DEVCOM DAC-TR-2023-061
August 2023

The Effects of Incorporating Individual Factors within Target Engagement and Decision-Making Shooting Performance of Elite Shooters

by David Scribner, Maria Talarico, and Frank Morelli

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REPORT DOCUMENTATION PAGE

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED	
		START DATE	END DATE
August 2023	Technical Report	April 2022	December 2022

4. TITLE AND SUBTITLE
The Effects of Incorporating Individual Factors within Target Engagement and Decision-Making Shooting Performance of Elite Shooters

5a. CONTRACT NUMBER	5b. GRANT NUMBER	5c. PROGRAM ELEMENT NUMBER
5d. PROJECT NUMBER	**5e. TASK NUMBER**	**5f. WORK UNIT NUMBER**

6. AUTHOR(S)
David Scribner, Maria Talarico, and Frank Morelli

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	8. PERFORMING ORGANIZATION REPORT NUMBER
Director DEVCOM Analysis Center 6896 Mauchly Street Aberdeen Proving Ground, MD 21005	DEVCOM DAC-TR-2023-061

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
DISTRIBUTION STATEMENT A. Approved for public release: distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
This report summarizes the current results of a U.S. Army Combat Capabilities Development Command (DEVCOM) Analysis Center (DAC) Human Systems Integration Division's effort to determine support or non-support of hypothesized relationships between individual factors and shooting performance. Data and analyses using a sample of elite shooters from the U.S. Army Marksmanship Unit (USAMU) suggest promising results for the future of such research within the shooting research community. Findings suggest that accounting for individual factors based on cognitive, physiological, psychological, anthropometric, and other measures in target engagement performance, in addition to experimental variables, increases the explained variance of the model. A higher-explained variance yields more robust data sets with measurably more information about the characteristics of the individual shooter when considering shooting performance and novel or next-generation weapons. Data was collected in August 2022 at Fort Benning, Georgia, with a group of six USAMU shooters.

15. SUBJECT TERMS
marksmanship, shooting performance, target engagement, methodology, individual factors, Soldier performance, shoot–don't shoot decision making, workload, working memory capacity

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES
a. REPORT	b. ABSTRACT	C. THIS PAGE		
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UU	63

19a. NAME OF RESPONSIBLE PERSON	19b. PHONE NUMBER *(Include area code)*
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STANDARD FORM 298 (REV. 5/2020)
Prescribed by ANSI Std. Z39.18

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1. INTRODUCTION

1.1 Purpose

This study was designed to use quantitative metrics to identify whether or not a theoretical general model of Individual Factors (IFs) on marksmanship performance could be supported (Scribner & Morelli, 2020). The proposed model outlines and connects factors that may influence shooting and marksmanship performance including weapon, ammunition, and target characteristics as well as IF of the shooter (Scribner & Morelli, 2020). This study is the first phase of a larger, multi-study effort to better understand the impact of IFs on shooting performance across varying levels of marksmanship expertise.

Further, this study aimed to examine IF model effects as various predictor and concomitant variables under a live-fire rules-of-engagement (ROE) target scenario with various target distances, exposure times, and workloads. General hypotheses on the effectiveness of this IF model were tested against standard experimental (or independent variable) models for both regression and analyses of variance and covariance.

1.2 Warfighter Basic Tasks

The standard paradigm for Warfighters is to shoot, move, and communicate; however, it could be adjusted to shoot, move, attend to information, make decisions, and then communicate. There are various environmental and operational stressors including varying rules of engagement, continuous operations, and information-processing tasks that increase information-processing and subsequent mental workload/stress. As the mental requirements for the Warfighter have become more onerous, our research paradigms must expand to include additional factors as a matter of practice to better align with the Warfighter's operational stressor and workload environment, especially for improved Warfighter systems' acquisition trade analyses. This natural increase in mental workload is the primary motivator for using a friend–foe target discrimination task to replicate the cognitive load a Warfighter might experience under operational circumstances rather than a simple target shooting task.

1.3 Factors Influencing Marksmanship

Marksmanship scores and accuracy are known to be affected by many factors including weapon, ammunition, target, shooting posture, and individual characteristics (Scribner & Morelli, 2020; Stafford et al., 2004; Weaver et al., 2003). Individual differences are becoming more important in human factors and ergonomics research (Weaver et al.,

2003) and very few factors that characterize individual differences have been investigated in shooting performance (Stafford et al., 2004). It can be argued that within the marksmanship and shooting literature, there is no unifying and cogent understanding of the human-element contribution within marksmanship and shooting studies. This gap speaks to the need for an overarching model framework with which to explain differences in performance (Figure 1). A list of general IFs along with weapon, ammunition, and target factors are listed on the left of the model schematic.

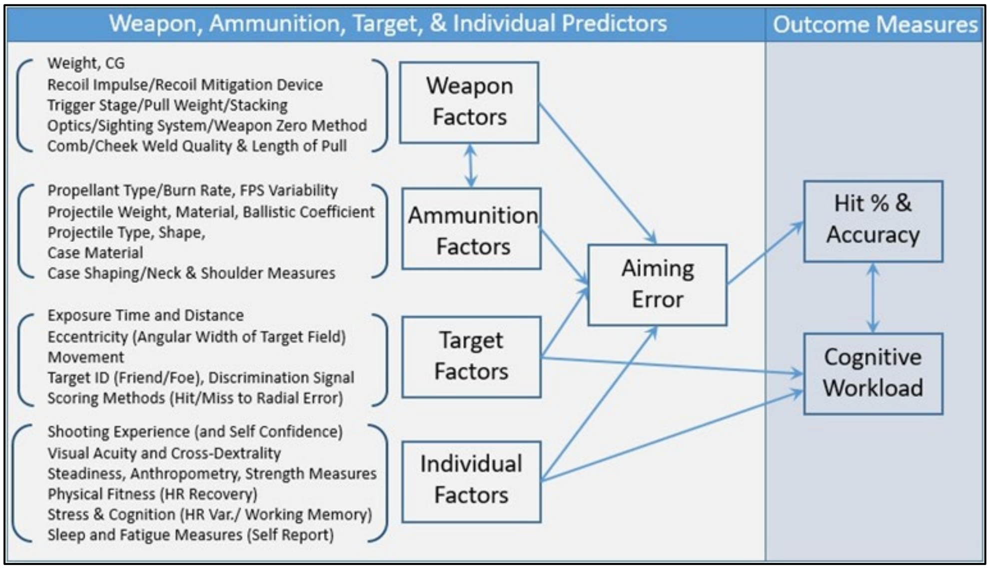

Figure 1. Potential factors that influence marksmanship performance (Scribner & Morelli, 2020)

1.3.1 Individual Factors

Various demographic, physical, physiological, cognitive, and psychological measures have been positively associated with marksmanship performance, but most have examined these IFs in isolation from other factors (Brown et al., 2013; Burke, 2007; Daniels, 1981; du Toit et al., 2012; Hatfield et al., 1984, 1987; Hoffman & Street, 1992; Ito et al., 2000; Lauterbach & Vielhaber, 1966; Rundell & Bacharach, 1995; Scribner & Harper, 2001; Scribner, 2002; Scribner et al., 2005; Scribner et al., 2007a). However, no study has attempted to merge several of these individual and target factors in a systematic way to capture the potential marksmanship and data cleaning effects that these factors have to offer. Individual differences identified in numerous theories have become increasingly more important in human factors and ergonomics research (Weaver et al., 2003) and that very little has been investigated in shooting performance (Stafford et al., 2004).

1.3.1.1 Demographics

Individual Factors are often collected via demographic survey, which is a highly important tool to understand the sample and specific sample variables such as age, sex, Military Occupational Specialty (MOS), time in MOS, time in service, injuries that may affect the shooting task, and especially various questions regarding shooting and combat experience (Burcham et al., 2018).

1.3.1.2 Physical Factors

Anthropometric Measures. Data yielded by Shorter et al. (2013) identified several anthropometric measures, including hand circumference and target distance, as important factors in accounting for individual variance in shooting performance. Hierarchical regression analyses on a subset of this data showed that adding the anthropometric measure of hand circumference to the accuracy prediction algorithm increased the explained variance from 38.3% to 57.4% (Shorter et al., 2013); this is a sizable increase. It is suggested that these measures will be both effective as covariates in explaining marksmanship performance outcomes as well as useful predictor variables for marksmanship.

Fitness Level. Physical fitness is associated with general increases in many physical performance tasks (Le Meur et al., 2010) as well as marksmanship (Brown et al., 2013).

Stability of Hold. The applied control of the autonomic nervous system (ANS), heart rate, and musculature can affect the stability of the shouldered rifle, thus affecting accuracy. As early as 1921, shooting accuracy associations with manual dexterity (Spaeth & Dunham, 1921) and tremor tests (Pellegrini et al., 2004) have been performed with laser pointers and air pistols to measure tremor in shooters. Several researchers have examined the postural stability of various shooting skill levels. In general, elite and well-practiced shooters tend to get their balance and stability under control significantly faster than do non-elite shooters (Hatfield et al., 1987; Hoffman & Street, 1992; Konttinen et al., 1998; Lakie, 2010).

It is suggested that a stability of hold measure be used to assess the time to hold a consistent bullseye pattern for a pre-determined number of seconds. This pre-measure may show a highly predictive nature for assessing both covariates in shooting performance and as a valuable predictor of marksmanship performance. It is proposed that a biomechanical measure of this type will be sought to determine the speed of a 4-s bullseye hold to determine each participant's postural stability disposition.

Dextrality. It is generally thought that pure dextral shooters, or those that have same-side hand and eye dominance, are better marksman than cross-dextral shooters (Sheeran, 1985). Daniels (1981) suggests that the dominant eye is a more important factor when considering training a contralateral dominant person. It is suggested that eye dominance in shooters is more important than the handedness and that several questions should be asked of shooters to include dominant hand, shooting hand, dominant eye, and aiming eye.

Visual Acuity. A strong relationship between visual acuity and marksmanship performance has been reported, suggesting a significant decrease in marksmanship performance when Snellen acuity ratings changed from 20/25 to 20/50 (Wells et al., 2009). It is important to document acuity for the right eye, left eye, and both eyes for far distance as acuity scores may affect marksmanship performance.

1.3.1.3 Physiological Measures

Heart Rate Variability (HRV). HRV is a specific measure of ANS activity on the circulatory system, typically R-wave to R-wave variability. HRV has proven to be a very good measure of stress (Esco et al., 2010; Grant et al., 2009; Lee & Mendoza, 2012; Ottaviani et al., 2007; Murray et al., 2007) and an effective pre-measure or predictor of stress under cognitive task demands (Morgan et al., 2007). Patton et al. (2013) demonstrated that R-R wave variability was significantly reduced under electrical shock feedback conditions in a simulated shooting task.

Research shows that lower-amplitude ANS responses were associated with better emotional regulation and concentration during shooting competitions (Hoffman & Street, 1992). Thus, anxiety, coping, and emotional regulation may all be related in terms of marksmanship performance. Further, it is reported that lower baseline HRV scores (RR), which are indicative of central-peripheral neural feedback mechanisms, were significant predictors of performance under stressful conditions (Caterini et al., 1995; Morgan et al., 2007).

Heart Rate Recovery (HRR). Ito et al. (2000) performed a study examining the effects of intense exercise involving load carriage and treadmill running upon subsequent shooting performance. While results logically demonstrated that shooting hit percentage dropped significantly under these conditions, they suggested that follow-up marksmanship studies employ a pre-measure of exercise recovery to assess exercise-induced psychomotor performance skills such as rifle shooting.

1.3.1.4 Cognitive Factors

Authors of several studies have examined shooting decision error, many of whom have yielded mutually supporting findings that show higher error and fratricide rates under dual-task workload (increased cognitive load) conditions (Burke, 2007; Scribner, 2002; Scribner et al., 2005; Scribner, Wiley, et al., 2007a). Stafford et al. (2004) posited that measures of stress, cognitive and emotional state, and personality tests were important factors in determining shooting ability. However, these researchers have not examined potential predictors of decision-making performance outside of experimentally manipulated information display types or target characteristics. Prediction of marksmanship and associated cognitive performance is a highly valuable tool for assessing various high-stress and high-workload occupations (Szalma, 2008), including Warfighters. High task and stress demands can show significantly reduced cognitive performance for Warfighters under arithmetic problem solving as a secondary task (Scribner, 2002). Several research efforts have examined intelligence, experience, stress and cognitive states, target saliency, and error punishment for friend–foe target discrimination shooting tasks (Burke, 2007; Kerick et al., 2007; MacCaslin & McGuigan, 1956; Patton et al., 2013; Scribner & Harper, 2001; Scribner, 2002; Scribner et al., 2005; Stafford et al., 2004). Both Scribner and Kerick found similarity between studies that shows higher error and fratricide rates among higher secondary task workload conditions. The primary body of research involving shooting tasks and secondary tasks has placed shooting as the primary task.

The effect of shooting under cognitive load has been studied by the U.S. Army Combat Capabilities Development Command (DEVCOM) Army Research Laboratory (ARL) in recent years (Kelley & Scribner, 2003; Kerick et al., 2007; Scribner, 2002; Scribner & Harper, 2001). Cognitive or mental workload is a factor in shooting and secondary processing tasks have been shown to degrade friend or foe decision-making (Scribner & Harper, 2001). Even the addition of a discrimination task over simple marksmanship increases cognitive workload (Scribner, 2002) Therefore, measures accessing the central executive function attentional resource such as working memory capacity (WMC) may have some effect under marksmanship shooting scenarios. WMC is a significant IF in cognitive performance, such as simulated driving (Scribner, 2013). It is highly feasible that WMC may be a generalizable IF that factors into such general cognitive tasks as marksmanship. Individual cognitive attributes may have a strong relationship with emotional attributes, as suggested by Rowden et al. (2011).

Sleep and Fatigue Factors. It is well known that alertness and cognitive readiness depend upon a well-rested and non-fatigued individual. Sleep is essential to normal cognitive functioning, especially under stressful conditions, and diminishing cognitive abilities are caused by lack of proper sleep and rest. Sleep deprivation can be detrimental to cognitive performance and particularly so for marksmanship performance. For example, Tharion et al. (2003) notes that during Navy Seal training "Hell Week" that marksmanship scores can drop by 136% and that reaction time to targets can increase by as much as 3 s. Scribner et al. (2007b) performed a continuous operations marksmanship study in which peak hit percentage of 40.3% at 18 h awake declined to a low at the conclusion of the study of 26.7% at 30 h awake.

1.3.1.5 Psychological Factors

Stress has often been imposed upon marksmanship scenarios to measure the effects of increased stress; however, resilience measures such as coping style, anxiety or stress traits and states, and self-efficacy and confidence are often overlooked.

Self-Efficacy. Self-efficacy self-reporting has also been shown to be related to performance in stressful situations (Bandura, 1977). For example, Lauterbach and Vielhaber (1966) concluded that the single best predictor of shooting performance was a participant's self-confidence. In this study, 480 military academy cadets performed marksmanship tasks under various stress conditions.

New General Self-Efficacy (NGSE) scale. Specific self-efficacy scales have been developed, yet many have come under scrutiny because of their specific task-focused nature (Lee & Bobko, 1994). Several self-efficacy scales have been developed recently and one has shown to have acceptable test–retest reliability and internal validity—the NGSE scale (Chen et al., 2001). Bandura (1977) showed that self-efficacy, or the belief in one's ability to focus and concentrate resources on a task to meet task demands, is an important IF in job performance. The NGSE has emerged with a reasonably good motivational trait measurement and is reported to have a test–retest reliability of $r = 0.67$ and an internal consistency of 0.86 (Cronbach's alpha) (Chen et al., 2001).

1.3.2 Target Factors

Along with IFs, this research concentrates on target characteristics known to help reveal human performance differences through "target stress" (Ahituv et al., 1998; Scribner et al., 2005; Scribner & Harper, 2001; Scribner et al., 2007a; Stern & Yudowitch, 1955). Target stress is an umbrella term that can include various variables including target exposure time, distance, eccentricity in presentation angles, and various target signatures (for shoot–don't shoot scenarios). If these target factors are not accounted for in shooting performance models, floor or ceiling performance effects could be prominent in showing little-to-no difference within an experiment.

1.3.2.1 Target Eccentricity

Target eccentricities of right, left, and center can be used to broaden the horizontal width range of targets and target scanning behavior. Shooting tasks can vary from targets centered upon the shooter center line to broad angle target arrays that meet the edges of range safety limits.

1.3.2.2 Target Distance

Target distances for rifle marksmanship tasks have traditionally varied between 25 and 300 m. However, target engagement distances can easily extend to 500 yards or beyond the range of the standard rifle into designated marksman or sniper rifle range, exceeding 1000 m. Of course, it is well known that target distance will affect accuracy much like Fitts's law applies to manual dexterity tasks (Fitts, 1954).

1.3.2.3 Target Exposure Time

Target exposure time can be directly associated with marksmanship accuracy and aiming error. In fact, Stern and Yudowitch (1955) were some of the first researchers to examine hit probability as it relates to target exposure time. The general trend of aiming error demonstrated a pattern of increased aiming accuracy as target time increases. Scribner (2002) also found that target exposure time for live-fire targets significantly affected hit percentage for 4-, 3-, and 2-s target exposures that dropped from 79.9%, 67.0%, to 31.9%, respectively.

1.3.2.4 Target Scoring Methodologies

There are numerous ways to score targets for shooting research and various target scoring zone systems as used by local, state, and federal law enforcement as well as competitive shooting organizations.

Hit/Miss Scoring. Hit and miss data are usually used for such studies examining shoot–don't shoot decision-making under secondary task loads while shooting to determine general target hit capability and the decision to fire the weapon. This lower-resolution methodology has been used in the past to assess friend–foe target identification (Scribner & Harper, 2001; Scribner, 2002) and in assessments of display modalities for secondary tasks while shooting (Scribner et al., 2005; Scribner et al., 2007b).

Radial Error Scoring. This method of scoring is calculated as to the distance from the center of mass or designated aim point of the target to the X-Y position of the shot. It is expected that this level of resolution will provide the greatest number of simple and interaction effects as well as covariate/predictor effects because of the resolution and associated variability of the data.

Zone Hit Scoring. The zone hit score on an e-silhouette is determined by the location of shot based upon A, C, and D zones on the target that have scores of either 5, 3, 1 or 5, 4, 2 based upon their power factor (United States Practical Shooting Association [USPSA], 2023). This method is used frequently in competitive shooting scenarios to focus the shooter on the quality of target hit while maintaining shooting speed.

Friend or Enemy Decision-Making Score. This type of score is determined not by the actual projectile path and contact area, but by the type of target presented (friend or enemy) and the decision to either appropriately or inappropriately fire a round at that target, or disinhibition and inhibition, respectively. This results in a decision score of either “correct” or “incorrect/error” and can be broken down further into error of inhibition (failing to fire appropriately at an enemy target) or an error of disinhibition (firing inappropriately at a friendly target).

1.4 Research Questions and Hypotheses

Research Question 1: Does individual shooting performance, as measured by hit percentage, significantly vary under different dual task demand levels when controlling for various individual physical, physiological, or cognitive covariates in a live-fire target discrimination context?

Hypothesis 1 (Null): There is no significant individual shooting performance differences as measured by hit percentage when controlling for covariates of various individual physical, physiological, or cognitive covariates in a live-fire target discrimination context.

Hypothesis 1 (Alternative): There are significant individual shooting performance differences as measured by hit percentage when controlling for covariates of various individual physical, physiological, or cognitive covariates in a live-fire target discrimination context.

Research Question 2: Does individual shooting performance, as measured by zone hits, significantly vary under different dual task demand levels when controlling for various individual physical, physiological, or cognitive covariates in a live-fire target discrimination context?

Hypothesis 2 (Null): There is no significant individual shooting performance differences as measured by zone hits when controlling for covariates of various individual physical, physiological, or cognitive covariates in a live-fire target discrimination context.

Hypothesis 2 (Alternative): There are significant individual shooting performance differences as measured by zone hits when controlling for covariates of various individual physical, physiological, or cognitive covariates in a live-fire target discrimination context.

Research Question 3: Does individual decision-making performance, as measured by correct decision and error rate, significantly vary under different dual task demand levels when controlling for various individual physical, physiological, or cognitive covariates in a live-fire target discrimination context?

Hypothesis 3 (Null): There is no significant individual shooting performance differences as measured by correct decision and error rate when controlling for covariates of various individual physical, physiological, or cognitive covariates in a live-fire target discrimination context.

Hypothesis 3 (Alternative): There are significant individual shooting performance differences as measured by correct decision and error rate when controlling for covariates of various individual physical, physiological, or cognitive covariates in a live-fire target discrimination context.

2. METHODS

This research effort is focused on developing a metric-based broad understanding of IFs within a structural marksmanship model framework guide to 1) enhance future marksmanship research methodologies, 2) create a forward-looking concept for data structure for multiple variable predictive statistical modeling (regression analyses), and 3) support future marksmanship and Warfighter lethality system decisions with higher statistical explanatory clarity (reduction of variance).

2.1 Participants

2.1.1 Voluntary Participation

All individuals were free to withdraw from the experiment at any time without consequence and encouraged to ask questions throughout the study. Command approval was given to DAC researchers and approved by the ARL Institutional Review Board prior to enrolling subjects. Individuals signed a consent agreement prior to data collection.

2.1.2 Inclusion and Exclusion Criteria

Participation constituted the following criteria were met for each individual: 1) self-reported good health, 2) successfully qualified with a rifle within the past year, and 3) aged 18–52 years at time of consent. Exclusion criteria included: 1) self-reported medical profile for illness or injury, 2) existing pain or injury in the legs, back, neck, or shoulders, 3) profile or restrictions against aerobic, high-impact, or firing of small arms, 4) medical conditions or current medications that affect balance, 5) known allergies to latex or adhesives, and 6) prior convictions of a misdemeanor crime of domestic violence.

2.1.3 Sample

Soldiers (n = 6) from the U.S. Army Marksmanship Unit (USAMU) were recruited from Fort Benning, Georgia. The sample description included a mean age of 31.7 years (standard deviation [SD] = 4.88), mean height (in.) = 71.5 (SD = 2.99), mean weight (lb) = 210.5 (SD = 32.7; all ranks were E-4 (No SD), and a mean years of time within their MOS of 10.3 years (SD = 4.7).

2.2 Test Procedures

2.2.1 Questionnaires and Surveys

A demographic questionnaire was used to collect biographical, health, and physical activity information from each participant (Appendix A). Information data were used as covariates during statistical analysis.

Anthropometric measures were taken of a participant's stature (body height), mass, bilateral upper arm (acromion-radiale), forearm (radiale-stylion), hand, and trunk length (Hotzman et al., 2011). Measures were used for data normalization (e.g., performance stature or segment length).

The Chalder Fatigue Scale was used to assess daytime sleepiness and fatigue (Chalder et al., 1993) (Appendix B).

The Stanford Sleep Scale was used to assess the quality of sleep the night before testing (Hoddes et al., 1973) (Appendix C).

The NGSE Scale was used to gauge the level of each participants' self-efficacy (Chen et al., 2001) (Appendix D).

The Subjective Workload Assessment Technique (SWAT) (Reid et al., 1989) will be completed after each shooting scenario and used to gauge the cognitive workload levels of the task (Appendix E).

2.2.2 Baseline Data Collection

In addition to the demographic questionnaire and anthropometric measures previously described, other assessments were completed prior to shooting tasks to gather individual shooter characteristics and factors that were estimated to influence target engagement decision-making performance.

A computerized version of the automated operational span (AOSPAN) test is used to quantify WMC (Turner & Engle, 1989; Unsworth et al., 2005). AOSPAN requires that participants maintain a list of letters in memory while processing unrelated mathematical information to measure the construct of WMC.

A Snellen visual chart was used to collect visual acuity of the left and right eyes. Color blindness was self-reported by the participant.

Eye dominance was assessed via an extended arm test and handedness was self-reported as dominant hand, shooting hand, dominant eye, and aiming eye.

2.2.3 Pre-Shooting Data Collection

Pre-shooting assessments were completed immediately before shooting testing was completed for optimal data collection and to best reflect the state of the participant prior to shooting.

Fatigue, sleep, and self-efficacy were collected as previously presented in Section 2.2.1.

Participants wore a heart rate enabled GPS watch (Instinct Tactical, Garmin International Inc, Olathe, Kansas) while seated comfortably and quietly for 5 min prior to any rigorous physical activity. Baseline heart rate (beats per minute [BPM]) was recorded over the 5 min. The average heart rate and maximum heart rate during the 5 min were calculated.

Isolated upper-body joint strength testing was recorded using portable handheld dynamometers (Lafayette Instrument Company, Lafayette, Indiana). Participants were asked to sit while holding the dynamometer for all testing. Isolation of the muscle group(s) to be tested were optimized by instructing the participant how to place the dynamometer device in the proper position and angle to conduct each test. The volunteer is instructed to apply their maximum force against the device using only the identified muscle group. The test lasted approximately 3–5 s, and the volunteer was verbally encouraged to contract as hard as they could throughout the test. To avoid fatigue or risk of muscle cramping, a minimum of 60 s between muscle contractions was provided. Strength testing was recorded bilaterally for grip and pinch.

A measure of upper-body muscle endurance was recorded to quantify endurance of the arm used to support the barrel of the rifle. Participants held a rifle with a mass (~1 kg) positioned on top of a Picatinny rail. The mass is considered the worst-case scenario for future rifle accessory purchases but may also act as a surrogate measure for future design changes, such as a longer barrel (Coleman et al., 2021). A laser was attached to the weapon to provide a visual identifier of weapon hold position. Instructions were given for the participant to engage in an unsupported standing firing position while holding the weapon aim at a designated bullseye approximately 5 m in front of them. Once weapon aim fell outside of the bullseye area as indicated by the laser, the test ended. Total endurance time was recorded.

2.2.4 Shooting Data Collection

U.S. Army M4A1 carbines chambered to fire 5.56- x 45-mm NATO standard cartridges with EOTech sights were used for all shooting data collection tasks. Weapons were zeroed at 25 m at the start of testing. Each participant confirmed zero prior to their individual data collection. Adjustments were made as necessary based on the participant's feedback. Instructions were given for participants to cheek the weapon naturally (i.e., in accordance with their training and shooting style) and to attempt consistent weapon placement throughout testing. The SWAT was completed after each shooting data collection assessment.

2.2.4.1 Rifle Qualification Test

A standard known distance (KD) qualification test was completed similar to the Standard Army Rifle Qualification test (Headquarters, Department of the Army, 2019). This assessment consists of 3 shooting phases: 1) 20 rounds at 300 m prone supported in 2 min, 2) 10 rounds at 200 m prone unsupported in 1 min, and 3) 10 rounds at 100 m kneeling in 1 min. Participants were given 10 s between each phase to transition between shooting stances and magazine changes. Total hits were scored, which is the same metric used in the Standard Army Rifle Qualification test.

2.2.4.2 Modified "El Presidente"

Since this competition drill is an evaluation of pistol target engagement rather than that of rifles, the test was modified for this study. Participants began by facing three targets positioned 10 m away with the weapon held at low ready and remained in standing position following weapon reload. The three targets were positioned in front of the participant with 1 m between each target. The center target was positioned directly in front of the participant. The left and right targets were positioned 1 m in their respective positions from the center target. Instructions were given for participants to equate priority between accuracy and timing, which attempts to approach target acquisition rapidly and accurately with as little researcher bias as possible. This approach more closely represents operational constructs for close- to mid-range (i.e., defined here as ranges no greater than 500 m) engagements, where time to engage is not typically abundant.

At the researcher's verbal and audio cues from a shot timer, the participant raised the weapon and aimed at the left target. Two rounds were shot at each target from left to right at their own pace (Figure 2). After the two shots were taken on the right target, the participant ejected the magazine, went into a kneel, loaded a new magazine on the ground, and stayed in a kneel. The participant then shot two rounds again at each target, but from right to left (Figure 3).

Figure 1. Modified "El Presidente" during left-to-right target shooting

Figure 3. USPSA target zones for modified "El Presidente"

Total completion time was recorded using a shot timer. Marksmanship performance was quantified according to standard competition scoring procedures (i.e., time penalties of 0, 1, 3, and 5 s added to recorded time based on regions hit on each target). Figure 4 displays the error zones on the target that corresponded to different time penalties. Zone A (Figure 4, green) corresponded to a time penalty of 0 s. Zone C (Figure 4, yellow) corresponded to a time penalty of 1 s. Zone D (Figure 4, red) corresponded to a time penalty of 5 s. The zone penalties were summed for an overall "El Presidente" trial zone penalty score.

Each participant completed two trials of "El Presidente" with at least 30 s rest between each trial.

Figure 4. Visual representation of the friendly and enemy targets

2.2.4.3 Shooting Test Scenarios

Participants were given time to familiarize themselves with the experimental shooting scenarios and mitigate any training effects in the record data. A limited training set of targets were set with the combinations of target discrimination, target exposure, and workload that participants would experience in experimental shooting. A dry-fire trial was completed where two targets (one friendly, one enemy) were presented at each of the three target ranges (25, 50, and 100 m) for a total of six targets; participants acquired weapon aim at the targets without live fire. All targets were presented for 4 s.

Four shooting conditions were completed by each participant: 1) non-randomized baseline, 2) randomized baseline, 3) low workload, and 4) high workload. All participants completed non-randomized baseline trials first, then randomized baseline trials second. The order of low and high workload trials were counterbalanced and randomized prior to participants' data collection. Three trials were completed for each shooting condition and all trials were completed for a given shooting condition before continuing to the next shooting condition. Approximately 5 min of rest was provided between each trial for optimum fatigue mitigation.

Both baseline shooting conditions presented only enemy V1 targets (Figure 5) (i.e., participants were instructed to shoot at each target presented) to determine foundational target engagement performance without decision-making cognitive load. All combinations of target exposure time levels (2 and 4 s) and target distances (25, 50, and 100 m) were presented in both non-randomized and randomized conditions. With non-randomized conditions, the order of target presentation was fixed as follows: 1) 2 s–25 m, 2) 2 s–50 m, 3) 2 s–100 m, 4) 4 s-25 m, 5) 4 s-50 m, and 6) 4 s–100 m). These six time–distance combinations were randomized for each trial and subject for the baseline randomized condition. A total of 12 targets were presented for each trial. Participants completed each baseline shooting condition for a total of three trials. The visual angle calculated for each target signature (measuring 25 cm tall) marking was 0.573°, 0.287°, and 0.143° for the target distances of 25, 50, and 100 m, respectively.

Figure 5. Low workload enemy target presented at 25 m

Low and high workload conditions implemented a decision-making component of target engagement by identifying a friendly and enemy target (Figure 5). The six enemy target presentation combinations of time and distance, as explained with baseline shooting conditions, were used for low and high workload conditions in addition to six combinations of friendly target presentations. A total of 24 targets were presented for each trial of a low and high workload condition (12 friendly, 12 enemy). Target presentation combinations were randomized for each trial. The low workload condition presented the friendly target and the enemy V1 target (Figure 5). The high workload condition presented the friendly target and the enemy V2 target (Figure 5). Figures 6 and 7 provide examples of the workload target setup with an enemy and friendly target, respectively.

Shot X-Y position as well as hit/miss status of the shots were collected via Oakwood Controls Open-air acoustic H-Bar system (Oakwood Controls, York, Pennsylvania).

Figure 6. Friendly target presented at 25 m

2.3 Statistical Analyses

The experimental design was a 2 × 2 within-subjects design with two levels of target exposure time (low = 2 s and high = 4 s) and two levels of induced cognitive workload (WL) via target discrimination (low WL and high WL). Target distances of 25, 50, and 100 m and target exposure times of 2 and 4 s were nested within each trial of this design. All of the IFs will be assessed for use as covariates after regression analyses.

2.3.1 Independent Variables

- Workload (shoot–don't shoot discrimination) (low, high; coded as 1 or 2))
- Target exposure time (2 or 4 s), nested (coded as 2 or 4)
- Target distance (25, 50, and 100 m), nested (coded as 25, 50, 100)

2.3.2 Dependent Variables

- Hit percentage
- Radial error
- Zone hit score
- Decision-making outcome (friendly fire)
- Decision-making outcome (enemy hold fire)

2.3.3 Covariate and Predictor Variables

- Demographics/shooter characteristics (including but not limited to age, sex, MOSs, time in service, rank, combat deployment, and shooting experience)
- Visual acuity (Snellen)
- Dextrality/handedness
- Anthropometrics
- Bilateral strength (hand grip, pinch grip) (Newtons)
- Muscular endurance: time to fatigue for weapon hold on target (seconds)
- Resting heart rate (BPM)
- Operational Span (OSPAN) task score (working memory–a measure of serial memory recall after distractor tasks: OSPAN absolute score and OSPAN accuracy error)
- Chalder Fatigue Scale – (summed score of fatigue questions)
- Stanford Sleep Scale – (summed score of sleepiness queries)
- New Self Efficacy Scale – (summed score of self-efficacy/task confidence queries)
- Rifle KD qualification score
- “El Presidente” score

2.3.4 Statistical Tests

Both Analyses of Variance (ANOVAs) and Analyses of Covariance (ANCOVAs) were calculated to determine if any differences existed between experimental-only (ANOVA) and experimental plus IFs (ANCOVA) models with regard to overall explained variance using R-squared values. P-values were also calculated to determine which experimental (Model 1) variables were significant and which experimental variables and IF variables (concomitant variables) (Model 2; ANCOVA) were significant.

Data screening analysis prior to ANOVA and ANCOVA tests was performed to find possible missing data or outliers. The dependent variables were assessed with descriptive statistics and analyzed for missing data cases. Assumptions of normality were met.

ANOVAs and ANCOVAs were run to determine the effects of hit percentage, radial error, zone hit scoring, and decision-making errors while controlling for covariates (concomitant variables). Within-subjects factors (independent variables) were accounted for in the ANCOVAs to determine the effects of test paradigms on dependent variables.

Univariate ANOVAs (Model 1) and univariate ANCOVAs (Model 2) were conducted to examine the main effects of experimental factors (target distance, target exposure time, and target discrimination).

Analyses using the stepwise multiple regression method were performed to determine if there were significant predictors of shooting performance for dependent variables in the experimental variables only (Model 1) as compared to experimental variables and predictor (covariate) variables (Model 2). Outliers were identified and assessed for transformation or removal. Normality assumptions were met. Multiple regression analyses using the backwards model were used to test the predictive nature comparison of Models 1 and 2.

3. RESULTS

Results indicated that in every case, the IFs within ANCOVA models yielded stronger explained variance over the ANOVA models, which only included experimental variables. Sections 3.1.1–3.1.5 demonstrate this effect by examining the R-squared values for each model comparison. In some cases, such as for radial error, simple effects became significant within the ANCOVA (Model 2) model, showing the power of the covariate set to reveal increased sensitivity to independent variables.

Additionally, in the case of friendly fire error, the covariates eliminated the single simple effect of “target discrimination” provided in the ANOVA model (Model 1) and demonstrated that the covariate set alone (ANCOVA; Model 2) provided the more powerful effect with an explained variance increase of 8.8%.

Tolerance statistics were all suitable with all values used in the following regression analyses, showing that multicollinearity was not an issue. The Variance Inflation Factors were well below the cut-off value of 10, reflecting satisfactory linear relationships among the Individual Variables (IVs). The IF models (Model 2) significantly predicted with greater predictive power the explained variance in all cases.

The following tables show the statistical outcomes for both ANOVA-ANCOVA model comparisons and experimental-only versus experimental plus IF multiple regression comparisons. These model comparisons are for the outcome measures of hit percentage (Tables 1 and 2), radial error (Tables 3 and 4), zone hit score (Tables 5 and 6), friendly fire decisions (Tables 7 and 8), and enemy hold fire decisions (Tables 9 and 10).

3.1 Hit Percentage

Table 1. ANOVA (Model 1) and ANCOVA (Model 2) results for fixed effects of experimental and IFs on hit percentage

Predictor	Sum of squares	df	Mean square	F	p	partial η^2	R-squared	Adjusted R-squared
Model 1 – Experimental variables							0.075	0.087
Target distance	5.924	2	2.962	13.810	**<0.001***	0.031		
Target exposure time	6.000	1	6.000	27.977	**<0.001***	0.032		
Target discrimination	0.463	1	0.463	2.159	0.142	0.003		
Target distance * target exposure time	2.299	2	1.149	5.359	**0.005**	0.012		
Target distance * target discrimination	0.100	2	0.050	0.232	0.793	0.001		
Target exposure time * target discrimination	0.116	1	0.116	0.540	0.463	0.001		
Target distance * target exposure time * target discrimination	0.002	2	0.001	0.005	0.995	0.000		
Model 2 – Experimental and individual variables							0.092	0.075
Target distance	5.924	2	2.962	13.974	**<0.001***	0.032		
Target exposure time	6.000	1	6.000	28.306	**<0.001***	0.032		
Target discrimination	0.463	1	0.463	2.184	0.140	0.003		
Target distance * target exposure time	2.301	2	1.151	5.429	**0.005***	0.013		
Target distance * target discrimination	0.100	2	0.050	0.236	0.790	0.001		
Target exposure time * target discrimination	0.115	1	0.115	0.543	0.461	0.001		
Target distance * target exposure time * target discrimination	0.002	2	0.001	0.006	0.994	0.000		
M4/M16 experience years	2.411	1	2.411	11.375	**<0.001***	0.013		
Chalder Fatigue Scale	0.988	1	0.988	4.662	**0.031***	0.005		
Right hand length	1.550	1	1.550	7.312	**0.007***	0.009		
Core exercise h/week	0.817	1	0.817	3.855	**0.050***	0.005		

Notes: df = degrees of freedom; F = F-Ratio; p = probability; **bold** indicates Significant Variables.
*Significant for p ≤0.05.

Table 2. Multiple regressions for experimental (Model 1) and experimental plus IFs (Model 2) on hit percentage

Regression predictors			**df**	**F**	**p**	**R-Squared**
Model 1 - Experimental variables			3, 863	19.119	**p<0.001**	0.250
	Standardized coefficients (Beta)	p				
Target discrimination	–0.048	0.143				
Target exposure time	0.174	**<0.001**				
Target distance	–0.173	**<0.001**				
Model 2 - Experimental + IFs			9, 863	8.120	**p<0.001**	0.281
	Standardized coefficients (Beta)	p				
Target discrimination	–0.048	0.141				
Target exposure time	0.174	**<0.001**				
Target distance	–0.173	**<0.001**				
Weapon experience, M4/M16	–0.040	0.617				
Chalder Fatigue Scale	–0.101	**0.019**				
Weapon hold steadiness(s)	–0.042	0.613				
Weights days min	–0.160	0.184				
OSPAN ABS score	0.052	0.483				
Right hand strength	0.061	0.085				

Notes: df = degrees of freedom; F = F-Ratio; p = probability; ABS = absolute; **bold** indicates Significant Variables.

3.2 Radial Error

Table 3. ANOVA (Model 1) and ANCOVA (Model 2) results for fixed effects of experimental and IFs on radial error

Predictor	Sum of squares	df	Mean square	F	p	partial η^2	R-squared	Adjusted R-squared
Model 1 – Experimental variables							0.123	0.090
Target distance	2058.507	2	1029.254	13.941	**0.000**	0.087		
Target exposure time	48.088	1	48.088	0.651	0.420	0.002		
Target discrimination	240.867	1	240.867	3.262	0.072	0.011		
Target distance * target exposure time	221.632	2	110.816	1.501	0.225	0.010		
Target distance * target discrimination	172.222	2	86.111	1.166	0.313	0.008		
Target exposure time * target discrimination	34.398	1	34.398	0.466	0.495	0.002		
Target distance * target exposure time * target discrimination	56.864	2	28.432	0.385	0.681	0.003		
Model 2 – Experimental and individual variables							0.223	0.160
Target distance	1377.222	2	688.611	9.757	**0.000**	0.108		
Target exposure time	54.522	1	54.522	0.773	0.381	0.005		
Target discrimination	45.122	1	45.122	0.639	0.425	0.004		
Target distance * target exposure time	149.106	2	74.553	1.056	0.350	0.013		
Target distance * target discrimination	351.467	2	175.733	2.490	0.086	0.030		
Target exposure time * target discrimination	6.860	1	6.860	0.097	0.756	0.001		
Target distance * target exposure time * target discrimination	269.955	2	134.978	1.913	0.151	0.023		
Experience Other Weapons	52.494	1	52.494	0.744	0.390	0.005		
Stanford sleepiness	0.037	1	0.037	0.001	0.982	0.000		

Notes: df = degrees of freedom; F = F-Ratio; p = probability; ABS = absolute; **bold** indicates Significant Variables.
*Significant for $p \leq 0.05$.

Table 4. Multiple regressions for experimental (Model 1) and experimental plus IFs (Model 2) on radial error

Regression predictors			df	F	p	R-squared
Model 1 - Experimental variables			3, 305	4.976	p = 0.002	0.047
	Standardized coefficients (Beta)	p				
Target discrimination	–0.124	**0.028**				
Target exposure time	0.001	0.989				
Target distance	–0.178	**0.002**				
Model 2 - Experimental + IFs			5, 305	5.805	p <0.001	0.088
	Standardized coefficients (Beta)	p				
Target discrimination	–0.126	**.023**				
Target exposure time	–0.008	.886				
Target Distance	–0.183	**.001**				
Stanford Sleepiness Score	–0.241	**.010**				
Chalder Fatigue Score	–0.090	.152				
OSPAN Absolute Score	–0.121	.213				

Notes: df = degrees of freedom; F = F-Ratio; p = probability; **bold** indicates Significant Variables.

3.3 Zone Hit Scoring

Table 5. ANOVA (Model 1) and ANCOVA (Model 2) results for fixed effects of experimental and IFs on zone hit score.

Predictor	Sum of squares	df	Mean square	F	p	partial η^2	R-squared	Adjusted R-squared
Model 1 – Experimental variables							0.052	0.040
Target distance	58.891	2	29.446	10.144	**0.000**	0.023		
Target exposure time	48.167	1	48.167	16.593	**0.000**	0.019		
Target discrimination	0.667	1	0.667	0.230	0.632	0.000		
Target distance * target exposure time	22.132	2	11.066	3.812	**0.022**	0.009		
Target distance * target discrimination	1.896	2	0.948	0.327	0.721	0.001		
Target exposure time * target discrimination	2.241	1	2.241	0.772	0.380	0.001		
Target distance * target exposure time * target discrimination	1.266	2	0.633	0.218	0.804	0.001		
Model 2 – Experimental and individual variables							0.073	0.058
Target distance	59.125	2	29.563	10.379	**0.000**	0.024		
Target exposure time	48.167	1	48.167	16.910	**0.000**	0.020		
Target discrimination	0.667	1	0.667	0.234	0.629	0.000		
Target distance * target exposure time	22.489	2	11.244	3.948	**0.020**	0.009		
Target distance * target discrimination	1.819	2	0.909	0.319	0.727	0.001		
Target exposure time * target discrimination	2.112	1	2.112	0.742	0.389	0.001		
Target distance * target exposure time * target discrimination	1.326	2	0.663	0.233	0.792	0.001		
Average HR, resting	47.683	1	47.683	16.740	**0.000**	0.019		
Chalder Fatigue Score	23.530	1	23.530	8.261	**0.004**	0.010		
Height (In.)	8.108	1	8.108	2.846	0.092	0.003		

Notes: df = degrees of freedom; F = F-Ratio; p = probability; **bold** indicates Significant Variables.
*Significant for $p \leq 0.05$

Table 6. Multiple regressions for experimental (Model 1) and experimental plus IFs (Model 2) on zone hit score

Regression predictors	Standardized coefficients (Beta)	p	df	F	p	R-Squared
Model 1 - Experimental variables			3, 863	11.620	<0.001	0.039
	Standardized coefficients (Beta)	p				
Target distance	–0.142	0.000				
Target discrimination	–0.016	0.633				
Target exposure time	0.136	0.000				
Model 2 - Experimental + IFs			6, 863	9.102	<0.001	0.060
	Standardized coefficients (Beta)	p				
Target distance	–0.142	**0.000**				
Target discrimination	–0.016	0.630				
Target exposure time	–0.142	**0.000**				
Right hand length	–0.043	0.237				
New general self-efficacy scale	–0.044	0.203				
AVG resting HR	0.161	**0.000**				
Chalder Fatigue Scale	0.109	**0.005**				

Notes: df = degrees of freedom; F = F-Ratio; p = probability; **bold** indicates Significant Variables.

3.4 Friendly Fire (Error of Disinhibition)

Table 7. ANOVA (Model 1) and ANCOVA (Model 2) results for fixed effects of experimental and IFs on friendly fire error decisions

Predictor	Sum of squares	df	Mean square	F	p	partial η^2	R-squared	Adjusted R-squared
Model 1 – Experimental variables							0.023	0.006
Target distance	0.025	2	0.012	0.631	0.532	0.002		
Target exposure time	0.000	1	0.000	0.000	1.000	0.000		
Target discrimination	0.151	1	0.151	7.729	**0.006**	0.012		
Target distance * target exposure time	0.019	2	0.009	0.473	0.623	0.001		
Target distance * target discrimination	0.025	2	0.012	0.631	0.532	0.002		
Target exposure time * target discrimination	0.012	1	0.012	0.631	0.427	0.001		
Target distance * target exposure time * target discrimination	0.080	2	0.040	2.051	0.130	0.006		
Model 2 – Experimental and individual variables							0.051	0.028
Target distance	0.026	2.000	0.013	0.674	0.510	0.002		
Target exposure time	0.000	1.000	0.000	0.000	0.991	0.000		
Target discrimination	0.153	1.000	0.153	7.973	**0.005**	0.012		
Target distance * target exposure time	0.017	2.000	0.008	0.442	0.643	0.001		
Target distance * target discrimination	0.025	2.000	0.013	0.656	0.519	0.002		
Target exposure time * target discrimination	0.011	1.000	0.011	0.589	0.443	0.001		
Target distance * target exposure time * target discrimination	0.079	2.000	0.039	2.055	0.129	0.006		
Chalder Fatigue Scale	0.236	1	0.236	12.353	**0.000**	0.019		
Snellen - right eye	0.302	1	0.302	15.799	**0.000**	0.024		
El Presidente score	0.163	1	0.163	8.521	**0.004**	0.013		
OSPAN accuracy error	0.102	1	0.102	5.337	**0.021**	0.008		

Notes: df = degrees of freedom; F = F-Ratio; p = probability; **bold** indicates Significant Variables.
*Significant for p ≤0.05.

Table 8. Multiple regressions for experimental (Model 1) and experimental plus IFs (Model 2) on friendly fire error

Regression predictors	Standardized coefficients (Beta)	p	df	F	p	R-squared
Model 1 - Experimental variables			3, 647	2.928	0.033	0.013
	Standardized coefficients (Beta)	p				
Target discrimination	0.109	**0.006**				
Target exposure time	0.011	0.779				
Target distance	–0.038	0.329				
Model 2 – Experimental + Ifs			4, 215	6.017	<0.001	0.102
	Standardized coefficients (Beta)	p				
Target Discrimination	0.259	**<0.001**				
Target exposure time	0.026	0.689				
Target distance	0.035	0.593				
El Presidente Score	0.183	**0.005**				

Notes: df = degrees of freedom; F = F-Ratio; p = probability; **bold** indicates Significant Variables.

3.5 Enemy Hold Fire (Error of Inhibition)

Table 9. ANOVA (Model 1) and ANCOVA (Model 2) results for fixed effects of experimental and Ifs on enemy hold fire error decisions (both non-significant)

Predictor	Sum of squares	df	Mean square	F	p	partial η^2	R-squared	Adjusted R-squared
Model 1 – Experimental variables							0.015	0.002
Target distance	0.006	2	0.003	0.501	0.606	0.002		
Target exposure time	0.003	1	0.003	0.501	0.479	0.001		
Target discrimination	0.012	1	0.012	2.005	0.157	0.003		
Target distance * target exposure time	0.006	2	0.003	0.501	0.606	0.002		
Target distance * target discrimination	0.006	2	0.003	0.501	0.606	0.002		
Target exposure time * target discrimination	0.003	1	0.003	0.501	0.479	0.001		
Target distance * target exposure time * target discrimination	0.006	2	0.003	0.501	0.606	0.002		
Model 2 – Experimental and individual variables							0.019	0.007
Target distance	0.008	2	0.004	0.505	0.604	0.002		
Target exposure time	0.004	1	0.004	0.490	0.484	0.001		
Target discrimination	0.015	1	0.015	1.991	0.159	0.004		
Target distance * target exposure time	0.008	2	0.004	0.505	0.604	0.002		
Target distance * target discrimination	0.007	2	0.004	0.499	0.607	0.002		
Target exposure time * target discrimination	0.004	1	0.004	0.478	0.490	0.001		
Target distance * target exposure time * target discrimination	0.007	2	0.004	0.493	0.611	0.002		
Snellen – right eye	0.001	1	0.001	0.190	0.663	0.000		
Weight (lb)	0.004	1	0.004	0.578	0.447	0.001		
Competition types	0.003	1	0.003	0.432	0.511	0.001		

Notes: df = degrees of freedom; F = F-Ratio; p = probability.
*Significant for p ≤0.05

Table 10. Multiple regressions for experimental (Model 1) and experimental plus Ifs (Model 2) on enemy hold fire error (both non-significant)

Regression predictors			df	F	p	R-squared
Model 1 - Experimental variables			3, 647	1.029	0.379	0.005
	Standardized coefficients (Beta)	p				
Target discrimination	0.011	0.157				
Target exposure time	0.039	0.317				
Target distance	–0.056	0.789				
Model 2 - Experimental + IFs			4, 323	1.288	0.275	0.016
	Standardized coefficients (Beta)	p				
Target discrimination	–0.039	0.479				
Target exposure time	–0.056	0.317				
Target distance	0.074	0.182				
Weapons experience, other	–0.076	0.174				

4. CONCLUSIONS AND IMPLICATIONS

4.1 General Findings

The general pattern of IF predictors that emerged from this analysis supported projected hypotheses suggested by Scribner and Morelli (2020) and supported all three alternative hypotheses described earlier in this report. All ANCOVAs and multiple regressions, with the exception of enemy hold fire decisions were superior in terms of increased R-squared values, or explained variance, when using the IF Models.

Within the IF models (Model 2 in each case), a pattern emerged that shows a significant contribution of physical, cognitive, experience factors, visual, and qualification shooting scores. These contributing factors were different for each outcome variable, but the pattern for hit percentage, radial error, and zone hit scores demonstrated a powerful effect for physical factors, experience, and shooting qualification scores. The decision-making errors examined in this study had these same general outcomes with an additional effect of including cognitive and psychological factors.

In particular, the IF model (Model 2) for each dependent variable demonstrated the superior contribution strength of these IFs for estimating target engagement marksmanship performance. These findings apply only to elite expert shooters, but the same general pattern is expected to be present with intermediate- and novice-level skilled shooters with a varying amount of contribution and less heterogeneity.

We chose to use multiple marksmanship scores so that we could examine the efficacy of IFs on effects with several shooting measures of various granularity. We also examined relevant decision-making error measures including friendly fire and enemy hold fire.

4.1.1 Multiple Regression and Modeling

The findings from multiple regression analyses were considered sufficient to reject all null hypotheses. Consistent with previous findings (Scribner, 2013), IF model constructs as operationalized in this study proved to be predictive of marksmanship and shoot–don't shoot decision-making outcomes by Warfighters.

4.1.2 The IF Model

The IF model (Scribner, 2013; Scribner & Morelli, 2020) demonstrates that marksmanship experiments based solely on target distance, target exposure time, target discrimination, weapon characteristics, and so on, may not be the best method in explaining target engagement decision-making performance under cognitive workload.

Beyond issues of predictive validity, the IF model has implications for both theoretical and practical ergonomics. The IF model, supported by multiple regression and correlation relationship analyses, implies that typical experimental variables and IFs are interrelated.

4.1.3 Limitations

Shortcomings of this study may have included the small sample size, yet ample power was achieved for the variable relationships for most analyses. Sample homogeneity could be diversified to include a wider military population and perhaps the law enforcement population.

4.1.4 Practical Application

For practical ergonomics, the data suggest various implications, including examining individual differences in IFs as a key aspect of equipment and research design, especially for marksmanship and shooting studies. The findings support utilization of individual differences in marksmanship research of all types where a Soldier or human is in the control loop.

4.2 Methodology Suggestions for the Department of Defense Shooting Community

It is proposed, with further research, that the structural model framework (Figure 1) be examined as a potential overarching guide for understanding the interrelationships within marksmanship and shooting data. The individual and target factors employed herein can be applied to almost any shooting study with minor time consideration and administrative planning. It is recommended that the target characteristics be assessed for statistical floor and ceiling effects so as not to waste any resources and ensure that they not diminish the purposes of the original studies themselves.

In conclusion, the findings within this analysis show that the combination of physical, cognitive, physiological, and demographic IFs provides greater experimental confidence and predictive power in marksmanship and shoot–don’t shoot performance studies than considering only experimental variables as traditionally practiced. The authors wish to convey to the shooting research community within the Joint community, and with our coalition partners, that IF data can be collected easily and in a time-efficient manner to provide an improved and higher-quality data set over traditional experimental variables alone. Section 4.3 outlines the primary benefits of this approach to marksmanship and shooting research.

4.3 Warfighter Benefit via Acquisition

Through this methodology application, future studies may reveal data that better inform small-arms decision makers and small-arms design decisions through 1) developing considerably stronger and cleaner data sets using pre-study Human System Integration measures as covariates, which essentially help clean up and filter unaccounted-for noise within the data, and 2) providing enhanced statistical explanation of effects and effect sizes.

This methodology may provide a better understanding of the holistic effects of IFs within the shooting research discipline that may serve as a future methodological change with benefits to the shooting research community.

The overarching model framework provided within may be refined through future research while serving to create more informed hypotheses through better understanding of the impact of complex variable structural and mediator/moderator relationships on shooting performance outcome measures.

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Appendix A – Demographic and Experience Questionnaire

This appendix appears in its original form, without editorial change.

A response to the following questions is highly suggested. If you do not want to answer any of these questions, you can opt to not continue participation in the study.

Demographic Information

D-1. Sex: □ Male □ Female

D-2. Age: ____________

D-3. Height: ______ft.__________in.

D-4. Weight:________________lbs.

D-5. Do you wear glasses or contact lenses?
□ Yes, glasses □ Yes, contact lenses □ Neither

D-6. Which hand do you write with? □ Left □ Right

D-7. What is your dominant shooting hand? □ Left □ Right

D-8. Which leg do you prefer to kick a ball with? □ Left □ Right

D-9. Which is your dominant (shooting) eye? □ Left □ Right □ Don't know

D-10. Do you have any unusual difficulties seeing objects during daytime?
□ Yes □ No

If YES, what difficulties do you experience?

____

____

Military/Tactical Experience

ME-1. What is your current tactical occupation? □ Military Personnel □ Non-Military Personnel

If 'Military Personnel', continue to ME-2. Otherwise, continue to ME-5.

ME-2. What is your primary MOS? Rank? (e.g., 11B, E6) ______________

Description (e.g., Infantry) ____________________________

Time in current MOS? _______________________________

ME-3. What is your secondary MOS? _____________

Description _____________________________

ME-4. What was your most recent Army Combat Fitness Test (ACFT) score?
3 Repetition Maximum Deadlift Points:_______
Standing Power Throw Points: ________
Hand-Release Push-Up Points:________
Sprint-Drag-Carry Points:_______
Plank Points:______
2-Mile Run Points (or alternative aerobic event):___________
Total Points:______

When did you complete your most recent ACFT: ____________________ (month/year)

For Non-Military Personnel, please answer the following questions:

ME-5. What is your current role as a non-military tactical operator?
□ Special Response Team (SRT) □ Special Weapons and Tactics (SWAT)
□ Police Officer/Law Enforcement □ Other: _______________

How long have you been in your current role? ______ yrs. _______ mo.

ME-5. Have you ever served in the military? □ Yes □ No

If YES, continue to ME-6. If NO, continue to the optional questions.

ME-6. What was your primary MOS? (e.g., 11B) ______________

Description (e.g., Infantry) ____________________________

Time in primary MOS? _______________________________

The following questions are optional to answer, but highly suggested. Your decision to respond or not to the following questions will not exclude you from participating in the study.

Weapons Experience

WE-1. List weapons you have carried during deployment/assignments/training and/or recreational/competition use.

____

____

____

WE-2. When was the last time you qualified with the M4 Carbine/M16 Rifle?

Month ______ Year _____

WE-3. What is your current level of qualification as rifleman?

□ Marksman □ Sharpshooter □ Expert □ Other__________

WE-4. What was your level of qualification as rifleman prior to qualification listed in WE-3?

□ Marksman □ Sharpshooter □ Expert □ Other__________
□ N/A

WE-5. Do you have a B4 skill identifier? □ Yes □ No

If YES, specify date and location:

Date: ________________ Location _________________________

WE-6. Weapon Experience:

M4/M16: _____________ years Mk12 SPR: _____________ years

M24E1: _____________ years M14 EBR: _____________ years

M110 SASS: _____________ years

Other (List Weapon): __________________ _____________ years

Other (List Weapon): __________________ _____________ years

Weapons Experience cont.

WE-7: At what target distances do you most frequently train?

____

WE-8. What types of targets do you typically fire at during training exercises that involve the use of small arms?

____

WE-9. Are you an active competitor in any of the shooting sports? □ Yes □ No

If YES, please list competition type(s) and frequency (e.g. # of matches per year):

____

____

Physical Activity

PA-1. During a normal week, indicate how much time you spend performing the following activities:
(military personnel should include PT time, but not military-specific training)

	Hours per day	Days per week
Cardiovascular exercise		
Weight lifting		
Core strengthening		
Playing sports		

Appendix B – Chalder Fatigue Scale

This appendix appears in its original form, without editorial change.

Physical symptoms	Better than usual	No more than usual	Worse than usual	Much worse than usual
1. Do you have problems with tiredness?				
2. Do you need to rest more?				
3. Do you feel sleepy or drowsy?				
4. Do you have problems starting things?				
5. Do you start things without difficulty but get weak as you go on?				
6. Are you lacking in energy?				
7. Do you have less strength in your muscles?				
8. Do you feel weak?				

Mental symptoms				
9. Do you have difficulty concentrating?				
10. Do you have problems thinking clearly?				
11. Do you make slips of the tongue when speaking?				
12. Do you find it more difficult to find the correct word?				
13. How is your memory?				
14. Have you lost interest in the things you used to do?				

Appendix C – Stanford Sleepiness Scale

This appendix appears in its original form, without editorial change.

Which of the following selections most accurately describe your sleepiness level NOW? (Circle One Choice)

1. “Feeling active and vital; alert; wide awake.”

2. “Functioning at a high level, but not at peak; able to concentrate.”

3. “Relaxed; awake; not at full alertness; responsive.”

4. “A little foggy; not at peak; let down.”

5. “Fogginess; beginning to lose interest in remaining awake; slowed down.”

6. “Sleepiness; prefer to be lying down; fighting sleep; woozy.”

7. “Almost in reverie; sleep onset soon; lost struggle to remain awake.”

Appendix D – New General Self-Efficacy Scale

This appendix appears in its original form, without editorial change.

Circle the best response where:

0= not at all
1=low
2=moderately agree
3=somewhat highly agree
4=very highly agree

1.	I will be able to achieve most of the goals that I have set for myself.	0 1 2 3 4
2.	When facing difficult tasks, I am certain that I will accomplish them.	0 1 2 3 4
3.	In general, I think that I can obtain outcomes that are important to me.	0 1 2 3 4
4.	I believe I can succeed at most any endeavor to which I set my mind.	0 1 2 3 4
5.	I will be able to successfully overcome many challenges.	0 1 2 3 4
6.	I am confident that I can perform effectively on many different tasks.	0 1 2 3 4
7.	Compared to other people, I can do most tasks very well.	0 1 2 3 4
8.	Even when things are tough, I can perform quite well.	0 1 2 3 4

Appendix E – Subjective Workload Assessment Technique

This appendix appears in its original form, without editorial change.

1. Circle the workload dimension in each pair that you think is more important than the other:

a. Mental Effort Load or Time Load

b. Time Load or Psychological Stress Load

c. Psychological Stress Load or Mental Effort Load

2. For the following scenarios, put an 'X' on the line and a written number corresponding to your perceived level of mental effort, time, and psychological stress load where 0 indicates nothing experienced of that dimension and 100 indicates the highest possible experienced:

<u>Qualification Test (Army Qual or KD)</u>

Mental Effort Load: 0--100

Time Load: 0--100

Psychological Stress Load: 0---100

<u>El Presidente</u>

Mental Effort Load: 0--100

Time Load: 0--100

Psychological Stress Load: 0---100

<u>Baseline Non-Randomized Shooting Scenario</u>

Mental Effort Load: 0--100

Time Load: 0--100

Psychological Stress Load: 0---100

Baseline Randomized Shooting Scenario

Mental Effort Load: 0---100

Time Load: 0---100

Psychological Stress Load: 0---100

Low Workload Shooting Scenario (‘T’ and ‘+’)

Mental Effort Load: 0---100

Time Load: 0---100

Psychological Stress Load: 0---100

High Workload Shooting Scenario (‘T’ and ‘t’)

Mental Effort Load: 0---100

Time Load: 0---100

Psychological Stress Load: 0---100

LIST OF ACRONYMS

(U) ANS	autonomic nervous system
(U) ANCOVAs	Analyses of Covariance
(U) ANOVAs	Analyses of Variance
(U) AOSPAN	automated operational span
(U) ARL	Army Research Laboratory
(U) BPM	beats per minute
(U) DAC	DEVCOM Analysis Center
(U) DEVCOM	U.S. Army Combat Capabilities Development Command
(U) df	degrees of freedom
(U) GPS	global positioning system
(U) HQDA	Headquarters, Department of the Army
(U) HRR	Heart Rate Recovery
(U) HRV	Heart Rate Variability
(U) IF	Individual Factor
(U) IV	Individual Variables
(U) KD	known distance
(U) MOS	Military Occupational Specialty
(U) NATO	North Atlantic Treaty Organization
(U) NGSE	New General Self-Efficacy
(U) OSPAN	operational span
(U) R-R	R-wave to R-wave
(U) ROE	rules of engagement
(U) SA	Situational Awareness
(U) SD	standard deviation
(U) SWAT	Subjective Workload Assessment Technique
(U) USAMU	U.S. Army Marksmanship Unit
(U) WL	workload
(U) WMC	working memory capacity

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