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Think before You Shoot: The Relationship between Cognition and Marksmanship

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14. ABSTRACT

In recent years, psychologists have begun to explore the relationship between cognition and sport performance, specifically the role of mental imagery in performance. One relatively unexplored learned skill, however, is marksmanship. The objectives of this exploratory study were 1) to document the relationship between cognitive processes and marksmanship performance and 2) to test the statistical validity of a friend/foe detection task as a measure of decision making (DM). Ninety US Army active duty Soldiers and Reservists completed a cognitive test battery including measures of DM, the standard marksmanship qualifying task, and a friend/foe detection task. A correlational analysis revealed significant relationships between marksmanship performance and measures of attention, spatial orientation, and visual scanning. However, the results do not support the validity of this friend/foe detection task a measure of DM. These results support the assertion that return-to-duty Soldiers experiencing cognitive impairments may require additional marksmanship training and re-learning prior to reintegration.

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Background

An essential skill in all military forces is marksmanship. Unfortunately, considerably less research has focused on marksmanship compared to other complex skills such as tennis, baseball, and golf. The U. S. Army has conducted the majority of the available research on marksmanship focusing on improving training and skill acquisition. Of the available literature, a number of factors influencing and predicting marksmanship performance have been identified, including environmental factors (e.g., wind velocity, gravity) and physiological factors (e.g., the shooter's heart rate, breathing rate, stability). Of particular interest to this study are the human cognitive abilities which play a role in marksmanship performance and are relatively unexplored. Chung et al. (2004) examined the role of cognitive variables in marksmanship performance, focusing on aptitude and knowledge. They found that performance of less experienced participants was moderately related to these aspects of cognition. However, in a sample of more experienced participants, perceptual-motor skills were a good predictor of performance. However, it has not yet been tested whether executive function and core cognitive abilities could be used to predict marksmanship abilities. Since this is not yet known, employing a general battery of cognitive tests may yield predictors of marksmanship performance.

One important factor contributing to marksmanship performance is vision. The aiming of a firearm relies upon a steady weapon along with the correct visual perception of the target and sight, which incorporates not only visual acuity but also cognitive aspects of visual perception. A recent study showed a relationship between visual acuity and marksmanship such that performance declines as acuity declines which supports the U. S. Army visual acuity requirements (Wells, Wagner, Reich, and Hardigan, 2009). However, there has yet to be a study, to the best of the authors' knowledge, examining the relationship between cognitive visuoperceptual abilities and marksmanship. Establishing these relationships could potentially differentiate skilled from unskilled marksmen and provide insight into training and skill acquisition. (Note that other factors, such as experience and environment play a role in performance capabilities and these relationships should also be further investigated.)

Engagement Skills Trainer 2000

The Engagement Skills Training 2000 (EST 2000) is the U. S. Army's small arms training device and is the Department of Defense (DoD) standard for marksmanship training (stipulated by PEOSTRI), in preparation for live-fire training and qualification attempts. This device is used in the United States Army Infantry Schools Basic Rifle Marksmanship (BRM) strategy and allows for weapons training in a controlled (simulated) environment. There are three training modes in the EST 2000: marksmanship, collective, and shoot/don't-shoot. This device has become increasingly popular for use in studying decision making processes by research psychologists in the U. S. Army (e.g., Murray, Frykman, Merullo, Cohen, & Bandaret, 2008).

In recent years, researchers at U. S. Army Medical Research and Material Command (USAMRMC) laboratories (U. S. Army Aeromedical Research Laboratory, USAARL; U. S. Army Research Institute of Environmental Medicine, USARIEM) have employed a weapons simulator to measure marksmanship performance under conditions of operational stress.

Additionally, researchers at USAARL have employed the weapons simulator for a friend/foe detection task. Similar tasks have been used by researchers at the Army Research Laboratory (ARL; e.g., Kerrick, Hatfield, & Allender, 2007). Arguably, the task of choosing which targets to engage appears to have face validity for measuring decision making skills. However, this task has not been tested for convergent construct validity. Specifically, it has not been explored whether performance on this task correlates with individual differences in decision making capabilities and styles.

Research objectives and hypothesis

In recent years, the EST 2000 has been utilized as a research tool by USAMRMC research laboratories (e.g., USAARL, USARIEM) in studies of operational stressors and cognitive performance (e.g., decision making). Showing the relationship between performance on this metric and performance on valid, reliable measures of cognitive abilities will help researchers interpret EST 2000 data.

At present, the role of cognition in marksmanship skill is largely unknown. Hence, the primary objective of this study was to explore the relationships between cognitive abilities and marksmanship performance. Given the exploratory nature of this objective, no theoretical hypotheses were tested. Secondly, the friend/foe detection task has been employed previously and has been loosely described as a face valid measure of decision making. Thus, the secondary objective of this study was to explore the relationships between decision making skill and style (e.g., analytical, impulsive) and performance on the EST 2000 friend/foe detection task to test the statistical convergent validity of the training device as a measure of decision making performance. Performance on the marksmanship qualifying task served as a control condition such that it was hypothesized that decision making style and level of decision making skill would predict performance on the EST 2000 during a friend/foe detection task but not during the standard qualifying task.

Methods

General

The protocol was reviewed and approved by the USAMRMC Institutional Review Board prior to implementation. To test the above stated objectives, the study employed a correlational research design. Valid and reliable cognitive and decision-making measures were included as predictor variables, whereas reaction time, proportion of hit targets, shot radius from center mass, and root mean square of aim trace on the EST 2000 (i.e., EST 200 performance) were the outcome variables.

Participants

Participants were 90 active-duty U. S. Army Soldiers. The mean age was 29.0 years and the mean education level was 14.85 years (e.g., 12 years = high school diploma). Of the 90 participants, 77 were male and all of them were tested for normal vision or corrected to normal vision.

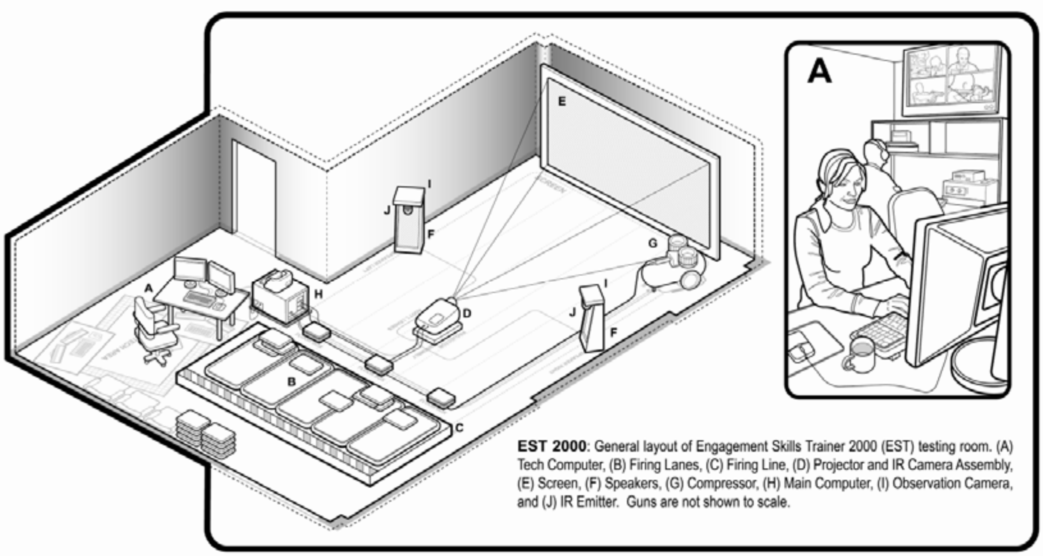
Procedure

Upon entering the laboratory, written informed consent was obtained from the volunteer. Next, the participant completed a medical history questionnaire and a visual acuity test. Participants then completed the CogScreen cognitive test battery (computer), the visuospatial tests (paper and pencil), the Adult Decision-Making Competence battery (paper and pencil), the Decision-Making Style questionnaire (paper and pencil), and the EST 2000 tasks. Total administration time averaged 3 hours. To control for fatigue and order effects, a pseudo-random number generator was employed to determine the order of the four sets of tasks (CogScreen, visuospatial tests, decision-making tests, and EST 2000 tasks) for each participant.

Task battery

EST 2000

As can be seen in figure 1, the participants fired from a lane (the USAARL laboratory has a five-lane configuration) at “targets” which appeared on a projection screen at a distance of 26 feet and 3 inches from the firing line. The weapons have been modified to use with the EST 2000 but maintain their form, fit, feel, and function.



EST 2000: General layout of Engagement Skills Trainer 2000 (EST) testing room. (A) Tech Computer, (B) Firing Lanes, (C) Firing Line, (D) Projector and IR Camera Assembly, (E) Screen, (F) Speakers, (G) Compressor, (H) Main Computer, (I) Observation Camera, and (J) IR Emitter. Guns are not shown to scale.

Figure 1. EST 2000 configuration.

Participants completed two tasks using the EST 2000: a friend/foe detection task and a standard marksmanship qualifying task. In the friend/foe detection task, on each trial, participants saw a pop-up target distinguished by a cue (e.g., either one circle [friend] on it or two circles [foe] on it) and choose whether to fire at the target (figure 2). They were instructed as to which target was friend and which was foe. In the standard qualifying task, participants engaged 40 total targets presented sequentially in three different shooting positions. Target size was varied to simulate changes in relative distance (50 meters [m], 100 m, 150 m, 200 m, 250 m, 300 m). The key dependent variables for these tasks were radius from center mass, reaction time, proportion of hits, and aim trace precision.

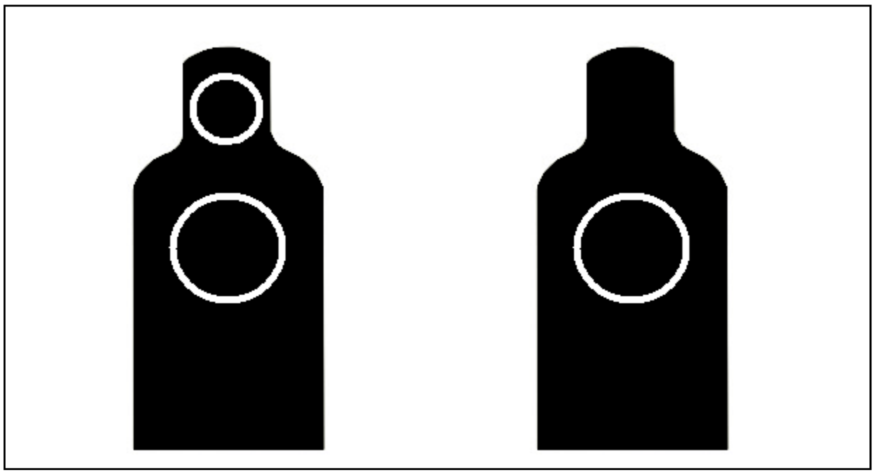


Figure 2. Targets in EST 2000 task.

Decision-making abilities

Research has shown individual differences in tendencies to avoid or fall victim to well-established decision making biases and errors (e.g., Stanovich, 1999). Stanovich and West (1998, 2000) measured performance on tasks assessing hindsight bias, logical reasoning, and statistical reasoning and reported positively correlated relationships between the tasks. Thus, they concluded that departures from normative standards on these tasks are not merely random errors in performance but rather indicative of level of decision-making skill. Given this, Parker and Fischhoff (2005) developed a battery of seven tasks to measure decision-making competency which was further shown to be reliable and valid by Bruine de Bruin, Parker, and Fischhoff (2007).

The Adult Decision-Making Competence (A-DMC) battery of Bruine de Bruin et al. (2007) is composed of seven tasks each related to a specific decision-making skill which is identified in parantheses: resistance to framing (value assessment, integration), recognizing social norms (belief assessment, value assessment) under/overconfidence (belief assessment, metacognition), applying decision rules (Integration), consistency in risk perception (belief assessment), resistance to sunk costs (value assessment), and path independence (value assessment, integration). Additionally, participants completed Scott and Bruce’s (1995) measure of decision-making style which is a self-report measure that categorizes respondents as rational, intuitive, dependent (reliant on other people's decisions), avoidant, or spontaneous.

Cognitive abilities

The CogScreen is a series of computerized cognitive tests/tasks which assess attention, immediate- and short-term memory, visual perceptual functions, sequencing functions, logical problem solving, calculation skills, reaction time, simultaneous information processing abilities, and executive functions using 11 sub-tests (Kay, 1995). The included sub-tests are as follows:

a. Backward digit span – In this test, three to six digits are presented visually in sequential order. The participant must reproduce the sequence of digits in reverse order. This is a test of visual attention, working memory, and verbal sequential processing.

b. Math – In this test, participants are presented with traditional multi-step math problems and must select the answer from three choices. This test measures computational math skills, attention, concentration, working memory, reading comprehension, and logical reasoning.

c. Visual sequence comparison – Participants are presented with two alphanumeric strings simultaneously, one on the right and one on the left side of the screen. The participant must decide whether the strings are the "same" or "different." This measures visual attention, working memory, verbal sequential processing, and visual perceptual speed.

d. Symbol digit coding – Participants are shown six, symbol-digit pairs and are told to memorize these symbols. The participant must then complete rows of symbols with the associated digits. This is followed by immediate and delayed recall of the symbol-digit pairs. This measures attention, visual scanning, working memory, and speed of information processing.

e. Matching to sample (MTS) – Participants are presented a checkerboard grid pattern and must memorize the pattern. The participant is then presented with two grids and must choose which of the two matches the original pattern. This measures visual-perceptual speed, spatial processing, and visual working memory.

f. Manikin – A figure of a man holding a flag is presented at various orientations (e.g., upside-down, facing backward). The participant must determine if the flag is in his left or right hand. This measures visual-spatial perception, spatial orientation, and the ability to mentally rotate visual images.

g. Divided attention test – Each participant must "monitor the vertical movements of a bar within a circle and returns the bar to the center position when its deviation from center exceeds an upper or lower boundary" (Kay, 1995). This measures visual monitoring, choice visual reaction time, divided attention, and working memory.

h. Auditory sequence comparison – Participants must compare two series of tone sequences and determine if they are the "same" or "different." This measures auditory attention, working memory, and sound pattern discrimination.

i. Pathfinder – Participants must sequence numbers, letters, and an alternating sequence of numbers and letters based on sequencing rules. This measures number and letter sequencing skills, the ability to apply an organizing principle, immediate memory, motor coordination, and visual scanning.

j. Shifting attention test – Participants learn three response rules, one of which is active for each trial. Participants must alter responses based on the changing active rules. This measures concept formation, mental flexibility, sustained attention, deductive reasoning, response interference, working memory, application of novel rules, visual scanning, choice visual reaction time, and perservative tendencies.

k. Dual task – Participants are presented with two tasks independently and then simultaneously. This task measures divided attention and multitasking capability.

Visuospatial tasks

Visuospatial tasks allow researchers to investigate the visuospatial domain of working memory, while avoiding the verbal or numerical paths. Five components of spatial ability have been suggested to exist (Carroll, 1993), with three of them demonstrated to consist of varying levels of executive functioning or controlled attention (Miyake et al., 2001).

All tasks employed in this study are available in the Kit of Factor-Referenced Cognitive Tasks (Ekstrom, French, Harman, & Dermen, 1976) from the ETS bank of testing. Tasks are all timed (using a stop watch) and conducted in a paper and pencil format. Scores were calculated as the number of correct responses minus total non-correct items (which is equal to the number of incorrect response plus the number of blank responses).

The first task and the one with the highest demand for executive functioning is the Paper Folding task, which taps into the spatial visualization domain of visuospatial processes. This task requires the participant to study a pictorial example of a piece of paper being folded and the location of a hole punched through the paper (see figure 3). After this, the participant must decide from five choices as to which output would be the correct choice if the paper was unfolded in the exact same manner as it was folded. There are two phases of the task and in each phase participants must complete as many as possible of ten trials in 90 seconds.

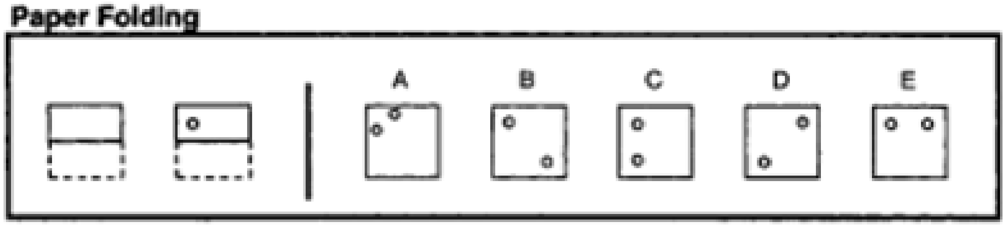


Figure 3. Paper Folding task. The image on the left is an example of a piece of paper folded in half (top to bottom) with a hole punched in the shown location. The correct response for this example would be "C" when the paper is unfolded.

The second and third tasks measure visuospatial perception speed; the Identical Pictures and Hidden Patterns tasks. Of the four tasks employed in this study, these tasks require the lowest amount of executive functioning for completion. The Identical Pictures task requires the individual to view an image on the far left, and match it with the identical image of five possible choices (see figure 4 left side). There are two phases of the task. In each phase, the participant must complete as many as possible of 48 trials in 90 seconds. The Hidden Patterns task requires an individual to compare a model image and determine if that image is embedded in any of the four provided images (see figure 4 right side). Again, this task has two phases and in each phase, participants must complete as many as possible of 200 trials in 90 seconds.

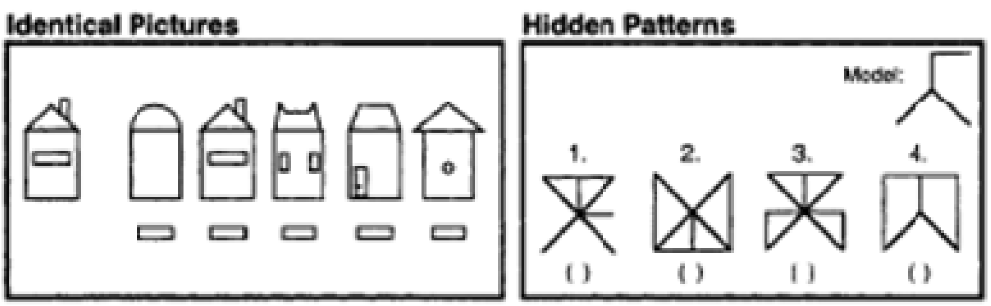


Figure 4. Identical Pictures (left) and Hidden Patterns (right) tasks. In identical pictures, the second choice would be the correct match for the original image, while choices "1," "3," and "4" would be correct for the model shown in the hidden patterns task.

The fourth task, the Card Rotation task, requires a moderate demand for executive functioning relative to the other tasks employed is the Card Rotation task. This task measures the Spatial Relations component of visuospatial abilities. Per trial, a model image is displayed on the far left, and the participant must compare it to the four images displayed to the right. Participants must indicate whether the comparative image is simply the model image rotated on a single plane or if it is a mirror image of the model (see figure 5).

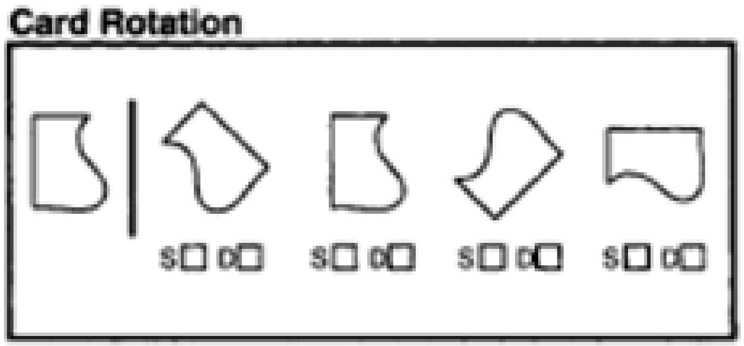


Figure 5. Card Rotation task. The model on the left is rotated in choices “2” and “3”, and choices “1” and “4” are mirror reflections of the model.

Results

To evaluate the relationship between cognitive abilities and marksmanship, the first necessary step was to conduct correlational matrices. This analysis then allowed for dependent variables that correlated with marksmanship to be entered into factor analyses. Finally, the cognitive measures that correlated with marksmanship performance were entered into a multiple linear regression model as predictors. Separate analyses were conducted for the marksmanship qualifying and friend/foe detection tasks in order to determine the validity of the friend/foe detection task as a measure of decision making.

Friend/foe detection task

Correlation matrix

A correlational analysis indicated significant relationships between the four aspects of marksmanship performance (reaction time, shot radius from center mass, aim trace, and proportion of hits) and aspects of cognitive abilities as summarized in table 1.

Table 1.
Significant results of correlational analyses for friend/foe detection task data summarized by cognitive tests (N = 89).

	Marksmanship dependent measure			
Cognitive Test Measure	Reaction time	Radius	Aim trace	Proportion of hits
Match to Sample				
Thruput	-0.268*	-0.219*	0.085	0.209*
Divided Attention				
Accuracy	-0.294**	-0.327**	-0.147	0.243*
Thruput	-0.191	-0.201	-0.058	0.213*
Dual Task				
Number of hits	-0.248*	-0.86	-0.189	0.05
Accuracy	-0.283**	-0.143	-0.016	0.033
Card Rotation	-0.28**	-0.208*	-0.078	0.216*
Symbol Digit Coding				
Thruput	-0.239*	-0.265*	0.167	0.166
Shifting Attention Test				
Accuracy	-0.154	-0.273*	0.047	0.051
Speed	0.141	0.251*	-0.131	-0.156
Thruput	-0.147	-0.24*	0.147	0.105
Number completed	-0.129	-0.269*	0.083	0.011
Applying Decision Rules	-0.035	-0.217*	0.132	0.087
Paper Folding	-0.199	-0.227*	0.102	0.273*
Math				
Speed	0.111	0.162	-0.325**	-0.127
Thruput	-0.046	-0.114	0.231*	-0.005
Pathfinder				
Speed	0.065	-0.009	-0.236*	0.016
Coordination	0.017	0.107	-0.094	-0.211*
Resistance to Sunk Costs	-0.090	-0.076	0.28**	0.089

* indicates $p < .05$
** indicates $p < .01$

Factor analysis

A Principal Axis Factor (PAF) with a Varimax (orthogonal) rotation of the cognitive test measures was conducted. Factors with loadings less than 0.50 were excluded and the results for the reaction time, radius from center mass, aim trace, and proportion of hits data are summarized in tables 2 through 5, respectively.

Table 2.
Significant results of factor analysis for the friend/foe detection task reaction time data summarized by cognitive tests (N = 89).

	Reaction time – 2 factors	
Cognitive Test Measure	1	2
Divided Attention		
Accuracy	0.730	
Dual Task		
Number of hits	0.574	
Accuracy	0.858	
Card Rotation		0.811
Match to Sample		
Thruput		0.752

Table 3.
Significant results of factor analysis for the friend/foe detection task shot radius data summarized by cognitive tests (N = 89).

Radius from center mass – 3 factors			
Cognitive Test Measure	1	2	3
Shifting Attention Test			
Number completed	0.913		
Accuracy	0.912		
Applying Decision Rules	0.628		
Match to Sample			
Thruput		0.843	
Shifting Attention Test			
Speed		-0.788	
Thruput		0.671	
Paper Folding		0.675	
Symbol Digit Coding			
Thruput		0.592	
Divided Attention			
Accuracy			0.928

Table 4.
Significant results of factor analysis for the friend/foe detection task aim trace data summarized by cognitive tests (N = 89).

Aim trace – 2 factors		
Cognitive Test Measure	1	2
Math		
Accuracy	-0.932	
Thruput	0.910	
Pathfinder		
Speed		-0.888
Shifting Attention		
Thruput		0.759

Table 5.
Significant results of factor analysis for the friend/foe detection task proportion of hits data summarized by cognitive tests (N = 89).

	Proportion of hits – 2 factors	
Cognitive Test Measure	1	2
Paper Folding	0.903	
Card Rotation	0.807	
Divided Attention		
Thruput		0.681
Accuracy		0.615
Pathfinder		
Coordination		0.612

Multiple linear regression analysis

Reaction time

A multiple linear regression model showed that four measures of visual-spatial ability predicted reaction time on the friend/foe detection task and accounted for 24.6% of the variance, R^2 = 0.246, $F(5, 83) = 5.409$, $p < .001$. Specifically, the four predictors were matching to sample thruput, β = -0.206, $t(88) = -2.015$, $p = 0.047$; divided attention test accuracy, β = -0.249, $t(88) = -2.270$, $p = 0.026$; dual task number of hits, β = -0.264, $t(88) = -2.733$, $p = 0.008$; and card rotation task score, β = -0.205, $t(88) = -1.905$, $p = 0.060$.

Radius from center mass

A multiple linear regression model showed that three measures of visual-spatial ability predicted radius from center mass on the friend/foe detection task and accounted for 27.9% of the variance, R^2 = 0.279, $F(9, 79) = 3.392$, $p = .001$. Specifically, the three predictors were divided attention accuracy, β = -0.321, $t(88) = -3.054$, $p = 0.003$; shifting attention task speed, β = 0.687, $t(88) = 2.820$, $p = 0.006$; and shifting attention task thruput, β = 0.998, $t(88) = -2.822$, $p = 0.006$.

Aim trace

A multiple linear regression model showed that mathematical processing speed, β = -0.320, $t(88) = -1.993$, $p = 0.050$, and value assessment, β = 0.230, $t(88) = 2.322$, $p = 0.023$, were significant predictors of aim trace. The predictors accounted for 20.9% of the variance, R^2 = 0.209, $F(5, 83) = 4.386$, $p = .001$.

Proportion of hits

A multiple linear regression model showed that visual scanning ability, β = -0.226, $t(88) = -2.192$, $p = 0.031$, significantly predicted proportion of hits on the friend/foe detection task and accounted for 18.7% of the variance, $R^2 = 0.187$, $F(5, 83) = 3.812$, $p = .004$.

Standard marksmanship qualifying task

Correlation matrix

A correlational analysis indicated significant relationships between the four aspects of marksmanship performance (reaction time, shot radius from center mass, aim trace precision, and proportion of hits) and aspects of cognitive abilities as summarized in table 6.

Table 6.
Significant results of correlational analyses for the standard marksmanship qualifying task data summarized by cognitive tests (*N* = 90).

	Marksmanship dependent measure			
Cognitive Test Measure	Reaction time	Radius	Aim trace	Proportion of hits
Divided Attention				
One target speed	0.153	0.394**	-0.096	-0.161
Dual target speed	0.209*	0.210*	-0.104	-0.155
Premature response	-0.219*	-0.146	-0.017	-0.049
Dual Task				
Number of hits	0.023	0.311**	-0.108	-0.276**
Accuracy	-0.226*	-0.230	-0.021	0.051
Speed	-0.217*	0.082	0.017	-0.033
Number of errors	0.088	0.227*	-0.103	-0.202
Thruput	-0.131	-0.256*	-0.083	0.183
Card Rotation	-0.082	-0.349**	-0.013	0.224*
Symbol Digit Coding				
Thruput	-0.299**	-0.187	-0.142	0.190
Shifting Attention Test				
Task 1				
Accuracy	-0.013	-0.216*	0.041	0.155
Speed	0.035	0.442**	0.005	-0.256*
Thruput	-0.079	-0.423**	-0.029	0.345**
Task 2				

Speed	0.113	0.249*	0.092	-0.207
Thruput	-0.168	-0.292**	-0.099	0.242*

Table 6 (continued)

Task 3				
Accuracy	-0.030	-0.241*	-0.180	0.240*
Speed	0.052	0.324**	0.177	-0.338**
Thruput	-0.106	-0.318**	-0.187	0.314**
Number completed	-0.016	-0.268*	-0.157	0.264*
Rule failures	0.025	0.217*	0.175	-0.255*
Errors	0.133	0.290**	0.143	-0.198
Task 4				
Speed	0.096	0.141	0.228*	-0.227*
Thruput	-0.103	-0.149	-0.174	0.215*
Applying Decision Rules	-0.008	-0.297**	-0.105	0.083
Paper Folding	-0.047	-0.232*	-0.110	0.170
Math				
Speed	0.230*	0.296**	0.023	-0.283**
Thruput	-0.191	-0.248*	-0.108	0.248*
Pathfinder				
Accuracy	-0.029	0.094	-0.242*	-0.035
Visual Sequence comparison				
Reaction time	0.219*	0.083	0.096	-0.191
Thruput	-0.206	-0.102	-0.110	0.222*
Auditory Sequence comparison				
Speed	0.252*	0.246*	0.094	-0.280**
Thruput	-0.202	-0.251*	-0.137	0.314**
Consistency in risk perception	-0.121	-0.255*	0.155	0.158

* indicates $p < .05$
** indicates $p < .01$

Factor analysis

A PAF with a Varimax (orthogonal) rotation of the cognitive test measures was conducted. Factors with loadings less than 0.50 were excluded and the results for the reaction time, radius from center mass, and proportion of hits data are summarized in tables 7 through 9, respectively. The results for the aim trace precision data resulted in one factor, thus no table is necessary to summarize.

Table 7.
Significant results of factor analysis for the standard marksmanship qualifying task reaction time data summarized by cognitive tests (*N* = 89).

Cognitive Test Measure	*Reaction time – 3 factors* 1	2	3
Math			
Speed	0.731		
Symbol Digit Coding			
Thruput	-0.717		
Visual Sequence comparison			
Reaction time	0.670		
Auditory Sequence comparison			
Speed	0.639		
Dual Task			
Speed		0.944	
Accuracy		0.858	
Divided Attention			
Premature response			-0.830
Speed			0.667

Table 8.
Significant results of factor analysis for the standard marksmanship qualifying task shot radius data summarized by cognitive tests (*N* = 89).

	Radius from center mass – 7 factors						
Cognitive Test Measure	1	2	3	4	5	6	7
Shifting Attention Test							
Task 3							
Number completed	0.946						
Accuracy	0.900						
Rule failures	-0.820						
Thruput	0.749						
Task 1							
Thruput		0.884					
Speed		-0.856					
Task 2							
Speed		-0.713					
Thruput		0.712					
Task 3							
Speed		-0.622					
Dual Task							
Errors			0.899				
Hits			0.842				
Card Rotation			-0.622				
Paper Folding			-0.506				
Math							
Thruput				0.784			
Speed				-0.778			
Consistency in risk perception				0.627			
Applying Decision Rules				0.538			
Auditory Sequence comparison							
Thruput					-0.870		
Speed					0.846		
Divided Attention							
One target speed						0.754	
Dual target speed						0.703	
Shifting Attention							
Task 1							
Accuracy							0.727
Task 3							
Errors							0.518

Table 9.
Significant results of factor analysis for the standard marksmanship qualifying task proportion of hits data summarized by cognitive tests (*N* = 89).

	Proportion of hits – 5 factors				
Cognitive Test Measure	1	2	3	4	5
Shifting Attention					
Task 1					
Thruput	0.845				
Speed	-0.801				
Task 4					
Speed	0.779				
Thruput	-0.731				
Task 2					
Thruput	0.705				
Task 3					
Speed	-0.568	-0.513			
Number completed		0.968			
Accuracy		-0.821			
Rule failures		-0.821			
Thruput		0.784			
Auditory Sequence comparison					
Thruput			0.879		
Speed			-0.869		
Math					
Speed				-0.891	
Thruput				0.872	
Dual Task					
Hits					0.812
Card Rotation					-0.626

Multiple linear regression analysis

Reaction time

A multiple linear regression model showed that speed on the dual task (measure of visual-motor tracking) significantly predicted reaction time on the qualifying task, β = -0.345, $t(89) = -2.105$, $p = 0.038$. The predictor variables accounted for 23.5% of the variance, $R^2 = 0.235$, $F(8, 81) = 3.106$, $p = .004$.

Radius from center mass

A multiple linear regression model showed that the independent variables entered into the model accounted for 45.1% of the variance, $R^2 = 0.451$, $F(24, 65) = 2.229$, $p = .006$. However, none of the independent variables were uniquely predictive.

Aim trace

A multiple linear regression model showed that measures of motor coordination and sustained attention significantly predicted aim trace precision and accounted for 11.2% of the variance, $R^2 = 0.112$, $F(2, 87) = 4.386$, $p = .001$. Specifically, accuracy on the pathfinder task, $\beta = -0.244$, $t(89) = -2.419$, $p = 0.018$, and speed during the shifting attention task, $\beta = 0.230$, $t(89) = 2.279$, $p = 0.025$, were significant predictors of aim trace.

Proportion of hits

A multiple linear regression model showed that thruput on the shifting attention task (measure of sustained attention) significantly predicted proportion of hits, $\beta = -0.800$, $t(89) = 2.192$, $p = 0.032$. The predictor variables accounted for 35.2% of the variance, $R^2 = 0.352$, $F(17, 72) = 2.301$, $p = .008$.

Discussion

The primary objective of this study was to explore the relationship between cognitive ability and marksmanship, a performance skill that has received substantially less research attention than other sport activities, such as golf and tennis. The findings suggest that the cognitive abilities related to marksmanship include visual spatial processing, visual monitoring, sustained attention, and visual perceptual speed. Additionally, this study tested the hypothesis that decision making style and skill are related to a friend/foe detection task. The main findings do not support the hypothesis that this friend/foe detection task is related to decision making more so than a standard marksmanship task.

Factors influencing performance on the friend/foe detection task

Reaction time

The results of the factor analysis suggest that the five cognitive test measures, which correlated with reaction time on the friend/foe detection task, load onto two factors. The accuracy on the divided attention, accuracy on the dual task, and number of hits on the dual task loaded onto one factor. Both of these tasks measure visual-motor tracking and divided attention suggesting that these abilities influenced marksmanship reaction time. The accuracy of the card rotation task and matching to sample thruput loaded onto a second factor. These measures of spatial processing and spatial relations thus influenced reaction time as well.

Radius from center mass

The factor analysis results suggest related measures load onto three factors. Measures that loaded onto factor 1 were all related to the application of rules. Given that all participants had been trained on marksmanship and developed this skill, it appears logical that shot radius was influenced by one's application of techniques for aiming the weapon. The second factor was composed of measures related to spatial processing and spatial relations. Finally, the third factor was related to divided attention.

Aim trace

The factor analysis results suggest related measures load onto two factors. Measures that loaded onto factor 1 were related to mathematical processing. The ability to aim, rotate, and orient a weapon may be influenced by one's ability to judge angles and accurately adjust the weapon. Measures that loaded onto the second factor were related to visual scanning.

Proportion of hits

The factor analysis results suggest related measures load onto two factors. The first factor included measures of spatial orientation and rotation. The second factor included measures of visual monitoring and scanning.

Factors influencing performance on the standard marksmanship qualifying task

Reaction time

The results of the factor analysis suggest the eight cognitive test measures that correlated with reaction time on the standard marksmanship qualifying task load onto three factors. The first factor included measures related to visual and auditory attention. The second factor included measures of visual-motor tracking and the third factor included measures of divided attention.

Radius from center mass

The results of the factor analysis suggest the 23 cognitive test measures that correlated with shot radius on the standard marksmanship qualifying task load onto seven factors. The first factor included measures related to visual scanning while the second factor was related to visual reaction time. The third factor included measures of spatial relations, the fourth measures of mathematical processing, the fifth measures of auditory processing, the sixth measures of divided attention, and the seventh measures of sustained attention.

Aim trace

The results of the factor analysis suggest the two cognitive test measures that correlated with aim trace on the standard marksmanship qualifying task load onto one factors related to visual scanning.

Proportion of hits

The results of the factor analysis suggest that the 16 cognitive test measures, which correlated with reaction time on the standard marksmanship qualifying task, load onto five factors. The first factor included measures related to visual reaction time, the second related to visual scanning, the third related to auditory processing, the fourth related to mathematical processing, and the fifth related to spatial relations.

Cognition and marksmanship

The results of the sequential analyses suggest that aspects of marksmanship performance were predicted by visual tracking, sustained attention, motor coordination, spatial processing, divided attention, and mathematical processing as well as related to visual scanning and auditory processing. The skill of marksmanship requires one to perceive an object in a three-dimensional plane, zero in on the object, and rotate the weapon to engage a target. The skill to orient a weapon is complex and requires one to process a large amount of information related to angle of orientation, visual and auditory sensations, and physiological sensations in a short amount of time during military operations.

Limitations

One limitation of the present study is that the standard marksmanship qualifying task is composed of targets of varying size, simulating varying distance, which is a factor that may have impacted differences in performance between targets. On a similar note, detecting artificial targets may result in a blurred image or multiple images if the visual angle does not match with the target size relative to other cues. Another limitation is that the investigators did not collect information regarding health and physiological conditions that may have influenced performance.

Conclusions

The primary objective of this study was exploratory in nature and yielded insight into the relationship between cognition and marksmanship. The secondary objective was hypothesis driven which the results did not support. Specifically, the results do not support that this friend/foe detection task was related to decision making style and skill in that performance on both tasks were unrelated to measures of decision making. Rather, the cognitive abilities that influenced performance on both tasks were related to visual spatial abilities, mathematical processing, and visual and auditory processing.

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