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THESIS

**ASSESSING MEMORY DECAY RATE: WHAT FACTORS
ARE THE BEST PREDICTORS OF DECREMENTS IN
TRAINING PROFICIENCY IN A THREAT VEHICLE
IDENTIFICATION TASK?**

by

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PREDICTORS OF DECREMENTS IN TRAINING PROFICIENCY IN A THREAT
VEHICLE IDENTIFICATION TASK?**

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ABSTRACT

Threat vehicle identification (TVI) is a key task in reducing fratricide on the battlefield. Military skills such as TVI are susceptible to memory decay. This research investigates the factors that are the best predictors of performance decrement in a TVI task. Thirty active-duty officers were randomly assigned to one of five groups of six. Each group was trained on vehicle identification using the U.S. Army's Recognition of Combat Vehicles (ROC-V). All participants trained on 10 thermal and 10 visible vehicle images and reached a training proficiency of at least 90 percent on training post-tests. Each group was assigned a day when they would return to retake the post-tests. The groups returned 1, 2, 4, 8, and 16 days later. Participants also completed a recognition memory test to assess their individual memory levels. The results of this research indicate that memory does not decay exponentially for the TVI task. However, participants performed worse on the thermal image set than on the visible image set. Performance on the recognition memory test and time to complete training were significant predictors of performance on the TVI task. Results of this study could help shape TVI training plans and reduce the risk of fratricide.

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LIST OF ACRONYMS AND ABBREVIATIONS

AAV	amphibious assault vehicle
ANOVA	analysis of variance
ASCIET	All Services Combat Identification Evaluation Team
APA	American Psychological Association
ASVAB	Armed Services Vocational Aptitude Battery
BFT	Blue Force Tracker
CERDEC NVESD	Communications-Electronics Research, Development and Engineering Center's Night Vision and Electronic Sensors Directorate
CIP	Combat Identification Panels
CPV	Command Post Vehicle
CVI	Combat Vehicle Identification
DLP	digital light processing
DOD	Department of Defense
FLIR	Forward Looking Infrared
FMTV	Family of Medium Tactical Vehicles
GB	gigabyte
GHz	gigahertz
GST	gunnery skills test
GT	General Technical
GTA	Graphic Training Aid
GWOT	Global War on Terror
HBCT	Heavy Brigade Combat Team
HEMTT	Heavy Expanded Mobility Tactical Truck
HSI	Human Systems Integration
HSIL	Human Systems Integration Laboratory
IFF	identification, friend or foe
KSAO	knowledge, skills, abilities, and other characteristics
LAV	light armored vehicle
LCD	liquid-crystal display

M	mean
MANPRINT	Manpower Personnel Integration
MGS	Mobile Gun System
MOS	Military Occupational Specialty
OPTEMPO	operational tempo
OS	operating system
PM	program manager
RAM	random access memory
REM	rapid eye movement
ROC-V	Recognition of Combat Vehicles
ROE	rules of engagement
RMT	Recognition Memory Test
SD	standard deviation
SWS	slow wave sleep
TIS	Thermal Imaging System
TVI	Threat Vehicle Identification

EXECUTIVE SUMMARY

Recent technological advances have provided today's warfighters with robust capabilities on the battlefield. With the proliferation of fighting occurring during limited visibility, U.S. warfighters have become dependent upon forward-looking infrared (FLIR) technology to allow them to identify and engage targets. While FLIR has been a combat multiplier, incidents of fratricide remain costly for the U.S. During Operation Desert Storm, approximately 80% of the M1 Abrams Main Battle Tanks and M2 Bradley Fighting Vehicles lost were destroyed by friendly fire (Harmeyer & Antal, 1992). Furthermore, 90% of combat engagements occurred using infrared and thermal technology (O'Connor & O'Kane, 2000). The need to train thermal imagery is a necessity to reduce fratricide given the preponderance of engagements occurring in limited visibility (Dyer, Westergren, Shorter, & Brown, 1997). This study investigates memory decay and what factors are the best predictors of performance decrement in a threat vehicle identification (TVI) task.

For this study, a laboratory experiment was conducted to assess recognition memory ability, memory decay, and performance on a TVI task using thermal and visible imagery on the U.S. Army's Recognition of Combat Vehicles (ROC-V) program. The research used a 2x5 mixed design to analyze performance between thermal and visible images over time. Thirty active-duty Army, Marine Corps, Navy, and Air Force officers took a recognition memory test (RMT). After 72-hours had elapsed, participants returned to begin self-guided ROC-V training and to retake the RMT to establish baseline memory abilities. Participants trained on two vehicle sets. The first set consisted of 10 thermal vehicle images, and the second set consisted of 10 different visible vehicle images. Participants had to achieve a score of 90% on training quizzes and final training post-tests for each vehicle set to be considered trained and capable of moving forward in the study. Participants were randomly placed in one of five groups that consisted of six people. Each group returned on a second test day to

retake the thermal and visible post-tests. Group one returned after one day. Group 2 returned two days after training. Group 3 returned four days after training. Group 4 returned after eight days, and group 5 returned after 16 days. Each group also took an additional RMT on their second test day. Participants also completed a sleep log for the duration of their involvement in the experiment.

Analysis from the study showed that the effect of time passing on performance for the thermal and visible post-tests was not significant. However, the time that it took participants to complete the training module was significant. The longer it took a participant to complete the training, the worse their performance was on the thermal post-test. Participants' performance on the RMT that occurred 72-hours after the initial RMT was a significant predictor of performance on the TVI task. There was a significant difference between the thermal and visible image sets across all participants. Scores for the thermal test were significantly lower than scores for the visible test. Scores for the visible test were high and did not have significant differences when analyzed against all other factors. Participants who had previous TVI training performed significantly better than those who did not.

The results of this research can help design training plans and increase operational performance. Results indicate that performance on a TVI task is higher for individuals with previous vehicle identification training. Therefore, ensuring that all warfighters are introduced to TVI in their careers can help mitigate the potential for fratricide. Significantly lower performance on thermal images still highlights the need to train more on this specific task, especially with the majority of combat engagements occurring during limited visibility. Warfighters' individual memory abilities are predictors of their performance in a TVI task. Commanders should be able to identify personnel that take more time to complete TVI training modules and that have lower recognition memory abilities. This will allow leaders to ensure they have identified individuals who need additional training and allocate resources as necessary to increase their unit's performance.

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I. INTRODUCTION

A. PROBLEM STATEMENT

Military tasks differ in how quickly they are forgotten (Hagman & Rose, 1983). The relevant literature identifies certain factors contribute to decay rate such as time and individual memory ability. The purpose of this study is to examine the factors that predict decay rate skills previously learned by warfighters. Minimizing decay rate for warfighters can increase their performance while decreasing training costs and resource expenditure.

Threat vehicle identification (TVI) is a task that is evaluated through a gunnery skills test (GST) in accordance with Army Field Manual 3–20.21, Heavy Brigade Combat Team (HBCT) Gunnery. Crew members must complete the GST to be considered qualified to operate their stations during live-fire gunnery qualification. Training TVI is necessary to reduce fratricide. The TVI test is administered with a two-dimensional presentation interface using either analog or digital delivery methods. Recently, the Army developed a computer-based training application, Recognition of Combat Vehicles (ROC-V), to aid in soldiers' learning. ROC-V (2013) "helps soldiers learn to identify the thermal signatures of combat vehicles through the use of an interactive curriculum that teaches the unique 'hotspots,' and overall shapes, characteristics, and capabilities for 276 U.S., Allied, and foreign vehicles." These skills are important given that 90% of the engagements during Operation Desert Storm occurred using thermal or night vision sights (O'Connor & O'Kane, 2000).

Fratricide is the misuse of friendly force against friendly personnel that results in death or injury (Department of the Army, 1992). Soldiers encounter stressful combat conditions that necessitate quick decision-making when faced with identifying a friend or foe. These high-pressure situations can greatly increase the probability for fratricide. Americans destroyed approximately 80% (27 out of 35) of the M1 Abrams tanks and M2 Bradley Fighting Vehicles (Harmeyer & Antal, 1992) lost during combat operations in Operation Desert

Storm. The U.S. Army experienced 55 instances of fratricide during the Global War on Terror (GWOT) from 11 September 2001 to 30 March 2008 that resulted in 30 fatalities (Webb & Hewett, 2010).

Blue Force Tracker (BFT) and identification, friend and foe (IFF) signals are technological assets that assist warfighters in identifying targets. Doctrine, rules of engagement (ROE), tactics, combat identification panels (CIP), and situation awareness also inform the identification process. Even with these tools, the identification and final decision of whether a vehicle is friendly or adversarial is still made by a human (Briggs & Goldberg, 1995). Visual recognition is a key factor that contributes to target identification. Visual recognition is often the last sensory input process that happens before a warfighter makes the final decision to engage a target (Webb & Hewett, 2010). Therefore, it is important that training identification of threats is emphasized to complement technology in order to reduce fratricide.

Soldiers reach a high level of skill proficiency upon completion of initial entry and advanced individual training. Performance decrement occurs during the period where no practice occurs between transfer from school to an operational unit (Knerr et al., 1984). The greater the lag between transfer of school to unit, the greater the memory decay. Soldiers must then be retrained once they get to their operational units in order to restore their high level of proficiency (Hagman & Rose, 1983). Hagman et al. also noted that opportunities for refresher training are limited due to resource constraints. A recent All Services Combat Identification Evaluation Team (ASCIET) report found that levels of proficiency were raised to greater than 90% accuracy using ROC-V (O'Connor, 2002). However, no studies have examined the rates of forgetting after using ROC-V.

Clark and Paivio (1991) proposed a dual-coding theory in which memory is enhanced by both semantic and visual encoding, since either can lead to recall. They propose that imagery facilitates memory because it provides a second kind of memory code, and two codes are better than one. This supports

the ASCIET report on ROC-V since visual encoding and semantic descriptions of vehicles help an operator's encoding of thermal vehicle signatures. McCauley, Eskes, and Moscovitch (1996) also found that the use of mental imagery could enhance memory in many situations.

Memory decay has been studied in great detail (Stahl et al., 2010). Ebbinghaus (1913) first hypothesized that forgetting was an exponential function. The concept of a forgetting curve was derived from his work. The forgetting curve plots retention and forgetting as a function of time (see Figure 1). Ebbinghaus asserted that in order to decrease the effects of time on memory retention as plotted on the curve, repetitive overlearning of information would cause the forgetting curve to become shallower. Ebbinghaus' research suggests that each rehearsal makes the forgetting curve less steep and restores performance to asymptotic stability. Ebbinghaus, however, conducted the experiment such that he was both the participant and the experimenter and the forgetting curve was based solely on his own individual results. Finkenbinder (1913) challenged Ebbinghaus' work when he reported that the forgetting curve was slower than suggested by Ebbinghaus.

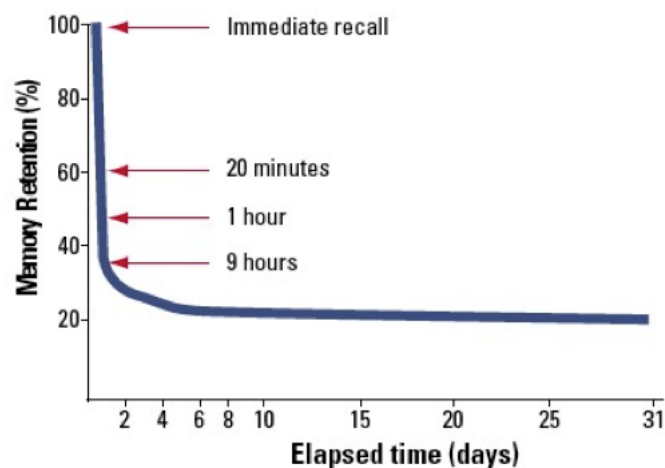


Figure 1. The Ebbinghaus Forgetting Curve (from Stahl et al., 2010)

Researchers have proposed multiple explanations for why humans forget and different strategies to improve retention. Brown and Craik (2000) found that when new information is learned, subsequent forgetting might occur as a result of ineffective or inappropriate encoding. Altmann and Gray (2002) suggested that memory decays over time unless it is actively maintained.

Bailey (1989) conducted an industrial-based experiment in which he determined forgetting was a multiplicative function of the amount of learning accrued and the log of the interruption period. He also found that since there is no constant component of forgetting, an intercept term near zero was theoretically correct and valid for the purposes of modeling forgetting rate. Bailey concluded that forgetting rates for continuous process tasks were negligible while forgetting rates for procedural tasks were significant. He used bicycle riding as an example of a continuous process and operating a computer program as an example of a procedural or discrete interval task. In Bailey's taxonomy, identifying thermal signatures of stationary armored vehicles from multiple two-dimensional angles would be considered a procedural task.

Measures to gauge forgetting include recall and recognition (Lockhart, 1992). Recall and recognition differ in that recall is retrieval without cues whereas recognition relies on assistance through various cuing techniques. Information retrieval using recall is more difficult than retrieval using recognition (Lockhart, 2000). The task of identifying a vehicle through thermal sights is based on a crewmember's recognition of previously learned thermal patterns. Hagman et al. (1983) determined that critical skills are difficult for the Army as a whole to maintain due to prolonged time between training events.

B. RESEARCH OBJECTIVES

This study investigated how the passage of time and presentation of training material affected a subject's ability to recognize military vehicles. The specific objectives of this research are:

- Analyze the accuracy of TVI task responses to determine whether there is a difference in performance based on testing interval.
- Analyze TVI task performance to determine any difference in accuracy between two types of imagery: visual and thermal.
- Assess which factors best predict performance decrement in a TVI task.

C. RESEARCH QUESTIONS

The research questions addressed by this study are:

- What factors are the best predictors of decrements in training proficiency in a threat vehicle identification task?
- Does the presentation of images (thermal or visual) influence an individual's ability to recognize a military vehicle?
- Does an individual's memory ability impact decay rate?

D. HUMAN SYSTEMS INTEGRATION

The Manpower and Personnel Integration (MANPRINT) Program is the U.S. Army's execution of Department of Defense's (DOD's) Human Systems Integration (HSI). MANPRINT is "comprehensive management and technical program that focuses on the integration of human considerations into the system acquisition process" (Manpower and Personnel Integration [MANPRINT], 2005, p. 1). The program was started in order to place an emphasis on the human in a system's total performance. The goal of the MANPRINT program is to enhance soldier-system design, reduce life-cycle costs, and optimize total system performance (MANPRINT, 2005). MANPRINT is divided into seven HSI domains that work towards achieving this goal:

- Manpower
- Personnel
- Training
- Human Factors Engineering
- System Safety

- Health Hazards
- Soldier Survivability

These domains interact with each other to varying degrees, depending on the system. Each domain has cost implications and potential cost-savings associated with them (MANPRINT, 2005). Changes in a domain will affect its cost and the costs of other domains that are related to a system. This creates a “trade space,” or the range between objective and threshold values that a program manager (PM) can manipulate. Managing the trade space among the HSI domains helps to effectively balance cost, schedule, and total system performance. The present research will focus on three HSI domains: personnel, training, and soldier safety.

Personnel: MANPRINT defines the personnel domain to be the cognitive and physical capabilities that are required to be able to train for, operate, maintain, and sustain materiel and information systems (MANPRINT, 2005). These capabilities are normally reflected as knowledge, skills, abilities, and other characteristics (KSAOs). The Army seeks to place soldiers in military occupational specialties (MOS) by identifying target audiences for a system and comparing cognitive and physical demands with projected personnel inventories.

A personnel attribute examined in this study is memory. Personnel selection criteria based on ability to be trained and process information are critical for mechanized crewmen who must remember characteristics of numerous vehicles in an operational environment in order to make the right decision. The Global War on Terrorism fratricide data show that most causal factors relating to friendly fire incidents were cognitive, perceptual, and psycho-behavioral factors of individuals (Webb & Hewett, 2010). This emphasizes the need to properly fill duty positions with the right mixture of personnel capable of remembering TVI training.

Training: Training is the instruction, education, on-the-job, or self-development training required providing all personnel and units with essential job skills, and knowledge. Training addresses the gap that exists between a target

audience's existing level of knowledge and the knowledge required to effectively operate and support a system (MANPRINT, 2005).

Sustaining the baseline training proficiency that personnel achieve during initial training could reduce training costs significantly. Also, sustainment training may reduce the need for time-consuming remedial training and provide more stable performance levels throughout a soldier's time in service. Training is more important in preventing fratricide than technological countermeasures (Webb & Hewett, 2010). This research will examine TVI training presentation in order to assess performance decrement over time.

Soldier Survivability: Soldier survivability addresses the characteristics of a system that can reduce fratricide, detectability, and probability of being attacked, as well as minimize system damage, soldier injury, and cognitive and physical fatigue (MANPRINT, 2005). The U.S. Army added soldier survivability to its MANPRINT domains to focus attention on those aspects of a system that that can minimize the loss of forces due to friendly fire.

Mitigating the effects of decay on a task such as TVI has the great potential to decrease fratricide. Engagements happen in a manner of seconds. Therefore, providing soldiers with a framework to accurately retrieve learned information can aid in the shoot/don't shoot decision-making process.

E. THESIS ORGANIZATION

This thesis is divided into six chapters. Chapter II reviews literature regarding forgetting theories and models, military skill retention, the effect of fatigue on memory, and TVI training development. Chapter III describes the methods used in the experiment and the research design of the study. Chapter IV presents the results of the experiment. Chapter V discusses the analysis of the results. Chapter VI provides conclusions and recommendations for future research.

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II. LITERATURE REVIEW

A. BACKGROUND

1. Decay Theory

Factors related to the memory processes of encoding, storage, and retrieval help determine what is remembered or forgotten (Brewer, Zaho, Desmond, Glover, & Gabrieli, 1998). Brewer et al. (1998) examined the degree of activation in the hippocampal regions of the brain and found that the extent to which a visual experience is encoded predicts whether it will be remembered or forgotten. Sensory inputs are transformed into memories, but the stability of these memories depends on the quality of encoding (Brainerd, Reyna, Howe, & Kingma, 1990). Once a memory is encoded and stored in a memory trace, it is vulnerable to a gradual degradation due to decay. Decay can cause storage failures to occur and make remembering difficult (Brainerd et al., 1990).

Brown (1958) and Peterson and Peterson (1959) conducted early studies examining decay theory. Brown (1958) proposed a decay theory hypothesis.

When a sequence of items is presented, the interval between the perception of each item and the attempt to recall that item will depend on the length of the sequence. If the sequence exceeds a certain length, decay of the memory traces of some of the items will proceed too far for accurate recall of the sequence to be possible. This length is the memory span. Thus the trace-decay hypothesis can explain both the origin of the span and why forgetting occurs when the span is exceeded. (p. 13).

Brown suggested that forgetting would not be expected if subjects were able to rehearse the presented material during the interval between presentation and the attempt to recall the item. Rehearsal increases the probability of counteracting the effects of decay (Brown, 1958). However, memory decay will occur when the memory trace is not activated. Brown also proposed that once a stimulus is perceived, it decays rapidly initially. The memory trace is still useable through recall and recognition until retention reaches a critical point where the

memory trace is no longer reliable. Beyond the laboratory, in many operational settings, rehearsal of information stored in memory does not happen at fixed intervals. Soldiers engaged in combat operations will experience periods of low and high operational tempo (OPTEMPO). During periods of high OPTEMPO, decay may occur because the time between information presentation and recall can exceed the memory span.

Peterson and Peterson (1959) expanded on Brown's work. Peterson and Peterson's study examined forgetting of verbal stimuli at time intervals from three to 18 seconds. Their study included having participants count backwards between presentation of a verbal stimulus of three letters and then asking them to recall the letters. The researchers found evidence that memory decay became worse over longer time intervals, even when the effects of rehearsal were blocked. The relationship between recall and passage of time decayed exponentially and followed forgetting curve postulations (Ebbinghaus, 1913; Bailey, 1989).

Signal detection theory is a viable tool to assess recognition memory (Wixted, 2007). Gold, Murray, Sekuler, Bennett, and Sekuler (2005) assessed memory decay within the scope of signal detection theory. Gold et al. proposed that memory decay was not just a function of acquiring more noise in the form of new memories. The new memories coupled with the passage of time took away from memory resources and allowed time to decay memory traces. Because of this, Gold et al. (2005) suggested that memory decays in a deterministic way and that future studies should seek to find the "forgetting function" that models how visual memory decays as a function of time.

2. Recognition Memory

Recognition memory involves selecting accurate responses from a choice of alternatives (Wisher, Sabol, & Ellis, 1999). This contrasts with recall memory where no alternatives are presented and a participant must produce an answer through more narrative methods. Recognition memory provides superior results

compared to recall memory due to the cues provided that drive recognition (Wisher et al., 1999). Recognition memory is dependent upon previous processing of the stimuli so that a judgment can be made about whether a previous encounter exists. The present study focused on analyzing recognition memory due to the visual cues presented in ROC-V. Participants did not freely recall any given name of a vehicle due to multiple-choice post-tests that provided an additional cue to supplement the visual cues.

Warrington (1984) developed the Recognition Memory Test (RMT) to determine memory deficits across a range of factors and materials. The test provides the ability to compare and assess verbal and non-verbal memory. Recognition memory tests are common methods for measuring memory performance (Snodgrass & Corwin, 1988). Successful recognition memory is dependent upon the right storage and retrieval of memory information of a particular event (Tulving & Thompson, 1971). Retrieval cues used in recognition memory depends on how the item to be retrieved was encoded at perception since encoding shapes the memory trace process. The memory trace serves as the link between how well a memory was encoded and the extent to which retrieval cues are effective (Tulving & Thompson, 1973). The need to examine recognition memory through the RMT is necessary given that explicit semantic memories such as recognition memory are not as enduring as implicit memories (Woltz & Shute, 1995).

Snodgrass and Corwin (1988) conducted an assessment of recognition memory tests used to examine memory deficits in cases of dementia and amnesia. The study found that as the number of similar features increases between test items and one's internal representation of the test items, subjective familiarity with new and old test items increases. This phenomenon can create high levels of familiarity for different test items if stimuli are not properly encoded at the moment of perception (Snodgrass & Corwin, 1988). Misidentification from memory can occur from having the wrong memory representations activated and by confusion from prior test and distractor items. Therefore, proper encoding of

stimuli at perception is important to prevent grouping new images with previously learned and poorly encoded memories.

Studies that examine recognition typically return high levels of accuracy below which performance cannot fall (Brainerd et al., 1990). Recognition memory tests also use more memorable testing materials in the form of photos (Brainerd et al., 1990). Recognition tests have also used short time intervals between training and testing from 1-3 days (Merriman, Azmita, & Perlmutter, 1988). Forgetting does not begin immediately after being introduced to information. Memory normally improves for periods of a few hours to a few days. This phenomenon occurs in both children and adults. Therefore, in order to gain more insight in age differences with regard to levels of forgetting, memory tests should be administered at intervals beyond the common 1-3 days to account for the beginning of the forgetting period (Brainerd et al., 1990).

3. Effects of Fatigue on Recognition Memory

Jenkins and Dallenbach (1924) examined Ebbinghaus' (1913) original study of forgetting. The purpose of the study was to compare forgetting rates after varying hours of sleep and wakefulness. Participants in the study learned nonsense syllables in a similar fashion to Ebbinghaus' original study. Participants were tested at intervals after sleep and wakefulness. The participants remembered twice as many words after the sleep interval than the wakefulness interval. This early work by Jenkins and Dallenbach led to further studies examining the role of sleep and its effects on memory processes from encoding to retrieval. Walker and Stickgold (2006) found that the effects of sleep deprivation over a 36-hour period severely impaired encoding of memories. This resulted in significantly worse retention involving learning lists of words in the days after the initial training.

Sleep is an important factor in the consolidation of memories (Drosopoulous, Wagner, and Born, 2005). Memory consolidation is the process by which new memories consolidate over time and become resistant to

interference without any form of rehearsal (McGaugh, 2000). Sleep also helps enhance memory consolidation after learning (Rasch & Born, 2008). Studies have hypothesized that the different stages of sleep affect learning and memories in different ways (Maquet, 2001; Stickgold, Hobson, Fosse, & Fosse, 2001; Karni, Tanne, Rubenstein, Askenasy, & Sagi, 1994). Recent studies suggest that sleep on the night after a visual perceptual learning session is critical to satisfactory follow-on performance (Maquet, 2001).

Sleep enhances explicit recognition memory (Drosopoulous et al., 2005). Drosopoulous et al. (2005) compared the effects of sleep on explicit and implicit memory formation for a word-discrimination task. Participants studied two lists of words before a three-hour retention interval of sleep or wakefulness. Participants then completed a recognition test during early parts of the sleep period where slow wave sleep (SWS) occurs and late at night towards the end of a sleep cycle when REM occurs. Drosopoulous et al. found that sleep during the SWS period significantly increased recognition for the list of words.

Rapid eye movement (REM) sleep has an integral role in memory processing for procedural learning of a visual memory task (Stickgold et al., 2001). Karni et al. (1994) found that performance of a visual discrimination task improved after participants were able to have a normal sleep cycle the night following training. Furthermore, human memory consolidation processes depend on REM sleep.

4. Background Summary

Previous studies suggest that memory decays at an exponential rate over time. This is important when analyzing military tasks that are dependent on memory retrieval. Consequences can be fatal when warfighters forget TVI training. Rehearsal improves performance on such tasks, but memory is still susceptible to decay. Recognition memory assesses the ability to choose among alternatives, whereas recall involves selecting a correct response without alternatives. Sensing and processing of visual cues are significant factors of

accurate recognition memory processing. Therefore, proper encoding and storage of visual stimuli in a TVI task are essential. Given that memory decays and that improper recognition memory processing put performance at risk, it is necessary to assess memory through a TVI task. Furthermore, sleep and fatigue are essential throughout the entire memory process. Adequate levels of rest strengthen memories and help make them less susceptible factors such as decay and interference. Memory and those factors that interact with it are key elements of training TVI.

B. RECOGNITION OF COMBAT VEHICLES

1. Evolution of Vehicle Identification Training

According to the DOD's 2009 Unmanned Systems Integration Roadmap, future systems must focus on specific warfighter capability needs. The second most important capability listed in the roadmap is target identification and designation (Department of Defense, 2009). The DOD highlights the need to precisely obtain positive military target identification in order to achieve faster and more accurate effects on the battlefield. This issue is not new, however. Identification of military vehicles has a long history in the U.S. military. Recognition of combat vehicles became a pressing issue when the first tank-on-tank battle occurred during World War I (Briggs & Goldberg, 1995). The issue of vehicle recognition extended beyond armor crewmen and reached to dismounted soldiers and aviators who also had to identify friend or foe on the battlefield. The sum of these efforts on the ground and in the air helped achieve tactical success. Gibson (1947) published a description of a research program used during World War II to improve aircraft identification and the general education of visual learning. Gibson described the aim of training aircraft recognition as two-fold: identification of friend or foe and range determination based on the size of the aircraft. Flight students who were taught to identify general forms of aircraft versus distinguishable characteristics of aircraft performed poorly on recognition tasks. The flight students repeatedly asked how they could distinguish between

two planes that closely resembled each other. Gibson found that these results necessitated a paradigm shift in training to move beyond a general total form approach of identification to an approach that included features of vehicles that distinguish them from others. Gibson developed a still and motion picture training series for the Army Air Force to train pilots and aircrews in recognizing friendly and enemy aircraft.

In the 1980s, the U.S. Army developed a basic combat vehicle identification (CVI) program (Warnick & Smith, 1989). The training program included instruction for both training and operational units. The program consisted of visual and thermal vehicle identification using 35mm slides. Combat identification flash cards supplemented the training slides (Warnick & Smith, 1989). Thermal images were available on a limited basis. Thermal imagery was needed because the M60A3 tank was equipped with infrared sights and the new M1 tank possessed an advanced Thermal Imaging System (TIS). Early iterations of thermal images had to be simulated and consequently had low fidelity. This program was the Army's first attempt at training its soldiers on thermal imagery (Smith, Shope, Heuckeroth, Warnick, & Essig, 1987). However, these solutions were interim and partial (Dyer, Westergren, Shorter, & Brown, 1997).

Training and testing of CVI consisted only of photographs and two-dimensional line drawings (O'Connor & O'Kane, 2000). In 1987, the Army supplemented its CVI training program with Graphic Training Aid (GTA) 17-02-13 (Department of the Army, 1987). GTA 17-02-13 is a deck of 50 cards available to soldiers as a self-study tool. The two-sided cards provide common views of a vehicle on one side with vehicle descriptions on the other (Figure 2). This approach allowed soldiers to train on their own without having to use robust resources to facilitate their learning. The low quality of the images and instruction provided on the cards led to the need for an improved training approach to vehicle identification.

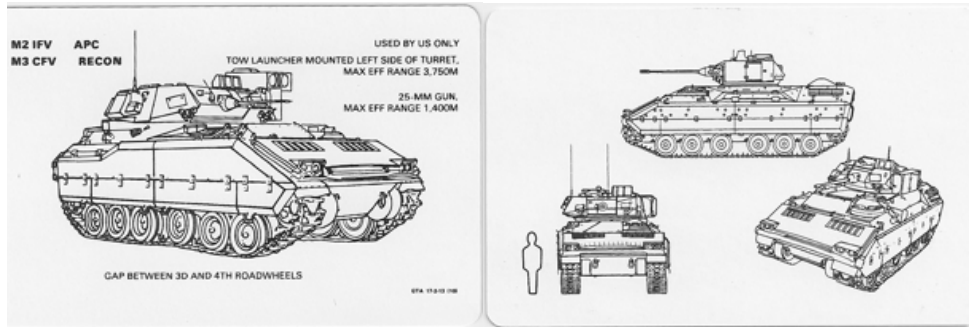


Figure 2. GTA for the M2/M3 Bradley
(from Department of the Army, 1987)

The U.S. Army tested a thermal training program, *CVIPLUS* in 1997. The program used actual thermal imagery and set out to field a generic thermal training program for all of the Army's thermal sights (Dyer et al., 1997). *CVIPLUS* allowed trainees to progress through the program at their own pace. This process was supported by previous research (Gibson, 1947; Warnick & Smith, 1989) that showed significant differences in individual ability to develop recognition skills. The *CVIPlus* framework became the foundation of ROC-V. The U.S. Army's Communications-Electronics Research, Development and Engineering Center's Night Vision and Electronic Sensors Directorate (CERDEC NVESD) developed ROC-V and it was fielded as a computer-based training system in 1999. ROC-V presents vehicle signatures through a variety of simulated sights that are currently in use in the United States (Boyd et al., 2005). CERDEC NVESD later developed ROC-V into a mobile application that was available to Android and Apple iOS users in 2013 (Rominiecki, 2013). This capability enabled soldiers to train on vehicle recognition on their mobile devices and on their own time, much like the GTA cards. However, with the mobile version of ROC-V, soldiers also had access to thermal signatures of vehicles.

2. Training Visible and Thermal Images

Recognizing vehicles is a difficult task to train and sustain (Dyer, Shorter, & Westergren, 1998). Recognizing thermal images of vehicles is even more difficult. Thermal image signatures differ from visible images of a vehicle's

superficial surface signatures. Thermal signatures are dynamic and are the function of radiation from vehicle heat sources, frictional sources, weapons systems, and solar sources during daylight hours (O'Connor & O'Kane, 2000). Further, operators manipulate brightness and contrast settings on sights that leave no two thermal images exactly alike (Dyer et al., 1997). The differences between thermal and visible signatures can cause confusion when trying to identify a vehicle, even though the physical surface structure of a vehicle may be known to the warfighter. O'Connor and O'Kane (2000) concluded that familiarity with vehicles in two-dimensional line drawings and photos without knowledge of thermal signatures was not sufficient to effectively complete combat vehicle identification with thermal sights.

While multiple types of sensors and sights exist today, the common technology used in most modern weapons systems is forward-looking infrared (FLIR, also known as thermal). Thermal sensors transform infrared energy produced by heat into visible light (Palmer, D'Agostino, & Lillie, 1982). This transformation presents a new stimulus to an operator that is different than visible images. This phenomenon necessitates thermal imagery training since high performance on visible image identification does not guarantee the same level of expertise on FLIR identification (Dyer et al., 1997). Another important issue for thermal image training is the need to use non-daylight thermal images. Environmental heating and cooling can change vehicle signatures enough to appear different to a warfighter (Dyer et al., 1998).

Thermal signature training has a theoretical basis derived from perceptual tasks. Biederman and Shiffrar (1987) suggested that with perceptual-learning tasks, basic instruction should include location and shape of critical features that can help increase recognition performance. Their research focused on sexing of day-old chicks with novice observers and experts. Within an hour of training using the specific recognition strategy, the novices were able to determine the sex of chicks at the same level of accuracy as the experts.

Knowledge of a vehicle's critical features is necessary for proper identification, according to a 1997 study by O'Kane, Biederman, Cooper, and Nystrom. The results of their study indicated that confusing two objects could be predicted based on the number of similar major characteristics shared by the vehicles. Two vehicles that share three similar major characteristics would not be as easily confused as vehicles that shared five characteristics. Warfighters must be able to observe and process critical cues that are visible in a target picture. These cues include a vehicle's hull, armament, turret, and suspension (Warnick & Smith, 1989). Time pressure further stresses a warfighter's decision to shoot because an engagement between two vehicles can be complete within 10 seconds (Briggs & Goldberg, 1995).

Biederman (1987) proposed a recognition-by-components theory that suggested an object could be identified by breaking it into major parts. This approach follows the training methodology used to evolve CVI and ROC-V, which focused vehicle identification on distinguishing features. Dyer et al. (1997) determined that if thermal signatures can be described in verbal terms, then training approaches should use verbal instruction. However, if thermal signatures are too vague to be described by verbal instruction, then perceptual learning should be stressed in the training scenario.

The order of the presentation of thermal and visible image sets is not a critical factor in determining a program of instruction (Smith et al., 1987). However, the presentation of image aspects is a critical factor in both visible and thermal vehicle identification. Dyer et al. (1998) recommended a minimum of eight aspect angles to be presented in training sets. ROC-V presents eight aspect angles in both its visible and thermal training modules. Soldiers perform at higher levels on a TVI task when they have practiced recognizing a vehicle's identity and aspect (Dyer et al., 1997).

Simulation-based military training can overwhelm a learner if too much information is presented (Andrews & Bell, 2000). During the evaluation of computer-based training on vehicle identification, Dyer et al. (1997) found that

too many vehicles with multiple aspect images increased training time and soldiers did not reach specified performance standards easily. The results of the computer-based training assessment for vehicle identification recommended that no more than six vehicles should be presented in a training set (Dyer & Salter, 2001). Six vehicles with eight aspect angles yields 48 images as opposed an original proposal of eight images with eight aspect angles (64 total images).

3. Vehicle Identification Skill Retention

Dyer et al. (1997) proposed that future research building on *CVIPLUS* should examine how quickly soldiers lose their vehicle identification skills and what factors affect forgetting rates. The need to address these issues is intuitive, as commanders need to know the current skill level of their soldiers and how to develop training schedules around their performance. However, research efforts have been limited to address these issues. The current study addresses the effect of time and image presentation factors on performance decrement for the TVI task.

Heuckeroth, Smith, and Shope (1988) tested four groups of 45 soldiers at Fort Hood, Texas, using visible images available in the Army's CVI training program. Their research had two findings relevant to the current research: 1) the greatest decrement in TVI performance occurred within a three-week interval immediately following training; and 2) different soldiers reach specific levels of performance initially, but performance on the TVI task decays at generally the same rate for all. Heuckeroth et al. (1988) suggested that performance decrement between weeks three and nine was minimal. Therefore, they recommended that retraining efforts be started after nine weeks in the interest of managing training resources.

General Technical (GT) scores on the Armed Services Vocational Aptitude Battery (ASVAB) are highly correlated with performance on a TVI task (Shope et al, 1988; Warnick & Smith, 1989). These scores were not collected in the present effort, as commissioned officers are not required to take the ASVAB and thus obtain a GT score. However, soldiers with GT scores over 100 and those with less than 99 showed a significant difference in performance of basic vehicle

identification (Warnick & Smith, 1989). This difference in performance difference suggests that training programs should allow for more training time for personnel with lower GT scores. Another consideration of GT scores is that a possible relationship exists with long-term memory and the implication for how frequently training should be repeated.

4. Recognition of Combat Vehicles Summary

Vehicle identification training has evolved tremendously over the last 70 years. However, thermal imagery is still relatively new and unfamiliar to warfighters. These factors necessitate added attention to training thermal imagery. While previous studies indicate that ASVAB scores are predictors of performance on a TVI task, studies that examine thermal imagery are limited. While the military identified the need to create a more robust training platform for thermal images, analysis of the differences in performance between thermal and visible images are needed to better understand thermal TVI skills.

C. HYPOTHESES

The literature review has identified several factors that relate to performance decrements in a TVI task. The issues reviewed in this chapter have been focused on addressing two of the most relevant factors in this study's objectives: time between training and image presentation. Two of the most relevant factors to this study's objectives are time between training episodes and image presentation. Recognition memory capability is used as a control variable across factors.

The alternative hypotheses derived from the research questions are:

- H_{a1} : Performance on a TVI task without rehearsal degrades at an exponential rate over time.
- H_{a2} : Performance on a TVI task is different between visible and thermal image presentation.
- H_{a3} : Recognition memory capability predicts performance on a TVI task.

III. METHOD

A. OVERVIEW

A controlled laboratory experiment was conducted to assess memory decay after completing TVI training using the ROC-V application. This study was a 2 x 5 mixed design that compared recognition of vehicle images (thermal or visible) at different time intervals (1, 2, 4, 8, and 16 days). Participants were randomly assigned to one of five groups that corresponded to one of the time intervals. Prior to the TVI training, participants completed a recognition memory test to determine individual memory capabilities. Participants completed a sleep log for the duration of their involvement in the experiment. Table 1 highlights the experimental design for this study.

	TIME SINCE TRAINING				
	1 DAY	2 DAYS	4 DAYS	8 DAYS	16 DAYS
VEHICLE IMAGES (THERMAL AND VISIBLE)	GROUP 1				
		GROUP 2			
			GROUP 3		
				GROUP 4	
					GROUP 5

Table 1. Experimental Design.

The study consisted of an initial recognition memory test (RMT) on one day, followed by a training day 72 hours later, and a final testing day. The initial recognition memory test day consisted of taking the RMT until participants achieved a 100% score. The second day consisted of completing the RMT and the ROC-V training thermal and visible modules. The ROC-V training modules included a pretest, a training presentation on vehicle identification basics and training on identifying the vehicles in the training sets. Multiple check-on-learning quizzes and a final post-test accompanied each vehicle training set. This training sequence was the same for the thermal and visible image modules. Participants trained until they achieved a 90% or higher score on the vehicle post-tests.

Participants repeated the thermal and visible post-tests and completed another iteration of the RMT on their group's second day.

B. PARTICIPANTS

1. Selection

The Naval Postgraduate School Institutional Review Board reviewed and approved the research methods used in this study. Participants were treated in accordance with Department of the Navy and American Psychological Association (APA) ethical standards. All participants were informed of their rights as subjects in the study and signed informed consent forms. Participants were recruited through personal communication and email. The exclusion criterion for the study was any service-certified tank or Bradley master gunner students. Master gunners are considered experts in vehicle identification and are certified to train and certify TVI test results.

2. Demographics

Thirty participants completed the study (average age = 32.1, standard deviation [SD] = 4.56). Participants included 29 male officers and one female officer from the U.S. Army, Navy, Marine Corps, and Air Force. The participants' specialty branches within their respective services included combat arms, combat support, and combat service support. All participants were graduate students at the Naval Postgraduate School. The pay grades of the participants included 21 O-3s, 8 O-4s, and 1 O-5. The participants' time in service ranged from 5 years to 25 years (average time in service = 11.1, SD= 5.07). Participants had no prior certification as an M1 tank or Bradley Fighting Vehicle master gunner. Twenty-eight participants reported having visual acuity at or correctable to 20/20, while two participants reported having visual acuities of 20/30 and 20/40. Participants reported any previous TVI training and the time since the last training session. Eleven of the 30 participants had previous TVI training within the last 11 years (average time since training = 5.55, SD= 3.64).

C. MATERIALS

1. Equipment

The experiment used a color projector to display the recognition memory test to groups of participants for the initial RMT. The experiment used workstations for running the ROC-V program. The workstations were comprised of a Dell computer, one flat-panel monitor, and audio headsets (see Figure 3).



Figure 3. Participant at ROC-V Workstation

The exact specifications for the equipment used in the study were:

- 1 x Dell Optiplex 380 desktop, running Windows 7, with an Intel Core Duo 2 processor, 2.93 GHz, 2.0 GB RAM
- 1 x Dell 2007FP Ultrasharp 20" LCD flat panel display
- 1 x Audiovox stereo headphones
- 1 x InFocus IN2102 EP DLP Projector

- 1 x Apple MacBook Pro laptop, running OS X 10.9.2, with an Intel Core i5 processor, 2.4 GHz, 4.0 GB RAM
- Microsoft PowerPoint for Mac 2011, version 14.3.9
- *Recognition of Combat Vehicles*, version 10.1.1.19

D. VARIABLES

1. Independent Variables

a. *Time since Training*

The time between initial training and second testing varied between the groups. Training intervals occurred at 1, 2, 4, 8, and 16 days. Each group was randomly assigned to one of these days. These intervals were chosen based on the binary algorithm used by Bailey (1989).

b. *Vehicle Image Presentation*

Ten visible and ten thermal two-dimensional images were used for training and testing. Twenty separate vehicles were used to build the two test sets (Table 2). Vehicle images were pre-loaded in the ROC-V program. All participants trained on all vehicles in both sets.

Thermal Images		Visible Images	
M1 Abrams	M2A2/M3A2 Bradley	2S1 Gvozdika	AAV7
T-72	BTR-70	Leopard II	Stryker MGS
BMP-1	ZSU-23-4 Shilka	M997 HEMTT	FV4034 Challenger 2
LAV-25	M113	M557/1068 CPV	M1083A1 FMTV
M551 Sheridan	M60A3 Patton	BRDM-2	SCUD B (9K72 Elbrus)

Table 2. Test Vehicle Sets

2. Dependent Variable

a. *ROC-V Post-Test Accuracy*

The ROC-V program provided feedback from the post-test that included the final total of correct vehicles and accuracy percentage. These results were used to determine any changes from initial proficiency and differences between the image conditions.

3. Covariate Variable

a. *Sleep*

Sleep influences an individual's ability to properly encode and store information in long-term memory. Participants were asked to complete a sleep log for the duration of their involvement in the study to determine any effects or interactions with their performance. Participants who completed their second test at the one and two day training intervals provided information on their last 72 hours of sleep.

4. Control Variable

a. *Recognition Memory*

Due to the study's objective of assessing performance based on a recognition task, determining individual memory levels was necessary. A recognition memory test provided an assessment of memory retention (Warrington, 1984). The RMT used in this study was based on Warrington's (1984) framework. The test was developed using random images available from Microsoft PowerPoint for Mac 2011. The RMT (see Appendix A) consisted of 12 images presented on individual slides to the participants on a projector. After all 12 images were presented, participants would see an array of 36 images randomly placed on one slide. The original 12 images were included in this array. Participants would then write down the images that they recognized from the original set of 12. Participants would complete the RMT until they were able to correctly identify all 12 of the original pictures. Participants would then be

presented with the array of 36 images 72 hours later and on their second test day to determine their level of performance decrement with the RMT. Participants were not aware that they would take the RMT a second and third time.

E. PROCEDURE

Participants signed up for an initial RMT and then gathered in the Human Systems Integration Laboratory (HSIL). The researcher introduced the participants to the study. Participants completed an informed consent form followed by a demographic questionnaire (see Appendix B). Participants completed the initial RMT and then received an email with the time for their ROC-V training 72 hours later.

Participants completed the RMT first by watching a timed presentation of the 12 images followed by the array of 36 random images. Participants were required to correctly remember the 12 images presented in the RMT. Participants completed the RMT until they had achieved this mark. The researcher recorded the number of trials that it took a participant to identify all 12 of the images in the RMT. After 72 hours had elapsed, participants returned to the HSIL where they were presented with the array of 36 images from the RMT. Participants were instructed to write down the images they remembered. At the completion of the initial training and testing day, the researcher randomly assigned participants to one of the five groups. No significant differences between the initial RMT and RMT that occurred 72 hours later led to the assumption that memory ability variability was not a potential confound.

Participants were then oriented to their computer workstation and given a set of instructions with screen shots of ROC-V to assist them with completing the training modules. Participants then opened the ROC-V program and entered an assigned participant number. Participants completed a ten-question pretest with randomly generated vehicles within the thermal image set. Participants were instructed to complete the first vehicle identification module. The first module consisted of thermal images. The self-guided training sequence started with an

introduction to basic vehicle identification techniques. Participants then completed the self-guided training module for the vehicle set. A check-on-learning quiz was administered after the second vehicle and every subsequent vehicle. The quiz presented a vehicle name and two vehicle images or one vehicle image with up to five choices of vehicle names. Participants had to match the correct vehicle with the displayed name. Participants had to score higher than 90% during the check-on-learning quizzes in order to progress to the next vehicle in the set. Participants then completed a 10-question post-test for the thermal image set. Ten vehicles were randomly generated for the post-test by ROC-V for every testing sequence. The post-test assessed participants' ability to identify combat vehicles in thermal images. Participants were shown a target image and given 10 seconds to select the answer from a set of five choices. Participants had to correctly identify 90% of the vehicles in the post-test to be considered trained for the study. Participants who did not meet the 90% criteria on the post-test were allowed to retrain at their discretion and then repeated the test until they reached the passing standard. Participants then completed the visible vehicle image set in the same training sequence as the thermal set. Once participants had reached 90% proficiency on the visible vehicle set, the researcher provided them with a sleep log (see Appendix C) and instructions on how to complete it. Participants agreed to not conduct any supplementary training on vehicle identification or to discuss the experiment until all second testing iterations were complete.

Participants returned to the HSIL on their second assigned day to complete both the visible and thermal post-tests again. Participants were shown the 36-image array from the RMT and asked to write down the images that they remembered from the initial test before taking the ROC-V post-tests. Participants used the same workstations with ROC-V to complete the post-test. Participants also turned in their completed sleep logs. The researcher interviewed the participants to solicit feedback on the study and to determine whether any extraneous life events might have impacted their performance in the study.

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IV. RESULTS

A. OVERVIEW

The present study collected ROC-V test data, recognition memory test data, participant sleep data, and demographic data during a threat vehicle identification task. Analysis was conducted to determine the effect of the passage of time (1, 2, 4, 8, and 16 days) on vehicle identification to address Hypothesis One. Analysis was also conducted to determine the effect of thermal and visible image presentation on TVI test scores to address Hypothesis Two. Further analysis was conducted to assess recognition memory in predicting performance on a TVI task to address Hypothesis Three. An alpha level of 0.05 was used for all statistical tests. There were no significant findings with the visible image condition across all factors.

B. GROUP ASSIGNMENTS

Results from the second RMT that participants took 72 hours after the initial battery did not produce significantly different results to establish sub-groups. No participants met the exclusion criterion of being a tank or Bradley master gunner. An analysis was conducted to determine if participants with previous TVI training were randomly assigned to one of the five groups (see Table 3). A significant difference was not detected using Fisher's Exact Test ($p=0.61$). Therefore, the assumption was made that participants were randomly assigned to address the potential confounding variable of previous training in the following analysis.

		GROUP 1 1 DAY	GROUP 2 2 DAYS	GROUP 3 4 DAYS	GROUP 4 8 DAYS	GROUP 5 16 DAYS
PREVIOUS TVI TRAINING	Yes	5	4	4	4	2
	No	1	2	2	2	4

Table 3. Previous TVI Training by Group.

C. ROC-V POST-TEST ACCURACY

All participants completed a thermal and visible TVI post-test on their assigned day. Scores were collected that gave the number of correct responses for the two tests. Figure 4 shows the number of correct responses for all participants by their assigned groups and the average number of correct responses across all five groups ($M=7.60$, $SD=1.65$) for the thermal post-test. Figure 5 depicts the results and the average number correct for all five groups ($M=9.33$, $SD=0.80$) for the visible post-test.

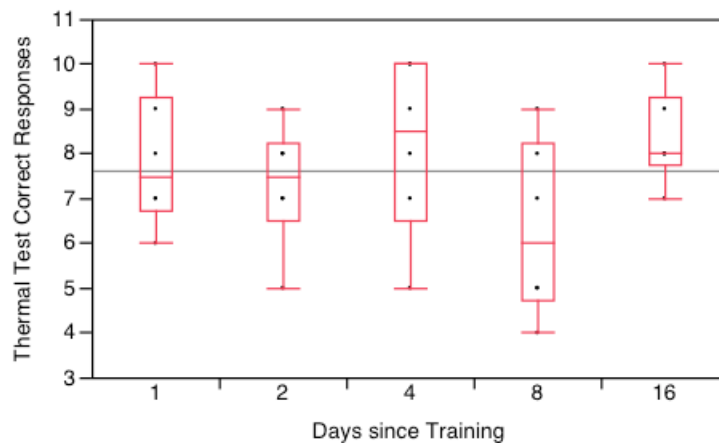


Figure 4. Thermal Test Scores by Group

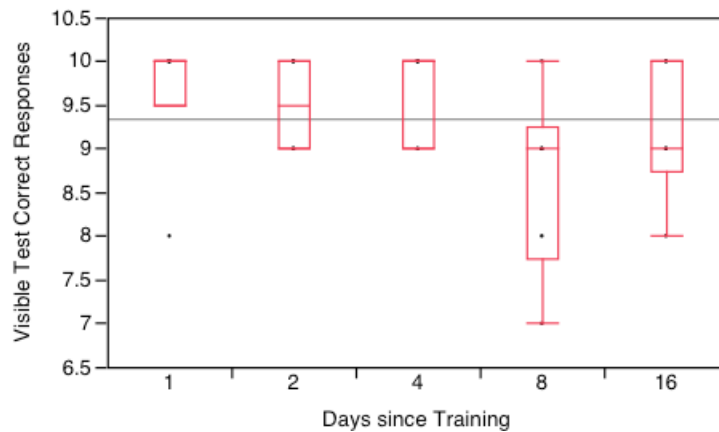


Figure 5. Visible Test Scores by Group

To determine the effect of time on TVI post-test accuracy, a Fisher's exact test for count data was conducted for the thermal and visible post-tests. A

significant difference was not found between groups for the thermal condition ($p=0.97$) or the visible condition ($p=0.26$).

D. IMAGE PRESENTATION

Thermal images present different cues than visible images. A Wilcoxon signed rank test was conducted to determine the impact of image presentation on the TVI post-tests. The Wilcoxon signed ranks test indicated that thermal image scores were significantly lower than visible test scores within all groups, $Z=120.5$, $p<0.0001$. Figure 6 shows the differences between each group's mean scores on the two post-tests.

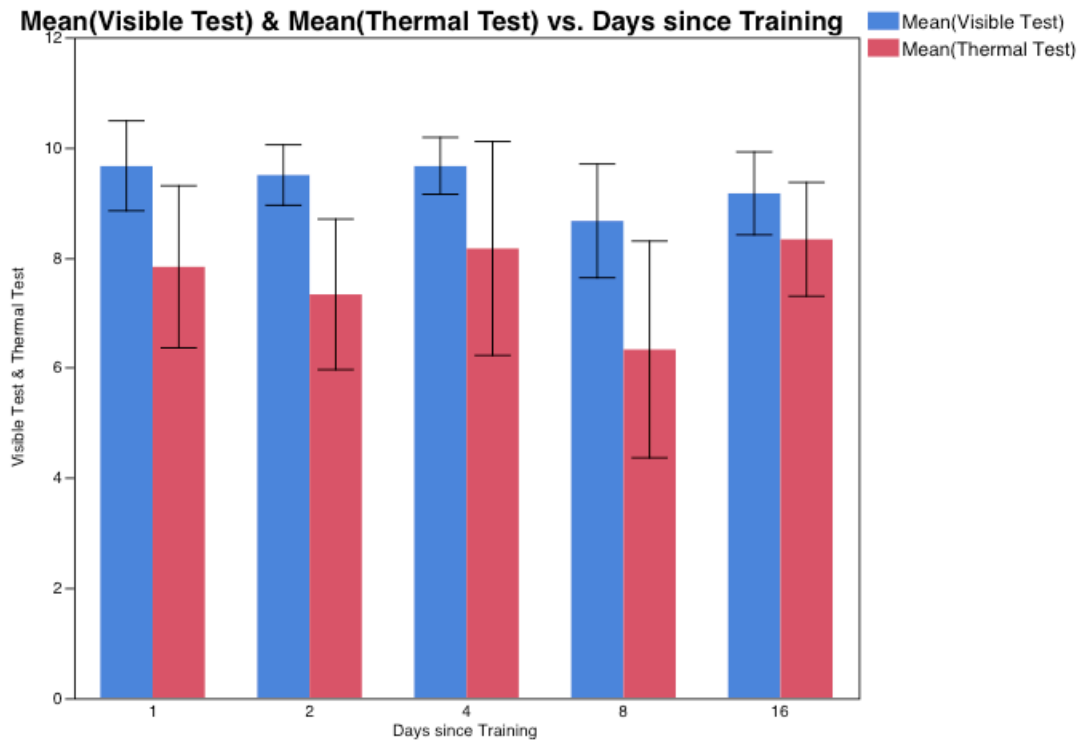


Figure 6. Mean Post-Test Scores by Group

E. COVARIANCE

1. Recognition Memory Test

An over-dispersed logistic regression model was fitted to determine the effect of recognition memory using the 72-hour RMT on thermal post-test performance. The relationship between the variables was significant ($p=0.038$), indicating that performance on the 72-hour RMT predicted post-test performance.

2. Previous TVI Training

Participants were asked if they had any previous TVI training. Eleven participants had previous TVI training, ranging from two to eleven years ago. Previous TVI training was assumed to have a binomial distribution and was used as a covariate during data analysis to account for previous training and on performance on the thermal post-test. The results from fitting a logistic regression model (see Figure 7, where $x=1$ if a participant had prior training and $x=0$ otherwise) indicate that if a participant had prior TVI training, the estimated proportion correct on the thermal post-test increased ($p=0.035$).

$$\hat{p} = \frac{e^{2.19+0.760x}}{1 + e^{2.19+0.760x}}$$

Figure 7. Previous Training Logistic Regression Equation

3. Time to Complete Training

Participants were timed from the beginning of their ROC-V training sessions until the completion of their baseline ROC-V post-tests. A logistic regression model was fitted to analyze the relationship between time to complete training (see Figure 8, where x represents time to complete training) and performance on the thermal post-test.

$$\hat{p} = \frac{e^{2.83+.025x}}{1 + e^{2.83+.025x}}$$

Figure 8. Time to Complete Training Logistic Regression Equation

The results indicate that time to complete training is a significant predictor of thermal post-test scores ($p=0.03$). As time to complete the training session increased, performance on the thermal post-test decreased (see Figure 9).

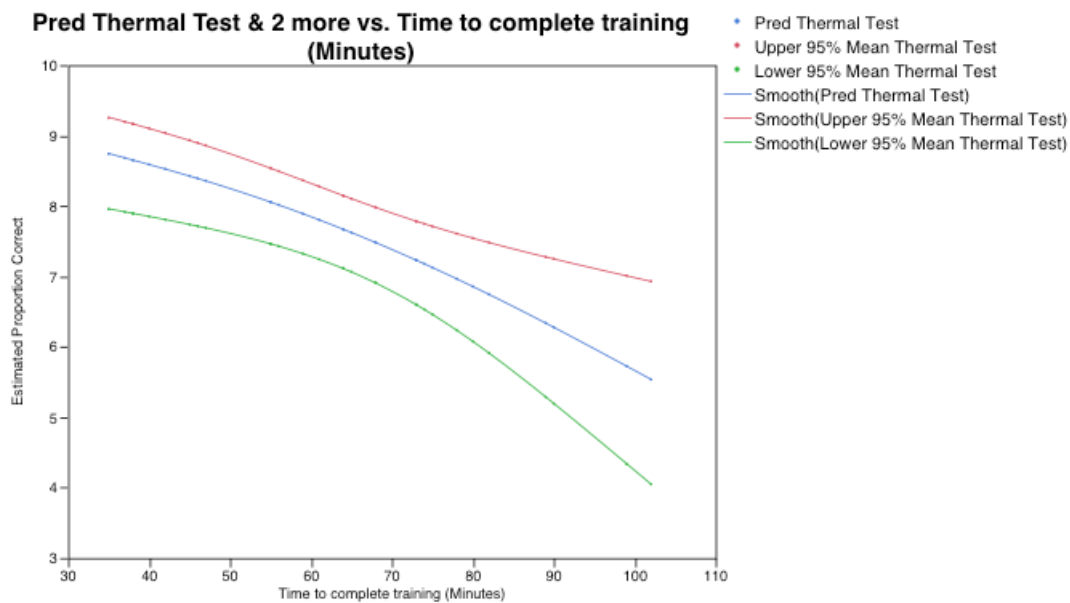


Figure 9. Regression Plot for Time to Complete Training

4. Sleep

Participants completed sleep logs for their duration in the study. Average sleep times were computed for each participant and used as a covariate during data analysis to account for the effects of fatigue on participants' recognition memory. The results of fitting a generalized linear model were not significant and indicated that sleep was not a significant predictor for the post-test scores or recognition memory test scores ($p=0.501$).

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V. DISCUSSION

A. TIME SINCE TRAINING (HYPOTHESIS 1)

The hypothesis that performance on a TVI task degrades at an exponential rate over time was not supported. Statistical tests for both types of imagery and TVI performance retained the null hypothesis that performance on the TVI task does not degrade exponentially. This suggests that memory is not as susceptible to decay on a TVI task.

1. Results Review

This study examined the rates of forgetting on a TVI task over a 16-day period. Thermal and visible image sets were used to measure performance on a TVI task. An analysis of variance (ANOVA) was conducted on each group's post-test scores for each image condition. Results showed that the passage of time since initial training was not significant between groups or image conditions. The independent variables of time since training and image presentation did not produce any significant interactions.

2. Relevance of Results to Previous Research

Dyer et al. (1997) proposed that future research should examine rates of forgetting and associated factors on a TVI task since research in this area was limited. Heuckerorth et al. (1988) determined that the greatest decrement in performance on a TVI task using visible imagery occurred within a three-week period following initial training. Based on this previous study, we predicted that performance would degrade significantly over the 16-day test period for both image conditions. The work of Ebbinghaus (1913) and Peterson and Peterson (1959) also led us to predict exponential rates of forgetting during the present study. The present study did not find forgetting to occur at these previously identified rates. This may be attributed to the difference between recall tasks completed in previous studies and the recognition task completed in ROC-V.

The battlefield task of TVI is representative of a cued recall task, where warfighters must recall a vehicle's characteristics by seeing visual cues. However, the ROC-V post-test presents a recognition task where participants select from a choice of alternatives after the program presents visual cues. The difference between the task in the present study and the work of Ebbinghaus (1913) and Peterson and Peterson (1959) may account for the difference in the results not showing exponential decay on the ROC-V post-test.

O'Connor (2002) found that the use of ROC-V helps to maintain TVI task proficiency above 90% with sustained usage. The results from the ANOVA indicate that ROC-V is indeed capable of achieving high levels of proficiency on a TVI task. However, the test metrics that ROC-V uses to measure performance are not representative of an actual TVI task since ROC-V uses a multiple-choice post-test. This sort of cueing does not exist for a warfighter who must remember vehicle characteristics without being presented response options.

3. Explanation of Non-significance

The lack of significance suggests that performance on a TVI task may not decay exponentially as predicted for either thermal or visible images. However, the battery used to test participants is not representative of a real-world TVI task. For instance, there is no menu of options that appears in a tank gunner's primary sight that relays vehicle information once a target has been identified. Warfighters must be able to detect, identify, and classify images as friend or foe using their knowledge of the battlefield-operating picture and their previous training on TVI. Participants in the present study reported that they were able to deduce which vehicle was the right answer by process of elimination. The choices for each question were limited to the vehicles in the 10-vehicle training set. This provided further assistance in answering the post-test questions since participants were familiar with the vehicle choices and had no unfamiliar vehicle names to consider.

B. THERMAL VERSUS VISIBLE IMAGE PRESENTATION (HYPOTHESIS 2)

The hypothesis that performance on a TVI task is different between visible and thermal image presentation was supported. Statistical tests for both types of imagery and TVI performance rejected the null hypothesis that performance on the TVI task does not differ between image presentations. The implications for this finding are important for both training plan design and fratricide mitigation.

1. Results Review

Participants' performance was measured by analyzing the number of correct responses for the thermal and visible post-tests. A Wilcoxon signed rank test indicated that the visible image test led to significantly higher scores on the visible post-test than the thermal image post-test.

2. Relevance of Results to Previous Research

Dyer et al. (1998) reported that thermal image recognition was more difficult than visible image recognition. Results from the present study support this finding. Even though the multiple-choice post-tests allowed participants to deduce their answers, a significant difference between thermal and visible image conditions still existed. Dyer et al. (1997) suggested that differences in thermal and visible image presentation could lead to confusion when conducting a TVI task, even when the physical surface structure of the vehicle may be known to a warfighter. Some participants reported seeing some of the vehicles while stationed at previous duty stations. While participants may have had limited knowledge of some of the vehicles, their performance indicated that the thermal condition was still more difficult than the visible condition.

The differences in thermal and visible images are informative. Thermal signatures are dynamic and change based on environmental and system operating conditions. Visible images do not present as many challenges to an observer (O'Connor & O'Kane, 2002). Dyer et al. (1997) proposed that high-performance on a visible TVI task was not predictive of the same performance on

a thermal TVI task. Results from the present study support this assertion since visible post-test scores were significantly higher than the thermal condition. All participants reported more difficulty with the thermal images due to their unfamiliarity with seeing infrared images. Participants reported that seeing thermal images was more difficult since they had to focus on specific cues in the images as opposed to being able to plainly see more vehicle characteristics in the visible condition. This follows the work of Palmer et al. (1982) who suggested that thermal sensors present a new and unfamiliar stimulus to an operator.

3. Explanation of Significance

Thermal imagery is a relatively new technology available to warfighters. As the United States began fielding systems with more robust infrared technology in the 1980s, the introduction of thermal images created a new challenge for warfighters since they had not previously been exposed to this sort of stimulus (Smith et al., 1987). Even though they knew some of the vehicles from previous work experience, participants reported being unfamiliar with seeing thermal images of vehicles. This led to confusion when taking the post-tests and lower scores on the thermal image set.

Lower performance on the thermal condition matters. In Operation Desert Storm Given, 90% of engagements occurred using thermal sights (O'Connor & O'Kane, 2000) and 80% of M1 Abrams and M2 Bradley Fighting Vehicles destroyed were the result of friendly fire (Harmeyer & Antal, 1992). More recently, 55 fratricide instances led to 30 fatalities in the GWOT from September 2001 to March 2008 (Webb & Hewett, 2010). These statistics along with performance on the thermal post-test in the present study highlight the need to effectively train and test warfighters with thermal imagery.

C. RECOGNITION MEMORY PREDICTING TVI PERFORMANCE (HYPOTHESIS 3)

The hypothesis that recognition memory predicts performance on a TVI task was supported. Statistical tests for the 72-hour recognition memory test rejected the null hypothesis that recognition memory did not predict performance on the TVI task. This suggests that recognition memory ability is an important predictor of performance on a TVI task and should be considered in training design.

1. Results Review

Participants' recognition memory was measured using a 12-image recognition memory test. Participants took the RMT on their first day in the study until they correctly remembered all 12 images. After 72 hours had elapsed, participants returned and took the RMT again. The effect of recognition memory on the thermal post-test was determined by using an over-dispersed logistic regression model. Results indicate that the 72-hour RMT scores were significant predictors of performance on the TVI task. Participants who did not remember all 12 images on the RMT did worse on the thermal post-test than those who remembered all of the images.

2. Relevance of Results to Previous Research

Snodgrass and Corwin (1988) assessed recognition memory tests that were used to examine memory deficits. The study found that as similar features between test items in the RMT increased, subjective familiarity with test items also increased. This phenomenon caused misidentification by having the wrong memory representations activated. In the present study, participants reported seeing images on the RMT before, but confused them with other similar items. This finding highlights the importance of proper encoding at stimuli perception (Tulving & Thompson, 1971). Participants who did not encode properly during the RMT had difficulties on the ROC-V thermal post-test. Using retrieval cues

only works when proper encoding occurs at the beginning of the memory trace process (Tulving & Thompson, 1973).

Recognition memory produces higher performance results than recall since cues are available to drive recognition (Wisher et al., 1999). While vehicle cues were available for participants to analyze, additional cues that were not representative of the TVI task were present in the form of multiple-choice answers. This indicates that even with the presence of additional cues that aided in identifying a vehicle, recognition memory is still a significant predictor of performance on the ROC-V thermal post-test.

3. Explanation of Significance

Results from the present effort follow previous research, which determined that recognition studies return levels of accuracy above 50% (Brainerd et al., 1990). The findings from the present study suggest that high levels of performance on recognition memory predict performance on a TVI task. However, as previously stated, the ROC-V task does not accurately represent the warfighter's battlefield task. Since results from the present study indicate that recognition memory is a significant predictor of performance on a TVI task, providing high fidelity training to more accurately gauge true TVI performance is necessary to give commanders a better understanding of the skill levels of their soldiers.

Assessing recognition memory abilities is an important aspect of developing a TVI training plan. Identifying individuals with lower recognition memory levels can help allocate training resources appropriately. Warfighters who demonstrate lower performance on a RMT may need additional training to improve their recognition memory. Furthermore, warfighters with low RMT performance may need more frequent refresher training for other recognition memory tasks in their occupational field.

D. TIME TO COMPLETE TRAINING AND PREVIOUS TVI TRAINING

Post-hoc analysis of covariates revealed two additional significant findings. Participants with previous TVI training did significantly better on the thermal post-test. Additionally, the longer it took participants to complete the training modules, the worse their performance was on the post-tests.

1. Previous TVI Training Results Review

A logistic regression model was fitted to analyze the effect of previous TVI training on TVI task performance. Results from the regression model predicted performance on the post-tests. Eleven participants reported having previous TVI training in some capacity throughout their careers. Training last occurred between 2 and 11 years prior to participation in the present study. These results suggest that providing some level of TVI training during a warfighter's career can have a beneficial impact on future TVI performance. ROC-V's availability on mobile platforms can potentially provide this sort of exposure to occupational specialties that do not focus on TVI as a part of their training regimen. Heuckeroth et al. (1988) recommended that retraining efforts be started after nine weeks of initial training. This finding suggests that warfighters can leverage ROC-V's availability on mobile platforms to train on TVI to not only reach high levels of proficiency, but also maintain them.

2. Time to Complete Training Results Review

A logistic regression model was fitted to analyze the relationship between time to complete the training module and performance on the post-test. The results indicated that the longer it took participants to complete the training module, the lower their scores were on the thermal post-test. This finding contradicts Heuckeroth et al.'s (1988) assertion that while different Soldiers reach different levels of performance initially, TVI performance decays at the same rate for all. Participants who took longer to complete the study experienced greater performance decrement. This finding also indicates that warfighters who take longer on the self-guided training modules may have memory deficits that

preclude retention over long periods and result in lower levels of performance on a TVI task. Commanders can shape their training programs to identify threshold values for training time that their units must achieve. Warfighters who fall outside of those values can be identified and provided more frequent fresher training to maintain their levels of performance. This may also serve as an exclusionary measure in personnel selection for military occupational specialties that are highly dependent on TVI task skills.

VI. CONCLUSION AND RECOMMENDATIONS

A. CONCLUSIONS

During this study, we found that performance on a TVI task did not decay exponentially over a 16-day period. While time since training did not serve as a significant predictor of performance, time to complete training and previous TVI training did. Decay over time not being significant was contrary to expectations based on previous studies. Performance on the thermal image test was significantly worse than the visible image test across all participants. Post-hoc analysis determined that recognition memory ability on the TVI task was a significant predictor of performance. Average sleep was not a significant predictor of performance.

The design of the experiment controlled for differences in individual recognition memory abilities in order to test the impact of passage of time in forgetting. While there was not enough difference between participants to assign them to groups with different recognition memory abilities, results of the recognition memory test was a significant predictor of performance on the TVI task.

Time since training was not a significant predictor of performance but previous TVI training was. While many participants did not have previous formal TVI training, they reported that they have seen many vehicles as a part of their daily activities while working on military bases. This may have contributed to the higher test scores across all participants. Previous training occurred at least two years prior to the present study. This implies that memory of TVI training may last longer than expected. This finding emphasizes the point that at least some level of TVI training can potentially mitigate fratricide. Furthermore, continued training over a warfighter's career can reinforce TVI skill level.

We did find significant results in training duration with respect to performance on the TVI post-tests. As time became longer for participants to

complete the TVI training, their post-test scores decreased. While this was a significant finding, it may not necessarily mean that training programs need to be short in duration. Initial entry Warfighters with no previous knowledge of military vehicles may need longer times to achieve minimum proficiency. However, if Warfighters need longer periods of self-guided training modules on ROC-V, it may indicate they have other problems with memory. This could mean that commanders will have to shape training programs to ensure total unit readiness.

The experimental design allowed for analysis of memory between recognition of thermal and visible images. The significant difference in performance between thermal and visible images is telling. Lower performance on the thermal image set emphasizes the point that more attention needs to be placed on these images in training plans. As the military continues to rely on infrared technology to conduct combat operations, recognition of thermal images continues to be low. The different cues that thermal imagery present are more difficult to recognize than visible imagery and necessitate increased attention to these differences.

B. RECOMMENDATIONS FOR FOLLOW-ON RESEARCH

Future research can expand our understanding of the effect of memory on TVI task performance. Increasing the amount of time between training and testing may reveal a significant impact of time on memory decay for a recognition task. While the training provided by ROC-V is robust and effective, the multiple-choice post-test is not representative of a real-world task. Tank gunners are not presented with options for the type of target in a tank gunner's sights and then asked to select the correct response. Future research using ROC-V should analyze "shoot/don't shoot" scenarios where participants have to decide whether the vehicle is a threat or not. Another study should investigate participants' ability to recall names of vehicles when presented only with an image of the vehicles. This would allow for more detailed analysis on the effect of memory decay on the TVI task. Future research must not only address the effects of

memory decay over time, but also on effective ways to train and test thermal images to reach higher levels of proficiency. Follow-on studies should analyze retraining intervals in order to determine effective refresher training schedules.

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APPENDIX A. RECOGNITION MEMORY TEST

The recognition memory test used in this study was derived using Warrington's (1984) framework.

You are about to take part in a test that measures your ability to remember images. You will be shown a sequence of images to remember. Immediately afterward, you will see a screen with 36 images randomly arrayed. Write down the names of the images you recognize. When you have written down all of the images you can remember, turn your answer sheet upside down.



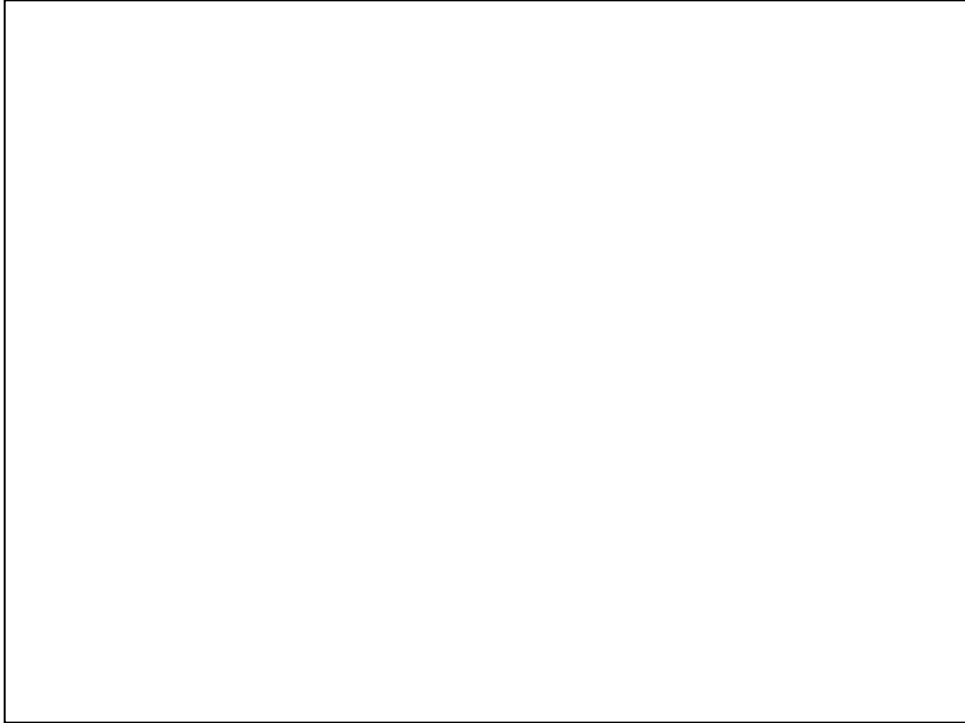
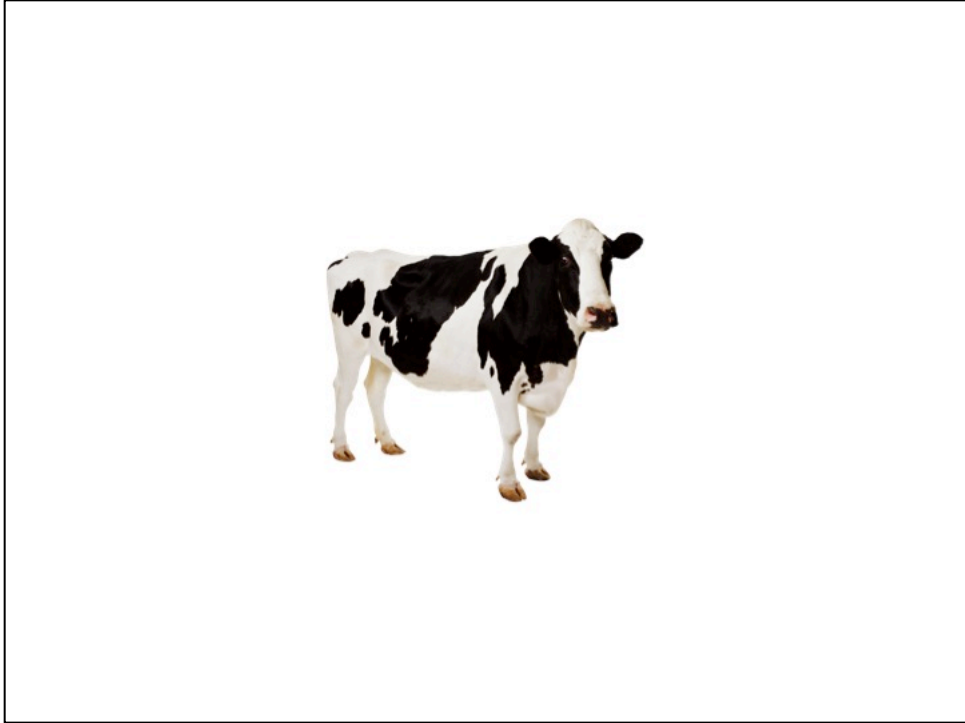














APPENDIX B. DEMOGRAPHIC QUESTIONNAIRE

1. What is your age?
2. What is your branch of service?
3. What is your military occupational specialty?
4. What is your rank?
5. How many years in service do you have?
6. What is your visual acuity?
7. Have you ever received fighting vehicle identification training?
 - 7a. If yes, when was the last time?

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