < 0.05$

Table 6 Two-way ANOVAs results of cognitive abilities and task complexity for task performance

	Completion time				Error rate			
	DF	F	p	Partial Eta^2	DF	F	p	Partial Eta^2
RA	1, 58	4.373	0.041*	0.070	1, 58	0.098	0.755	0.002
CC (RA)	1,58	37.729	0.000*	0.394	1,58	38.254	0.000*	0.397
RA × CC	1, 58	0.145	0.705	0.002	1, 58	0.942	0.336	0.016
MA	1, 58	15.910	0.000*	0.215	1, 58	23.956	0.000*	0.292
CC (MA)	1,58	45.332	0.000*	0.439	1,58	51.411	0.000*	0.470
MA × CC	1, 58	4.886	0.031*	0.078	1, 58	4.476	0.039*	0.072
SAA	1, 58	26.590	0.000*	0.314	1, 58	20.699	0.000*	0.263
CC (SSA)	1,58	56.555	0.000*	0.494	1,58	54.472	0.000*	0.484
SAA × CC	1, 58	5.202	0.026*	0.082	1, 58	5.407	0.024*	0.085

RA reaction ability, *CC* (*RA*) complexity condition in reaction ability analysis, *RA* × *CC* reaction ability × complexity condition, *MA* memory ability, *CC* (*MA*) complexity condition in memory ability analysis, *MA* × *CC* memory ability × complexity condition, *SAA* sustained attention ability, *CC* (*SSA*) complexity condition in sustained attention ability analysis, *SAA* × *CC* sustained attention ability × complexity condition

*$p < 0.05$

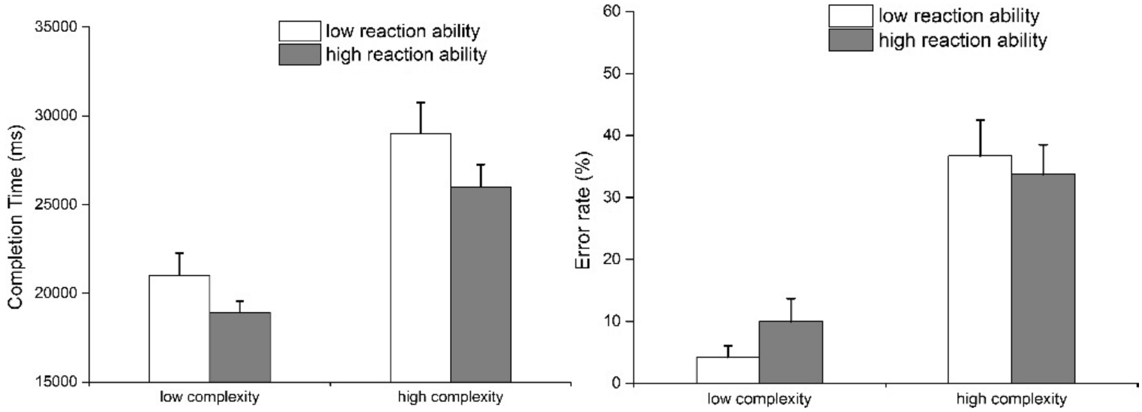

Fig. 3 Task performance of individuals with high and low reaction ability in different complexity conditions. Data are expressed as mean ± SE

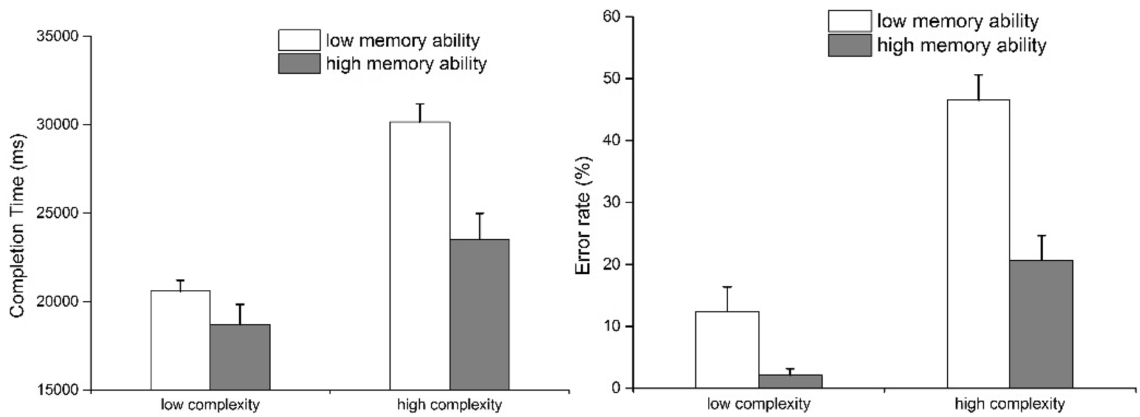

Fig. 4 Task performance of individuals with high and low memory ability in different complexity conditions. Data are expressed as mean ± SE

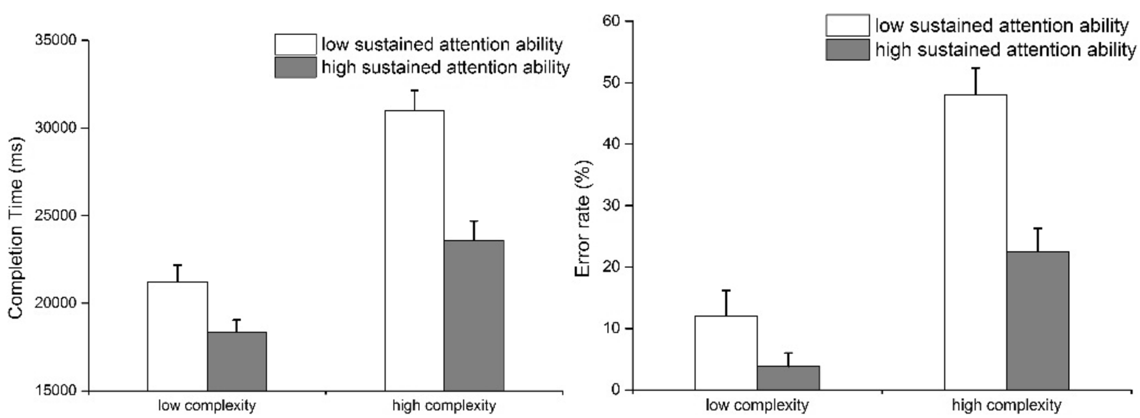

Fig. 5 Task performance of individuals with high and low sustained attention ability in different complexity conditions. Data are expressed as mean ± SE

18923.5 to 25987.3 ms, which indicated that operation speed decreased by 27.2%. The completion time of individuals with low reaction ability increased by 7998.2 ms from 21020.2 to 29018.4 ms, implying a decrement of operation speed by 27.6%. However, only complexity condition [F (1, 58) = 38.254, p = 0.000] had an effect on error rate. The influence of reaction ability [F (1, 58) = 0.098,

$p=0.755$] or the interaction [F (1, 58) = 0.942, $p=0.336$] on error rate was not observed.

Both memory ability [F (1, 58) = 15.910, $p=0.000$] and complexity condition [F (1, 58) = 45.332, $p=0.000$] had main effects on completion time. A memory ability × complexity condition [F (1, 58) = 4.886, $p=0.031$] interaction was also found. As task complexity increased, completion time of individuals with high memory ability increased by 4834.2 ms from 18692.7 to 23526.9 ms, which indicated that operation speed decreased by 20.5%. The completion time of individuals with low memory ability increased by 9559.5 ms from 20593.6 to 30153.2 ms, implying a decrement of operation speed by 31.7%. Similarly, both memory ability [F (1, 58) = 23.956, $p=0.000$] and complexity condition [F (1, 58) = 51.411, $p=0.000$] had significant effects on error rate. There was also a memory ability × complexity condition [F (1, 58) = 4.476, $p=0.039$] interaction. In high complexity, error rate of individuals with high memory ability increased by 18.6% from 2.1 to 20.7%, which indicated that operation accuracy decreased by 89.7% compared to that in low complexity. The error rate of individuals with low memory ability increased by 34.1% from 12.4 to 46.5%, implying a decrement of operation accuracy by 73.4%.

Significant effects of both sustained attention ability [F (1, 58) = 26.590, $p=0.000$], complexity condition [F (1, 58) = 56.555, $p=0.000$] and sustained attention ability × complexity condition [F (1, 58) = 5.202, $p=0.026$] interaction were observed on completion time. In high complexity, completion time of individuals with high sustained attention ability increased by 5224.6 ms from 18347.6 to 23572.2 ms, which indicated that operation speed decreased by 22.2%. The completion time of individuals with low sustained attention ability increased by 9773.2 ms from 21215.1 to 30988.3 ms, implying a decrement of operation speed by 31.5%. Similar effects were found on error rate [F (1, 58) = 20.699, $p=0.000$, F (1, 58) = 54.472, $p=0.000$, F (1, 58) = 5.407, $p=0.024$]. With the increment of task complexity, error rate of individuals with high sustained attention ability increased by 18.8% from 3.8 to 22.5%, which indicated that operation accuracy decreased by 83.3% compared to that in low complexity. The error rate of individuals with low sustained attention ability increased by 36.0% from 12.0 to 48.0%, implying a decrement of operation accuracy by 75.0%.

3.3 Predictive ability of cognitive abilities on task performance

Stepwise multiple regression analysis was conducted to build models predicting task performance with cognitive abilities in two task complexity conditions. As shown in Table 7, for completion time, reaction ability ($p=0.000$) was a significant predictor and accounted for 40.8% of the variance in low complexity. Reaction ability ($p=0.025$), memory ability ($p=0.002$) and sustained attention ability ($p=0.017$) were significant predictors and accounted for 65.2% of the variance in high complexity. For error rate, sustained attention ability ($p=0.014$) was a significant predictor and accounted for 19.2% of the variance in low complexity. Both memory ability ($p=0.000$) and sustained attention ability ($p=0.002$) were significant predictors and accounted for 63.9% of the variance in high complexity.

4 Discussion

The results indicate that cognitive abilities are associated with task performance, which agrees with previous studies (Schmidt 2002; Hunter and Burke 1994). Thus one of the reasons for task performance difference can be recognized as the individual characteristic of cognitive ability. To reduce this kind of performance difference, more attention should be paid to cognitive ability in crew selection. Reaction ability, memory ability and sustained attention ability are suggested to be considered as indicators of task performance in crew selection.

The findings also suggest that task complexity has different effects on task performance between individuals with

Table 7 Results of stepwise multiple regression analysis

	Predictors	B	p	R^2	Tolerance	VIF
Completion time						
Low complexity	Reaction ability	30.1	0.000*	0.408	1	1
High complexity	Sustained attention ability	−0.356	0.017*	0.652	0.708	1.413
	Memory ability	−1776.6	0.002*		0.813	1.229
	Reaction ability	23.1	0.025*		0.824	1.213
Error rate						
Low complexity	Sustained attention ability	−0.001	0.014*	0.192	1	1
High complexity	Memory ability	−7.457	0.000*	0.639	0.816	1.226
	Sustained attention ability	−0.002	0.002*		0.816	1.226

Only the significant predictors are listed; *$p<0.05$

high and low cognitive ability, which is partly accordance with the previous studies that pointed out a greater effect of high workload on individuals with low cognitive ability than individuals with high cognitive ability (Gonzalez 2005). Intriguingly, the effects on task completion time and error rate are found to be even contradictory in this study. For task completion time, high complexity has a greater effect on individuals with low memory ability (or sustained attention ability) than with high memory ability (or sustained attention ability). As to task error rate, in contrast, high complexity has a greater effect on individuals with high memory ability (or sustained attention ability) than with low memory ability (or sustained attention ability). We attribute this contradiction to the task characteristic and operation scenario. Dynamic decisions in military vehicle operation are real-time and interdependent. Thus, the accuracy of operation in each stage will have an important impact on the overall operation. Although the priority of the two performance metrics is not instructed before the tests, when the cognitive resource is not sufficient to support performance in high complexity, operation accuracy would be given priority over operation speed unconsciously. Specifically, the crew has to sacrifice the operation speed by spending time memorizing and reproducing for maintaining a certain level of accuracy when necessary. This compromise between performances relates to intensions and decisions (Vanderhaegen and Carsten 2017). Under this circumstance, the advantage of high memory ability or sustained attention ability is highlighted. Since the less cognitive resource is available to individuals with low memory ability or sustained attention ability, they are more likely to sacrifice the operation speed for the operation accuracy when task complexity increases. Compared to individuals with high memory ability or sustained attention ability, employing this operation scenario leads to a relatively larger decrement on operation speed and a smaller decrement on operation accuracy for individuals with low memory ability or sustained attention ability in high complexity. Consequently, high task complexity is more detrimental to individuals with low cognitive ability in terms of operation speed, and to individuals with high cognitive ability in terms of operation accuracy. This kind of performance difference, caused by operation scenario rather than individual characteristic, could be reduced by pertinence training on balancing operation speed and accuracy.

Additionally, cognitive abilities show different effects between different task conditions, which is in line with previous studies (Jipp 2016b). The stepwise multiple regression analysis reveals that reaction ability and sustained attention ability are significant predictors of task performance, whereas the advantage of high memory ability appears to be not obvious in low complexity. However, memory ability is ultimately added to significant predictors in high complexity. This result indicates that high memory ability becomes increasingly demanded in high complexity task. Our proposition is not that memory ability is more significant than reaction ability or sustained attention ability in high complexity; rather, our results demonstrate that the influence of memory ability is more significant in high complexity compared to in low complexity. Therefore, individuals with high memory ability are more recommended for high complexity tasks than for low complexity tasks in task assignment. This result also confirms the previous statement that cognitive abilities may be analogous but different parts. Different types of cognitive ability are supposed to be included independently rather than as a whole, when the effects on task performance are investigated.

There is a limitation that real military vehicle crews were not recruited as participants in this study. However, the students recruited as participants were crew candidates that were trained to be real crew after graduating. Besides, crew candidates have more similar training experience than real crew, which helps alleviate the effects of training experience on task performance. This should be considered when the results of this study are referred to.

5 Conclusions

The results indicate that cognitive abilities are effective predictors of task performance. High task complexity is more detrimental to individuals with low cognitive ability in terms of operation speed, and to individuals with high cognitive ability in terms of operation accuracy. And high memory ability becomes increasingly demanded in high complexity. The reasons for task performance difference can be classified as individual characteristic and operation scenario. As a consequence, crew selection based on cognitive ability test and pertinence training on balancing operation speed and accuracy are suggested for the sake of improvement in task performance. This result can help to improve the understanding of the reasons for performance difference in military vehicle operation, and provides valuable references for crew selection, pertinence training and the rationalization of task assignment. In addition, it is hopefully applied to most tasks of dynamic decision making that demands operation speed and accuracy, even in other areas, such as aircraft pilots and unmanned armored vehicle operators.

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