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# **A Methodology to Examine the Effects of Individual and Target Characteristic Factors on Marksmanship Task Performance Based Upon a Structural Shooting Model Framework**

by David Scribner and Frank Morelli

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*CCDC Data & Analysis Center*

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## 1. INTRODUCTION

Marksmanship scores and accuracy are known to be affected by many factors including weapon, ammunition, target, and individual characteristics. Human System Integration (HSI) is about understanding the system as well as the human within the system. 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 framework with which to explain differences in performance.

Numerous studies exist that highlight such mechanical factors as weapon weight, weapon configuration, shooting position, and recoil dynamics. There is not much research in the open literature regarding the effect of ammunition characteristics on marksmanship, but as many reloaders and Army Marksmanship Unit personnel know, the “secret sauce” for accuracy can be the individual ammunition load selected. There have also been studies that include target size, target type, target motion, and target exposure time. This research proposal concentrates on the individual and target factors within the shooting research domain.

The first category of factors to be investigated is the individual differences identified in numerous theories that have become increasingly more important in human factors and ergonomics research (Weaver et al., 2003). Very few of these factors have been investigated in shooting performance (Stafford et al., 2004). Stafford et al. (2004) posited that measures of stress, cognitive and emotional state, and personality tests were important factors in determining shooting ability. Individual characteristics such as shooting experience, visual acuity, strength, physical fitness, postural steadiness, stress susceptibility, and cognitive traits may also contribute to marksmanship performance. Many marksmanship studies that examined separate characteristics have been performed in isolation; however, no study has attempted to merge many of these weapon, target, and individual factors into a singular study to assemble the covariates or predictors of shooting performance.

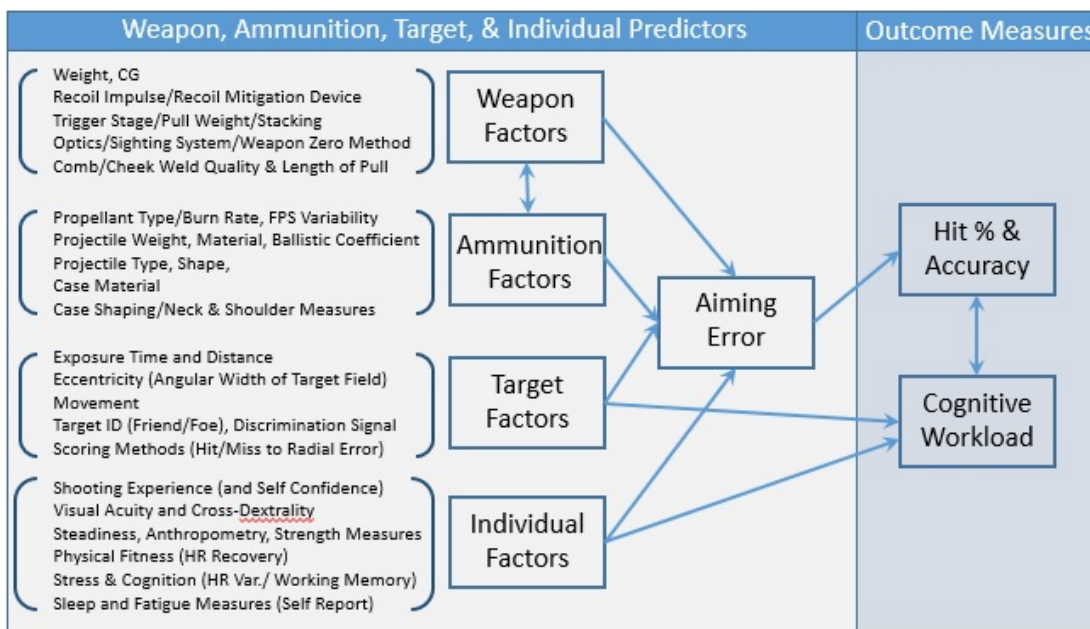
The second aspect of this proposal concentrates upon the target characteristics that are known to help reveal performance differences through “target stress”. Target stress is the recognition that if target exposure time, distance, and eccentricity in presentation angles are not accounted for, it is quite easy to experience floor and ceiling effects that could show no to little difference. This is why target characteristics for each study must be carefully considered within each marksmanship or shooting study.

This is highly important as many shooting studies have not provided enough task stress to reveal significant differences among shooting conditions. For example, a group of Soldiers within a shooting study that employs 8-s target exposures within a narrow field of view will not reveal the same difference that a higher-stress target set will; perhaps 3-s target exposures using a wider field of view for available targets would produce more useful results. This type of target-induced



stress is critical to the examination of marksmanship performance that could allow for statistical floor or ceiling effects that would be a waste of critical research effort, time, and funding.

These various factors are briefly explored and discussed to formulate a broad multifaceted and multi-theoretical approach toward examining predictors of marksmanship and even secondary task performance. A model of shooting performance is offered as a structural framework by which to test the various measures and constructs that are examined in this research proposal. An overall structural model of marksmanship performance is included to give the reader a sense of the layout of proposed variables, and those individual and target factors that are believed to be highly relevant to the future success of shooting research (Figure 1).



**Figure 1. Shooting performance model**

Marksmanship scores and accuracy effects can be well studied in conjunction with individual characteristics such as shooting experience and confidence, visual acuity and dexterity, steadiness and strength, physical fitness (resting beats per minute [bpm] and heart-rate recovery [HRR]), stress and cognition, as well as the sleep and fatigue levels of the shooters. As mentioned, many marksmanship studies that examined separate characteristics have been performed in isolation; however, no study has attempted to merge many of these 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 that may reveal statistical and practical differences that prior to this may have been concealed within the data as nonsignificant.

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These various factors are briefly explored and discussed to formulate a broad multifaceted and multi-theoretical approach toward examining predictors of marksmanship task performance based upon these individual and target factors. *These factors can be combined with currently planned and future marksmanship studies with a relatively small time investment in the pre-study data collection phase.*

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## **2. INDIVIDUAL CHARACTERISTICS**

Individual characteristics are often collected via a demographic survey, which is a highly important tool to understand the sample for a shooting study. Various physical, cognitive, and other characteristic measures have been positively associated with marksmanship performance. Individual differences identified in numerous theories have become increasingly 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).

### **2.1 Experience and Self-Efficacy (Confidence) via Demographic Questionnaire**

#### **2.1.1 Shooting Experience**

A demographics questionnaire should be used to collect background and individual characteristic information from each participant. Data should include age, gender, military occupational specialty (MOS), time in service, rank, and various questions regarding shooting and combat experience.

#### **2.1.2 Situational Self-Efficacy (Self-Confidence in Shooting Ability)**

Bandura (1977) has shown 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 individual factor in job performance. As such, self-efficacy scoring is a good indicator of how individuals may perform under task loads. Self-efficacy scales have been developed, yet many have come under scrutiny because of their specific task-focused nature (Lee & Bobko, 1994). Lauterbach and Vielhaber (1966) demonstrated that a subject's confidence in their firing ability is the single best predictor of their scores. Several self-efficacy scales have been developed recently and one has shown to have acceptable test-retest reliability and internal validity: the New Self-Efficacy Scale (NGES) (Chen et al., 2001) has emerged as a reasonably good motivational trait measurement. The new NGSE is reported to have a test-retest reliability of  $r = 0.67$  and an internal consistency of 0.86 (Cronbach's alpha).

### **2.2 Visual Acuity and Dextrality**

#### **2.2.1 Visual Acuity**

There is a strong relationship between visual acuity and marksmanship performance (Du Toit et al., 2011; Wells, 2009). Data yielded strong results citing a statistically significant correlation of 0.735 between marksmanship scores and visual acuity. Explained variance for visual acuity in this study that accounted for 54% of the variance in marksmanship performance was accounted for by visual acuity. Regression modeling suggested that there was a significant ( $p = 0.001$ ) decrease in marksmanship performance when Snellen acuity ratings are changed from 20/25 to

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20/50. Based on this simple and highly telling study, it is suggested that acuity scores will significantly affect marksmanship performance and that an accurate Snellen acuity rating should be assessed for each participant via a 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.

### **2.2.2 Dextrality**

Although there is not much data on the topic, it is generally thought that pure dextral shooters, or those who 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 contra-lateral dominant or cross-dextral person. A young small-bore shooter who could not raise their scores above intermediate range switched positions to give the dominant eye favor with great success (Anderson, 1980). Very few contra-lateral shooters exist in the top 50 for each shooting discipline. 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.

## **2.3 Steadiness, Strength, and Anthropometry Measures (Physical Factors)**

### **2.3.1 Steadiness (Stability of Hold)**

The applied control of the autonomic nervous system (ANS), heart rate (HR), 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. For example, Hoffman et al. (1992) found that the intensity of exertion immediately prior to biathlon shooting affected the stability of hold for standing much more than for prone firing. The decrease of rapid heartbeat by biathlon shooters was accomplished by their extreme physical fitness and drops from 90% of maximum HR to 85%–87% in the 50–60 s while approaching the firing line and then down to 61%–73% at the shooting position. This HR drop shows the effect of physical fitness on the body in elite shooters to reduce their HR by as much as 20 bpm in the prone position (Hoffman & Street, 1992). Further, Konttinen et al. (1998) found that in a simulated shooting study examining barrel movement, elite shooters tend to balance their rifles significantly better than pre-elite shooters, thus increasing their accuracy in shooting scenarios. Elite shooters concentrated on stabilizing the rifle faster through psychomotor regulation while pre-elite shooters concentrated on visual-spatial processing. This shows interesting differences that may have physical, experience, and cognitive factors. Evidence in electroencephalography (EEG) support also showed that skilled shooters demonstrated more left-hemispheric brain activity during the aiming process until trigger pull (Hatfield et al., 1984, 1987). Further, Lakie (2010) suggests that the large sources of muscle tremor in the 8- to 12-Hz range are affected by muscle cooling and heating, adrenaline, alcohol,

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and other biological sources. Lakie also states that tremors in elite shooters are roughly half that of control subjects.

It is suggested that a stability of hold measure be used to assess the time to hold a consistent bull's-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 be sought to determine the speed of a 4-s bull's-eye hold to determine each participant's postural stability disposition.

### **2.3.2 Strength and Anthropometric Measures**

Data yielded by Shorter et al. (in press) identified several anthropometric measures as important to accounting for individual variance in shooting performance. In this study, both target distance and the anthropometric measure of hand circumference were important. 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%, a sizable increase to say the least. The data also suggests that several other hand and arm anthropometric measures may have moderate correlation with marksmanship outcome measures.

Preliminary hierarchical regression results for this data subset set shows that two different prediction models were significant. Two significant hierarchical regression models emerged based upon several different groupings for predictor variables: target distance, anthropometric body measurements, and strength characteristics. Model 1 (target distance) explained 38.3% of the variance, whereas model 2 (target distance and hand circumference) explained 57.4% of the explained variance.

### **2.4 Physical Fitness Level**

Physical fitness is associated with general increases in many physical performance tasks (Le Meur et al., 2010). Physical fitness is also associated with marksmanship (Brown et al., 2013). ANS activity is often associated positively with stress and anxiety. Elite Olympic shooters are able to control certain aspects of their ANS including the ability to decelerate their HR prior to squeezing the trigger and have suggested that VO<sub>2</sub> max levels may be important in predicting success in biathlon shooting scores (Rundell & Bacharach, 1995). Because VO<sub>2</sub> max levels are more complicated than other physical fitness measures, it was suggested that alternative measures of physical fitness be assessed for field-expedient use.

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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 skill such as rifle shooting. It is suggested that a physical fitness measure of *baseline beats per minute* and *HRR* be used to assess this aspect, using the number of seconds to regain previous individual resting HR levels after an 80% aerobic treadmill run.

**Baseline beats per minute and HRR.** For 1-min resting, this baseline measure will be used as the recovery goal for a sustained 2-min running aerobic test at 80% of maximum calculated HR for that participant's age.

## 2.5 Stress and Cognitive Factors

### 2.5.1 Stress Measures

There is ample research positing that measures of stress, cognitive and emotional state, and personality tests were important factors in the determination of shooting ability (Sade et al., 1991; Stafford et al., 2004). They found that stress outcomes were sensitive to the shooting task, but that personality measures yielded little useful information. There is also a proposed relationship between stress and performance (Delahajj & Gaillard, 2008; Delahajj et al., 2011; Eysenck, 2007; Hayes et al., 2008).

Shooting error research, which is relatively new, has primarily focused on the measurement of fratricide. Several studies have been published that discuss shooting decision error (Burke, 2007; Kerick et al., 2007; Scribner 2002; Scribner & Harper, 2001). Both Scribner and Kerick have 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. Morgan et al. (2007) found that lower baseline HR variability (HRV) scores (RR), which are indicative of central-peripheral neural feedback mechanisms, were significant predictors of performance under stressful conditions.

It is proposed that two physiological measures be used as covariates/predictors of marksmanship performance. These physiological premeasures have been shown to be related to cognitive performance and stress resilience, although induced stress will not be manipulated in this study. The ANS consists of both the sympathetic nervous system (SNS) and parasympathetic nervous system (PNS), respectively (Pinel, 2009). The active SNS is associated with stress, tension, heightening of arousal, and energy use responses, while the PNS is associated with relaxation, lower arousal, and energy conservation (Pinel, 2009). When stress is increased, the SNS is more active than the PNS.

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**Baseline HRV or R-R wave.** HRV is a specific measure of ANS activity on the circulatory system, typically R-wave to R-wave variability. This type of analysis was termed the inter-beat-interval by some. There are three wave components associated with electrocardiography (ECG) wave patterns called Q-, R-, and S-waves. The R-wave is the positive wave component (or upward portion of the wave in a single heartbeat). There are several frequency components used in the measurement of R-wave variability according to Berntson et al. (1994). HRV has been shown to be a very good measure of stress (Esco, 2010; Grant et al., 2009). Ottaviani et al. (2007) performed a study with 45 participants, in which the Berntson model of SNS-PNS activity was supported. The measurement of HRV was required to generalize cardiovascular reactivity to different daily tasks consisting of simple hand strength, cognitive processing of math problems, thinking situations of past or present stressors, and visual-psychomotor tasks. The authors found that ANS reactivity in their laboratory tasks may reflect ANS reactivity to physiological responses to everyday life situations. Murray et al. (2007) have claimed that HRV is the new standard by which ANS functioning and response will be measured. The R-R wave may also be a good premeasure or predictor of stress under cognitive task demands.

There is ample evidence that HRV and HRR measures are related (Lee & Mendoza, 2009). Morgan et al. (2007) have demonstrated that the R-R wave (HRV) is an effective premeasure for demanding cognitive tasks and/or stressful events. Patton (2014) demonstrated that R-R wave variability was significantly reduced under electrical shock feedback conditions in a simulated shooting task.

### **2.5.2 Cognitive Factors**

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 simultaneously with shooting tasks. Theoretical models regarding human multiple task performance are best explained by Wickens (1984a; 1984b) who expanded an attentional resource theory by Navon and Gopher (1979). One of the other related and recent theoretical models of working memory was proposed by Baddeley and Hitch (1986). Cognition certainly has a place within shooting research, as some of the literature reviewed in short format provides evidence of this. It is believed that working memory capacity (WMC) is one of the central measures to cognition that may well serve tightly controlled marksmanship studies where target stress and other factors may be of concern (Baddeley, 1992; Beilock & DeCaro, 2007; Engle, 2002; Turner & Engle, 1989). As early as 1956, MacCaslin and McGuigan performed a study showing that both cognitive function and firing experience had a positive effect on predicted marksmanship.

Single- and multitasking, in their most demanding and crucial form for the dismounted infantry Soldier, and the effects of shooting under cognitive load have been studied by the U.S. Army Combat Capabilities Development Command (CCDC) Army Research Laboratory (ARL) in recent years (Coolidge & Wynn 2005; Kelley & Scribner, 2003; Kerick et al., 2007; Scribner,

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2002; Scribner & Harper, 2001; Scribner et al., 2004) to characterize discriminatory friend or foe shooting tasks with secondary tasks to beneficial task displays for use with shooting (Ogden et al., 1979). Further, Scribner (2016) found that WMC was significant in predicting shoot/don't shoot decision making.

Cognitive or mental workload is a factor in shooting and secondary processing tasks has been shown to degrade friend or foe decision making (Scribner, 2016; Scribner & Harper, 2001). Therefore, measures accessing the central executive function attentional resource such as WMC may have some effect under marksmanship shooting scenarios (Catarini et al., 1995). It is highly feasible that WMC may be a generalizable individual factor that factors into such general cognitive tasks as marksmanship. It is proposed that WMC, as measured by the Operational Span (OSPAN; Turner and Engle [1989]) 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. This OSPAN task requires that participants maintain a list of letters while processing unrelated mathematical information to measure the construct of WMC. There exists an automated version called the AOSPAN (Unsworth et al., 2005).

## **2.6 Sleep and Fatigue Factors**

### **2.6.1 Sleep Quality**

It is well known that alertness and cognitive readiness depend upon a well-rested and nonfatigued individual. Sleep is essential to normal cognitive functioning especially under stressful conditions. It is also thought that diminishing cognitive abilities are caused by lack of proper sleep and rest (Hoddes et al., 1973). 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. Sleep deprivation can be detrimental to cognitive performance and especially so for marksmanship performance. Scribner et al. (2007) performed a continuous operations marksmanship study in which a significant curvilinear relationship between enemy hit percentage and the number of sleepless hours was found.

It is proposed that a simple measure, the Epworth Sleepiness Scale (ESS; Johns, 1992), can be effective. A validated sleep scale could be employed to capture each participant's restfulness. The Stanford Sleep Scale has also been used widely, and is fairly simple and expedient to administer to a large number of participants. Daytime sleepiness is a construct that is distinct from fatigue, which is discussed next.

### **2.6.2 Chalder Fatigue Scale (CFS)**

As for fatigue, the CFS (Chalder et al., 1993) is reported to have both physical and mental fatigue reliability ratings of  $r = 0.86$  and  $r = 0.85$ . The ESS and CFS can be used to assess daytime sleepiness and fatigue, respectively (Bailes et al., 2006).



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### 3. TARGET CHARACTERISTICS

#### 3.1 Target Exposure Time

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 data in Table 1 demonstrate a trend for older weapons systems and are not thought to reflect the same pattern for today's military weapons, yet the general trend demonstrates a pattern of increased aiming accuracy as target time increases. The overall aiming error ratio, in mils, for experts to novice shooters, was 2.3 to 1 and increases for standing versus prone fire. Unharassed accuracy for permanent targets with the rifle was 3 mils.

**Table 1. Aiming Error (mils) for Both Rifles/Carbines by Target Exposure Time**

<b>Target Exposure Time (s)</b>	<b>1</b>	<b>1.5</b>	<b>2</b>	<b>4</b>	<b>8</b>
Rifle/Carbine Aiming Error	20.3	10.3	7.5	4.5	3.3
Pistol Aiming Error	40.0	29.0	24.2	19.5	17.2

Ahituv et al. (1998) have identified the importance of time pressure on general decision making. Aiming error can be directly associated with marksmanship accuracy. For example, Scribner (2002) found that target exposure time for live-fire targets significantly affected hit percentage in 2-, 3-, and 4-s target exposures and hit percentages 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. Further, it is also expected that hit percentage and accuracy will suffer a degradation of at least 50% under this set of target exposure times, based on previous research. It is interesting to note that target accuracy under increasing time constraints acts much the same as predicted by Fitts' law (1954).

#### 3.2 Target Distance

Various distances for targets will also be randomized among 25, 50, 100, 200, and 300 m.

#### 3.3 Target Eccentricity (Total Field of Target Presentation Angles)

#### 3.4 Friend-or-Foe Target ID Discrimination and Target Saliency Signal Strength

Scribner (2002) found that the number of friendly targets engaged under cognitive load as compared to no cognitive load increased by approximately three times. The percentage for no load to loaded increased from 1.6% to almost 5%. This is a highly practical finding that should be considered by dismounted warrior systems and by all Army and other services' systems. The effect of cognitive load in this case is also considered quite conservative. It is projected that in a

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dual-task scenario that was channel competitive, such as two visual tasks, the percentage of friendly targets engaged would dramatically increase over 5%. Note that the gray friendly target signature, which increased workload because of higher discrimination difficulty and longer target identification time, increased friendly fire engagements for nonloaded to loaded from 1.2% to almost 10%. It is thought that the white friendly target signature was too easy a discrimination task because of the high contrast that it provided on the E-type silhouette.

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## 4. TARGET SCORING METHODOLOGIES

There are numerous ways to score targets for shooting research including providing simple hit or miss scores and ratios; target scoring systems as used by local, state, and federal law enforcement; and directional radial error data.

### 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 et al., 2001) and in assessments of display modalities for secondary tasks while shooting (Scribner et al., 2004, 2007). This is not recommended as it is the least-granular data.

### 4.2 E-Silhouette Target Scoring

There are numerous target scoring methods available from civilian, state, and federal law enforcement, and military branches. The commonality among all of these scoring methods is the higher incapacitation probabilities equate to higher target scoring for the areas of the target. It can be seen from the various target styles provided (Figure 2) that central nervous system (CNS), major organ, and center of mass vascular system hits render the highest score, followed by peripheral-central and outside head hits. These are followed by the lowest-scoring outer torso hits. It can be seen on some targets that pelvis hits are scored differently, as this would provide a shot under typical body armor and creating a certain incapacitation level. Incapacitation or projectile wounding can be calculated with many different formulas. Some formulas use penetration depth (which is dependent upon velocity and projectile qualities), permanent cavity, temporary cavity, and fragmentation (Patrick, 1989).

Figure 2 provides examples of National Rifle Association (NRA), United States Practical Shooting Confederation (USPSC), Department of Energy (DOE), Federal Bureau of Investigation (FBI) QIT, and U.S. Marine Corps Marksmanship targets (from left to right).



**Figure 2. E-silhouette scoring targets (NRA, USPSC, DOE, FBI, and USMC)**

The overall purpose of these targets is to provide a simple interval scale for hit quality in terms of general incapacitation or stopping ability. While this very simple incapacitation scoring system is not based on any incapacitation models, it is well established that the accuracy of hits in the center of the target produces better incapacitation. Future efforts may rely on “overlying” higher-resolution radial quadrant data onto other various mapping methods for scoring incapacitation that may be of interest to other military and federal agency audiences.

### **4.3 Radial Error Quadrant Scoring**

This method of scoring is related to the distance from the center of mass of the target and is provided in X-Y distance (millimeters). The X-Y coordinate system allows the shot to be placed in one of four quadrants in the target as high right, high left, low right, or low left with an associated exact shot placement distance. *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.*

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## 5. STRUCTURAL SHOOTING MODEL FRAMEWORK AND METHODOLOGY OBJECTIVES

This report outlines a multitude of variables that can be identified prior to most shooting and marksmanship studies. The many variables are likely interrelated and a model of shooting performance is proposed to account for the many variables that interact to summarize basic shooting performance in Figure 1. This model is general in nature but proposes that there are several interactions and mediator effects that take place to achieve hit percentage or shot placement accuracy. This model is also proposed as a tool with which to define general hypotheses for pre-experimental estimates of shooting performance. As it can be seen, the variable of central importance is aiming error, which is the culmination of all weapon, target, and individual characteristics that influence the outcome measures of either hit percentage, or with further data resolution, shot placement accuracy. It does not account for secondary tasks as this will lend itself to many more complex interactions. However, there is data that discusses various types of helmet-mounted displays and the resulting shooting task accuracy, secondary task accuracy, and decision errors (fratricide and missed enemy shots) made (Scribner et al., 2004).

The purpose of this model is to help structure potential data collection techniques formed from hypotheses generated from literature in these foundational domains. In short, this model has been formulated to assist future research efforts to collect and account for the many individual differences that can shape the outcome of such shooting research studies. The intended effect is to structure a more-thorough research paradigm to provide data that better identifies true differences in Soldier-borne equipment that is to be used in the live-fire context.

The second purpose of this model is to structure data for systems analysis so that particular aspects of data collection efforts can be highlighted to show the scope of a study and how that study might be portrayed in a model format.

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## 6. CONCLUSION

It is proposed that a structural model framework be examined as a potential overarching prediction model for marksmanship and shooting data. The individual and target factors discussed herein can be applied to almost any shooting study with minimal change through the pre-study administration of the measures discussed in this proposal. 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.

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

1. Considerably stronger and cleaner data sets through the use of these pre-study HSI measures as covariates, which essentially help clean up unaccounted-for noise within the data.
2. Enhanced statistical explanation of effects and effects sizes.
3. A better understanding of the holistic effects of individual factors within the shooting research discipline that may serve as a future methodological change and benefit to the shooting research community.
4. An overarching model framework 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.

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## Appendix B – List of Acronyms

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ANS	autonomic nervous system
AOSPAN	Automated Operational Span
ARL	Army Research Laboratory
bpm	beats per minute
C2	Command and Control
CCDC	U.S. Army Combat Capabilities Development Command
CFS	Chalder Fatigue Scale
CNS	central nervous system
DOE	Department of Energy
ECG	electrocardiography
EEG	electroencephalography
ESS	Epworth Sleepiness Scale
FBI	Federal Bureau of Investigation
HR	heart rate
HRR	heart-rate recovery
HRV	heart-rate variability
HSI	Human System Integration
MOS	Military Occupational Specialty
NSES	New Self-Efficacy Scale
NRA	National Rifle Association
OSPAN	Operational Span
PNS	parasympathetic nervous system
SNS	sympathetic nervous system

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USPSC

United States Practical Shooting Confederation

WMC

Working Memory Capacity

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## **Appendix C – Distribution List**

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## ORGANIZATION

U.S. Army CCDC Data & Analysis Center  
FCDD-DAD-OL/T. Handlir  
FCDD-DAD-OL/T. Resetar-Racine  
FCDD-DAS-LHC/D. Scribner  
FCDD-DAS-LHD/F. Morelli  
6896 Mauchly Street  
Aberdeen Proving Ground, Maryland 21005-5071

U.S. Army CCDC Army Research Laboratory  
FCDD-RLD-DCI/Tech Library  
2800 Powder Mill Rd.  
Adelphi, MD 20783-1138

Defense Technical Information Center  
ATTN: DTIC-O  
8725 John J. Kingman Rd.  
Fort Belvoir, VA 22060-6218