IDENTIFYING PREDICTORS OF ARMY MARKSMANSHIP: A COGNITIVE, AFFECTIVE, AND PSYCHOMOTOR PERSPECTIVE

Marksmanship is a core competency every U.S. Army Soldier must attain in order to achieve combat readiness (James & Dyer, 2011). To enhance overall marksmanship proficiency, the current research aims to develop a model to predict Soldier marksmanship qualification scores based on individual differences. The results of the current study found several psychomotor, cognitive, and affective variables predicted marksmanship qualification scores. These findings bring research a step closer to identifying skill deficiencies and individual needs prior to training. More research is needed to maximize understanding and improvement of marksmanship performance and to improve overall combat readiness.

INTRODUCTION

Marksmanship is a core competency every U.S. Army Soldier must master to achieve combat readiness (James & Dyer, 2011). However, marksmanship is a complex skill: not only does it involve firing a weapon using accurate and precise pscyhomotor coordination (Clavarelli, Platte, & Powers, 2009), but it is influenced by many other factors including body movement, muzzle deflection, and environmental change (Chung, Delacruz, de Vries, Bewley, & Baker, 2006; Pojman et al., 2009). The multi-determined nature of marksmanship makes it both difficult to control and important to understand.

To enhance overall marksmanship proficiency and support the acquisition of this complex skill, it is critical to identify differences between Soldier skill levels early on in training. By doing so, instructors will be able to allocate attention to Soldiers' individual needs and customize training to ensure that all Soldiers develop proficiency. The current research aims to develop a predictive model based on individual differences according to an Army marksmanship metric.

Predicting Marksmanship

Although the Army requires each Soldier to complete marksmanship training, each serviceman brings individual differences (e.g., psychological traits, operational and leadership experiences, task proficiencies, and sustainment skills) that are often overlooked. Extant literature suggests that these background variables can influence training outcomes (e.g., Ackerman, 1996; Grossman & Salas, 2011; Gully & Chen, 2010) and overall marksmanship performance (Chung et al., 2011). Research should therefore investigate individual differences related to shooting performance as part of an attempt to improve marksmanship training.

As the predictors of the current research are introduced, it is pertinent to note the underlying theoretical framework of learning a skill. An adapted version of Bloom and Krathwohl's (1956) Taxonomy of Educational Objectives (Simpson, 1972) breaks learning down into three skill domains: psychomotor, cognitive, and affective components. Prior research has explored marksmanship within each domain and highlighted several cognitive, affective, and psychomotor factors believed to underlie skilled shooting performance (Chung et al., 2006; Ciavarelli, Platte, & Powers, 2009). Chung et al. (2011) further provided an overview of empirically-tested predictors of marksmanship, which includes perceptual-motor (psychomotor), cognitive, affective, equipment, and environmental factors.

Despite the attention various predictors have received in regard to marksmanship, no prior research has operationalized marksmanship using the Army's metric of marksmanship proficiency - Basic Rifle Marksmanship (BRM) qualification score, which would arguably be the most relevant and valid measure of marksmanship. The current paper uses the BRM qualification score as the outcome in its investigation of various psychomotor, cognitive, and affective variables influencing marksmanship. Each domain is described further below, and Table 1 summarizes the variables of interest in each domain.

Table 1. Independent Variables

Domain	Constructs
Psychomotor	Motor Speed and Accuracy Reaction Time Inhibition Small Animal Hunting Experience Large Animal Hunting Experience Sports Experience Musical Ability Mechanical Work Firearms Experience
Cognitive	Marksmanship Domain Knowledge Education
Affect	Perceived Stress Openness to Experience Grit Self-Efficacy Initiative Locus of Control

Psychomotor. Psychomotor skills are learned physical tasks that may include movement, coordination, and motor-skills (Simpson, 1972; Sottilare, 2015). Importantly, psychomotor measures are found to be highly related to task performance both early and late in practice (Ackerman & Cianciolo, 2000), which may be attributed to the importance of innate abilities and development of procedural behavior.

Fleishman (1954) developed a taxonomy to identify potential abilities underlying desired motor skills (Haibach, Reid, & Collier, 2011). Psychomotor abilities include control precision, rate control, aiming, response orientation, reaction time, manual dexterity, finger dexterity, arm-hand steadiness, wrist and finger speed. In general, the greater the psychomotor ability (e.g., lower reaction time, greater precision), the better the task performance.

In the current research, the psychomotor abilities hypothesized to influence marksmanship included exercises such as motor speed and accuracy, reaction time, inhibition and further enhanced by experience with video-games, hunting, sports, mechanical work, and playing music.

Cognition. Cognition refers to the structure, store, and use of knowledge (Sternberg & Sternberg). Cognitive learning occurs during skill acquisition when there is an increase of knowledge and/or a change in the mental structure of the information taught (Tannenbaum et al., 1993). According to Cognitive Load Theory, processes in working memory create an interaction between long-term memory and learning content and performance, and the amount of knowledge already acquired within a domain alters learning and performance (Plass, Moreno, & Brünken, 2010; Sweller, 1994). Consequently, knowledge should positively influence performance. The current paper focuses on general knowledge through education (i.e., academic degree) as well as domain-specific knowledge regarding marksmanship.

Affect. Affect is the self-regulatory processes that supports personal development and adaption (Bandura, 1993, 2014) and includes personality traits, moods, and emotions that vary in length, influence, and cause (Gebhard, 2005). While attention is generally centered on psychomotor and cognition in regards to skill acquisition, performance requires more than understanding the knowledge and actions necessary for the given skill. Therefore, the affective domain cannot be neglected. Although there are many variables associated with this domain, the current paper focuses on the affect variables of perceived stress, openness to experience, grit, self-efficacy, initiative, and locus of control.

Given that performance on a complex skill is well-predicted by a variety of traits (e.g., Ackerman, 2007; Chung et al., 2011), the objective of the current research is to predict marksmanship based on the specified variables. Here, the predictors and their associated domain are identified in Table 1, and the criterion is the Basic Rifle Marksmanship (BRM) qualification score which is the Army's metric to identify the level of marksmanship proficiency. The current effort aims to develop a predictive model that identifies underperformers based on the identified variables.

METHOD

Participants

A total of 84 Soldiers participated in the study during their marksmanship training at the U.S. Army's Ft. Benning as part of the overall Basic Officer Leader Course (BOLC). Participants ranged in age from 21 to 39 years old (M = 24.29, SD = 3.24). Nine participants (11%) were left-handed and left-eye dominant, fifty-nine (70%) were right-handed and right-eye dominant, and sixteen (19%) were cross-dominant. Eighty-three participants (99%) were male. In regard to experience with a weapon, all participants reported having prior experience with guns: among those with prior experience, fifteen participants (18%) reported themselves as novices, fifty-two (62%) as moderate, seventeen (20%) as enthusiasts, and zero (0%) as expert.

Measures

A tablet-based Cambridge Neuropsychological Test Automated Battery (CANTAB) was administered to assess psychomotor abilities such as motor speed and accuracy, reaction time, and inhibition. The following paper measures were also included: Demographic Survey, Marksmanship Self-Efficacy Scale, Openness to Experience Factor Scale (Barrick & Mount, 1991), Perceived Initiative Scale (Frese, Kring, Soose, & Zempel, 1997), Grit Scale (Duckworth, Peterson, Matthews, & Kelly, 2007), Conscientiousness Factor Scale (Barrick & Mount, 1991), Perceived Stress Scale (Cohen, Kamarck, & Mermelstein, 1983), and Marksmanship Knowledge Test.

The demographic survey, self-efficacy measure, and marksmanship knowledge test were developed specifically for this effort. Bandura's (2006) guide for constructing self-efficacy scales was used during the development of the marksmanship self-efficacy scale, and a subject matter expert provided materials currently used in training that resulted in the questions found in the marksmanship knowledge test. The other survey measures were developed and validated through other research efforts and are publicly available.

Procedure

Data collection occurred in conjunction with Soldiers' marksmanship training during the Basic Officer Leader Course (BOLC) at Ft. Benning, GA. The BOLC course involves a brief train-up and service rifle qualification test.

On the first day of data collection, Soldiers completed the battery of tests and measures relevant to the discussed predictors. On the second day, Soldiers completed four CANTAB tests (motor task, reaction time, stop signal, and stop signal inhibition) presented on a tablet.

The criterion (i.e., marksmanship performance) was collected during qualification fire where Soldiers shot at 40 timed targets that pop up for different durations of time. Soldiers engaged 20 single or multiple targets from the prone supported firing position, 10 targets from the prone unsupported firing position, and 10 targets from the kneeling unsupported firing position. To pass, trainees must hit 23 targets to qualify as a Marksman, 30 to 35 hits to qualify as Sharpshooters, and 36 to 40 hits to qualify as Experts. If Soldiers hit less than 23 targets, they did not qualify. Each Soldier had up to five attempts to qualify. Here, the BRM score is the highest score a Soldier achieved during their qualification.

RESULTS

SPSS 23.0 was used for all analyses. First, preliminary analyses were conducted to ensure that proper data assumptions were met. Correlational analyses then examined the relationships between the predictors identified in Table 1 and marksmanship performance to assess basic relationships, determine potential multicollinearity, and to consolidate the number of variables to be considered for subsequent regression analyses [as per recommendations regarding sample size for hierarchical regression analysis (Tabachnick & Fidell, 2013)].

Regarding the cognitive predictors, the basic marksmanship knowledge test correlated significantly with marksmanship performance (r = .25, p = .02), but education did not (r = -.18, p = ns). Among the individual difference and affective predictors, neither grit (r = -.02), perceived stress (r = .13), openness to experience (r = .01), or locus of control (r = -.05) significantly correlated with marksmanship performance (all ps = ns). However, self-efficacy of behavior (r = .27, p = .02) and initiative (r = -.23, p = .04) were significantly related to marksmanship performance. The last result was surprisingly in the opposite direction of the hypothesized relationship.

Among the psychomotor and experience predictors, no CANTAB variables were significantly related to marksmanship performance (rs ranging from .01 to .14; all ps = ns). Further, of the prior experience predictors, only familiarity with handguns (r = .23, p = .04) and hunting large animals (r = .220, p = .04) correlated significantly with marksmanship performance. Others, including participation in sports (r = .19), hunting small animals (r = .15), fishing (r = -.09), playing a musical instrument (r = .04), experience with mechanical work (r = .17), and playing video games (r = -.01), were not significantly related to marksmanship performance (all ps = ns).

Based on these correlations, five predictors were identified as candidates for hierarchical regression analysis: knowledge test (cognitive), familiarity with handguns (psychomotor), hunting large animals (psychomotor), initiative (affective), and self-efficacy (affective). Hierarchical multiple regression (block entry) examines whether subsequently entered (i.e., have a lower likelihood of prediction) variables add significant explanation of the variance in the criterion (marksmanship performance) after controlling for earlier entered (i.e. have a higher likelihood of prediction) variables. Entry was determined based on prior literature finding that cognitive variables decrease in predictive ability during the progression of the skill, while psychomotor variables become more predictive (Ackerman, 1998; Fleishman, 1972). In addition, the size of prior documented correlations of similar variables to the ones in the current study were considered (Chung et al., 2011). Thus, the psychomotor variables were entered in Step 1, followed by the cognitive variable at Step 2, and finally the affective variables at Step 3.

The Step 1 model with psychomotor predictors was significant, F (2, 81) = 3.62, p = .03, and accounted for 8.2% of the variance in marksmanship performance. Adding the cognitive predictor in Step 2 was significant, helping to explain an additional 5% of the variance after controlling for prior experience, F change (1, 80) = 4.60, p = .04. Finally, adding the affective predictors in Step 3 also significantly increased explanation of the variance in marksmanship performance after controlling for prior experience and marksmanship knowledge, explaining an additional 14.2% of the variance, F change (2, 78) = 7.61, p = .001. The final model accounted for 27.4% of the variance in marksmanship performance. In the final model, hunting large animals remained a significant predictor (β = .22, p = .04, 95% CI [.03, 1.23]), as did marksmanship knowledge (β = .25, p = .01, 95% CI [.08, .62]), and initiative (β = -.38, p < .001, 95% CI [-.49, -.15]). Familiarity with handguns and self-efficacy were no longer significant predictors.

DISCUSSION

The results of the current study found that several psychomotor, cognitive, and affective variables predicted the Army’s metric of marksmanship performance (BRM qualification score). The significant predictors were prior experience hunting large animals, marksmanship domain knowledge, and initiative. Below we detail the findings and potential implications for Army training and procedures.

First, large animal hunting experience significantly predicted marksmanship. Hunting experience is considered a form of practice (Tierney et al., 1979), which has been found to increase performance (e.g., Ericsson, 2006; Fitts & Posner, 1967; Grossklags, & Reitter, 2014; Chase & Simon, 1973). Practice compiled during prior experience provides individuals the opportunity to understand the nature of the required task and concentrate on refining motor skills (Chase & Simon, 1973) and is suggested to offer analogous situations that result in the formation of memories, which are then used as indicators of how to react in future situations (Fitts & Posner, 1967). Therefore, large animal hunting experience provides Soldiers with analogous situations that improves overall marksmanship performance.

The finding that marksmanship domain knowledge is significantly predictive of marksmanship is consistent with prior research showing that expert marksmen understand the fundamentals of rifle marksmanship more than the novice or average marksmen (Chung et al., 2004; Thompson et al., 1980). It is possible that Soldiers utilize domain knowledge to understand the relationships between the fundamentals and outcomes, how to recognize problems associated with the fundamentals, how to fix those problems (Baker, 2003), and thus improve marksmanship performance.

One implication of the current findings is that emphasis should be placed on ensuring that Soldiers have a concrete understanding of marksmanship fundamentals. Instructors can assess Soldiers’ knowledge periodically in the classroom using paper or electronic formats (e.g., iClicker), and take prompt action to correct and improve deficiencies in knowledge through additional explanation and demonstration.

Finally, initiative is the affective variable included in the predictive model. Personal initiative is defined as an active behavior characterized by a persistent, self-starting, and proactive approach to pursue a goal (Fay & Frese, 2001; Frese, Kring, Soose, & Zempel, 1996). Initiative is also identified as the willingness to act when faced with uncertain situations and when orders are either absent or no longer fit the situation (Department of the Army, 2006a; Aude et al., 2014). Although initiative is theoretically implied to increase performance due to the associated motivational components (Aude et al., 2014; Fay & Frese, 2001), the current findings suggest a negative relationship between initiative and marksmanship performance. We postulate that individuals high in initiative may focus on getting the job done quickly rather than the accuracy and precision required for shooting. Therefore, initiative may negatively influence marksmanship performance. However, further research is needed to better understand the relationship between initiative and performance.

Limitations and Future Directions

The current research tested a model that significantly predicted Soldiers' BRM qualification scores, which included prior experience, knowledge, and initiative. However, the study is not without limitations and future research should continue the current efforts to replicate findings and expand knowledge of the predictors of marksmanship performance.

First, the final hierarchical regression model accounts for only 27% of the variance of marksmanship performance, meaning that the majority of performance variance is due to unincluded and/or unmeasured factors. Although it is impossible to account for total variance, there is significant room for improved understanding, and further research is needed to identify additional variables that increase the explained variance.

Furthermore, it is important to note that the psychomotor, cognitive, and affective labels used to categorized skill domains are not necessarily mutually exclusive, nor have the predictors in this study always been consistently classified under the same domain. For instance, almost all learning involves more than one domain: psychomotor behaviors contain cognitive and affective elements within them (Merritt, 2008), and CANTAB measures have been described as both cognitive and psychomotor. Thus, for the current results, attention should focus on the specific predictors found significant rather than on the domain with which they were associated.

The final constraint of the current study is the limitations within the BRM qualification score. Specifically, the qualification scores represented only the Soldiers' overall performance and was not broken down into sub-categories. For example, no data were available regarding the level of difficulty of different targets (e.g., distance) or the position from which the Soldier shot (prone supported, prone unsupported, or kneeling). Despite this limitation, overall qualification score is the established metric the Army uses to identify marksmanship proficiency. However, future research may wish the fine-tune measurement of overall performance scores by measuring these or other factors.

Conclusion

The results from this study will contribute to marksmanship training programs. Specifically, the current study identifies predictive variables of performance in an applied setting using the Army metric of marksmanship performance, bringing research a step closer to the identification of skill deficiencies and individual needs prior to training. Accordingly, instructors will become increasingly able to provide individualized training that adapts to each Soldier's specific needs rather than a "one-size-fits-all" approach currently implemented during BRM Training. More research is needed to maximize understanding and improvement of marksmanship performance and to improve overall combat readiness.

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