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An Analysis of Individual Factors Correlational Relationships for Estimating Soldier Marksmanship and Decision-Making Performance Model Data

by David Scribner, Maria Talarico, and Frank Morelli

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14. ABSTRACT This report is an analysis of a combined multistage research and analysis project of the U.S. Army Combat Capabilities Development Command Analysis Center Human Systems Integration Division. This analysis effort is an examination of correlational relationships between experimental and individual factors variables for Soldier marksmanship and decision-making performance for modeling efforts. Previously supported hypotheses (DEVCOM DAC-TR-2023-061) demonstrated that explained variance is increased to yield more robust data sets with measurably more information about the characteristics of the individual shooter based on cognitive, physiological, psychological, anthropometric, and other measures termed "Individual Factors." Data was collected both at Fort Moore, Georgia, with a group of 6 Army Marksmanship Unit elite level shooters in August 2022 and at Aberdeen Proving Ground, Maryland, with a group of 15 Army infantry shooters from Joint Base Lewis-McChord, Washington (1-2 Stryker Brigade Combat Team, 7th Infantry Division) in May 2023. It is posited that data collected and analyzed using the individual factors methodology creates a more accurate and robust outcome for such modeling tools as IMPRINT Pro and associated human-based modeling efforts.					
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1. INTRODUCTION

1.1 Purpose

This analysis effort was designed to provide support for a general structural model of Individual Factors (IFs) that was first conceived in a Scribner and Morelli report (2020). This report proposed a model that outlines and connects factors that may influence marksmanship performance including weapon, ammunition, target characteristics, and those IFs brought by the individual Warfighter to a shooting task. This study is the second step in a multistudy program to better understand the impact of IFs on marksmanship performance with multiple samples that crosscut the shooting populations within our services.

This study was also designed to examine IF model effects within correlation structures including both shooting performance and decision-making variables under a live-fire shoot–don’t shoot target scenario using various target distances and exposure times. The general hypotheses for the IF model are to examine the general model first proposed by Scribner and Morelli (2020) and to test the actual structure of the correlational relationships against this hypothesized model.

Aside from an IF model outcome, this effort also aims to provide fundamental marksmanship performance data to support future Soldier performance modeling efforts. A quantitative repeated-measures experimental approach was used to provide this modeling data with two convenience samples including 6 U.S. Army Marksmanship Unit (AMU) shooters from Fort Moore, Georgia, and 15 1-2 Stryker Brigade Combat Team (SBCT), 7th Infantry Division infantry Soldiers from Joint Base Lewis-McChord, Washington.

1.2 Warfighter Basic Tasks

The standard paradigm for Warfighters is to move, shoot, and communicate. The current paradigm, however, could be to move, shoot, attend to information, make decisions, and communicate. There are various environmental and operational stressors, including varying rules of engagement (ROE), continuous operations, and information-processing tasks driven by Army information systems that dictate researchers perform our shooting efforts with tasks that increase information-processing and subsequent mental workload/stress. As the Warfighter mental requirements have become more onerous, research paradigms must adapt to be more complex by including additional factors to better align with the Warfighter’s operational stressor and workload environment, especially for improved Warfighter systems acquisition trade analyses. This natural increase of mental workload is the primary reasoning for using a friend-foe target

discrimination task to increase the Warfighter's cognitive load further 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). IFs are becoming more important in human factors and ergonomics research (Weaver et al., 2003) and very few of them 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 individual performance. A suggested framework for hypothetical research was offered by Scribner and Morelli (2020) and is presented in the next section.

1.4 Hypothesized Model of Marksmanship Factors

The hypothetical framework (Figure 1) lists general IFs (left-bracketed text in Figure 1) that were included in this study to better understand the IFs in this research effort.

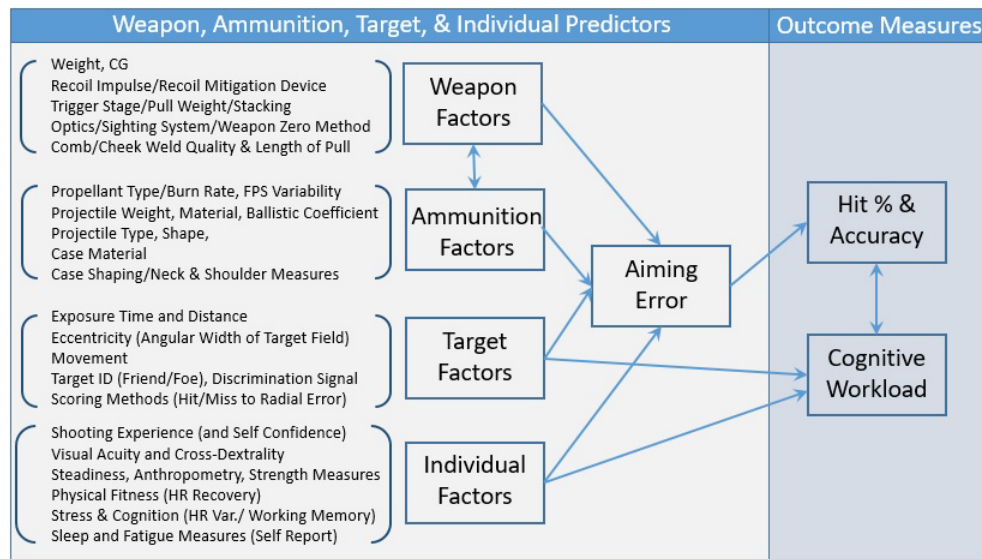


Figure 1. Hypothetical model of factors that influence marksmanship performance (Scribner & Morelli, 2020)

The secondary aspect of this research concentrates upon the target characteristics that are known to help reveal human performance differences through “target stress” (Ahituv et al., 1998; Scribner et al., 2001, 2004, 2007; Stern & Yudowitch, 1955). Target stress is an umbrella term that includes target exposure time, distance, eccentricity in presentation angles, and various target signatures (for friend-foe shoot scenarios). If these target factors are not accounted for, floor or ceiling performance effects could show little-to-no difference within an experiment.

Many marksmanship studies have only examined a single factor or one “family” of IFs (e.g., only physical characteristics of the shooter) (Brown et al., 2013; Burke, 2007; Daniels, 1981; Du Toit et al., 2011; Hatfield et al., 1984, 1987; Hoffman et al., 1992; Ito et al., 2000; Lauterbach & Vielhaber, 1966; Rundell & Bacharach, 1995; Scribner, 2002; Scribner et al., 2001, 2004, 2007). However, no study has attempted to merge several individual and target factors in a systematic way to capture the potential marksmanship and data cleaning effects of these covariates or predictors of marksmanship and shooting performance. A comprehensive and holistic approach to including an array of IFs in marksmanship studies may reveal statistical and practical differences that may otherwise be missed.

2. TARGET FACTORS

In order to isolate the influence of IFs on marksmanship performance, other factors like target characteristics were kept constant to control for error.

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.

2.2 Target Distance

Although target distances for rifle marksmanship tasks have traditionally varied between 25 and 300 m, advances in target equipment allows for engagements beyond 300 m. Additionally, ranges from 500 to 1000m are for designated marksman or sniper experimentation. Of course, it is well-known that target distance will affect accuracy much like Fitt's law applies to manual dexterity tasks (Fitts, 1954), which also applies to marksmanship tasks.

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. This study cleverly mapped the differences in aiming error by classifying proficient shooters versus newly trained recruits with no previous shooting experience. The general trend of aiming error demonstrated a pattern of increased aiming accuracy with longer target exposure time. Scribner (2002) also found that target exposure time for live-fire targets significantly affected hit percentage in 2-, 3-, and 4-s target exposures and associated hit percentages that dropped from 79.9%, 67.0%, to 31.9%, respectively. Based upon previous studies, it is expected that target exposure time will significantly affect accuracy by decreasing hit percentage and accuracy on multiple measurement regimes as target exposure time decreases.

2.4 Target Scoring Methods

There are numerous ways to score targets for shooting research including simple hit/miss scores and ratios, radial error scoring, and various target scoring zone systems as used by local, state, and federal law enforcement as well as competitive shooting

organizations. For the purpose of this study, only hit percentage, radial error, and decision-making to shoot or don't shoot will be addressed.

2.4.1 Hit/Miss Scoring

This scoring method will be used as the lowest resolution data to provide hit percentages. 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. Such systems have been used in the past to assess friend and foe target identification (Scribner, 2002; Scribner & Harper, 2001) and in assessments of display modalities for secondary tasks while shooting (Scribner et al., 2004).

2.4.2 Radial Error Scoring

This method of scoring is related to the distance from the center of mass of the target (i.e., aimpoint) and is provided in X-Y distance (millimeters). 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.

2.4.3 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], 2024). This method is used frequently in competitive shooting scenarios to focus the shooter on the quality of target hit while maintaining shooting speed.

2.4.4 Shoot-Don't Shoot 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 (disinhibition) or inappropriately (inhibition) fire a round at that target. This results in a decision score of either "correct" or "incorrect" 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).

3. INDIVIDUAL FACTORS

Various demographic, physical, physiological, cognitive, and psychological measures have been positively associated with marksmanship performance (Scribner et al., 2023). Individual differences identified in numerous theories have become increasingly more important in human factors and ergonomics research (Weaver et al., 2003); however, little research has been investigated in shooting performance (Stafford et al., 2004).

Individual characteristics such as shooting experience, visual acuity, strength, physical fitness, postural steadiness, stress, and cognitive performance may also contribute to marksmanship performance. Many Army and other service marksmanship studies that examined separate characteristics have been performed in isolation (Burcham et al., 2018; Lakie, 2010; Lee & Mendoza, 2012; Shorter et al., 2014; Turner & Engle, 1989) and are too numerous to cite; however, no study has attempted to merge many of these weapon, target, and IFs into a singular study to assemble the covariates or predictors of shooting performance.

3.1 Demographics and Experience

IFs 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.

3.2 Physical Factors

3.2.1 Anthropometric Measures

Data yielded by Shorter et al. (2014) identified several anthropometric measures as contributors for individual variance in shooting performance, such as hand circumference. Hierarchical regression analyses on a subset of this data showed that adding hand circumference to the accuracy prediction algorithm increased the explained variance from 38.3% to 57.4%; a sizable increase to say the least. It is suggested that these measures will be both effective as covariates in explaining marksmanship performance outcomes as well as useful predictors for marksmanship.

3.2.2 Physical 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). Autonomic

nervous system (ANS) activity is often positively associated with stress and anxiety. It seems that elite shooters are able to control certain aspects of their ANS including the ability to decelerate their heart rate prior to squeezing the trigger. This lends to including heart rate activity as a possible indicator of marksmanship performance.

3.2.3 Stability of Hold

The applied control of the ANS, heart rate, and musculature can affect the stability of the shouldered rifle thus affecting accuracy. 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 (Hoffman et al., 1992; Hoffman & Street, 1992; Lakie, 2010; Konttinen et al., 1998).

It is suggested that a stability of hold measure be used to assess the time to hold a consistent bulls-eye pattern for a predetermined number of seconds. This premeasure may show a highly predictive nature for assessing both covariates in shooting performance and as a valuable predictor of marksmanship performance. As early as 1921, shooting associations with dexterity tests have been performed (Spaeth & Dunham, 1921). Laser pointers and air pistols have also been used to measure tremor in shooters (Pellegrini et al., 2004). It is proposed that a biomechanical measure of this type will be sought to determine the speed of a 4-s bulls-eye hold to determine each participant's postural stability disposition.

3.2.4 Visual Acuity

A strong relationship between visual acuity and marksmanship performance has been reported (Wells et al., 2009). Regression modeling suggested that there was a significant decrease in marksmanship performance when Snellen acuity ratings changed from 20/25 to 20/50. It is suggested that acuity scores will significantly affect marksmanship performance and that an accurate Snellen acuity rating be assessed for each participant via the Snellen acuity chart or a Titmus II eye-testing device. It is important to document acuity for the right eye, left eye, and both eyes for far distance.

3.3 Physiological Measures

3.3.1 Resting Heart Rate

Baseline beats per minute (bpm). This baseline measure is captured as beats per minute while resting and will be used as the recovery goal for a sustained 2-min running aerobic test at 80% of maximum calculated heart rate for that participant's age.

3.3.2 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; Murray et al., 2007; Ottaviani et al., 2007) and an effective premeasure 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 (R-to R-wave), 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).

3.3.3 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 premeasure of exercise recovery to assess exercise-induced psychomotor performance skills such as rifle shooting.

3.4 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 conditions (i.e., increased cognitive load) (Burke, 2007; Scribner, 2002; Scribner et al., 2005, 2007). 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 and foe discrimination shooting

tasks (Burke, 2007; Kerick et al., 2007; Patton et al., 2013; Scribner, 2002; Scribner & Harper, 2001; Scribner et al., 2004; Stafford et al., 2004; Szalma, 2008). Both Scribner and Kerick found 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.

3.4.1 Multitasking During Shooting

Increased cognitive tasking is inevitable because of the expansion of digital command and control (C2) systems in the Army, and many tasks will be performed either simultaneously with shooting tasks or rapidly switched in focus of attention. Multitasking, in its most demanding and crucial form for the dismounted infantry Soldier, is a scenario where a Soldier is shooting or being shot at while having to attend to pertinent information. The fire fight is thought to be the most stressful, highest demand scenario. 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 (Scribner, 2002; Scribner & Harper, 2001; Kelley & Scribner, 2003; Kerick et al., 2007).

3.4.2 Working Memory Capacity

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). The sources for these attributes may include transactional stress theory (TST) and information-processing theory (IPT).

3.4.3 Operation Span (OSPAN) Task

Turner and Engle (1989) created an interleaved working memory span test that uses simple mathematical equations that are followed by unrelated letters. This task was based on the theoretical model of working memory proposed by Baddeley and Hitch (1986). This OSPAN task requires that participants maintain a list of letters while processing unrelated mathematical information to measure the construct of WMC. The

version of the OSPAN task that will be presented via a touch-screen software interface is the Automated OSPAN task (AOSPAN; Unsworth et al., 2005) to ensure reliability of participant responses. The OSPAN is scored by representing the sum of correctly recalled letters in perfectly recalled sets and also reports the total number correct and erroneous math responses for all trials. Redick et al. (2011) reported internal consistency ($N = 6,077$) using Chronbach's alpha as $r = 0.80$ and 0.86 for partial and absolute scores, respectively, while Unsworth et al. (2005) reported $r = 0.78$. It is proposed that WMC, as measured by the OSPAN test as a predictive measure, will assist in better accounting for marksmanship performance as either a covariate in general linear model statistics or as a predictor in regression analyses.

3.4.4 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. Diminishing cognitive abilities are caused by lack of proper sleep and rest. Sleep deprivation can be detrimental to cognitive performance and especially 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. (2007) 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. Sleepiness and fatigue scales are examined in the next two sections.

3.4.4.1 *Stanford Sleep Scale (SSS)*

It is suggested a validated sleep scale be employed to capture each participant's restfulness. The SSS has been used widely and is fairly simple and expedient to administer to a large number of participants. The SSS is a repeatable and internally valid measure of sleepiness associated with sleep disruption (Hoddes et al., 1973). Daytime sleepiness is a construct that is distinct from fatigue, which will be discussed next.

3.4.4.2 *Chalder Fatigue Scale (CFS)*

As for fatigue, the Chalder Fatigue Scale (CFS) (Chalder et al., 1993) is reported to have both physical and mental fatigue reliability ratings of $r = 0.86$ and $r = 0.85$, respectively. The CFS can be used to assess daytime sleepiness and fatigue, respectively.

3.5 Psychological Factors

3.5.1 Self-Efficacy

Self-Report Measures. 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.

3.5.2 New General Self-Efficacy (NGSE) Scale

Bandura (1977) showed that self-efficacy, or the belief on one's ability to focus and concentrate resources on a task to meet task demands, is an important IF in job performance. The NGSE scale (Chen et al., 2001) has emerged with a reasonably good motivational trait measurement and is reported to have a test-retest reliability of $r = 0.67$ and internal consistency of 0.86 (Cronbach's alpha).

4. METHODS

This research effort as a whole 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 a data structure for a multiple-variable structural model for predictive Soldier performance modeling (correlation and predictive regression analyses), and 3) support future marksmanship and Warfighter performance modeling for lethality and systems acquisition decisions with higher statistical explanatory clarity.

Data collection was completed at Fort Moore, Georgia, and M-Experimental Facility (M-Range) at Aberdeen Proving Ground, Maryland. All use and safety procedures in the range and facility standard operating procedures (SOPs) were followed throughout the study. Participants were thoroughly briefed on the conduct of the test, all standard operating procedures, and safety requirement.

4.1 Participants

4.1.1 Voluntary Participation

All individuals were free to withdraw from the experiment at any time without consequence and encouraged to ask questions throughout the study.

4.1.2 Sample Size

The convenience sample size for this study was $n = 21$ (total; two data collection phases). These Soldiers were ages 18 to 39 (mean 33 years), rank E-2 to E-7 (mean E-4), with a range of service time in their MOS from 2 to 17 years (mean 11 years). All participants were recruited from the AMU ($n = 6$) in Fort Moore, Georgia, and 11B (dismounted infantry) 1-2 SBCT Soldiers ($n = 15$) from Joint Base Lewis-McChord, Washington.

4.1.3 Inclusion and Exclusion Criteria

Inclusion criteria for participation included self-reported: 1) 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.

4.2 Questionnaires/Surveys/Measurements

4.2.1 Surveys and Preliminary Data Collection

4.2.2 Informed Consent Form

An informed consent form was presented to and signed by all the participants in this study.

4.2.3 Demographics Questionnaire

The demographics questionnaire, shown in Appendix A, included additional questions relating to combat and weapons experience and self-reported injury states for each individual participant.

4.2.4 Stanford Sleepiness Scale

Appendix B includes the SSS for reference.

4.2.5 Chalder Fatigue Scale

The CFS is shown in Appendix C.

4.2.6 New General Self-Efficacy Scale

The NGSE scale is shown in Appendix D.

4.2.7 Anthropometric Data

This data was collected via 1) handheld dynamometer, which measures force produced by grip strength (forearm and hand muscle groups), 2) pinch grip dynamometer to accurately measure lateral, three-point, or tip pinch strength up to 50 lb (23 kg), and 3) anthropometric digital calipers to collect various body dimensions including but not limited to hand breadth, hand length, stature, acromion-radiale length, radiale-stylian length, and sleeve-out seam length.

4.2.8 The Operational Span

The test was conducted on a laptop with a mouse for task input. Participants were sitting in an isolated location when completing OSPAN. The OSPAN was completed prior to shooting tasks as a baseline IF metric. The OSPAN score was used to quantify working memory.

4.2.9 Zephyr Wristwatch and Heart Rate Sensor Strap

This was used to capture each participant's baseline resting heart rate. HRV was not collected during this first phase study.

4.3 Tasks and Procedures: Preexperimental Measures

A series of cognitive, demographic, physical, and marksmanship assessments were completed by participants to quantify a comprehensive IF analysis in human performance modeling. Participants completed data collection in three phases: 1) baseline data collection, 2) preshooting data collection, and 3) shooting data collection. Baseline data collection can be completed up to 120 days prior to preshooting data collection. Preshooting data collection occurred prior to shooting data collection but on the same day as live-fire shooting.

4.3.1 Participant Scenario: IFs Collection

4.3.1.1 Demographics and Experience

A demographic questionnaire (Appendix A) was used to collect biographical, health, and physical activity information from each subject. Subject age, sex, and anthropometric data was recorded on a subject data sheet. Information recorded on these forms was used in data normalization (e.g., performance relative to body mass or stature) or as covariates (e.g., shooting experience) during statistical analysis. Responses to the demographic questionnaire were used to verify participation in the study following consent. Prior to consent, prospective participants reviewed the inclusion and exclusion criteria to determine eligibility. No demographic information was collected prior to consent.

4.3.1.2 Visual Acuity

A standard Snellen chart was used to assess visual acuity and color blindness for right, left, and both eyes for each participant. Alternatively, a Snellen visual chart was used to collect visual acuity, and color blindness was self-reported by the participant. The method of data collection was recorded.

4.3.1.3 The Chalder Fatigue Scale

The CFS was used to assess daytime sleepiness and fatigue just prior to live-fire shooting (Chalder et al., 1993) (Appendix C).

4.3.1.4 The Stanford Sleep Scale

The SSS (Appendix B; Hoddes et al., 1973) was used to assess the quality of sleep the night before live-fire testing.

4.3.1.5 The Self-Efficacy Scale

The NGSE Scale (Appendix D; Chen et al., 2001) was used to gauge the level of each participant's self-efficacy prior to live-fire shooting.

4.3.1.6 Dextrality

Dextrality was assessed through a simple test to determine if each individual is dextral or cross-dextral. Eye dominance was assessed via an extended arm test. Handedness was asked including dominant hand, shooting hand, dominant eye, and aiming eye.

4.3.1.7 Anthropometrics

Anthropometric measures, including but not limited to subject's stature and mass (without shoes), was recorded. Hand, arm, and other anthropometric measures were collected with an anthropometric kit (Appendix E).

4.3.1.8 Strength Measures

Isolated upper body joint strength measurements were recorded using portable handheld dynamometers (Lafayette Instrument Company, Lafayette, Indiana). Strength testing was performed by positioning the volunteer to isolate a muscle group and placing the dynamometer device in the proper position (grip and pinch) and angle to conduct the test. The volunteer was 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 can throughout the test. To avoid fatigue or risk of muscle cramping, a minimum of 60 s between muscle contractions was provided.

4.3.1.9 Muscular Endurance Task

A measure of muscle endurance was recorded for the arm used to support the barrel of the rifle. Subjects held a rifle with a mass (~1 kg) positioned on the top rail of the rail grabber. The mass was considered the worst-case scenario for future rifle accessory purchases but may also acted as a surrogate measure for future design changes, such as a longer barrel (Coleman et al., 2021). A laser was also attached to the weapon. Instructions were given for the subject to engage in an unsupported standing firing

position while holding the weapon aimed at a designated bulls-eye approximately 5 m in front of the subject. Once weapon aim fell outside of the bulls-eye area as indicated by the laser, the test stopped. Total endurance time was recorded.

4.3.1.10 Resting Heart Rate

Baseline heart rate (bpm) was recorded prior to activity. Subjects donned the heart rate monitor and were asked to sit in a quiet place while resting for 5 min.

4.3.1.11 Working Memory Capacity (Automated Operational Span Task)

WMC was measured by the AOSPAN test (Turner & Engle, 1989; Unsworth et al., 2005) as a predictive measure on a laptop with a mouse for user input. This AOSPAN task requires that participants maintain a list of letters in memory while processing unrelated mathematical information to measure the construct of WMC.

4.3.2 Participant Scenario: Preexperimental Rifle Qualification Measures

4.3.2.1 Safety Briefing and Range Familiarization

Subjects were thoroughly briefed on the conduct of testing, all standard operating procedures and safety requirements relative to the live-fire range used at Fort Moore, Georgia.

4.3.2.2 Live-Fire Weapon Calibration

The weapon will be zeroed at 25 m to calibrate the optic and weapon for accurate marksmanship evaluation. Researchers will zero the weapon prior to initiation of the test session. Subjects will confirm and adjust zero as necessary.

4.3.2.3 Shooter Baseline Scoring

Note: For all live-fire tasks in this study, researchers are relying on verbal self-report for the Lautenberg Amendment verification and that no documentary evidence is requested.

4.3.2.4 Standard Army Rifle Qualification Test

The standardized qualification test for the carbine rifle will be implemented to collect qualification requirements (Department of the Army, 2019). In the case where a range cannot accommodate for the Standard Army Rifle Qualification Test (e.g., range cannot have targets engaged past a certain distance from the firing line), an alternative rifle qualification test will be implemented. A standard known distance (KD) qualification test

will be completed by subjects, which is similar to the Army Qualification test. This assessment consists of shooting 20 timed rounds (2 min) at 300 m prone supported, 10 timed rounds (60 s) at 200 m prone unsupported, and 10 timed rounds (60 s) at 100 m kneeling. Subjects will be given 10 s between each phase to allow for transition between shooting stances and magazine changes. Total hits will be scored, which is the same metric used in the Standard Army Qualification test.

4.3.2.5 Modified “El Presidente”

The “El Presidente” is a popular competition shooting drill.* Since this test is an evaluation of rifles rather than pistols, we use a modified version of the standard drill. Subjects begin facing the three targets positioned 10 m away with the weapon held at low ready (rather than facing backward) and remain in standing position following weapon reload. The three targets are positioned in front of the subject with 1 m between each target. The center target is positioned directly in front of the subject. The left and right targets are positioned 1 m in their respective positions from the center target. At the researcher’s verbal cue and audio cue from the shot timer, the subject will raise the weapon and aim at the left target and shoot two rounds at each target for a total of 12 shots. The subject will be instructed to engage the targets from left to right. After the two shots are taken on the right target, a magazine change will occur, and the subject will engage the targets from right to left repeating the two shots on each target. El Presidente total completion time will be recorded using a shot timer. Shooters will be instructed to equate priority between accuracy and timing. By equating accuracy and timing in terms of shooter priority, shooters will be forced to approach target acquisition rapidly and accurately. 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. Marksmanship performance will be assessed 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). Section 5.2.3 provides the error zones on the target that correspond to different time penalties. Zone A corresponds to a time penalty of 0 s Zone C corresponds to a time penalty of 1 s. Zone D corresponds to a time penalty of 5 s. The number of shots hit in each zone will be added along with the corresponding time penalties. The total time penalties will be added to the total completion time, thus increasing the time score for El Presidente.

* <https://www.pewpewtactical.com/el-presidente-shooting-drill/>

4.3.2.6 M4 Rifle with EOTECH Sights

Figure 2 shows one of the four zeroed M4 rifles with EOTECH sight attached.



Figure 2. M4 carbine with EOTECH sight

4.3.2.7 Stability of Hold Weapon

One weapon with a 1-kg weight mounted on the forward picatinny rail was used to assess the length of time (seconds) each participant could hold their aim in a standing unsupported position, specified by a rail-mounted laser on the M4 rifle, in a 4-in. bullseye at 5 m distance.

4.3.2.8 Modified El Presidente Task Target Array

Figures 3 and 4 represents the three side-by-side targets at 10 m that were used for the collection of this task for standing and kneeling positions, respectively.



Figure 3. Modified El Presidente shooting task as qualification measure (standing)



Figure 4. Modified El Presidente shooting task as qualification measure (kneeling)

4.4 Participant Scenario: Experimental Measures

4.4.1 E-Silhouettes with Friend or Enemy Markings

The E-silhouettes were driven by wireless electric motors to move the targets into an upright position from the Oakwood control and data collection system (Figures 5 and 6).



Figure 5. 25-m E-silhouette with friendly target marking



Figure 6. 25-m E-silhouette with enemy marking (low workload)

4.4.2 Baseline Nonrandomized Trials

Three 12-target trials will be captured for response time and accuracy. Each trial will consist of a fixed order of target distance and target exposure time presentations: 1) 25 m, 2 s; 2) 50 m, 2 s; 3) 100 m, 2 s; 4) 25 m, 4 s; 5) 50 m, 4 s; and (6) 100 m, 4 s. The fixed order will be repeated two times for a total of 12-target exposures for one trial. All targets will be presented as “enemy.”

4.4.3 Baseline Randomized Trials

Three 12-target trials will be captured for response time and accuracy. There are six possible combinations of target distance and target exposure time presentations: 1) 25 m, 2 s; 2) 50 m, 2 s; 3) 100 m, 2 s; 4) 25 m, 4 s; 5) 50 m, 4 s; and 6) 100 m, 4 s. All six combinations will be repeated two times for a total of 12-target exposures. The order of the 12 targets will be randomized for each trial. All targets will be presented as “enemy.”

4.4.4 Workload Trials

Three 24-target experimental trials will be captured for response time and accuracy. These three trials will be randomized for presentation order. Each target set (or experimental trial) will have 24 targets presented; 12 of which are marked friendly and 12 of which are marked enemy (see Section 5.2.3). Each of the exposure times (2 and 4 s) and distances (25, 50, 100 m) will be nested within each 24-target experimental trial.

4.5 Research Questions and Hypotheses

4.5.1 Research Question 1

Does a correlational matrix for various shooting performance and decision-making variables support the general Scribner and Morelli (2020) hypothetical model?

4.5.1.1 Hypothesis 1 (Null)

The correlational matrix either demonstrates no significant relationships or is not structurally similar to the general hypothesized model.

4.5.1.2 Hypothesis 1 (Alternative)

The correlational matrix demonstrates significant relationships and is structurally similar to the general hypothesized model.

4.5.2 Research Question 2

Does individual shooting performance, as measured by various mean and standard deviation measures under the IF model vary from an experimental-only model?

4.5.2.1 Hypothesis 2 (Null)

There are no individual shooting performance differences for mean and standard deviation differences under the IF model as compared to the experimental-only model.

4.5.2.2 Hypothesis 2 (Alternative)

There are significant individual shooting performance for mean and standard deviation differences under the IF model as compared to the experimental-only model.

4.6 Design and Analyses

4.6.1 Experimental Design

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. Experimental baseline trials of 12 targets each with no discrimination required were collected prior to the experimental trials. All trials were counterbalanced by randomizing the presentation order of the two experimental trials as evenly as possible for the experimental sample. Mean and standard deviation data provided is based upon the two-way interaction analysis of variance (ANOVA) (Model 1) and analysis of covariance (ANCOVA) (Model 2) effects within these analyses for target exposure time and distance only, for modeling purposes.

Correlations were amassed in large tables and assessed for significance of 0.05 (alpha) or higher. Correlations were then graphically reproduced into visual format so that all significant relationships could be created and visualized.

4.6.2 Independent Variables

- Workload (shoot–don't shoot discrimination) (baseline + 2 levels: low, high)
- Target exposure time (2 or 4 s), nested
- Target distance (25, 50, and 100 m), nested
- Shooter skill level (Elite AMU, 11B Infantry)

4.6.3 Dependent Variables

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

4.6.4 IF Variables

- Demographics/shooter characteristics/experience (including but not limited to age, gender, MOSs, time in service, rank, combat deployment, and shooting experience with various platforms)
- Visual acuity
- Anthropometrics
- Strength (hand grip, pinch grip) (Newtons)
- Muscular endurance: time to fatigue for weapon hold on target (seconds)
- OSPAN absolute score
- CFS
- SSS
- NGSE
- Rifle KD qualification score
- EI Presidente score

5. RESULTS

5.1 Correlational Relationship Structures and Tables

Correlational relationship structures were created to demonstrate the connections between IFs, important measures of pretask shooting, and the shooting performance and decision-making task variables. The figures in this section show only significant correlations (≥ 0.300) identified with a heavy box outline around them, signifying a large effect. These depictions are followed by tables of all significant correlations.

These correlation tables include all significant correlations categories for IFs highlighted in medium blue. Specific IF with intuitive directions (correlations that make sense that are either positive or negative) are highlighted by category in light blue backgrounds. The correlation tables include correlations of IFs and shooting task measure, IFs and structural stability of hold, IFs and premeasure shooting tasks (KD qualification, EI Presidente), and IFs and shooting skill level (general infantry and AMU).

5.1.1 Hit Percentage

Figure 7 shows the correlational relationship model for hit percentage. Tables 1–6 include all significant correlation hit percentage categories for hit percentage and IF correlations, stability of weapon hold and IF correlations, experimental factors and IF correlations, EI Presidente and IF correlations, KD qualification and IF correlations, and shooter experience level and IF correlations, respectively.

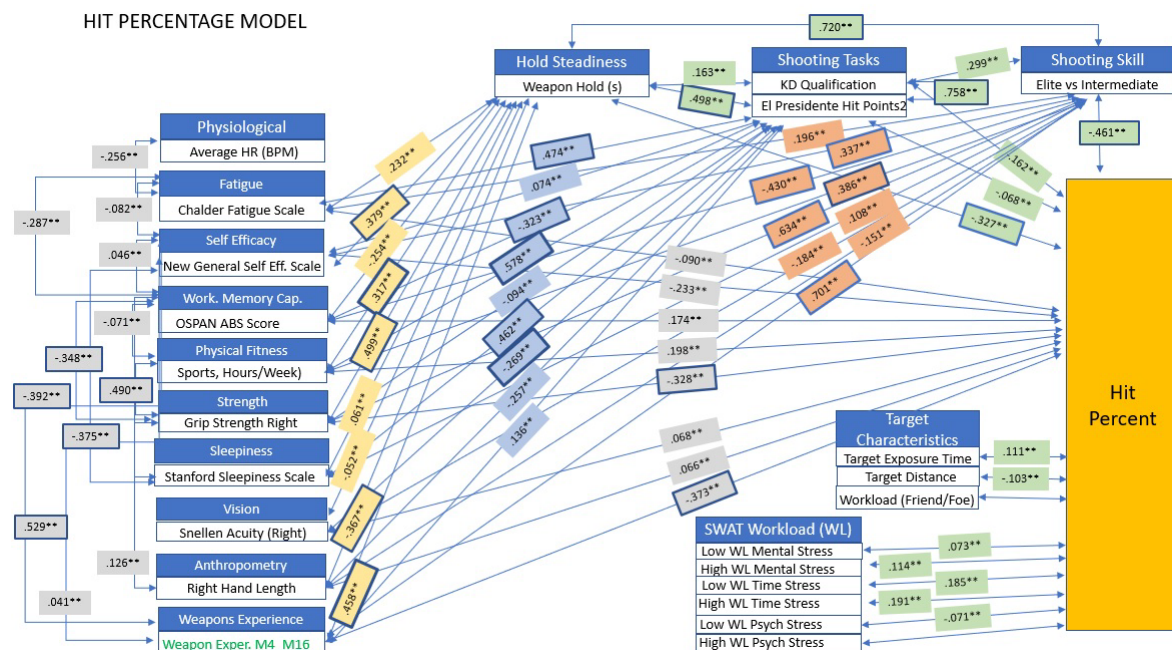


Figure 7. Hit percentage correlational relationship model

Table 1. Hit percentage and IF correlations

IFs	Specific IF variable	Hit Percentage	
		<i>R</i>	<i>p</i>
Physiological	Average Heart Rate (bpm)	n/a	n/a
	Snellen Visual Acuity, Right Eye	0.068	0.007
Psychological	Chalder Fatigue Scale	−0.090	0.000
	New General Self Efficacy	−0.233	0.000
	Stanford Sleepiness Scale	n/a	n/a
Cognitive	Working Memory Capacity ABS	0.174	0.000
Physical Fitness	Core Hours/Week	0.198	0.000
Physical Strength	Grip Strength, Right Hand	0.068	0.007
Anthropometric	Right Upper Arm Length	0.225	0.000
Experience	M4/M16 Weapons Experience	−0.373	0.000
	M110 SASS Experience	−0.240	0.000
	Types of Rifles Carried	0.146	0.000
	Rank	−0.086	0.022
	Time in MOS	−0.339	0.000
Shooting Tasks	El Presidente Hit Points	−0.068	0.046
	Known Distance Qualification	−0.162	0.000
Physical Steadiness	Weapon Hold (s)	−0.327	0.000
Demographics	Age	−0.339	0.000

Table 2. Hit percentage: stability of weapon hold and IF correlations

IFs	Specific IF variable	Weapon Hold (s)	
		<i>R</i>	<i>p</i>
Physiological	Average Heart Rate (bpm)	n/a	n/a
	Snellen Visual Acuity, Right Eye	-0.052	0.004
Psychological	Chalder Fatigue Scale	0.232	0.000
	New General Self Efficacy	0.379	0.000
	Stanford Sleepiness Scale	0.061	0.001
Cognitive	Working Memory Capacity ABS	-0.254	0.000
Physical Fitness	Core Hours/Week	-0.114	0.000
Physical Strength	Grip Strength, Right Hand	0.499	0.007
Anthropometric	Right Upper Arm Length	-0.436	0.000
Experience	M4/M16 Weapons Experience	0.458	0.000
	M110 SASS Experience	0.498	0.000
	Types of Rifles Carried	-0.192	0.000
	Rank	n/a	n/a
	Time in MOS	0.382	0.000
Shooting Tasks	EI Presidente Hit Points	0.620	0.046
	Known Distance Qualification	0.163	0.000
Physical Steadiness	Weapon Hold (s)	n/a	n/a
Demographics	Age	0.354	0.000

Table 3. Hit percentage: experimental factors and IF correlations

Experimental Factors	Hit Percentage	
	<i>R</i>	<i>p</i>
Target Distance (m)	-0.103	0.000
Target Exposure time (2s or 4s)	0.111	0.000
Target Discrimination (L or H)	n/a	n/a
Shoot Level (Inf(2) or AMU(3))	-0.461	0.000

Table 4. Hit percentage: EI Presidente and IF correlations

IFs	Specific IF variable	EI Presidente	
		<i>R</i>	<i>p</i>
Physiological	Average Heart Rate (bpm)	−0.358	0.000
	Snellen Visual Acuity, Right Eye	−0.430	0.000
Psychological	Chalder Fatigue Scale	0.300	0.000
	New General Self Efficacy	0.396	0.000
	Stanford Sleepiness Scale	0.408	0.000
Cognitive	Working Memory Capacity	−0.426	0.000
Physical Fitness	Cardio Hours/Week	0.395	0.000
Physical Strength	Pinch Strength, Left Hand	0.444	0.007
Anthropometric	Right Upper Arm Length	−0.280	0.000
Experience	M4/M16 Weapons Experience	0.338	0.000
	M110 SASS Experience	0.714	0.000
	Types of Rifles Carried	n/a	n/a
	Rank	n/a	n/a
	Time in MOS	0.590	0.000
Shooting Tasks	EI Presidente Hit Points	n/a	n/a
	Known Distance Qualification	0.758	0.000
Physical Steadiness	Weapon Hold (s)	0.498	0.000
Demographics	Age	0.526	0.000

Table 5. Hit percentage: KD qualification and IF correlations

IFs	Specific IF variable	KD Qualification	
		<i>R</i>	<i>p</i>
Physiological	Average Heart Rate (bpm)	n/a	n/a
	Snellen Visual Acuity, Right Eye	−0.742	0.000
Psychological	Chalder Fatigue Scale	.0199	0.000
	New General Self Efficacy	0.096	0.000
	Stanford Sleepiness Scale	0.172	0.000
Cognitive	WMC - OSPAN Math Accuracy	0.339	0.000
Physical Fitness	Sports Hours/Week	0.132	0.000
Physical Strength	Grip Strength, Right Hand	0.168	0.000
Anthropometric	Right Upper Arm Length	−0.249	0.000
Experience	M4/M16 Weapons Experience	0.312	0.000
	M110 SASS Experience	0.183	0.000
	Types of Rifles Carried	n/a	n/a
	Rank	0.127	0.000
	Time in MOS	0.590	0.000
Shooting Tasks	EI Presidente Hit Points	0.758	0.000
	Known Distance Qualification	n/a	n/a
Physical Steadiness	Weapon Hold (s)	0.163	0.000
Demographics	Age	0.121	0.000

Table 6. Hit percentage: shooter experience level and IF correlations

IFs	Specific IF variable	Shoot Level	
		<i>R</i>	<i>p</i>
Physiological	Average Heart Rate (bpm)	−0.120	0.000
	Snellen Visual Acuity, Right Eye	−0.184	0.000
Psychological	Chalder Fatigue Scale	0.196	0.000
	New General Self Efficacy	0.337	0.000
	Stanford Sleepiness Scale	0.108	0.000
Cognitive	Working Memory Capacity	−0.430	0.000
Physical Fitness	Sports Hours/Week	0.386	0.000
Physical Strength	Grip Strength, Right Hand	0.634	0.000
Anthropometric	Right Upper Arm Length	−0.524	0.000
Experience	M4/M16 Weapons Experience	0.701	0.000
	M110 SASS Experience	0.555	0.000
	Number of Rifles Carried	−0.205	0.000
	Rank	0.111	0.000
	Time in MOS	0.603	0.000
Shooting Tasks	EI Presidente Hit Points	n/a	n/a
	Known Distance Qualification	0.299	n
Physical Steadiness	Weapon Hold (s)	0.720	0.000
Demographics	Age	0.565	0.000

5.1.2 Radial Error

Figure 8 shows the correlational relationship model for radial error. Tables 7–12 include all significant correlation categories for radial error and IF correlations, stability of weapon hold and IF correlations, experimental factors and IF correlations, EI Presidente and IF correlations, KD qualification and IF correlations, and shooter experience level and IF correlations, respectively.

Table 7. Radial error and IF correlations

IFs	Specific IF variable ¹	Radial Error	
		<i>R</i>	<i>p</i>
Physiological	Average Heart Rate (bpm)	-0.244	0.000
	Snellen Visual Acuity, Right Eye	n/a	n/a
Psychological	Chalder Fatigue Scale	0.076	0.016
	New General Self Efficacy	n/a	n/a
	Stanford Sleepiness Scale	0.082	0.010
Cognitive	Working Memory Capacity ABS	n/a	n/a
Physical Fitness	Weights Hours/Week	0.129	0.000
Physical Strength	Grip Strength, Right Hand	n/a	n/a
Anthropometric	Right Upper Arm Length	n/a	n/a
Experience	M4/M16 Weapons Experience	n/a	n/a
	M110 SASS Experience	n/a	n/a
	Types of Rifles Carried	n/a	n/a
	Rank	n/a	n/a
	Time in MOS	n/a	n/a
Shooting Tasks	EI Presidente Hit Points	n/a	n/a
	Known Distance Qualification	n/a	n/a
Physical Steadiness	Weapon Hold (s)	n/a	n/a
Demographics	Age	n/a	n/a

Table 8. Radial error: stability of weapon hold and IF correlations

IFs	Specific IF variable	Weapon Hold (s)	
		<i>R</i>	<i>p</i>
Physiological	Average Heart Rate (bpm)	n/a	n/a
	Corrective Lenses Use	−0.195	0.000
Psychological	Chalder Fatigue Scale	0.232	0.001
	New General Self Efficacy	0.379	0.000
	Stanford Sleepiness Scale	0.061	0.001
Cognitive	Working Memory Capacity ABS	−0.254	0.000
Physical Fitness	Core Hours/Week	−0.114	0.000
Physical Strength	Grip Strength, Right Hand	0.499	0.000
Anthropometric	Right Upper Arm Length	−0.436	0.000
Experience	M4/M16 Weapons Experience	0.458	0.000
	M110 SASS Experience	0.498	0.000
	Types of Rifles Carried	−0.192	0.000
	Rank	n/a	n/a
	Time in MOS	0.382	0.000
Shooting Tasks	EI Presidente Hit Points	0.620	0.000
	Known Distance Qualification	0.163	0.000
Physical Steadiness	Weapon Hold (s)	n/a	n/a
Demographics	Age	0.354	0.000

Table 9. Radial error: experimental factors and IF correlations

Experimental Factors	Radial Error	
	<i>R</i>	<i>p</i>
Target Distance (m)	n/a	n/a
Target Exposure time (2s or 4s)	n/a	n/a
Target Discrimination (L or H)	n/a	n/a
Shoot Level (Inf(2) or AMU(3))	n/a	n/a

Table 10. Radial error: EI Presidente and IF correlations

IFs	Specific IF variable	EI Presidente	
		<i>R</i>	<i>p</i>
Physiological	Average Heart Rate (bpm)	−0.358	0.000
	Snellen Visual Acuity, Right Eye	−0.430	0.000
Psychological	Chalder Fatigue Scale	0.300	0.000
	New General Self Efficacy	0.396	0.000
	Stanford Sleepiness Scale	0.408	0.000
Cognitive	Working Memory Capacity	−0.426	0.000
Physical Fitness	Cardio Hours/Week	0.395	0.000
Physical Strength	Pinch Strength, Left Hand	0.444	0.000
Anthropometric	Right Upper Arm Length	−0.280	0.000
Experience	M4/M16 Weapons Experience	0.338	0.000
	M110 SASS Experience	0.714	0.000
	Types of Rifles Carried	0.244	0.000
	Rank		
	Time in MOS	0.590	0.000
Shooting Tasks	EI Presidente Hit Points	n/a	n/a
	Known Distance Qualification	0.758	0.000
Physical Steadiness	Weapon Hold (s)	0.498	0.000
Demographics	Age	0.526	0.000

Table 11. Radial error: KD qualification and IF correlations

IFs	Specific IF variable	KD Qualification	
		<i>R</i>	<i>p</i>
Physiological	Average Heart Rate (bpm)	n/a	n/a
	Snellen Visual Acuity, Right Eye	−0.742	0.000
Psychological	Chalder Fatigue Scale	0.199	0.000
	New General Self Efficacy	0.096	0.000
	Stanford Sleepiness Scale	0.172	0.000
Cognitive	WMC – OSPAN Math Accuracy	0.339	0.000
Physical Fitness	Sports Hours/Week	0.132	0.000
Physical Strength	Grip Strength, Right Hand	0.168	0.000
Anthropometric	Right Upper Arm Length	−0.249	0.000
Experience	M4/M16 Weapons Experience	0.312	0.000
	M110 SASS Experience	0.183	0.000
	Types of Rifles Carried	0.173	0.000
	Rank	0.127	0.000
	Time in MOS	0.290	0.000
Shooting Tasks	El Presidente Hit Points	0.758	0.000
	Known Distance Qualification	n/a	n/a
Physical Steadiness	Weapon Hold (s)	0.163	0.000
Demographics	Age	0.121	0.000

Table 12. Radial error: shooter experience level and IF correlations

IFs	Specific IF variable	Shoot Level	
		<i>R</i>	<i>p</i>
Physiological	Average Heart Rate (bpm)	−0.120	0.000
	Snellen Visual Acuity, Right Eye	−0.184	0.000
Psychological	Chalder Fatigue Scale	0.196	0.000
	New General Self Efficacy	0.337	0.000
	Stanford Sleepiness Scale	0.108	0.000
Cognitive	WMC – OSPAN Math Accuracy	0.126	0.000
Physical Fitness	Sports Hours/Week	0.386	0.000
Physical Strength	Grip Strength, Right Hand	0.634	0.000
Anthropometric	Right Upper Arm Length	−0.524	0.000
Experience	M4/M16 Weapons Experience	0.701	0.000
	M110 SASS Experience	0.555	0.000
	Number of Rifles Carried	−0.205	0.000
	Rank	0.111	0.000
	Time in MOS	0.603	0.000
Shooting Tasks	EI Presidente Hit Points	n/a	n/a
	Known Distance Qualification	0.299	0.000
Physical Steadiness	Weapon Hold (s)	0.720	0.000
Demographics	Age	0.565	0.000

5.1.3 Zone Hit Scoring

Figure 9 shows the correlational relationship model for zone hit scoring. Tables 13–18 include all significant correlation categories for zone hit scoring and IF correlations, stability of weapon hold and IF correlations, experimental factors and IF correlations, EI Presidente and IF correlations, KD qualification and IF correlations, and shooter experience level and IF correlations, respectively.

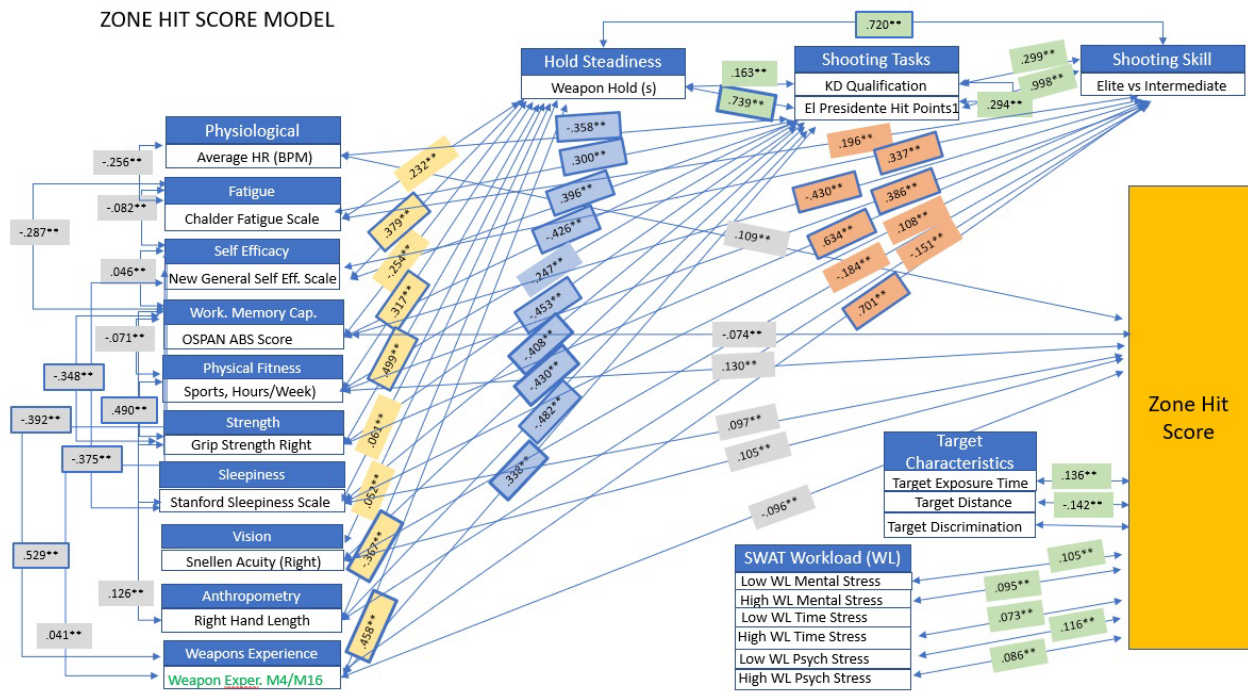


Figure 9. Zone hit score correlational relationship model

Table 13. Zone hit scoring and IF correlations

IFs	Specific IF variable	Zone Hit Score	
		<i>R</i>	<i>p</i>
Physiological	Average Heart Rate (bpm)	0.109	0.001
	Snellen Visual Acuity, Left Eye	−0.074	0.029
Psychological	Chalder Fatigue Scale	n/a	n/a
	New General Self Efficacy	n/a	n/a
	Stanford Sleepiness Scale	0.097	0.004
Cognitive	WMC – OSPAN Math Accuracy	0.096	0.005
Physical Fitness	Weights Hours/Week	−0.085	0.013
Physical Strength	Grip Strength, Right Hand	n/a	n/a
Anthropometric	Weight	−0.069	0.043
Experience	M4/M16 Weapons Experience	−0.096	0.005
	M110 SASS Experience	n/a	n/a
	Types of Rifles Carried	n/a	n/a
	Rank	n/a	n/a
	Time in MOS	−0.095	0.005
Shooting Tasks	El Presidente Hit Points	n/a	n/a
	Known Distance Qualification	n/a	n/a
Physical Steadiness	Weapon Hold (s)	n/a	n/a
Demographics	Age	−0.128	0.000

Table 14. Zone hit scoring: stability of weapon hold and IF correlations

IFs	Specific IF variable	Weapon Hold (s)	
		<i>R</i>	<i>p</i>
Physiological	Average Heart Rate (bpm)	n/a	n/a
	Snellen Visual Acuity, Left Eye	−0.115	0.000
Psychological	Chalder Fatigue Scale	0.232	0.000
	New General Self Efficacy	0.379	0.000
	Stanford Sleepiness Scale	0.061	0.001
Cognitive	Working Memory Capacity ABS	−0.254	0.000
Physical Fitness	Core Hours/Week	−0.114	0.000
Physical Strength	Grip Strength, Right Hand	0.499	0.000
Anthropometric	Right Upper Arm Length	−0.436	0.000
Experience	M4/M16 Weapons Experience	0.458	0.000
	M110 SASS Experience	0.498	0.000
	Types of Rifles Carried	−0.192	0.000
	Rank	n/a	n/a
	Time in MOS	0.382	0.000
Shooting Tasks	El Presidente Hit Points	0.620	0.000
	Known Distance Qualification	0.163	0.000
Demographics	Age	0.354	0.000

Table 15. Zone hit scoring: experimental factors and IF correlations

Experimental Factors	Zone Hit Score	
	<i>R</i>	<i>p</i>
Target Distance (m)	−0.142	0.000
Target Exposure time (2 or 4 s)	0.136	0.000
Target Discrimination (L or H)	n/a	n/a
Shoot Level (Inf(2) or AMU(3))	n/a	n/a

Table 16. Zone hit scoring: EI Presidente and IF correlations

IFs	Specific IF variable	EI Presidente	
		<i>R</i>	<i>p</i>
Physiological	Average Heart Rate (bpm)	−0.358	0.000
	Snellen Visual Acuity, Right Eye	−0.430	0.000
Psychological	Chalder Fatigue Scale	0.300	0.000
	New General Self Efficacy	0.396	0.000
	Stanford Sleepiness Scale	0.408	0.000
Cognitive	Working Memory Capacity	−0.426	0.000
Physical Fitness	Cardio Hours/Week	0.395	0.000
Physical Strength	Pinch Strength, Left Hand	0.444	0.000
Anthropometric	Right Upper Arm Length	−0.280	0.000
Experience	M4/M16 Weapons Experience	0.338	0.000
	M110 SASS Experience	0.714	0.000
	Types of Rifles Carried	n/a	n/a
	Rank	n/a	n/a
	Time in MOS	0.590	0.000
Shooting Tasks	EI Presidente Hit Points		
	Known Distance Qualification	0.758	0.000
Demographics	Age	0.526	0.000

Table 17. Zone hit scoring: KD qualification and IF correlations

IFs	Specific IF variable	KD Qualification	
		<i>R</i>	<i>p</i>
Physiological	Average Heart Rate (bpm)	n	n
	Snellen Visual Acuity, Left Eye	−0.871	0.000
Psychological	Chalder Fatigue Scale	0.199	0.000
	New General Self Efficacy	0.096	0.000
	Stanford Sleepiness Scale	0.172	0.000
Cognitive	WMC – OSPAN Math Accuracy	0.339	0.000
Physical Fitness	Sports Hours/Week	0.132	0.000
Physical Strength	Grip Strength, Left Hand	0.229	0.000
Anthropometric	Right Upper Arm Length	−0.249	0.000
Experience	M4/M16 Weapons Experience	0.312	0.000
	M110 SASS Experience	0.183	0.000
	Types of Rifles Carried	n/a	n/a
	Rank	0.127	0.000
	Time in MOS	0.290	0.000
Shooting Tasks	El Presidente Hit Points	0.758	0.000
	Known Distance Qualification	n/a	n/a
Demographics	Age	0.121	0.000

Table 18. Zone hit scoring: shooter experience level and IF correlations

IFs	Specific IF variable	Shoot Level	
		<i>R</i>	<i>p</i>
Physiological	Average Heart Rate (bpm)	−0.120	0.000
	Snellen Visual Acuity, Left Eye	−0.190	0.000
Psychological	Chalder Fatigue Scale	0.196	0.000
	New General Self Efficacy	0.337	0.000
	Stanford Sleepiness Scale	0.108	0.000
Cognitive	WMC – OSPAN Math Accuracy	0.126	0.000
Physical Fitness	Sports Hours/Week	0.386	0.000
Physical Strength	Grip Strength, Right Hand	0.634	0.000
Anthropometric	Right Upper Arm Length	−0.524	0.000
Experience	M4/M16 Weapons Experience	0.701	0.000
	M110 SASS Experience	0.555	0.000
	Number of Rifles Carried	−0.205	0.000
	Rank	0.111	0.000
	Time in MOS	0.603	0.000
Shooting Tasks	EI Presidente Hit Points	n/a	n/a
	Known Distance Qualification	0.299	0.000
Demographics	Age	0.565	0.000

5.1.4 Friendly Fire (Error of Disinhibition)

Figure 10 shows the correlational relationship model for friendly fire decision error. Tables 19–24 include all significant correlation categories for friendly fire decision error and IF correlations, stability of weapon hold and IF correlations, experimental factors and IF correlations, EI Presidente and IF correlations, KD qualification and IF correlations, and shooter experience level and IF correlations, respectively.

FRIENDLY FIRE DECISION MODEL

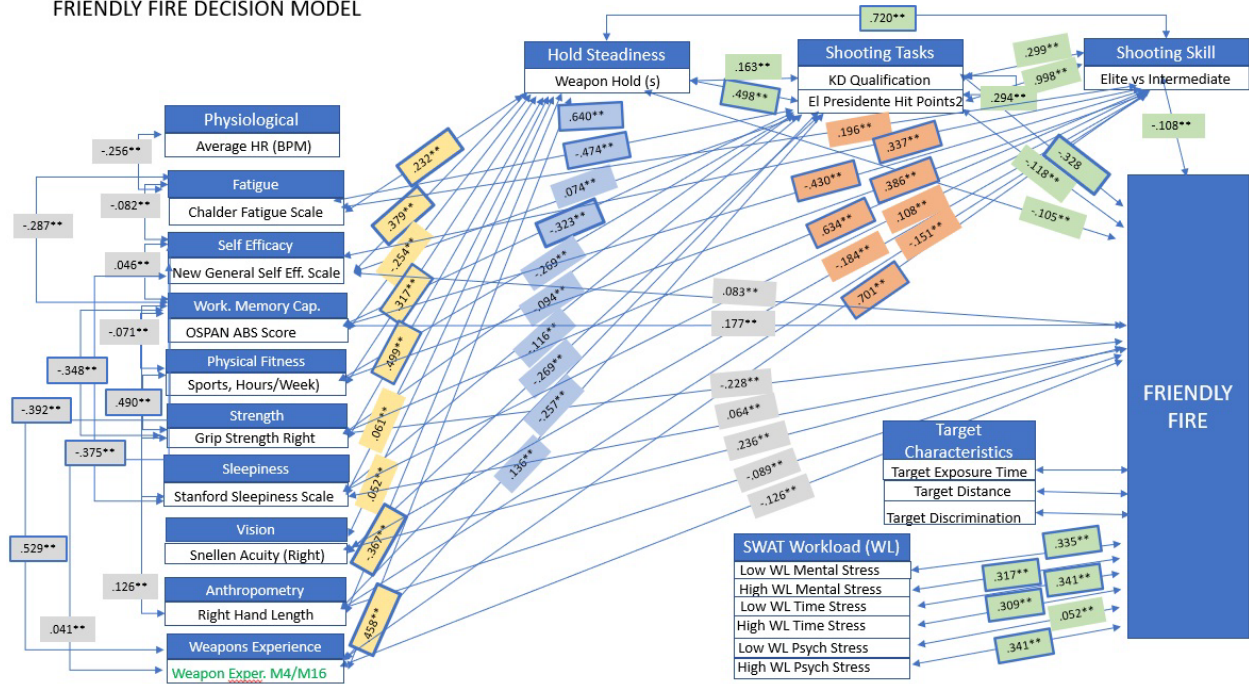


Figure 10. Friendly fire decision error correlational relationship model

Table 19. Friendly fire and IF correlations

IFs	Specific IF variable	Friendly Fire Error	
		<i>R</i>	<i>p</i>
Physiological	Average Heart Rate (bpm)	0.276	0.000
	Snellen Visual Acuity, Right Eye	0.236	0.000
Psychological	Chalder Fatigue Scale	0.048	0.009
	New General Self Efficacy	0.083	0.000
	Stanford Sleepiness Scale	-0.064	0.001
Cognitive	WMC – OSPAN Speed Errors	0.111	0.001
Physical Fitness	Sports Hours/Week	n/a	n/a
Physical Strength	Grip Strength, Left Hand	-0.228	0.000
Anthropometric	Right Upper Arm Length	0.141	0.000
Experience	M4/M16 Weapons Experience	-0.126	0.000
	M110 SASS Experience	-0.043	0.020
	Types of Rifles Carried	0.220	0.000
	Rank	0.064	0.000
	Time in MOS	-0.092	0.000
Shooting Tasks	El Presidente Hit Points T2	-0.118	0.003
	Known Distance Qualification	-0.328	0.000
Physical Steadiness	Weapon Hold (s)	n/a	n/a
Demographics	Age	-0.099	0.000

Table 20. Friendly fire: stability of weapon hold and IF correlations

IFs	Specific IF variable	Weapon Hold (s)	
		<i>R</i>	<i>p</i>
Physiological	Average Heart Rate (bpm)	n/a	n/a
	Snellen Visual Acuity, Left Eye	−0.115	0.000
Psychological	Chalder Fatigue Scale	0.232	0.000
	New General Self Efficacy	0.379	0.000
	Stanford Sleepiness Scale	0.061	0.000
Cognitive	WMC – OSPAN ABS Score	−0.254	0.000
Physical Fitness	Core Hours/Week	−0.114	0.000
Physical Strength	Grip Strength, Right Hand	0.499	0.000
Anthropometric	Right Upper Arm Length	−0.436	0.000
Experience	M4/M16 Weapons Experience	0.458	0.000
	M110 SASS Experience	0.498	0.000
	Types of Rifles Carried	−0.192	0.000
	Rank	n/a	n/a
	Time in MOS	0.382	0.000
Shooting Tasks	El Presidente Hit Points	0.620	0.000
	Known Distance Qualification	0.163	0.000
Physical Steadiness	Weapon Hold (s)	n/a	n/a
Demographics	Age	0.354	0.000

Table 21. Friendly fire: experimental factors and IF correlations

Experimental Factors	Friendly Fire Error	
	<i>R</i>	<i>p</i>
Target Distance (m)	n/a	n/a
Target Exposure time (2 or 4 s)	n/a	n/a
Target Discrimination (L or H)	n/a	n/a
Shoot Level (Inf(2) or AMU(3))	−0.108	0.000

Table 22. Friendly fire: EI Presidente and IF correlations

IFs	Specific IF variable	EI Presidente	
		<i>R</i>	<i>p</i>
Physiological	Average Heart Rate (bpm)	−0.358	0.000
	Snellen Visual Acuity, Left Eye	−0.485	0.000
Psychological	Chalder Fatigue Scale	0.300	0.000
	New General Self Efficacy	0.396	0.000
	Stanford Sleepiness Scale	0.408	0.000
Cognitive	Working Memory Capacity	−0.426	0.000
Physical Fitness	Cardio Hours/Week	0.395	0.000
Physical Strength	Pinch Strength, Left Hand	0.444	0.000
Anthropometric	Right Upper Arm Length	−0.280	0.000
Experience	M4/M16 Weapons Experience	0.338	0.000
	M110 SASS Experience	0.714	0.000
	Types of Rifles Carried	n/a	n/a
	Rank	n/a	n/a
	Time in MOS	0.590	0.000
Shooting Tasks	EI Presidente Hit Points T2	0.235	0.000
	Known Distance Qualification	0.758	0.000
Physical Steadiness	Weapon Hold (s)	n/a	n/a
Demographics	Age	0.526	0.000

Table 23. Friendly fire: KD qualification and IF correlations

IFs	Specific IF variable	KD Qualification	
		<i>R</i>	<i>p</i>
Physiological	Average Heart Rate (bpm)	n/a	n/a
	Snellen Visual Acuity, Left Eye	−0.871	0.000
Psychological	Chalder Fatigue Scale	0.199	0.000
	New General Self Efficacy	0.096	0.000
	Stanford Sleepiness Scale	0.172	0.000
Cognitive	WMC – OSPAN Math Accuracy	0.338	0.000
Physical Fitness	Sports Hours/Week	0.132	0.000
Physical Strength	Grip Strength, Left Hand	0.229	0.000
Anthropometric	Right Upper Arm Length	−0.249	0.000
Experience	M4/M16 Weapons Experience	0.312	0.000
	M110 SASS Experience	0.183	0.000
	Types of Rifles Carried	n/a	n/a
	Rank	0.127	0.000
	Time in MOS	0.290	0.000
Shooting Tasks	EI Presidente Hit Points	0.758	0.000
	Known Distance Qualification	n/a	n/a
Physical Steadiness	Weapon Hold (s)	−0.328	0.000
Demographics	Age	0.121	0.000

Table 24. Friendly fire: shooter experience level and IF correlations

IFs	Specific IF variable	Shoot Level	
		<i>R</i>	<i>p</i>
Physiological	Average Heart Rate (bpm)	−0.120	0.000
	Snellen Visual Acuity, Left Eye	−0.190	0.000
Psychological	Chalder Fatigue Scale	0.196	0.000
	New General Self Efficacy	0.337	0.000
	Stanford Sleepiness Scale	0.108	0.000
Cognitive	WMC – OSPAN Math Accuracy	0.119	0.000
Physical Fitness	Sports Hours/Week	0.386	0.000
Physical Strength	Grip Strength, Right Hand	0.634	0.000
Anthropometric	Right Upper Arm Length	−0.524	0.000
Experience	M4/M16 Weapons Experience	0.701	0.000
	M110 SASS Experience	0.555	0.000
	Number of Rifles Carried	−0.205	0.000
	Rank	0.111	0.000
	Time in MOS	0.603	0.000
Shooting Tasks	EI Presidente Hit Points	n/a	n/a
	Known Distance Qualification	0.299	0.000
Physical Steadiness	Weapon Hold (s)	−0.108	0.000
Demographics	Age	0.565	0.000

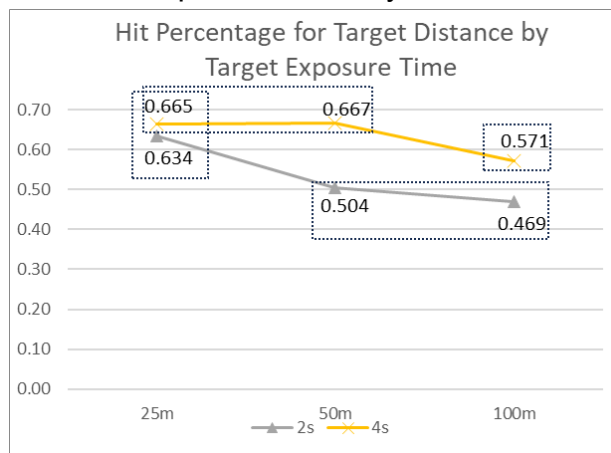
5.2 Data Outcomes

Analyses are depicted in terms of the experimental variables only (Model 1) as compared to experimental variables and IF (also known as predictor or covariate) variables (Model 2). All mean data are charted so that numeric and visual comparisons of values and trends can be made between the two models. All data plotted are for the two-way interaction effect of target exposure time (2 or 4 s) by target distance (25, 50, or 100 m) only. Significant post-hoc analyses (least significant difference) are depicted with dotted boxes to show statistically similar groupings of data (within a box) and dissimilar groupings of data (separate boxes, unless otherwise noted as no significant differences at all).

5.2.1 Hit Percentage

It can be easily seen that the effect of the IF-included models (Model 2) had a drastic effect upon the mean values as compared to the experimental model only (Model 1). For example, the hit percentage was drastically lower and yielded more specific significant condition separation data via post-hoc analyses (Figure 11).

Model 1: Experimental Only



Model 2: Experimental + IFs

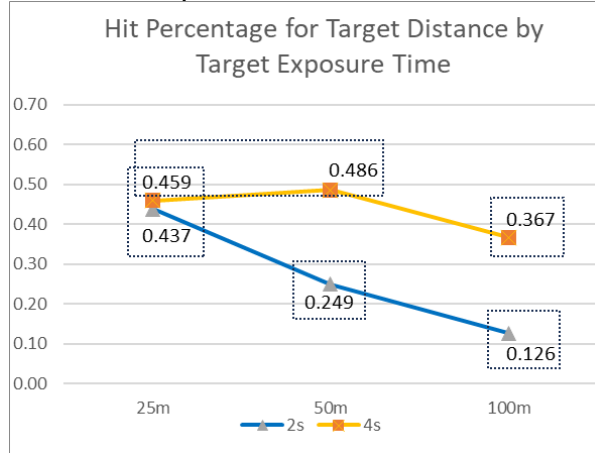
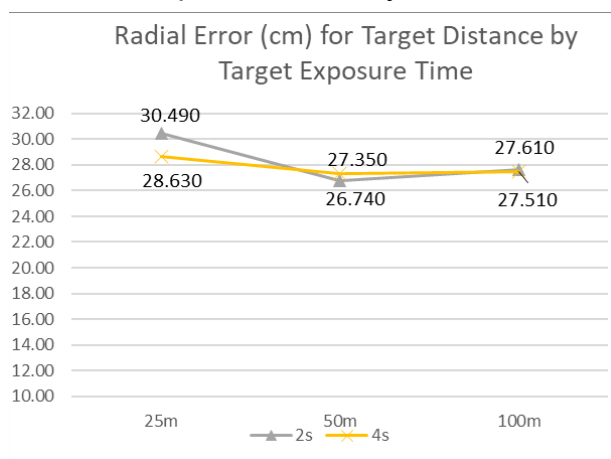


Figure 11. Hit percentage: mean comparison by model type

5.2.2 Radial Error

The same can be said for radial error outcomes, showing that Model 1 had no significant post-hoc differences while Model 2 yielded drastically lower performance outcomes and clearer distinctions between specific cell performance (Figure 12).

Model 1: Experimental Only



Model 2: Experimental + IFs

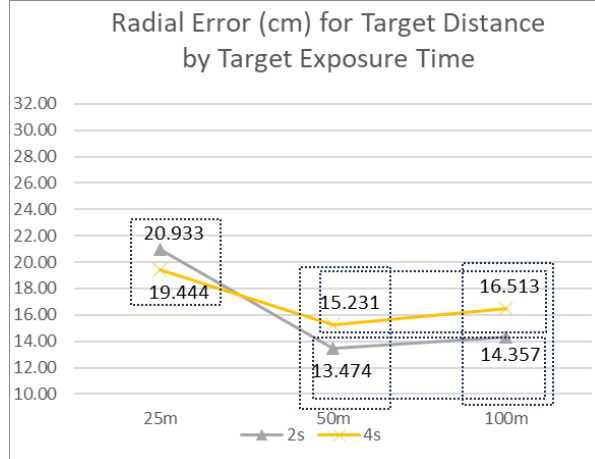


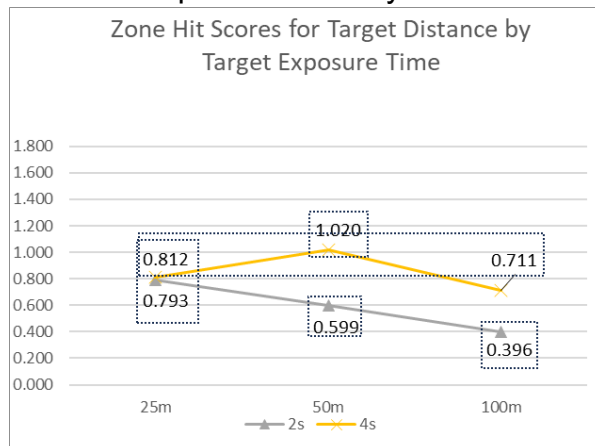
Figure 12. Radial error: mean comparison by model type

5.2.3 Zone Hit Scores (A, C, D)

For zone hit scores, the cell differences remained almost the same except for a cell difference between 2 and 4 at 25 m. However, the scoring change direction was changed to yield higher zone hit scores for Model 2 over Model 1 (Figure 13).

Model 2: Experimental + IFs Model

Model 1: Experimental Only



Model 2: Experimental + IFs

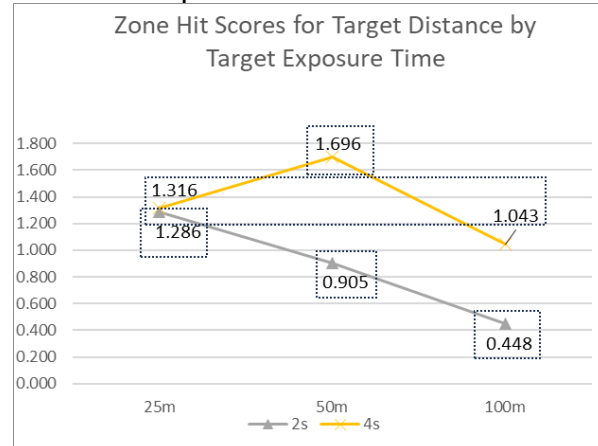
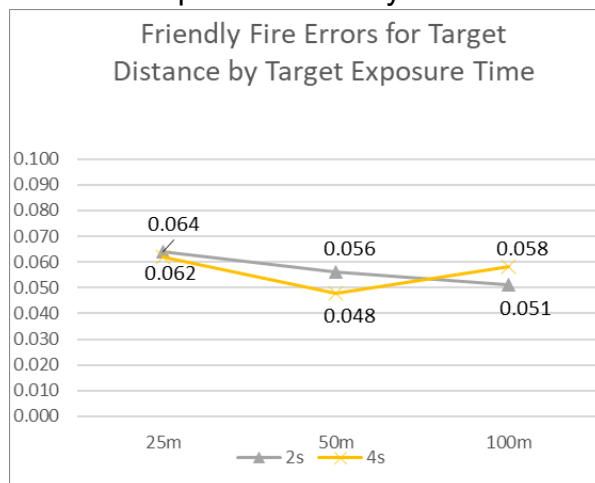


Figure 13. Zone hit score: mean comparison by model type

5.2.4 Friendly Fire Decision Error

Additionally, within Figure 14, friendly fire error rates showed no cell differences at all; however, Model 2 error rates were largely increased by about 30%.

Model 1: Experimental Only



Model 2: Experimental + IFs

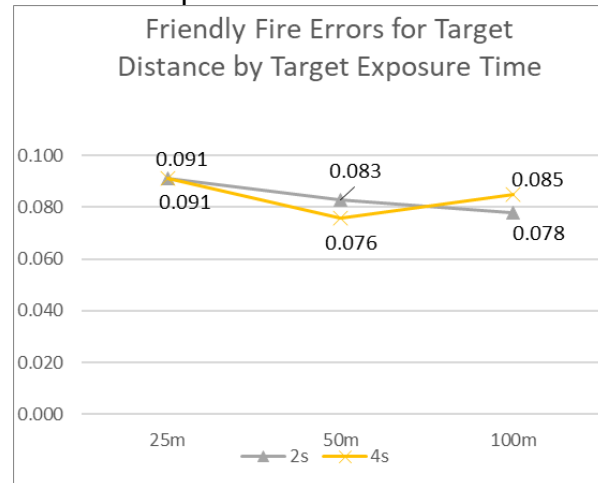


Figure 14. Friendly fire decision error: mean comparison by model type

5.3 Principal Component Analyses (PCA): IFs

This PCA analysis was added to demonstrate if any of the IFs variables were measuring the same physical/psychometric constructs. Table 25 shows all the IFs employed in the correlational and ANOVA/ANCOVA analyses for mean and standard deviation (SD) data development within. From the 12 IF variables that were both significant and intuitive in directional effects, PCA component 1 consisted of four apparently related IFs: weapon hold stability, El Presidente shooting task points, right-hand grip strength, and

M4/M14 experience elements. Components 2 through 9 each loaded onto their own individual constructs and were uniquely separate for right-hand length, right eye acuity, CFS score, KD qualification shooting score, sports physical activity hours per week, OSPAN absolute score (working memory capacity), NGSE score, and SSS scores, respectively. The method of PCA used employed Varimax rotation for maximal separation of construct effects.

Table 25. PCA for IF measures

Rotated Component Matrix	1	2	3	4	5	6	7	8	9
Weapon Hold Stability (s)	0.614	-0.505	0.278	0.189	0.199	0.033	0.107	0.139	-0.380
KD Qualification Score	0.135	0.016	-0.161	0.081	0.961	0.031	0.029	0.026	0.102
EI Presidente Points	0.764	-0.221	-0.056	0.028	0.273	0.282	-0.225	0.096	-0.110
Chalder Fatigue Scale Score	-0.021	0.017	-0.129	0.944	0.072	-0.032	-0.137	-0.042	0.224
New General Self-Efficacy Score	0.140	-0.203	-0.055	-0.057	0.032	0.029	0.124	0.945	-0.147
Stanford Sleepiness Score	0.069	0.072	-0.129	0.450	0.173	0.024	-0.025	-0.204	0.816
OSPAN Absolute Score	-0.186	0.022	0.209	-0.138	0.032	0.012	0.932	0.128	-0.027
Grip Strength - Right Hand	0.759	0.078	0.420	-0.029	0.015	0.309	-0.158	-0.080	0.147
Visual Acuity - Right Eye	-0.044	-0.027	0.894	-0.170	-0.213	-0.013	0.261	-0.050	-0.129
Right Hand Length	0.031	0.974	0.005	0.047	0.036	0.009	0.034	-0.170	0.031
M4/M16 Experience (yrs)	0.868	0.182	-0.361	-0.063	-0.013	0.056	-0.048	0.173	0.118
Physical Activity - Sports (h/wk)	0.272	0.006	0.001	-0.028	0.031	0.956	0.018	0.029	0.012

5.4 Means and Standard Deviation Data by Target Distance and Target Exposure Time for Modelling Soldier Performance

Tables 26–29 list potential Soldier performance behavior distributions for such systems as IMPRINT Pro. The distributions may be built using the means and SDs for each dependent measure to build out the ± 3 SDs to create the 68% (1 SD), 95% (2 SD), and 99.7% (3 SD) distributions.

Table 26. Hit percentage means and SDs for target distance by target exposure time

Time	25 m	50 m	100 m
2 s	Mean = 20.933 SD = 10.525	Mean = 13.747 SD = 8.167	Mean = 14.357 SD = 8.478
4 s	Mean = 19.444 SD = 7.714	Mean = 15.231 SD = 8.470	Mean = 16.513 SD = 7.915

Table 27. Radial error (cm) means and SDs for target distance by target exposure time

Time	25 m	50 m	100 m
2 s	Mean = 1.286 SD = 1.687	Mean = 0.905 SD = 1.735	Mean = 0.448 SD = 1.326
4 s	Mean = 1.316 SD = 1.687	Mean = 1.696 SD = 2.032	Mean = 1.043 SD = 1.655

Table 28. Zone hit score means and SDs for target distance by target exposure time

Time	25 m	50 m	100 m
2 s	Mean = 0.091 SD = 0.270	Mean = 0.083 SD = 0.273	Mean = 0.078 SD = 0.263
4 s	Mean = 0.091 SD = 0.283	Mean = 0.076 SD = 0.255	Mean = 0.085 SD = 0.270

Table 29. Friendly fire decision error percentage means and SDs for target distance by target exposure time

Time	25 m	50 m	100 m
2 s	Mean = 0.437 SD = 0.498	Mean = 0.249 SD = 0.435	Mean = 0.126 SD = 0.332
4 s	Mean = 0.459 SD = 0.500	Mean = 0.486 SD = 0.502	Mean = 0.367 SD = 0.484

6. DISCUSSION

6.1 General Findings

6.1.1 General Hypothesis Support

Overall, the general pattern of IF predictors that emerged from this analysis supported projected hypotheses suggested by Scribner and Morelli (2020) and fully supported all three alternative hypotheses described within Scribner et al. (2023) which specifically demonstrated that increased explained variance was observed when adding IFs into the experimental and statistical design of marksmanship/shooting studies.

6.1.2 Correlational Structure Analysis

Within this report, detailed correlational structure analysis supported the hypothetical model structure outlined by Scribner and Morelli (2020) for several measures of shooting performance, particularly within the target, prestudy shooting tasks, shooting stability, and experimental independent Soldier performance shooting and decision-making measures. Included are newly found significant general relationships between IF and shooting measures as well as direct and indirect effects of target characteristics upon shooting measure outcomes (Figure 15).

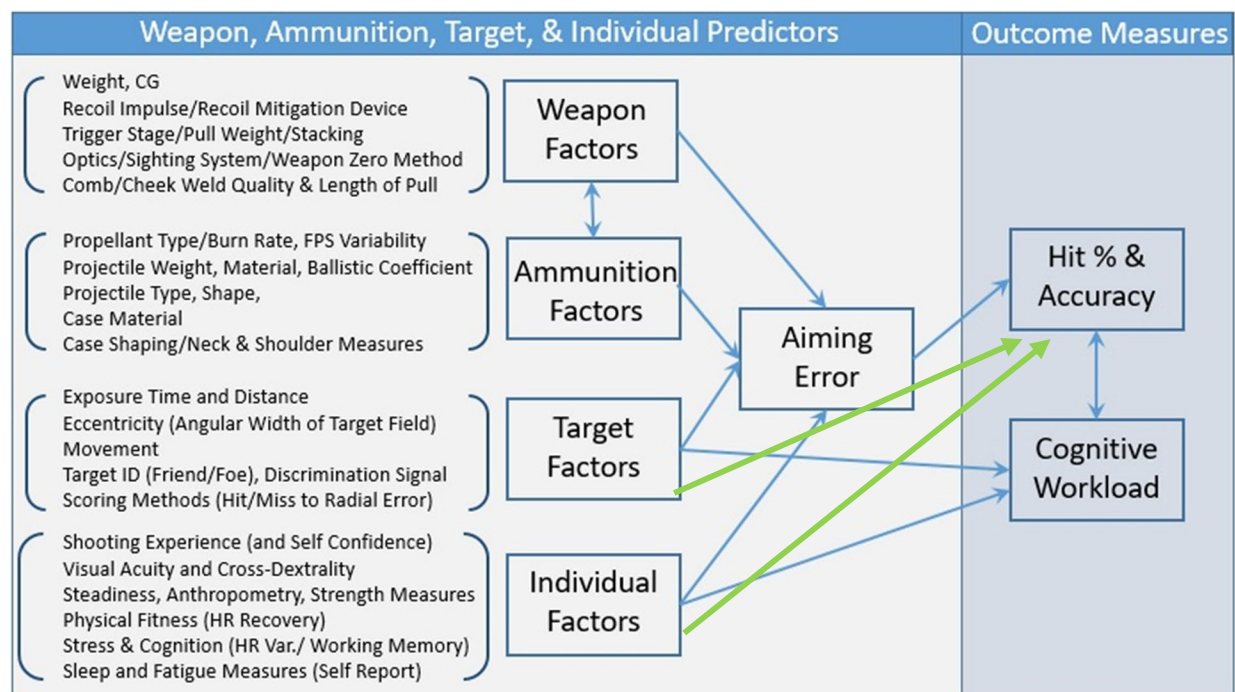


Figure 15. Updated model of factors that influence marksmanship performance

6.1.3 IF Variable Categories

As it can be seen throughout the tables of Section 5, all categories of IFs including cognitive, psychological, physiological, anthropometric, and strength measures had a positive effect upon providing improved data sets for either field experiments to analyze outcomes for systems within the acquisition cycle or for modeling Soldier performance within systems such as IMPRINT Pro.

6.1.4 IF Model Mean Values

Specifically, data sets for mean values were demonstrated to be disparate between all Model 1 and Model 2 marksmanship/shooting scores. It is easily determined through numerical and visual comparison that the two different models create two disparate sets of data in most cases. Specifically, scores were different when including IFs for hit percentage, radial error, and friendly fire decision making errors, but not for zone hit scores, which remained essentially the same when including IFs.

6.1.5 Experimental Model Mean Values

The Soldier performance is typically inflated for experimental-only performance and lower when IFs are added to the model. It is believed that the IFs offer a truer picture of Soldier performance because of the accounting of individual differences within the data and considering the unanimous increased explained variances in all models published by Scribner et al. (2023).

6.1.6 Principal Component Analysis

PCA revealed that eight of the IFs were considered separate constructs and individually different from each other while one component included four of the IFs into it as one (see Section 5.3). This suggests that while there is a shooting task/experience/anthropometric link among some variables, the others are capturing essentially nonoverlapping constructs for all other IF.

6.1.7 Mean and Standard Deviation Modeling Data

Finally, examples of means and SD data were included for potential modeling purposes using the experimental and IF data sets, which may be inserted into an IMPRINT Pro model.

6.2 Hypothesis and Structural Model Support

6.2.1 IF Model Support

The IF model (Figure 15; Scribner, 2013; Scribner & Morelli, 2020) demonstrates that marksmanship experiments based solely upon experimental-only variables such as target distance, target exposure time, target discrimination, weapon characteristics, etc. may not be the best method in explaining marksmanship and decision-making performance under cognitive workload and stress (Gaillard, 2008). Beyond issues of predictive validity, the IF model has strong implications for both theoretical and practical ergonomics. The IF model has been supported by ANOVA/ANCOVA models, multiple regression, and correlation relationship analyses, which implies that typical experimental variables and IF are often strongly interrelated. Such future research and analysis efforts should include IFs for superior data outcomes and systems analysis clarity for analysis associated with acquisition within the Army and other services. Figure 15 has within it two additional relationships; target factors affecting Soldier marksmanship measures and IFs that directly affect Soldier marksmanship measures, as supported by numerous correlational analyses within.

6.2.2 Research Question

Research question 1 clearly shows that there is a general, yet more specific, similarity to the hypothesized model, supporting the first hypothesis. Research question 2 is clearly supported as there is a distinct difference in mean data using the IF models for hit percentage, radial error, zone hit score, and friendly fire decision errors.

6.2.3 Practical Application

For practical ergonomics, the correlation data and associated structural models 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 using individual differences in marksmanship research of all types where a Soldier or human is in the control loop, especially in modeling contexts.

6.3 Methodology Suggestions for the DOD Modeling Community

It is proposed, with further research, that the new correlational structural model frameworks (Section 5.1) be examined as a potential overarching guide for understanding the interrelationships within marksmanship and shooting data. The individual and target factors discussed herein can be applied to almost any shooting study with minimal change through the prestudy administration of the measures discussed in this proposal.

7. CONCLUSIONS

Through this methodology application, future studies may continually reveal data that better informs small-arms decision makers and small-arms design decisions through the following:

- An overarching IF model framework, based upon supporting correlational analysis, for shooting and marksmanship research that may serve to create more informed hypotheses and increase understanding the impact of more complex variable structural and mediator/moderator relationships on outcome measures.
- Considerably stronger and cleaner data sets through the use of these prestudy HSI measures as covariates, which essentially help clean up and filter unaccounted-for noise within the data to provide data with truer mean and standard deviation values of performance data via higher explained variance.
- A better understanding of the holistic effects of IFs variables within the shooting research discipline that may serve as a future methodological change and benefit to the shooting research community.

Additionally, conclusions from the previous study (Scribner et al., 2023) support the idea that this methodology provides:

- Enhanced statistical explanation of effects and effect sizes.
- Higher confidence in quantitative statistical and practical significance of effects and effects size differences for acquisitions and various ACAT systems within the Army.
- A better overall understanding of the HSI aspects and variables associated with marksmanship and shooting studies.

In summary, the general application of this methodology is also highly likely to provide notable beneficial HSI analysis for systems evaluation outside of marksmanship and shooting research studies, of which there is some yet unpublished but strong evidence.

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Appendix A – Demographic and Experience Questionnaire

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

Date: _____

Subject number: _____

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 _____

Weapons Experience cont.

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

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		
Weightlifting		
Core strengthening		
Playing sports		

Appendix B – 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 C – 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 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

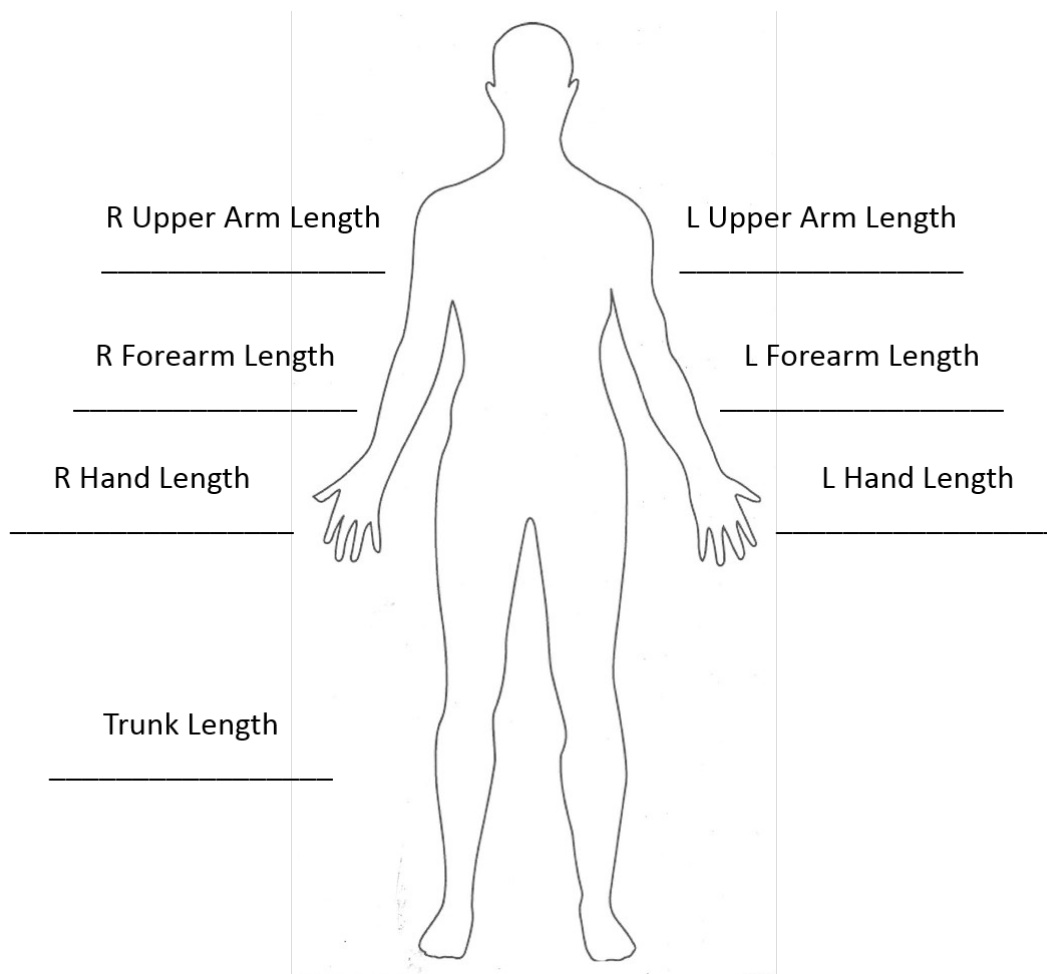
3=somewhat highly agree

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 – Anthropometry: Individual Body Dimensions and Strength Measurements

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



Body Dimension Measures

- Upper arm length = acromion to radiale landmark at elbow
- Forearm length = radiale landmark at elbow to inner stylium at wrist
- Hand length = inner stylium on the wrist to tip of middle finger
- Trunk height = height between acromion and omphalion

LIST OF ACRONYMS

AMU	U.S. Army Marksmanship Unit
ANCOVA	analysis of covariance
ANOVA	analysis of variance
AOSPAN	Automated OSPAN task
ARL	Army Research Laboratory
ANS	autonomic nervous system
bpm	beats per minute
C2	command and control
CFS	Chalder Fatigue Scale
DEVCOM	U.S. Army Combat Capabilities Development Command
DOD	Department of Defense
HRR	Heart Rate Recovery
HRV	Heart Rate Variability
IF	Individual Factor
IPT	information-processing theory
KD	known distance
M-Range	M-Experimental Facility
MOS	Military Occupational Specialty
NGSE	New General Self-Efficacy
OSPAN	Operational Span
PCA	Principal Component Analyses
ROE	rules of engagement
SD	standard deviation
SOP	standard operating procedure
SSS	Stanford Sleep Scale
TST	transactional stress theory
WL	workload
WMC	working memory capacity