Developing a Predictive Model of Army Rifle Marksmanship Performance

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ABSTRACT

Rifle marksmanship has been a required combat skill for Soldiers in the U.S. Army since its inception. As such, the Army is heavily invested in training this fundamental skill. However, the extent to which the Army assesses marksmanship performance is limited. Currently, a recruit's marksmanship performance is only assessed during practice and final qualification events at the culmination of basic rifle marksmanship training. If performance were assessed throughout the training process rather than just at the end, instructors would have opportunities to forecast specific shooter problems, rapidly diagnose errors when they happen, and provide tailored feedback based on the root cause of an individual shooter's issues. The U.S. Army Research Laboratory is taking a first step toward adapting training for marksmanship by developing a predictive model of marksmanship performance. Our previous research (Goodwin et al., 2016) described the process used to identify constructs related to marksmanship. The resulting model of cognitive, affective, psychomotor, and other skills was evaluated in the current research with a sample of Soldiers in the Army's Basic Officer Leader's Course at Fort Benning, GA. Data were collected during the one week rifle marksmanship training process. Survey-based measures of demographics, attitudinal constructs, and domain knowledge were collected during classroom instruction. Psychomotor skills were measured using tablet-based software. Performance measures from the Engagement Skills Trainer II (EST II), a commercially available marksmanship training device, were collected. Finally, practice and final qualification scores were collected. The results of the current study found that several variables significantly correlated with the first qualification fire round score. The significant predictors were prior experience with firearms, familiarity with handguns, EST II score in the kneeling position, practice qualification score, and self-efficacy of behavior. However, when simultaneously tested in the multiple regression model, the only significant predictor was Soldiers' practice qualification score. The current paper suggests new technology as well as the simulators currently deployed, such as EST II, to include predictive capabilities before they are used as a diagnostic tool. As such, further research is recommended to diagnose marksmanship performance.

ABOUT THE AUTHORS

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INTRODUCTION

Rifle marksmanship is a fundamental skill required for combat readiness. The U.S. Army leverages resources and technology to support the mastery and instinctual application of marksmanship. Proper training of the fundamental skills is specifically important to develop and determine Soldier proficiency (McCullough, 2007). Therefore, the U.S. Army is heavily invested in training this skill and requires each Soldier to attain marksmanship proficiency through Basic Rifle Marksmanship (BRM) training. Despite the well-established training process supporting the development of marksmanship proficiency, there are still deficiencies apparent during the qualification fire at the end of BRM training. For example, Soldiers often exceed the set limit of 40 rounds of ammunition to qualify on record fire, and 25% do not qualify in the first round of training (Dyer et al., 2012).

Skill deficiencies are not identified in time because data concerning the recruit's ability are only collected and assessed during the practice and final qualification events at the culmination of basic rifle marksmanship training. If Soldiers were assessed throughout the training process rather than just at the end, opportunities would be available to forecast specific shooter problems, rapidly diagnose errors when they happen, and provide tailored feedback based on the root cause of an individual shooter's issues.

To support performance diagnosis, assessments should use data that predicts qualifying scores prior to the final qualification test (Chung et al., 2004). Prediction through measurement plays a vital role in understanding future performance (Bennett, Lance, & Woehr, 2014) and may include underlying psychological constructs associated with the objective (e.g., conscientiousness, grit, perceptual speed), analogous performance (e.g., practice qualification score), or a combination of both (Muchinsky, 2006). While research has identified various predictors associated with marksmanship (e.g., Chung, Dionne, & Elmore, 2006; Espinosa et al., 2008; Nagashima et al., 2009; Hagman, 1998; Smith & Hagman, 2003), no prior research has associated such predictors with the Army's metric for marksmanship (the BRM qualification event). As a result, prior studies are limited in their ability to apply and generalize their findings.

To address this gap in the existing research, the U.S. Army Research Laboratory (ARL) has taken a first step toward developing a predictive model of marksmanship performance. During our previous effort, Goodwin, Murphy, and Medford (2016) identified variables relating to marksmanship by conducting a literature review of research on measures of marksmanship training as well as a user needs analysis with subject matter experts (SMEs). The objective of the present research is to build a predictive model using the collection of potential demographic, experience, psychomotor, cognitive, and affective variables (see Table 1) and scores on the qualification test for Soldiers undergoing BRM training. In so doing, the current study also validates these measures to show utility for performance diagnosis.

Table 1. Rifle Marksmanship Assessment Domains and Variables

Domain	Variables	
Demographic	• Age in years • Height in inches • AFQT Score • APFT Score	• Level of education • Hand/eye dominance • Education
Experience	• Prior experience with firearms • Familiarity with handguns • Familiarity with rifles • Familiarity with shotguns • Years of law enforcement experience • Years of military experience • Participation in team sports • Participation in individual sports	• Participation in hunting large animals • Participation in hunting small animals • Participation in fishing • Participation in outdoor activities • Participation in playing a musical instrument • Participation in mechanical work
Psychomotor	• Motor Speed and Accuracy • Reaction Time • Inhibition	• EST Prone Supported Dry-Fire • EST Prone Unsupported Dry-Fire • EST Kneeling Dry-Fire
Cognitive	• Marksmanship Domain Knowledge	
Affective	• Perceived Stress • Openness to Experience • Grit • Self-Efficacy	• Conscientiousness • Initiative • Locus of Control

METHOD

Participants

Participants were 84 Soldiers completing marksmanship training at the U.S. Army's Fort Benning as part of the overall Basic Officer Leader Course (BOLC). Ages ranged from 21 to 39 years old (M = 24.29, SD = 3.24). All participants had prior experience with guns: 15 participants reported themselves as novices, 52 as moderate, 17 as enthusiasts/professional, and zero as expert. All participants in this study were volunteers and received no compensation for participation in this research. It was emphasized to them that their performance has no impact on their standing with the Army, that their participation was voluntary, and there would be no penalty if they chose to no longer participate.

Measures

Data were collected over three sessions. First, a battery of paper measures was administered. The battery included a Demographic Survey, Marksmanship Self-Efficacy Scale, Openness to Experience Factor Scale (Barrick & Mount, 1991), Perceived Initiative Scale (Frese, Kring, Soose, & Zempel, 1996), 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.

During the second session the tablet-based Cambridge Neuropsychological Test Automated Battery (CANTAB) was administered. It was administered to assess psychomotor abilities such as motor speed and accuracy, reaction time, and inhibition. The third set of data was collected using the Engagement Simulation Training (EST) 2000. The EST was developed to expose Soldiers to the interacting elements of marksmanship and supports all aspects of instruction (Goldberg, Amburn, Brawner, & Westphal, 2014). This simulator uses a blend of analog and digital video, synchronized image projection, laser hit detection, and microcomputer technology to display an array of target arrangements and courses of fire to recording the number of hits and misses and thus measure performance. Each Soldier obtained a score for prone-supported, prone-unsupported, kneeling, and overall shots.

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 three phases of training and service rifle qualification test. Figure 1 depicts these phases and the succession of data collection. On the first day of data collection, Soldiers completed the battery of measures identified by Goodwin et al. (2016). On the second day, Soldiers completed both the tablet-based CANTAB tests and dry-fire drills in the EST II. On the third day of data collection, Soldiers engaged in practice qualification fire. This practice is identical to the final qualification event where the Soldiers shot at 40 timed targets that pop up for different durations of time.

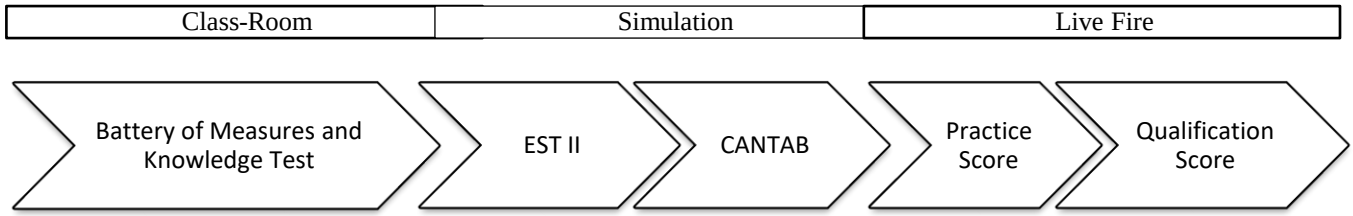


Figure 1. BOLC Data Collection

The criterion (i.e., marksmanship performance) was collected during the qualification event. Soldiers shot at 20 targets from the prone supported firing position, 10 targets from the prone unsupported firing position, and 10 targets from the kneeling unsupported firing position. Trainees need to 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 fewer than 23 targets, they did not qualify. Each Soldier had up to five attempts to qualify. In the current paper, the criterion is the first score a Soldier achieved during their qualification. The Army allows Soldiers to have up to five attempts to qualify and counts the highest qualification score. However, previous research used the first round of fire as a dependent variable (Dyer, 2012). We further postulate that due to the uncertainty and urgency associated with combat environments, the first round of fire counts more in combat than an eventual 'best effort.' Therefore, the first score during the qualification event indicates critical skill deficiencies.

RESULTS

SPSS 23.0 was used for all analyses. First, preliminary analyses were conducted to ensure that data assumptions were met. For instance, we tested the skewness and kurtosis of each variable for normality, as well as identified and removed any outliers using box plot tests. Table 1 represents the correlations between the criterion and predictor measures. We also collected the Soldiers' highest qualification score to compare against the first round of fire. The criterion (first qualification fire round) significantly correlated with highest qualification score ($r = .633$, $p < .01$).

Among the predictive measures, marksmanship performance correlated significantly with prior experience with firearms ($r = .317$, $p < .01$, familiarity with handguns ($r = .28$, $p = .01$), EST II score in the kneeling position ($r = .21$, $p = .05$), practice qualification score ($r = .62$, $p < .01$), and self-efficacy in doing ($r = .23$, $p = .04$). Practice qualification is significantly correlated with prior experience with firearms ($r = .33$, $p > .01$), familiarity with handguns ($r = .23$, $p = .04$), and self-efficacy ($r = .19$, $p = .03$). Self-efficacy in doing is significantly correlated with prior experience with firearms ($r = .26$, $p = .02$) and familiarity with handguns ($r = .44$, $p > .01$). Prior experience with firearms is also highly correlated with familiarity with handguns ($r = .44$, $p > .01$). Although marksmanship performance did not significantly

correlate with participation in team sports (r = -.21, p = .06) and law enforcement experience (r = .19, p = .09), we postulate that further exploration of these variables in future research is necessary.

A linear multiple regression analysis was then conducted to predict marksmanship performance using the set of predictors that significantly correlated with the criterion. The predictors were entered simultaneously, resulting in a significant model, $F(5, 195) = 11.1$, $p < .01$, $R_2 = .42$. The final model accounts for 42% of the variance. In a multiple regression model, the strength of each predictor to the criterion is assessed after controlling for the influence of all the other entered predictors, leaving only the unique variance associated between that predictor and the criterion. As such, after controlling for the influences of all other predictors in the model, the only predictor that was significant was the practice qualification score ($p < .01$).

Table 2. Correlations between predictors and criterion

Measures	Pearson Correlation With Criterion	Sig (2-tailed)
CANTAB	.09	.40
Highest Qualification Score	.63**	.00
Age in years	.08	.48
Height in inches	-.04	.75
AFQT Score	.28	.27
APFT Score	.11	.33
Level of education	-.09	.40
Eye dominance	-.05	.63
Congruity of eye and hand	.04	.72
Prior experience with firearms	.32**	.00
Familiarity with handguns	.28*	.01
Familiarity with rifles	.14	.22
Familiarity with shotguns	.10	.38
Years of law enforcement experience	.19	.09
Years of military experience	.06	.58
Participation in team sports	-.21	.06
Participation in individual sports	-.03	.83
Participation in hunting large animals	.14	.22
Participation in hunting small animals	.05	.62
Participation in fishing	-.06	.61
Participation in outdoor activities	-.10	.36
Participation in playing a musical instrument	.09	.43
Participation in mechanical work	.08	.45
Initiative scale total score	-.15	.19
Grit scale total score	.10	.35
Self-efficacy in marksmanship knowledge	.13	.25
Self-efficacy in marksmanship behavior	.23*	.04
Perceived stressed scale total	.17	.12
Conscientiousness scale total score	-.12	.27
Openness to experience scale total score	.09	.43
Locus of control total score	-.15	.18

Knowledge test	.06	.56
EST Prone Supported hits	.19	.29
EST Prone Unsupported hits	.08	.50
EST Kneeling hits	.21*	.05
EST total score	.15	.17
Practice qualification score	.62**	.00

DISCUSSION

General Discussion and Implications

The results of the current study found that several variables significantly correlated with the first qualification fire round score. The significant predictors were prior experience with firearms, familiarity with handguns, EST II score in the kneeling position, practice qualification score, and self-efficacy of behavior. However, when simultaneously tested in the multiple regression model, the only significant predictor was Soldiers' practice qualification score. This result is in contrast with Dyer's (2012) assertion that the relationship between practice and record fire is not sufficient and suggests the Soldiers' stress may not sabotage their performance as previously thought. Rather, our results suggest immediate remediation if the Soldier does not hit 23 or more targets during practice qualification. However, the practice qualification may be too late to fix any skill deficiencies. Other assessments must be implemented in an effort to diagnose performance and be used to direct personalized training.

Although simulations like the EST II were designed and implemented to help diagnose performance with aiming, breathing, trigger control, and shot recovery (Jones, King, & Gaydos, 2011), our results found that EST II may not be an accurate or sufficient diagnostic tool. Literature further identifies the limitations associated with collecting performance measurements using the current simulators. For example, the EST 2000 provides data that are limited due to accuracy, such as the shooter's trigger. Research also fails to find consistent correlations between simulator and live-fire scores (Chung et al, 2006; Keefe & Tikuisis, 2003; Smith & Hagman, 2003; Temby et al, 2005).

While there are limitations with using current simulators for predicting performance, technology and simulations are the most appropriate method of collecting performance. They can depict a task and elicit specific behaviors (Scalese, Obeso, & Issenberg, 2008), which then produces data that are collected and stored for immediate or subsequent analysis (Wiese, Wheeler, Roberts, & Ramouter, 2012). As a result, the data from these technologies and simulators may be used as a diagnostic performance measurement to identify skill competency as well as indicate future performance (Scalese, Obeso, & Issenberg, 2008). However, it is required to identify the extent to which technology and simulation data reliably diagnose performance. Therefore, further research must identify and enhance the predictive nature of simulators, especially those currently deployed, before using them as a diagnostic tool.

Limitation and Future Directions

The current research generated a significantly predictive model for Soldiers' first round of BRM qualification score. However, results should be interpreted with caution. Although the final regression model accounts for 41.9% of the variance of marksmanship performance, the only significant predictor remaining in the model was practice qualification. Thus, the remainder of performance variance is due to unincluded and/or unmeasured factors. As such, research is required to identify additional variables that increase the explained variance and that remain uniquely significant in the model. Future research should also consider re-conceptualizing the constructs and measures used in the current study given the significant intercorrelations between predictors.

Last, there are limitations associated with the BRM qualification score. Specifically, the qualification scores only represent the Soldiers' overall marksmanship performance (i.e., number of targets hit) rather than detailing specific deficiencies. For example, credit for targets are not weighed based on level of difficulty or the Soldiers' shooting position, nor was there a distinction between near vs. far targets or the order in which the Soldier engages in them. Therefore, future research could look at predicting the performance along more detailed variables such as shooting

position and level of difficulty rather than the overall performance to get a better understanding of marksmanship proficiency.

Conclusion

Soldiers must develop a proficiency in marksmanship to achieve combat readiness. However, significant skill deficiencies are apparent at the end of BRM training. The results from this study will contribute to marksmanship training programs by identifying predictive variables of performance in an applied setting. Our results provide a step closer to identifying skill deficiencies and individual needs prior to and during training. Additional research is necessary to identify measurements that could feed into adaptive training and support the instructors' ability to provide individualized training that adapts to each Soldier's specific needs. Therefore, we suggest further research to support training Soldiers into combat-ready marksmen.

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