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TESTING A COGNITIVE ALIGNMENT-BASED TRAINING MODEL TO ACCELERATE OPTIMAL MILITARY DECISION-MAKING IN A PLATOON-FORMATION TASK

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THESIS

TESTING A COGNITIVE ALIGNMENT-BASED TRAINING MODEL TO ACCELERATE OPTIMAL MILITARY DECISION-MAKING IN A PLATOON-FORMATION TASK

by

Brian M. Hanley

June 2018

Thesis Advisor:	Quinn Kennedy
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13. ABSTRACT (maximum 200 words)

Determining which platoon formation (PF) should be used is a decision that all junior Army leaders must execute during training. Yet, current military training in PF is tailored to the masses rather than adapted to an individual's current abilities. This thesis had two goals: (1) to develop a computer-based platoon formation decision task (PFDT) and associated software that can be used as a training aid and (2) to apply a recently developed adaptive training model, CAPTTIM, to the PFDT to provide greater insight into a trainee's cognitive state and decision performance. Thirty subjects completed the PFDT in about 15 minutes. On average, subjects performance improved as they progressed through 128 trials. CAPTTIM revealed three distinct groups of learners. The results indicate that the PFDT and CAPTTIM have the potential to accelerate learning through incorporation into an adaptive training tool.

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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN MODELING, VIRTUAL ENVIRONMENTS, AND SIMULATION

from the

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ABSTRACT

Determining which platoon formation (PF) should be used is a decision that all junior Army leaders must execute during training. Yet, current military training in PF is tailored to the masses rather than adapted to an individual's current abilities. This thesis had two goals: (1) to develop a computer-based platoon formation decision task (PFDT) and associated software that can be used as a training aid and (2) to apply a recently developed adaptive training model, CAPTTIM, to the PFDT to provide greater insight into a trainee's cognitive state and decision performance. Thirty subjects completed the PFDT in about 15 minutes. On average, subjects performance improved as they progressed through 128 trials. CAPTTIM revealed three distinct groups of learners. The results indicate that the PFDT and CAPTTIM have the potential to accelerate learning through incorporation into an adaptive training tool.

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LIST OF ACRONYMS AND ABBREVIATIONS

.csv	comma separated value file
ADP	Army Doctrine Publication
ATP	Army Technique Publication
CAPTTIM	Cognitive Alignment with Performance Targeted Training Intervention Model
CRA	Charles River Analytics
DoD	Department of Defense
FM	Field Manual
H0	Null Hypothesis
HA	Alternate Hypothesis
ITS	Intelligent Tutoring System
MDMP	Military Decision Making Process
METT-TC	Mission, Enemy, Terrain, Troops, Time, Civilians
NDM	Naturalistic Decision Making
NPS	Naval Postgraduate School
PFDT	Platoon Formation Decision Task
ROTC	Reserve Officer Training Corps
SBT	Simulation-based Training
TGT	Terrain Generation Tool
TLP	Troop Leading Procedures
USMA	United States Military Academy
USMC	United States Marine Corps

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First, I would like to thank my wife, Melissa, and children, Brendan, Sara, and Avery, for all of their support and understanding over the last two years. Melissa's efforts to homeschool, run the household, and manage three very active children's schedules has been a daily feat that I have all too often failed to properly acknowledge. My children's understanding and selflessness allowed me to focus on my studies, and they continue to impress me on a daily basis. I could not be prouder of the way my children have grown and matured over these two years and how their caring and compassion for others always shines through.

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I.   INTRODUCTION

A.   MOTIVATION

Often during my time as a cadet and junior officer, I would find myself wishing I could have more time with a task I was supposed to be learning or more repetitions of that task. I felt that, if I could get more exposure, I would gain a greater understanding of the thought process or the expected reaction to a given event. Of my 17 years in the service, I have spent nearly 10 of those years involved in some aspect of training, as either the trainee, trainer, planner, and/or developer of training. One of the things I have always attempted to identify is how to design a training event that generates the most experience possible. Here I define experience as the knowledge gained through repetitive exposures to similar circumstances in a variety of situations. By gaining experience, an individual can reach a level of proficiency that allows an individual to react instinctively without the need to think about the necessary reaction (Klein, 1993).

In this thesis, I wanted to try to find a tool that gives the users understanding and proficiency normally gained through repetitive exposure and training iterations. I wanted to focus on a task that met the following criteria: the task is (1) relevant to the military, (2) moderately challenging to those trying to learn it for the first time, and (3) required for almost all junior leaders at some point in their training. I wanted to find a task that was rooted in doctrine that lends itself to an easily discernible "right" or "wrong." After seeing the work done by Major Travis Carlson for his thesis, using a military relevant decision task and the Cognitive Alignment with Performance Targeted Training Intervention Model (CAPTTIM) (Carlson, 2016; Kennedy Nesbitt, Alt, and Fricker 2015), I thought it might be possible to adapt Carlson's experiment to meet the criteria above.

Based on these criteria, I decided to create a platoon formation decision task (PFDT). All junior leaders receive a comprehensive level of training on basic infantry squad and platoon instruction while in their initial entry training or their first level of professional military education. They employ this training when they rotate through a squad or platoon leader position and receive a performance-based evaluation of their

leadership. I have seen extremely intelligent people struggle with the most basic decision necessary to conduct operations in a squad or platoon. The struggle to decide which formation to use for the situation can cause a young leader to lose focus and cause more difficulty later in the mission. I wanted to develop a tool that could give those individuals additional opportunities to practice making those decisions outside of the normal training time. Providing those individuals and their instructors a tool that could augment their training, which does not require additional training time or personnel to run, could be a valuable asset to increase the users' proficiency.

B. BACKGROUND

1. Decision-Making

The two most dominant categories of decision-making that emerge in research are analytical and recognition (Cohen, Freeman, Fallesen, Marvin, & Bresnick, 1996). Cohen et al. (1996) describe the analytical category as decision-making that uses logic to identify and assess possible courses of action and evaluating the value of their outcomes, which can be time consuming. Conversely, Cohen et al. (1996) describe the recognition category as an expert applying their expertise to identify the situation and using their experience to respond to the situation often in an intuitive manner. Both decision-making categories are used routinely in the different planning methods and the various tactical training exercises used within the Department of Defense (DoD).

The analytical category is exemplified by the Army design methodology, the military decision-making process (MDMP), and troop leading procedures (TLP) (ADP 5–0 The Operations Process, 2012). Each method becomes less analytical as the problem becomes more defined and time between mission receipt and execution shortens. Unit staffs execute Army design methodology and MDMP providing a series of briefs and recommendations to the unit commander. TLPs are executed at the small unit level where the unit leader does not have a staff to assist in the planning. The TLP level is where leaders begin to transition from the analytical to the recognition methods of decision-making.

Cohen et al. (1996) describe the recognition approach to decision-making as perceiving events, recognizing them as a known pattern, and responding with a plan of

action or categorizing the events. These aspects of recognition decision-making are the types of decisions young military leaders must make daily in combat.

The naturalistic decision-making (NDM) model (Klein, Orasanu, Calderwood, & Zsambok, 1993) fits this recognition approach to decision-making in many ways. The model focuses on how people make decisions with a number of competing influencers. NDM is characterized by eight factors that influence the decision-making task (Orasanu & Connolly, 1993). Any mission in the military might include all eight of these factors, but routinely small unit leaders encounter scenarios that include five or six of the factors identified by Orasanu & Connolly. These eight factors are:

1. Ill-structured problems

2. Uncertain dynamic environments

3. Shifting, ill-defined, or competing goals

4. Action/feedback loops

5. Time stress

6. High stakes

7. Multiple players

8. Organizational goals and norms

A critical component to both the recognition and NDM models is domain-relevant experience. Domain-relevant experience provides the decision maker the ability to distinguish, categorize, and understand the situation (Klein, 1993). These abilities are the mechanisms that allow leaders to react quickly to the situation and make decisions.

a. Decision-making at the Tactical Level

At the small unit level, platoons and squads, leaders make life or death decisions in an instant. The leaders of platoons and squads are lieutenants and staff sergeants often under the age of 25. They make decisions based on whatever information they have about

their situation, the situation of other units around them, and their previous experiences. Often the information available is only a small portion of the whole situation. Small unit level decision-making experience is gained with time and exposure to similar but varied situations, events 25 year olds typically have not yet accrued. The U.S. Army tries to provide these young leaders with training venues during their professional military education to gain experience in making many routine tactical decisions through situational training exercises, field training exercises, field leadership reaction courses, and tactical vignettes.

A now superseded Army field manual, FM 7–8 March 2001, defines skills required by the leaders:

> Infantry platoon and squad leaders must be tacticians. They cannot rely on a book to solve tactical problems. They must understand and use initiative in accomplishing the mission. This means that they must know how to analyze the situation quickly and make decisions rapidly in light of the commander's intent. (Change 1, p. 1–3)

When a platoon makes contact with the enemy, the platoon leader must decide how to maneuver the squads into an advantageous position that allows the platoon to achieve a favorable outcome. The key for a platoon leader is to put their platoon in a formation that not only allows the platoon to maintain their integrity and keep momentum, but also allows the flexibility for the platoon leader to maneuver the squads not in contact with the enemy. Effective management of a platoon in contact depends on the platoon leader's position within the formation and their ability to maintain situational awareness and rapidly make decisions.

b.   *Current tactical Decision-making Instruction and Evaluation*

The U.S. Army currently uses basic infantry tactics as a tool to evaluate future leaders (Training and Doctrine Command, 2002). Cadets at both the United States Military Academy (USMA) at West Point and those enrolled in Reserve Officer Training Corps (ROTC) programs across the United States receive evaluations based on how well they plan and lead basic infantry missions. Part of leading the mission is determining which formation the unit should use during movement. This decision is one of the simplest tasks

a leader must accomplish; however, a number of conditions factor into the decision. The mission at hand, enemy situation, terrain, troops available, time to accomplish the mission, and civilian considerations (METT-TC) are all processed by the leader as they make the decision on which formation to use; this formation decision may change throughout the duration of the mission (Headquarters, Department of the Army, 2016).

Current methods to evaluate the Army's junior leaders are cumbersome and time consuming. Throughout the course of their third year, cadets receive as few as five opportunities in which their tactical decision-making serves as the primary focus of their evaluation and they receive detailed feedback on their decision performance. The evaluation process requires a number of personnel to serve as members of the cadet's squad/platoon. The squad/platoon then executes a two- to four-hour tactical exercise during which the cadet receives their evaluation. This process is extremely expensive in terms of time and personnel. Conversations with several current and recent ROTC instructors confirmed U.S. Army Cadet Command, the command responsible for ROTC, does not use a digital training aide to augment the current training methods.

I have found no published evidence that a validated research task including these complexities currently exists. Thus, the platoon formation task designed and tested for this thesis could fill an important training gap. If the task is successful in training novice participants in accurately recognizing and incorporating multiple factors into their platoon formation decisions, it could be further developed and modified for use in augmenting training or as a training aide for cadets and other junior leaders as they learn infantry tactics.

2. Adaptive Training

a. What is Adaptive Training?

Charles R. Kelley defined adaptive training as training where "the problem, the stimulus, or the task is varied as a function of how well the trainee performs" (Kelley, 547, 1969). My interpretation of this definition is that adaptive training adjusts to the individual's or group's current knowledge and ability level. Much of the training in the military begins with large group instruction in a traditional classroom prior to transitioning to small group instruction. The traditional classroom, with an instructor standing at the

front of the class using visual aids and a chalkboard and all of the students sitting at desks taking notes, is a good example of non-adaptive training. If we take that same classroom, but the instructor gives the students a pretest, breaks the students into groups based on the pre-test scores, and provides assignments to each group at the group's knowledge and ability level, then this activity would now constitute adaptive training. One end of the adaptive training spectrum, referred to as macro-adaptive, might only have a few levels of assignments based on the skill/knowledge level of the student or group. The other end of the spectrum, micro-adaptive, uses a continuous or ongoing assessment of performance to adjust the difficulty of the assignments (Spain et al., 2012). A classic example of micro-adaptive instructional methods is a tutor helping a student having trouble with a task. The tutor adapts the difficulty of the problems they work with the student based on the student's performance and abilities (Spain et al., 2012). While an optimal method of training, this one-on-one method is very expensive in terms of time and resources. The scale at which the military conducts training makes it unfeasible to assign every trainee a personal human tutor. Technology-based systems present the most promising avenue for the military to incorporate micro-adaptive training for individuals.

b.   *How is Adaptive Training Useful to the Military?*

Adaptive training techniques provide enough promise for military use that the journal *Military Psychology* devoted the entire March 2012 issue to the topic. Research conducted by Benjamin Bloom in 1984 has found those learning in a one-on-one setting far outperform those learning in a traditional classroom setting (as cited in Landsberg, Astwood, Van Buskirk, Steinhauser, & Mercado, 2012). Technology, becoming increasingly ubiquitous in everyday life, has found its way into the training regiments of the DoD. Over the course of the last 15 years, more and more training that previously used a human instructor in front of service members in a large venue has migrated to a web based session; a simple search of Joint Knowledge Online or Army Knowledge Online will reveal hundreds of available courses. The Navy, Marines, and Army have all identified cognitively agility or improved decision-making as key aspects of their leader development strategies (Naval Aviation Enterprise, 2014; United States Marine Corps Training and Education Command, 2012; Department of the Army, 2014).

The increasing prevalence of computer-based training provides an excellent avenue for adaptive training to enter the military's training and education system. Computer-based adaptive training allows flexibility not available in large group instruction. With students working on individual computer systems that use an adaptive training application, instructors can focus on those individuals experiencing more difficulty with the task. Feedback and adaptation may even be manipulated based on a variety of variables from task performance, overall aptitude, learning style, or even personality (Landsberg et al., 2012).

The military has used simulation as a means of training their personnel for decades. The technology available today has allowed simulations to become more advanced, and to migrate tools once used only for training to instructional aides on a near daily basis (Schatz, Oakes, Folsom-Kovarik, & Dolletski-Lazar, 2012). Schatz et al. (2012) discuss this migration and the potential for when an instructional tool using an intelligent tutoring system (ITS) and a simulation-based training (SBT) tool intersect in a "Situated Tutor." The concept of a situated tutor is that it combines the benefits of both the ITS and SBT so that the situated tutor can automatically adapt its instructional strategy and provide direct feedback to the user. Schatz et al. (2012) conclude that situated tutors have great potential to improve both effectiveness and efficiency of training. However, there is a lack of data to test their prediction and more research is still needed.

Schaefer and Dyer (2012) examined adaptive training practices in the Army across 51 different courses. A combination of adaptation methods were found in these courses: micro-adaption, or adjustments based on current training task performance for struggling students (Landsberg et al., 2012), small group assessment, and varying task/assignment difficulty based on student progress either at the collective or individual level (Schaefer & Dyer, 2012). For courses in which instructors implemented few to no adaptive training approaches, the instructors cited limited resources including the time, technology, equipment, or material to allow them to adapt the training program (Schaefer & Dyer, 2012). Those courses that employed adaptive training techniques tended to focus on skill mastery. Schaefer and Dyer (2012) concluded the diversity of the courses taught in the Army make it difficult to define a single method of adaption that would work for all

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courses. The range of class size, topics covered, and instructor certification processes makes it nearly impossible to find the one adaptive training panacea that will work the Army. One limitation of the researchers' work is that they focused solely on live-person adaptive training. It is unclear as to whether their findings generalize to computer-based adaptive training.

Previous research demonstrates that the integration of adaptive training techniques generally leads to more effective and efficient training (Landsberg et al., 2012; Schaefer & Dyer, 2012; Schatz et al., 2012; Spain et al., 2012). In a time when fiscal stability is uncertain, training requirements are increasing, and technology is becoming more prevalent, adaptive training offers the military a method to reduce the cost and time it takes to train its personnel. The Army has deemed adaptive training a valuable tool to support the U.S. Army Learning Model (Johnston et al., 2015). The Army Research Laboratory published a series of reports in 2015 outlining desired areas of research and their goals (Goldberg, Sinatra, Sottilare, Moss, & Graesser, 2015; Goodwin, et al., 2015; Johnston, et al., 2015; Ososky, Sottilare, Brawner, Long, & Graesser, 2015; Sottilare, Sinatra, Boyce, & Graesser, 2015).

3.   Cognitive Alignment with Performance Targeted Training Intervention Model (CAPTTIM)

CAPTTIM facilitates the detection of suboptimal decision-making by comparing the subject's cognitive state to his decision performance. The term cognitive state refers to whether the subject is exploring or exploiting his environment. During exploration, the subject feels they are figuring out the task and are gaining situational awareness and understanding of the environment. In the exploitation state, the subject feels they have figured out the task and is ideally applying the understanding he gained during exploration. Exploration/exploitation is operationalized by variability in trial-to-trial decision times; high variability indicates exploration, while little variability indicates exploitation. Regret delineates optimal from suboptimal decision performance. The level of regret is determined by comparing the best possible outcome for a particular trial to the actual outcome. The difference between the two is the regret for given trial, in which high regret means suboptimal decision-making (Auer & Ortner, 2010). The metric of regret is determined by

comparing the best possible outcome for a particular trial ($r_{i,t}^*$) to the actual outcome ($r_{i,t}$), represented by the equation:

$$R = r_{i,t}^* - r_{i,t}$$

As regret is cumulative, at any point in the task it can tell us how far a subject is deviating from the ideal decision path. As a subject begins a decision task, the expectation is that they will spend some time in the yellow area (Exploration and High Regret) of the model before transitioning to the green area (Exploitation and Low Regret) (see Figure 1). This transition demonstrates the ideal progression of learning through exploration. Concern arises when a subject strays to the red or orange regions of the model for a substantial period; this is an indication the subject's cognitive state is no longer aligned with his decision performance and may require intervention (Kennedy et al., 2015).

If the subject remains in either the red or the orange category, training intervention should be considered. In the orange zone, the subject is making correct decisions, but may be unaware the decisions are correct. The red zone is the most alarming; here, the subject is making incorrect decisions, but believes they are making the correct choice. In this case, the subject has not correctly learned the appropriate cues to make correct decisions, and should be reminded of the cues (Kennedy et al., 2015).

Figure 1 illustrates how the subject's performance and cognitive state may not align.
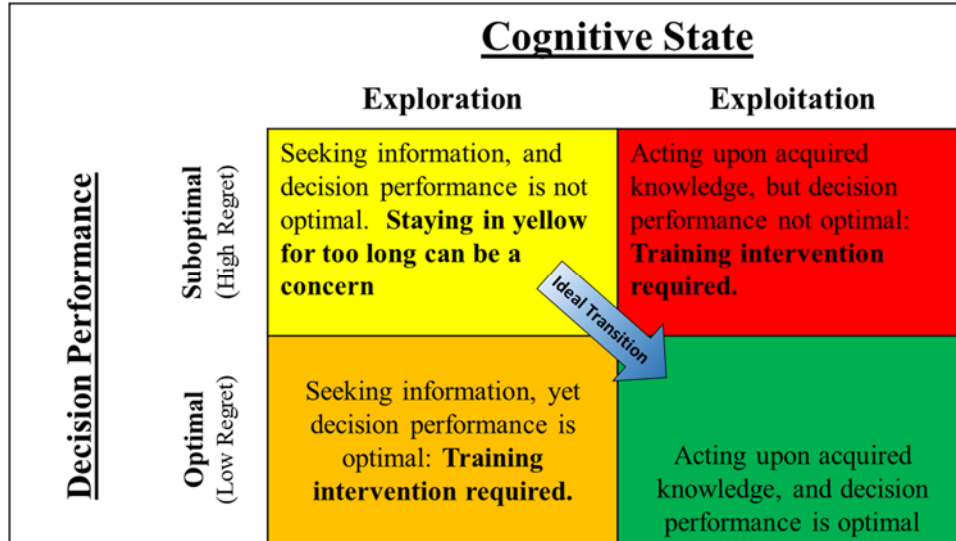
Figure 1.   Illustration of the main components of CAPTTIM. Source:
Kennedy et al. (2015)

Critz (2015) and Carlson (2016) applied CAPTTIM to the convoy task (Nesbitt et al., 2015). In this task, the study subject sees four identical pictures of a dirt road. The subject must chose the route that will provide the best long-term benefit. Each route has varying rewards, with one being high reward and very high penalty and another route being lower reward with a much lower penalty. The other two routes fall in between these two in regards to reward and penalty. Figure 2 is an example of what the subject sees while conducting the Convoy Task. The top-right number tracks the score while the bottom numbers display the result of the most recent trial.
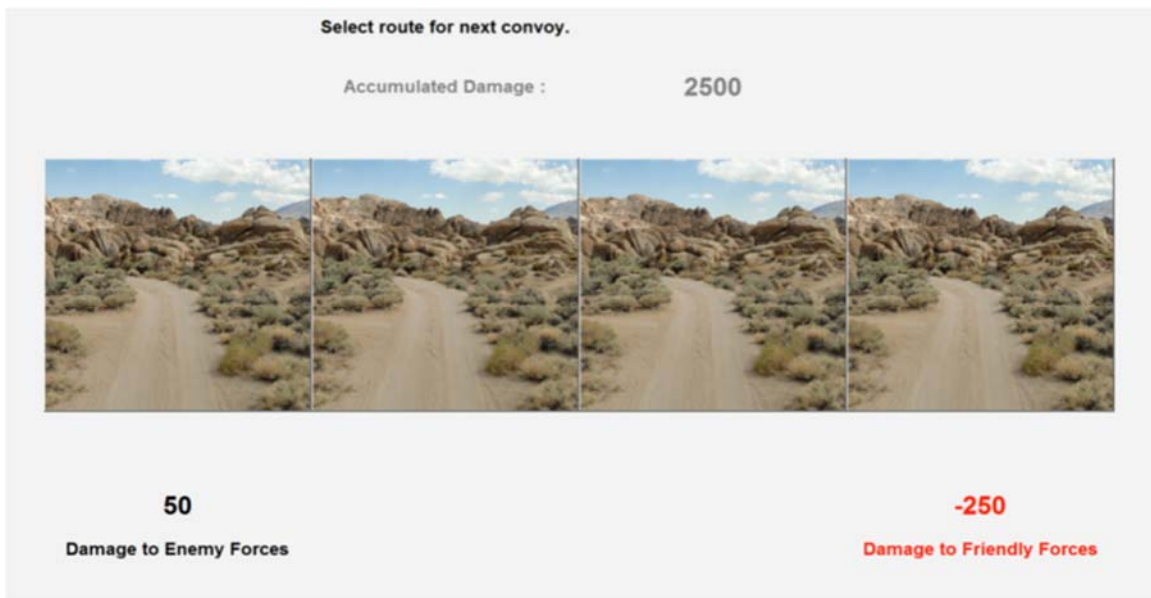
Figure 2.   Example of what the subject sees when conducting the Convoy Task. Source: Nesbitt et al. (2014).

Critz's and Carlson's research suggests CAPTTIM can determine when a military decision-maker's cognitive state properly aligns with their decision performance when conducting a simple tactical task. Figure 3 shows the ideal transition from exploration to exploitation during the convoy task (Critz, 2015). The colored bar across the top of the figure represents the corresponding CAPTTIM category. The subject started in the orange area of low regret and exploration, which is less than optimal; however, in fewer than 50 trials, the subject shifted to the green category. The subject identified the hazards of his environment, and, in the next 150 trials, was able to avoid the largest hazards in all but two trials.
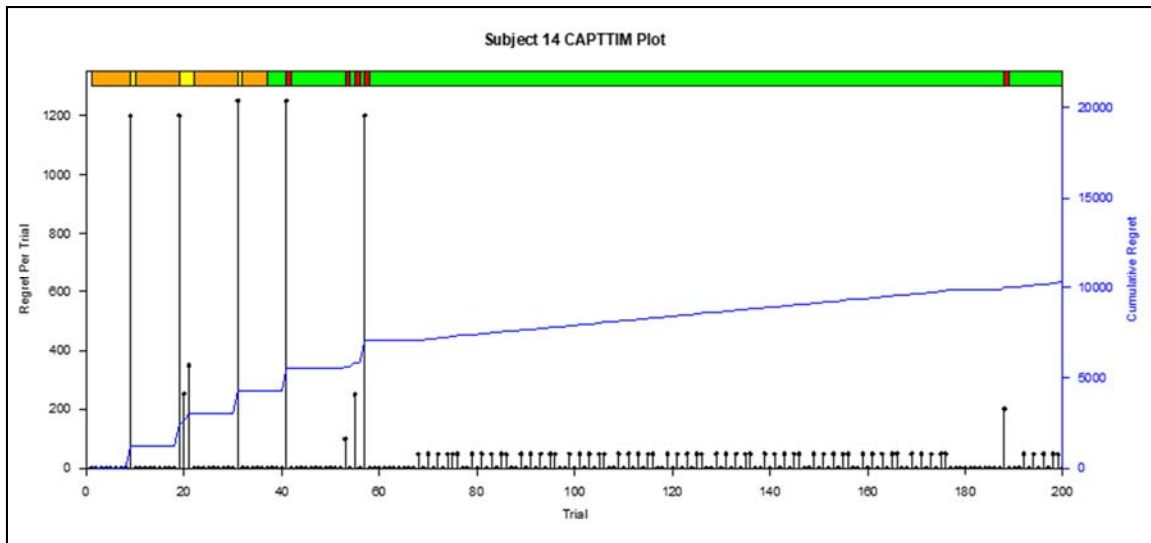
Figure 3.   Example of ideal transition from exploration to exploitation.
Source Kennedy et al. (in preparation), adapted from Critz (2015).

Figure 4 represents a subject that did not successfully transition to optimal decision-making (Critz, 2015). The bar at the top shows the subject in the orange category for about the first half of the task: this individual did not realize that they were making some good decisions. In this case, providing intervention to the subject around trial 50 could have guided them towards successfully transitioning to the green cell. Instead, the subject continued to select options resulting in large regret values throughout his 200 trials.
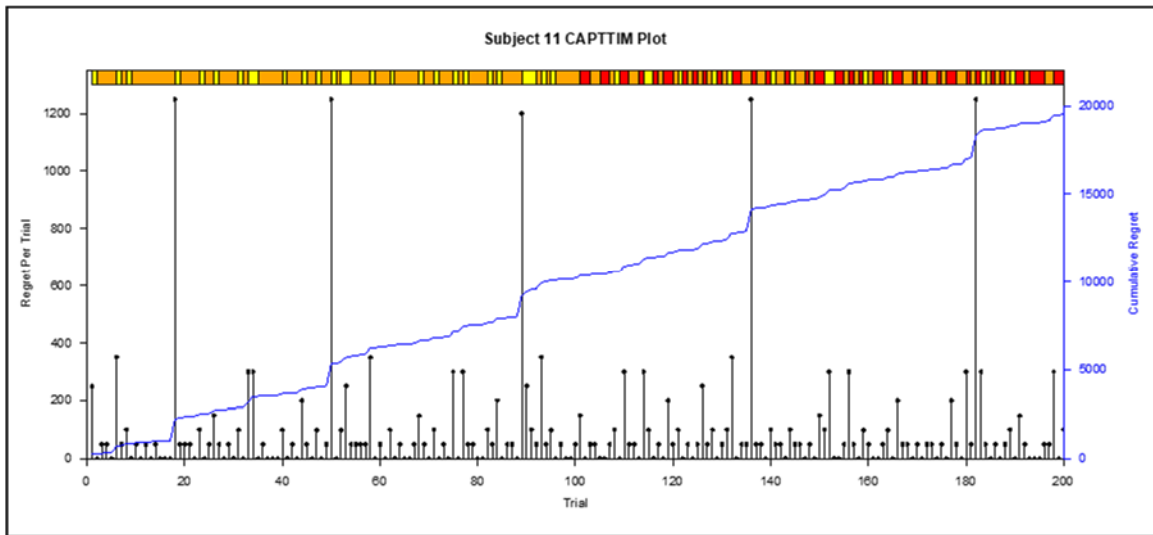
Figure 4. Example of a subject that never made the transition to optimal decision-making. Source: Kennedy et al. (in preparation), adapted from Critz (2015).

C.   RESEARCH QUESTIONS

This thesis has two goals. The first goal is to develop a dynamic PFDT and associated software that will be used as both a training aide and in analyzing the cognitive states of participants as they make decisions. This task will require the participants to make a platoon formation decision based on their recognition of visual terrain cues and brief scenario data. Participants will execute multiple trials of the task in which certain aspects of the video and scenario data vary across trials.

The second goal is to apply CAPTTIM (Kennedy, et al. 2015) to the platoon formation decision task data to provide an understanding of when and why some participants pursued suboptimal decisions.

a. Can a platoon formation decision task that simulates some of the decision-making factors be created?

Prediction: The majority of participants eventually learn to make correct platoon formation decisions based on a combination of visual cues and type of enemy situation.

H0$_1$: Average percent of acceptable decisions equal to or less than 70%. $\mu \le 70\%$

HA$_1$: Average percent of acceptable decisions is greater than 70%, $\mu > 70\%$

H0$_2$: Individual participants' average percent of acceptable does not change in a moving window of 32 trials. $\overline{x}_D \le 0\%$

HA$_2$: Individual participants' average percent of correct decisions increases by greater than 10% in a moving window of 32 trials. $\overline{x}_D > 0\%$

Exploratory Question:

Are some combinations of cues easier to learn than others?

b. Can CAPTTIM be applied to a platoon-formation decision task?

Exploratory Questions:

1. As seen in Critz (2015), will CAPTTIM classification reveal three distinct decision performance profiles: (1) those participants who transition from exploration (yellow or orange categories) to optimal exploitation (green category); (2) those participants who predominantly use suboptimal exploitation (red category) throughout the task; and (3) those participants who fluctuate between exploration and exploitation without successfully transitioning to optimal exploitation (green category)?

2. Does CAPTTIM classification provide a more accurate depiction of which participants successfully figured out the task than percent of optimal decisions?

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II. METHODOLOGY

This chapter explains the steps the research team took to design and develop the study. First, the discussion focuses on the design and development of the PFDT. The next section looks at previous work using CAPTTIM and explains the steps taken to adapt CAPTTIM for the PFDT and the methods for computing cognitive state and regret. The final section of this chapter discusses the pilot test of the PFDT and its results.

A. PLATOON FORMATION DECISION TASK

The PFDT focuses on a fundamental decision required of platoon leaders. The PFDT attempts to replicate real world settings where young leaders would find themselves. Through the manipulation of a limited number of factors, the task aims to provide junior leaders the opportunity to gain an understanding of when different formations are appropriate.

The Army has evaluated formations based on five characteristics: control, flexibility, fire capabilities and restrictions, security, and movement (Department of the Army [DA], 2016). Leaders determine which formation is most appropriate for the situation based on their characteristic strengths and weaknesses. Table 1 describes the five characteristics.

Table 1. Characteristics defined

Characteristics	Description
Control	The ease with which the leader is able to manage the formation
Flexibility	How easy it is for the leader to react to contact with the enemy and maneuver the platoon
Fire Capabilities and Restrictions	Direction where fires can be concentrated or where they are masked by other members of the platoon
Security	Where the formation is well suited to react to contact
Movement	Relative speed at which the formation can move

1.   Task Requirements

The PFDT has three main requirements. First, it should incorporate the mission factors described in Table 1. A mnemonic used to help leaders remember the factors is METT-TC, which stands for Mission, Enemy, Terrain, Troops, Time, and Civilians (DA, 2016).   Second, the task should help the subject transition from analytical to recognition decision-making. Finally, the task must provide positive/negative feedback to the subject for each trial.

2.   Design of Study

This thesis uses a 2^5 factorial design, meaning there are five factors with two levels of manipulation. This results in 32 possible treatments. For sufficient data points, each treatment is presented four times to each of the participants. Thus, the task entails a total of 128 trials.

Several factors led the research team to select a 2^5 factorial design for this study. First, the design keeps the treatments relatively simple. Second, limiting each factor to two levels ensures factor independence. Third, it allows for enough variability between treatments to make the task relatively challenging, but with enough repetition for participants to be able to make good decisions.

3. Design of the Platoon Formation Decision Task

For the purpose of this study, the METT-TC factors of time, enemy, and terrain were employed to develop a scenario to present to the subject. Enemy and terrain are each broken into two sub-factors; see Table 2 for a description of the factors and their levels.

Table 2. Factor descriptions

Factor		Description	Low	High
1	Time	Time of day, represented by amount of light	Daylight	Twilight
2	Terrain — Height	Degree of variation in the height of the terrain	Flat	Hilly
3	Terrain — Vegetation	Primary type of vegetation in the environment	Scrub Brush	Dense Trees
4	Enemy — Direction	Where contact with the enemy is expected to come from	Front	Side
5	Enemy — Likelihood	What is the probability of contact with the enemy	Possible	Likely

(1)   Terrain Generation

To convey each of the 32 situations to the subject, the research team created eight first-person videos moving through a terrain scenario. Charles River Analytics (CRA) developed a computer application capable of procedurally generating terrain Charles River Analytics, 2017). In this case, the terrain generated is a natural environment with hills and vegetation. CRA was gracious enough to share the application, hereafter referred to as TGT, for use in this project. TGT uses four variables (time of day, weather, height, and vegetation) to manipulate the terrain. These four variables facilitate the manipulation of three of the five PFDT factors: time, terrain height, and terrain vegetation.
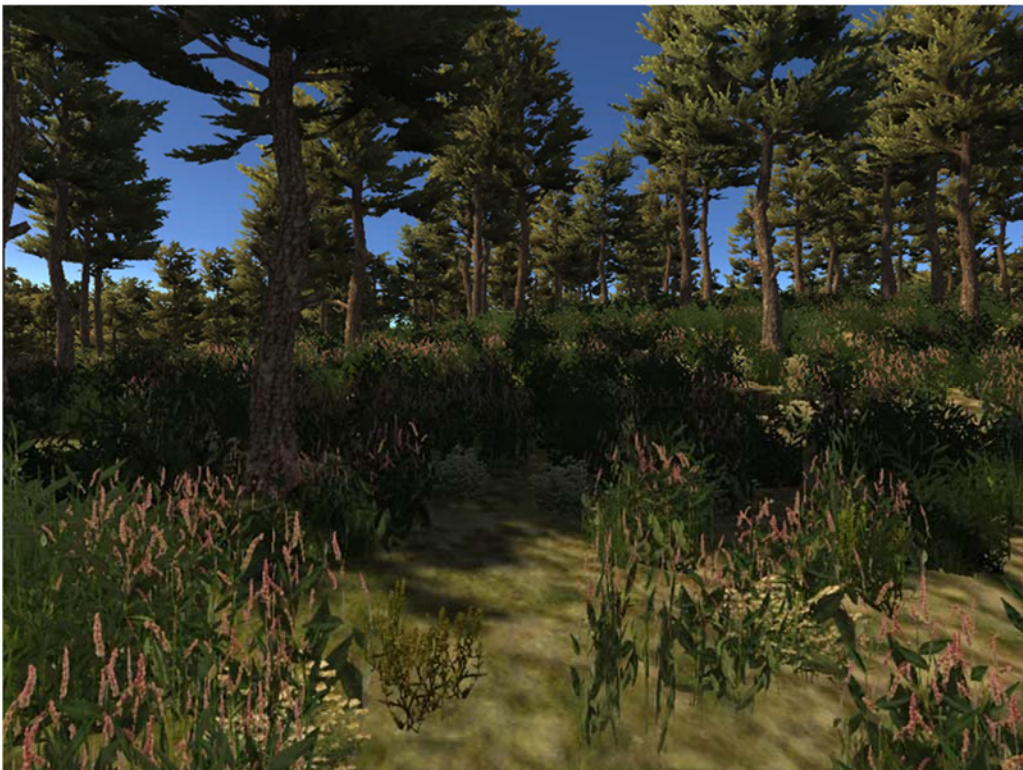
Figure 5.   Example of generated terrain This image shows the low terrain height, high vegetation, and daylight levels of the factors.

(2)   Video Generation

TGT has a built-in capability to move through the generated terrain and create a recording. Movement though the terrain occurs using a scripted sequence of commands to

move forward and look left/right for a period of time and a speed. Moving through the terrain in a zigzag pattern allows the subject to see a greater area of the terrain than if moving in a straight line. Appendix A provides detail on the analysis behind the generation of the videos and the movement pattern through the terrain.

(3)   Inclusion of the Enemy

Incorporating the enemy situation into the scenario attempts to simulate the real world mission process. As part of the mission process, the leader receives an operations order that includes an enemy situation paragraph. The enemy situation paragraph includes information about the known or assumed enemy locations and strength. The leader uses this information to assess where the enemy may be located within their area of operation and the likelihood his formation will make contact with the enemy during the mission. Written cues provide the subject a simplified enemy situation. The enemy situation for the PFDT consists of an expected direction of contact and the likelihood of contact.

(4)   Formation Options

The outcome measure in this task is which platoon formation the subject selects on each trial. Army doctrine describes six formations; in this task, participants select from three dismounted infantry platoon formations. The determination to use only three of the six formations facilitates a more focused study period prior to commencing the task. The research team worked with several combat arms officers as the subject-matter experts to determine which three formations are the most common options for 32 treatment scenarios based on the doctrinal characteristics listed in the Army's *ATP 3–21.8 Infantry Platoon and Squad* (DA, 2016). The three selected formations are the platoon file, platoon column, and platoon vee. These formations thus serve as the possible answers for each of the scenarios in the platoon formation task.

For each scenario, there is an optimal, less than optimal, and non-optimal response. The less than optimal response has the potential to be an acceptable response if the subject has made only optimal decisions in the last several trials. For example, losing a $5 bill occasionally is annoying, but acceptable; losing a $5 bill daily is not acceptable. Combat is not a clear-cut black and white or right and wrong event, and neither is the PFDT. Using

this method of acceptable answers instead of only correct or optimal more closely represents the realities of combat.

4.   Development of the Platoon Formation Decision Task

Figure 6 shows the initial interface concept for the PFDT prior to any refinement. The design process reduced the number of formations from five to three. After the research team determined the mission variable did not affect the doctrinally appropriate platoon formation, the team decided to focus on the enemy direction and likelihood.
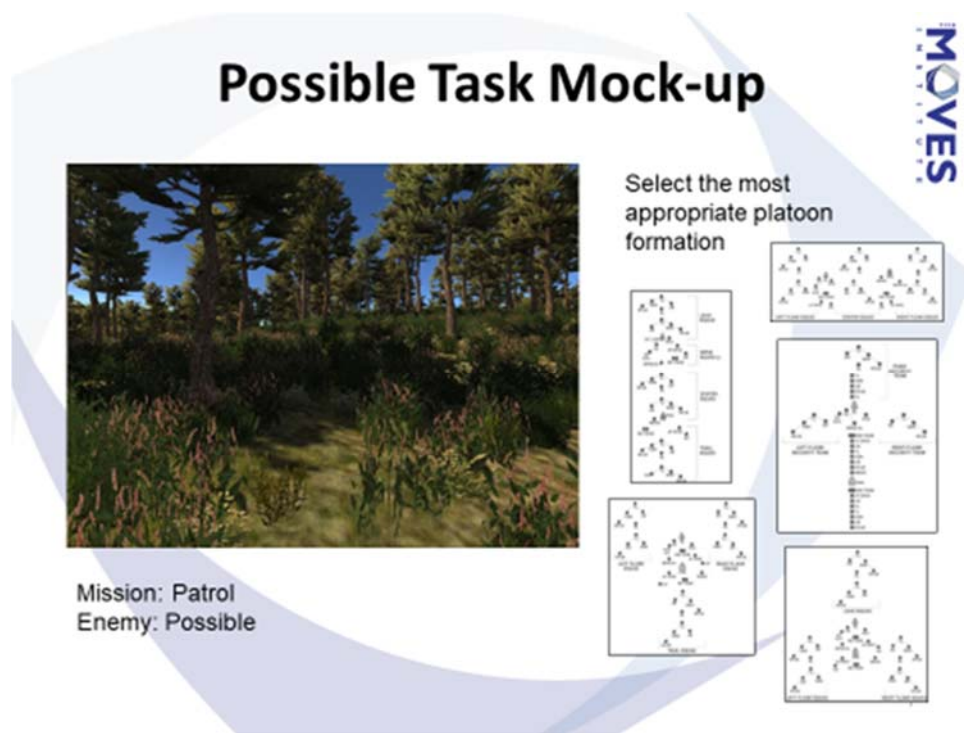
Figure 6.   Initial concept of the PFDT interface

Figure 7 shows the final interface for the PFDT. The subject sees the video in the upper left portion of the screen while the enemy situation is highlighted in the lower left. Brighter and bolder text highlights the active levels of the enemy factors. Having both levels visible allows the participants to recognize the location of the highlighted text and does not require the subject to read the situation for each scenario presented. Along the right side of the screen are the three formation options for the subject to choose. When the subject holds the mouse over a formation, the image is highlighted blue.
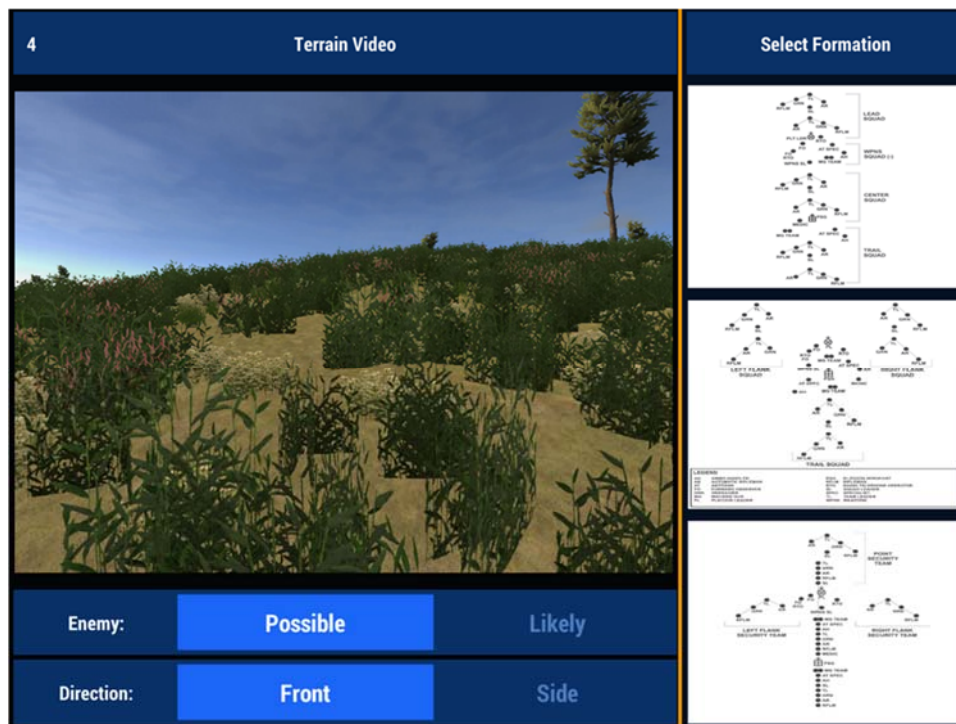
Figure 7.   Final user interface for the PFDT

The FutureTech Team from the Naval Postgraduate School's MOVES Institute produced the application to run the PFDT. The application reads from a reference file to identify the correct video and enemy factor levels to play for each scenario. Additionally, the application records the subject's selections and times of selection. The application compares the subject's response to the correct response contained in the reference file and provides the subject feedback. The feedback tells the subject if he selected the optimal formation or a non-optimal formation. When a subject completes his session, the

application creates an output file that contains the subject's responses and decision times for the application of CAPTTIM.

5.   Task Summary

The resulting final task design included 32 treatments presented four times for 128 total scenarios. The subject sees the video playing in the upper left of the screen with the enemy situation below the video and the formation options stacked vertically on the right side of the screen. Each video is ten seconds in duration, but the subject may make the formation selection at any time. Following the selection of the formation, the subject receives one of two messages: "You made the optimal Choice." or "You did not make the optimal choice." The message remains on screen until the subject selects the "NEXT" button and the next scenario begins. Appendix B contains a list of the 32 scenarios with the optimal formation and the associated regret levels. Appendix C shows the sequence if the 128 trials with the associated treatment, optimal formation, and regret levels.

B.   APPLYING CAPTTIM

The application of CAPTTIM is the synthesis of cognitive state and decision performance. It requires the calculations of two levels of cognitive state, exploration and exploitation, and two levels of decision performance, optimal and non-optimal (Kennedy, Nesbitt, Alt, & Fricker, 2015). This section discusses those calculations and describes the initial formula used to apply CAPTTIM to the platoon formation task.

Figure 8.   Illustration of the main components of CAPTTIM. Source: Kennedy et al. (2015).

1.   Cognitive State

Cognitive state is operationalized by each subject's intra-individual variability in decision time from trial to trial: large intra-individual variability indicates exploration; relatively stable decision times indicate exploitation. This thesis retrospectively calculated the intra-individual variability of decision times from the 128 trials. The research team followed similar steps to Kennedy et al. (2015) to categorize the cognitive state of the subject:

1. To establish a person's inherent processing speed, baseline mean ($\overline{x}_{Baseline}$) and standard deviation ($s^2_{Baseline}$) of decision times (t_i) were calculated. Decision

times immediately following trials in which the subject made an optimal decision serve as the basis for these statistics. The times following a non-optimal decision are excluded because of the possibility for the subject to hesitate before making their next selection. (See Figure 9 for more detail.)

2. Starting with trial 2, the calculation of a moving standard deviation (s^2_{Moving}) for each of the remaining 127 trials provided the comparator to determine relative size of intra-individual variability in decision times.

$$s^2_{moving} = \sqrt{\frac{\sum_{i-16}^{i}(t_i - \bar{t}_{i-16,i})^2}{n-1}}$$

3. For trials 2–128 the following formulas apply, where x = a scalar:

If $s^2_{moving} \leq xs^2_{Baseline}$ the cognitive state is classified as exploitive.

If $s^2_{moving} > xs^2_{Baseline}$ the cognitive state is classified as explorative.

Measured Values		Calculated Values	
Subject Regret	Subject Time		
0	24.1064	Baseline	
0	4.5597	Mean	
4	2.2958	14.1379	
0	14.1725		
0	19.1789	Baseline	
0	6.9646	Std Dev	
6	9.1355	11.1870	
0	7.9794		
0	9.3739		
7	37.4886		
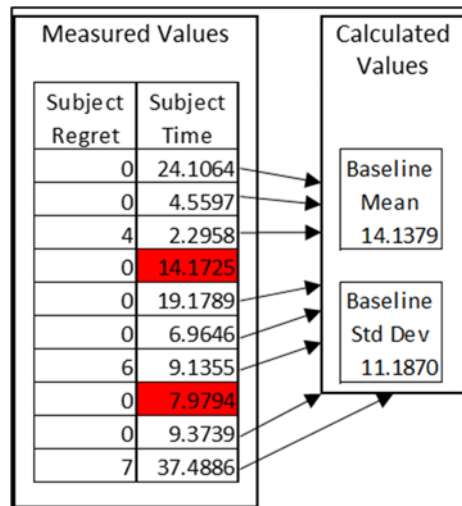
Figure 9.   Example of baseline calculation This figure illustrates the baseline calculations for the time a subject takes to make a formation selection. Baseline calculations exclude times for a trial after the subject received any regret (highlighted by the red cell).

2.   Decision Performance

Decision performance is measured by regret. Regret is determined by comparing the subject's single trial performance to the best possible outcome for that trial (Kennedy et al., 2015). Regret is delineated into one of two levels: low, indicating that the person is making optimal decisions; or high, indicating that the person is making non-optimal decisions. The classification of regret uses a comparison of actual regret to acceptable regret. The calculation of regret level occurred retrospectively after the subject completed all 128 trials. The research team followed similar steps to Critz (2015) to classify regret. The steps below outline the process used to classify regret as either high or low.

1. <u>Identify amount of regret (R)</u>. As described earlier in section I.B.3, the calculation for regret is relatively simple: take the best possible result ($r_{i,t}*$), subtract the actual performance ($r_{i,t}$), and the remainder is regret.

$$R = r_{i,t}* - r_{i,t}.$$

   For the PFDT, the research team chose to assign regret on a scale of zero to ten. An optimal selection results in a regret of zero. A non-optimal choice incurs regret based on the level of risk associated with the selected formation; see Table 3 for the frequency that regret values may occur. This results in a simplified regret equation of:

$$R = r_{i,t}$$

Table 3. Times each regret value may occur

Regret value	Possible times to receive
0	128
4	100
5	28
6	20
7	92
8	8
9	8

Each trial has three possible regret values ranging from 4–9 sSee Appendix C for a list of trials and regret by formation). The regret value corresponds to the subject's formation selection.

2. <u>Calculate acceptable regret</u>. The calculation for acceptable regret (R_A) uses an exponentially weighted moving average (EWMA). Critz (2015) used mean regret between two change points to calculate expected regret. Carlson (2016) used a EWMA considering only the previous ten trials. The smaller regret scale of the platoon formation task and the low possible frequency of the highest level of regret does not work well for a change-point analysis methodology. Therefore, the research team used an EWMA as a starting point for calculations.

3. <u>Delineate high vs low regret</u>. To distinguish between high and low regret, the research team compared the subject's trial regret to the acceptable regret:

If $R > R_{A,i}$ the regret is considered high.

If $R \leq R_{A,i}$ the regret is considered low.

3. Initial Formula for each CAPTTIM Category

Figure 10 illustrates the initial conditions for each of the CAPTTIM categories. The research team used the same multiplier as Critz (x = 2) for the classification of cognitive state resulting in the comparative equation:

$$s^2_{moving} (\leq or >) 2s^2_{Baseline}$$

To determine regret level, the research team decided to use a continuous EWMA, weighting the most recent trial as 75% of the EWMA.

$$R_{A,i} = (0.75)R + (0.25)R_{A,i-1}$$

Figure 10.   Initial conditions for each CAPTTIM category. Adapted from Kennedy et al. (2015).

C.   PILOT TEST

Members of the research team with no infantry experience and one infantry officer with two deployments in support of Operation Enduring Freedom participated in the five sessions of pilot testing. The two objectives for the pilot test included verification and validation of the software application and confirmation of the CAPTTIM formula.

1.   Initial Results

When the research team applied CAPTTIM using the initial formula, the results looked promising. CAPTTIM results from each pilot session, including the infantry officer, included all four CAPTTIM categories. Additionally, the inexperienced team members improved their decision performance as they progressed through their sessions. These two outcomes indicated that the CAPTTIM model was functioning.

The PFDT software application functioned very well; the users found the interface intuitive and the application performed as intended. The infantry officer validated the correct formation selections. Interestingly, the officer chose the non-optimal formation on 15 of the 128 scenarios, but after reviewing the doctrine from ATP 3–21.8, the officer agreed with the PFDT software application's optimal formation.

2. Adjustments to the Application

The application functioned as desired; however, the research team identified two items to adjust. Team members took significantly longer, up to three times longer than their average time, to make a selection on the first trial. Decision times on the first trial were so long because team members tried to understand the user interface of the application in addition to making a decision. The second issue was that some of the videos did not play for a full ten seconds.

To address the first issue, the research team requested the FutureTech team add a familiarization trial after the fourth pilot session. The FutureTech team made this adjustment in less than a day, and the fifth pilot session used the updated version. In this session, there was no significant difference between the decision time for the first trial and the average decision time across all 128 trials.

To address the second issue, in the same update as above, FutureTech adjusted the video player of the application. The adjustment set each video to start from the beginning in every trial instead of where it had previously stopped. This adjustment resulted in all videos playing for their entirety during the final pilot session.

3. Changes Made to CAPTTIM Formula

The initial formula used to compute cognitive state called for the comparison of the decision times for the subject to make a selection to twice the baseline standard deviation (explained above in section B.1). Some of the standard deviations were so large that this formula resulted in less than 5% of the trials categorized as exploration. After testing several different methods and values, the research team determined an even comparison of

selection time to baseline standard deviation resulted, $(t_t (\leq or >)s^2_{Baseline})$ in the best ratio of exploration to exploitation.

Examining the regret values compared to the calculated levels of regret of the pilot participants revealed an interesting trend. Every time a subject made a non-optimal decision, it resulted in a high regret level. This did not seem appropriate when a range of answers exists for each trial, and the subject selects an option with a lesser regret score. After experimenting with several methods, the research team settled on comparing the EWMA to three, resulting in the formula where RL equals the regret level, R_t equals Regret received for trial t, and RE equals the EWMA of regret.

$$RL = \quad \text{High if } (.75)Rt + (.25)RE,t\text{-}1) > 3,$$
$$\text{Low if } (.75)Rt + (.25)RE,t\text{-}1) < 3$$

The team settled on the value of three because the lowest possible value of regret is four. Using the value of three means a subject who has answered several consecutive questions optimally can select a formation with lesser regret, and receive a penalty. This adjustment to the formula resulted in one or two trials per subject changing from a high level of regret to a low level of regret. Other values tried included the running standard deviation of regret, actual regret (R) versus EWMA of regret (RE), and non-weighted moving average.

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III. HUMAN IN THE LOOP STUDY

This study employed the single-group time-series design with continuous treatment. Both the Naval Postgraduate School (NPS) and United States Marine Corps (USMC) Institutional Review Boards approved this study.

A. STUDY PARTICIPANTS

The target population for this event are personnel familiar with the military, but who have not received advanced tactical training. In this case, "familiar with the military" means the person has served, is currently serving, or has worked with the military. The study's target population is consistent with its intended user: if the platoon formation task is adapted as a training tool, cadets enrolled at the USMA and in ROTC, who would have a familiarity with the military, but not a detailed knowledge of infantry tactics, would use it. The study excludes combat arms specialists from the population of interest because they have received in depth training of tactics.

Subject recruiting efforts included fliers posted around the NPS campus, two bulk emails to the NPS students and military faculty, an announcement posted on the student announcement/muster page, and word of mouth. All subjects volunteered to take part, and the research team provided no compensation to the participants.

The subject pool for this study included the students and faculty of the NPS. A total of 30 participants volunteered to take part in this study. Table 4 shows the descriptive statistics for the participants. None of the participants have any experience leading troops in dismounted infantry operations, and eight received a basic level of training on infantry tactics while going through initial military training.

Table 4.   Demographic descriptors

Age	$\mu = 38.2$, $s = 10.04$
Gender	Male:19, Female: 11
Service	Army: 2, Navy: 12, Marines: 6, Air Force: 4, Coast Guard: 2, Civilian: 4
Years Service (Mil Only)	$\mu = 13.6$, $s = 5.8$
Number that have deployed	22

B.   SURVEYS

The study used two surveys: a demographic survey and a post-task survey.

1.   Demographic Survey

The demographic survey collected basic data concerning the participants' age, gender, military service, and video game experience. (See Appendix D.) This survey allowed the research team to conduct a final screening of the participants to ensure they did not meet the exclusion criteria. Participants recorded their answers on a computer.

2.   Post-Task Survey

The post-task survey focused on the subject experience and thought process. (See Appendix D.) The survey focused on what information the subject used to make his formation choice. The survey also asked about any strategy used during the task and if the strategy changed during the execution of the task. The subject also completed this survey on a computer.

C. EQUIPMENT

This study used two computers. One computer would be sufficient, but the researchers put the survey on one computer to allow the experimenter to review the demographic survey while the subject completed the PFDT on a second computer. A typical office computer capable of running the standard applications used for office and student work hosted the survey. The PFDT application requires a computer with a separate graphics processor to support the playing of the videos. The computer used for this study is an older Alienware Aurora R4 with an NVIDIA GeForce GTX690 video card.

D. PROCEDURES

Both the NPS and USMC Human Research Protection Program Institutional Review Boards reviewed and approved the study design (See Appendix E for approvals). Each subject's participation included one visit to the research office typically lasting 30 – 45 minutes. Researchers used a script (See Appendix F for study script) to guide each subject's session in order to keep the sessions uniform.

When a participant arrived for their session, the researcher welcomed them. The welcome included an explanation of the session process and provided informed consent. After consenting to participate, the subject filled out the demographic survey.

After completing the demographic survey, participants completed a study session. Researchers used the script to inform the participants about the study session. The subject received a study sheet (see Appendix G) with information extracted from ATP 3–21.8. Participants had five minutes to review and study the three formations they could choose during the execution of the platoon formation task. Researchers only answered questions clarifying the information of the study sheet (i.e., meaning of words, the distance markers). Researchers did not answer any question about the employment of a formation (i.e., when appropriate, how, why). Following the study session, participants executed the platoon formation task consisting of one familiarization scenario and 128 measured scenarios (see Appendix C for the sequence of scenarios). During the familiarization scenario, participants could ask any questions they had about the interface. The familiarization

scenario did not provide the participant any feedback; the purpose was strictly to demonstrate how to interact with the application.

Participation concluded with the post-task survey and review. The review was the least scripted portion of the session and was driven by the interest level of the participant. For some participants, the review consisted of informing the participant of the percent of optimal responses, while others lasted for ten minutes or more discussing the discriminators for the optimal formations and a more detailed explanation of CAPTTIM.

IV.   RESULTS

This chapter is organized into five sections. The first section, discusses data preparation and consolidation. The second and third sections discuss statistical methods and preliminary analysis of the data collected during the PFDT and application of CAPTTIM. The final two sections provide the results from hypothesis testing related to the research questions.

A.   DATA PREPARATION

This study uses two data sources: the data recorded by the PFDT software and the survey data. The PFDT software outputs a file with trial data that includes treatment, selection, and selection time. The study participants filled out a survey on a computer that consolidated their information into a database.

The research team used two software applications to analyze the data. The application of CAPTTIM and related graphs and charts used Microsoft's Excel 2016. Statistical analysis was computed with JMP Pro 13.

1.   Platoon Formation Decision Task Application Data

To conduct data analysis, the research team transferred the data from the raw format of the PFDT software into a more usable structure. The software recorded raw time and decision data in a comma separated value (.csv) file. From the .csv, the team transferred the data into the Microsoft Excel workbook that computed regret, cognitive state, and performance values, as well as applying the CAPTTIM categorization (see Appendix H for more information on the CAPTTIM workbook). After transferring all participants' data to the CAPTTIM workbook, the research team consolidated this data in JMP for more detailed analysis.

2.   Survey Data

Participants completed the demographic and post-task surveys in Microsoft Access. The research team exported this data to JMP and combined it with the overall performance

values of the participants. The overall performance values captured include percent optimal answers, percent acceptable answers, accumulated regret, and percent of trials classified as yellow, orange, red, or green CAPTTIM categories.

B.   STATISTICAL ANALYSES

Statistical methods used for hypothesis testing and exploratory analyses include one sample t-test, paired t-test, linear regression, and ANOVA. Assumptions and conditions for each statistical method were met: independence, normal distribution, representative population for the t – methods; and linearity, independence, equal variance, and normality for regression. Distribution comparisons for regret, number of correct and acceptable answers, and distribution of CAPTTIM categories all showed relatively normal distributions. Because the study examined the effectiveness of a newly developed task, the PFDT, two tailed alpha levels of .10 were employed.

C.   PRELIMINARY ANALYSIS

Prior to addressing the research questions, the research team first conducted descriptive statistics on the main performance measures: percent of acceptable decisions and regret. During the preliminary analysis, two outliers (see Figure 11) stood out in the overall percent of acceptable decisions. As the outliers are not influential, they remained in the data for analysis.

▼ Summary Statistics	
Mean	0.8252604
Std Dev	0.0916495
Std Err Mean	0.0167328
Upper 90% Mean	0.8536916
Lower 90% Mean	0.7968292
N	30
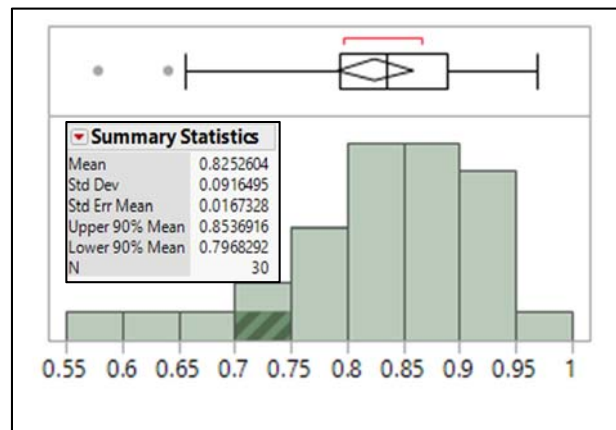
Figure 11.   Distribution of percent of overall acceptable answers

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Additionally, each participant's summary CAPTTIM categorizations were compared against expectations. Figure 12 shows each participant's breakdown of CAPTTIM categorization for the thirty participants. The top bar shows the average breakdown of categorization across the 30 participants (10.4% yellow, 18.8% red, 23.1% orange, and 47.7% green). The participants' overall CAPTTIM categorizations for the PFDT reflects the research team's expectations.

Figure 12. Comparison of participants' overall CAPTTIM categorizations

D.   RESEARCH QUESTION 1: CREATION OF PLATOON FORMATION TASK

This section examines the results of the 30 participants who completed the PFDT study. The objective behind this examination is to determine if the task is both difficult enough and intuitive enough to provide training value to the user of the PFDT task. This section describes results from two hypotheses testing the utility of the PFDT and from exploratory analyses to (1) determine if some scenarios (ie, combination of factors) were easier to learn than others and (2) examine whether any demographic characteristics were associated with PFDT performance.

1.   Prediction: Majority of participants eventually learn to make acceptable platoon formation decisions.

The two similar hypotheses indicate very different characteristics of the desired outcome. Hypothesis 1 indicates the difficulty of the task; too high of a percent correct indicates an easy task while too low of a percent indicates too difficult of a task. Hypothesis 2 indicates the degree to which the participant learns from the task. A low percentage in this metric indicates participants do not learn while conducting the PFDT. The outcome measure for each hypothesis is the percent of acceptable decisions; answers that result in regret of 0 or 4. Correct decisions are decisions that result in a regret of 0.

a.   *Hypothesis 1: Overall percent of acceptable decisions.*

H0: Average percent of acceptable decisions is 70%, $\mu = .70$.

HA: Average percent of acceptable decisions is greater than 70% $\mu > .70$.

Figure 13 shows the distribution of acceptable decisions across the 30 participants. Twenty-seven of the thirty participants exceeded 70% acceptable decisions. Results of the *t*-test show the mean percent of acceptable decisions is greater than 70%. Thus, the null hypothesis is rejected, providing support that the percent of acceptable decisions is greater than 70% for the PFDT.

Test Mean	
Hypothesized Value	0.7
Actual Estimate	0.82526
DF	29
Std Dev	0.09165

t Test	
Test Statistic	7.4859
Prob > |t|	<.0001*
Prob > t	<.0001*
Prob < t	1.0000

Summary Statistics	
Mean	0.8252604
Std Dev	0.0916495
Std Err Mean	0.0167328
Upper 90% Mean	0.8536916
Lower 90% Mean	0.7968292
N	30
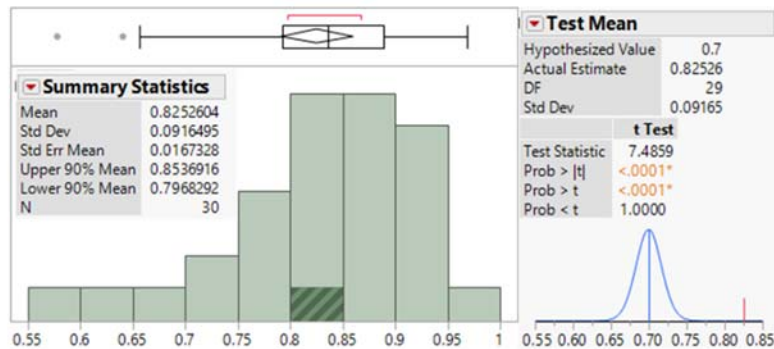
Figure 13.   Descriptive statistics on the percent of acceptable decisions and *t*-test results

Additional analysis examined the percent of only the optimal decisions using the same threshold of 70%. Results indicated that the percent of optimal decisions is not significantly different from 70% ($\bar{x} = 68.75, \mu = 70, s = 12.87, t(29) = -.532, p = 0.59,$ $90\% CI = 64.75, 72.74\%$).
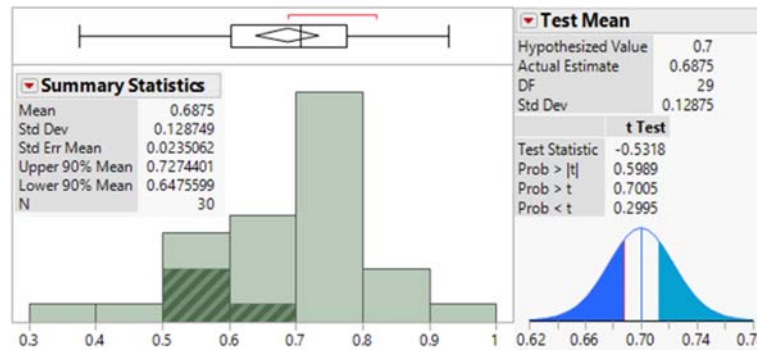
Figure 14. Descriptive statistics on the percent of optimal decisions and
t-test results

b. *Hypothesis 2: There is an increase in acceptable answers as participants advance through the Platoon Formation Decision Task.*

H0: Individual participants' average percent of acceptable decisions remains level in a moving window of 32 trials.

HA: Individual participants' average percent of correct decisions increases in a moving window of 32 trials.

To confirm this hypothesis, the research team used two methods: a paired *t*-test and regression. The measure of performance used for this hypothesis is a moving average of acceptable answers over 32 trials. A moving average allows a direct comparison of a participant's performance at different times in the PFDT.

(1) Paired *t*-Test Results

The paired *t*-test compares the percent of acceptable answers from trials 1–32 to the percent of acceptable answers from trials 97–128 for each participant. The difference

between the measures provides the values used for the *t*-test. The histogram for this data revealed no outliers and is relatively normal (see Figure 15). Although seven participants' percent of acceptable answers dropped from the first measure to the last, results of the paired *t*-test $(\overline{x_D} = 5.52, s = 10.2, t(29) = 2.96, p = 0.003, \; 90\% \; CI : 2.35, 8.68\%)$ show on average a significant increase in the percent of acceptable answers.
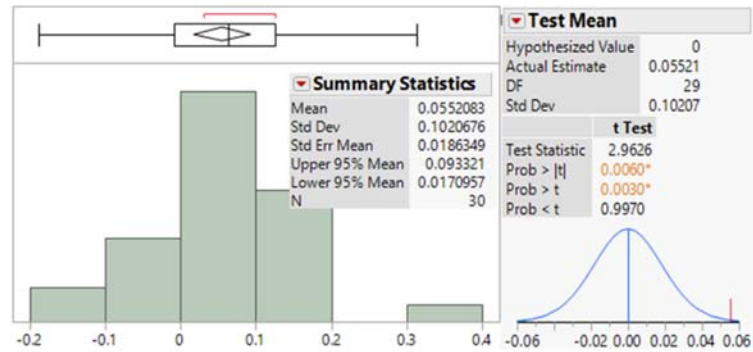
Figure 15.   Distribution and *t*-test for acceptable decision improvement

(2)   Regression

All conditions for regression were confirmed by examining the scatter plot of percent acceptable decisions (y-axis) vs trials (x-axis) and residuals. The distribution of residuals has a long left tail, and there are outliers on the low end but the distribution is relatively normal. The long left tail is expected as the PFDT is designed to be a learning task.
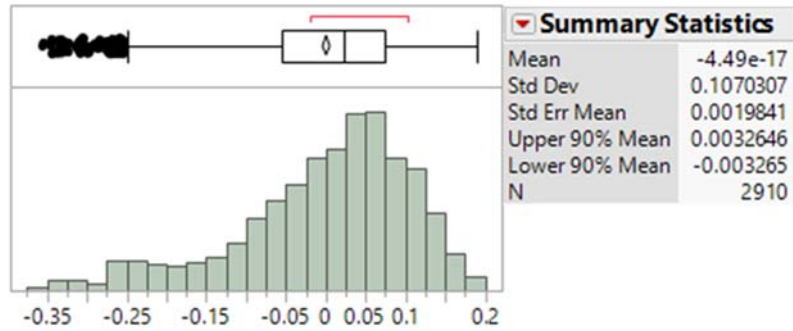
Figure 16. Distribution of residuals for the percent acceptable moving window

Regression calculations using JMP result in a significant positive slope for the linear model. With each additional trial, the percent of acceptable decisions increased by .07%.
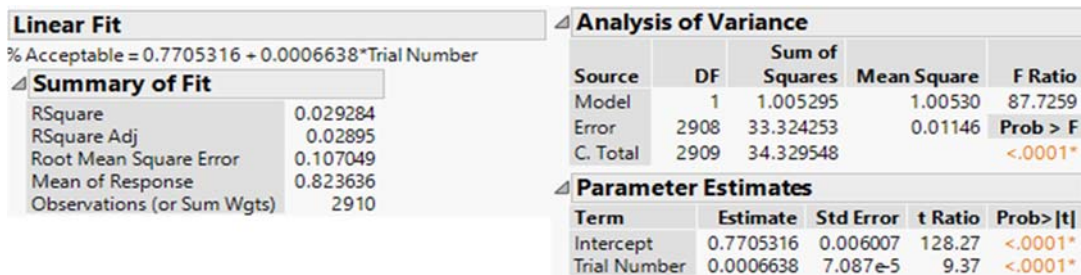
Figure 17. Linear regression model of percent acceptable decisions in moving window by number of trials

Additionally, the research team examined the regression line plots of all 30 participants. Similar to the measures used for the *t*-test above, seven participants' regression lines have negative slopes. Figure 18 shows the individual regression lines for all 30 participants and the mean regression line.
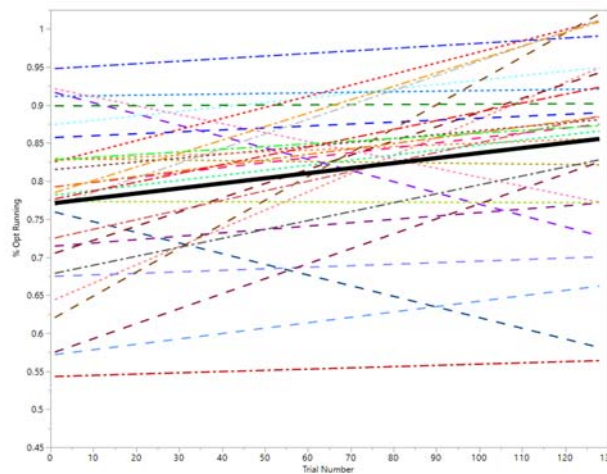
$$\% \; Acceptable = 0.7705316 + 0.0006638*Trial \; Number$$

Figure 18.   Linear regression model for percent acceptable answers in a moving window Each colored line illustrates an individual subject's regression line.

Both the paired *t*-test (*p*=.003) and linear regression (*p*<.0001) indicate that on average, participants improved their performance as they progressed through the trials. The null hypothesis is rejected.

2.   Exploratory Question: Are some combinations of cues easier to learn?

The research team examined the mean regret for each scenario by trial and the distributions of the regret levels across the scenarios (see Appendix K). The overall trend for 25 of the 32 scenarios showed that participants' choices improved from the first time they saw a scenario to the last. Of the eight scenarios that had a decrease of mean regret from the first presentation to the last, the combination that stands out the most is flat terrain with the enemy contact from the side. A decrease in mean regret indicates participants are making better decisions.

Examining the contingency plots for the different scenarios for overall optimal decisions, several scenarios stood out. Scenarios that had low light level and sparse vegetation, tended to have lower percentages of optimal decisions. Additionally, scenarios with high light levels and expected enemy contact from the side had the highest percentage of optimal decisions.

3. Exploratory Question: Are participants demographic characteristics associated with PFDT performance?

The research team examined all major demographic groups by branch of service, years of service, gender, deployment experience, and age. The number of service members from the USCG, USAF, and USA did not meet the minimum number requirement to make comparisons across the groups. The two demographics categories that had the largest indicators of performance are gender and deployment history. Interestingly, once civilians were removed from consideration, years of service did not indicate performance level.

(1) Gender

Examining the regression models for regret by trial indicates the female participants improved their performance faster than the male participants. Regret was examined because it takes into account the three levels of optimality, as opposed to acceptable or not acceptable. The intercepts of the female and male models lie only 0.0006 regret points apart. After 128 trials the models project the female participants will incur 0.3623 less regret points per trial than male participants. Comparing the percent of acceptable answers shows similar characteristics with the females having less than a 1% advantage at the intercept, but over 5% after 128 trials. See Figure 19 for comparison.
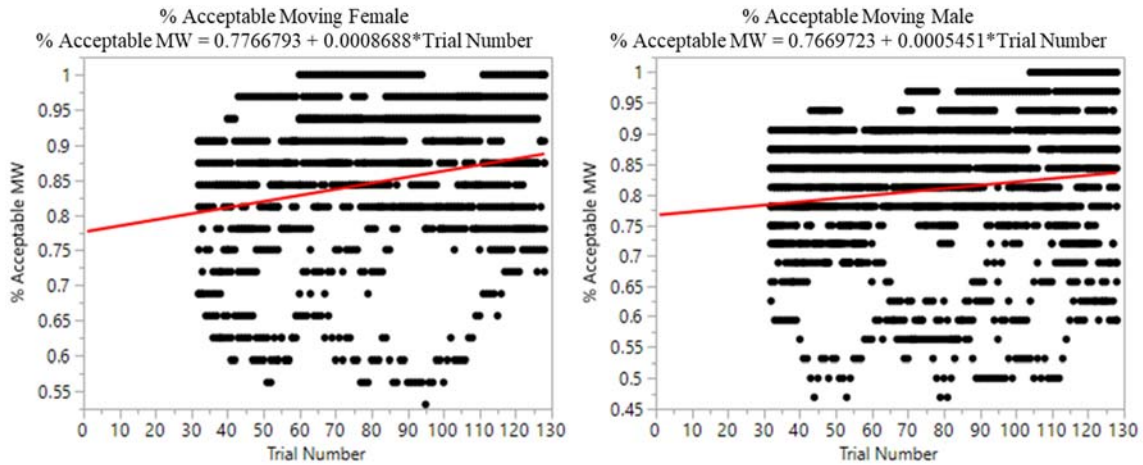
Figure 19.   Female vs Male moving average of acceptable decisions

(2)   Deployment History

Participants' deployment history played little role in their performance improvement. While those participants that have deployed started with a slightly higher percent of acceptable answers in the first 32 trials, the slopes for the regression models of those who have deployed and those who have not deployed result in a difference of less than 0.2% after 128 trials. The slope of those that have not deployed is higher than the slope of those that have deployed. See Figure 20 for comparison.
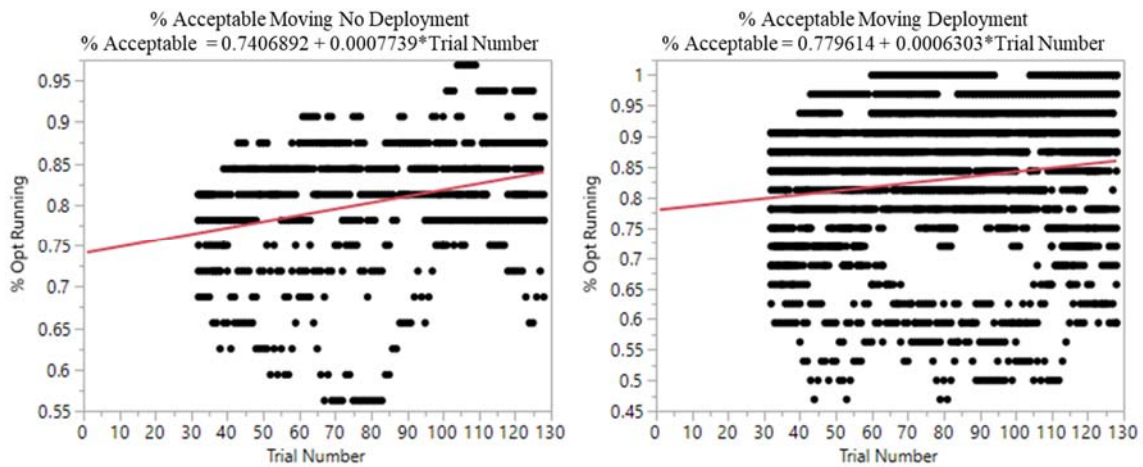
Figure 20.   No Deployment vs. Deployment moving average of acceptable answers

E.   RESEARCH QUESTION 2: APPLYING CAPTTIM TO THE PFDT DATA

Figure 21 shows a chart of overall CAPTTIM categorization for each participant over 128 trials. The mean percent of trials in each category for all 30 participants is the top entry of the chart. This chart shows participants received low regret about 71% of their trials and spent about 34% of trials in an exploration mode.
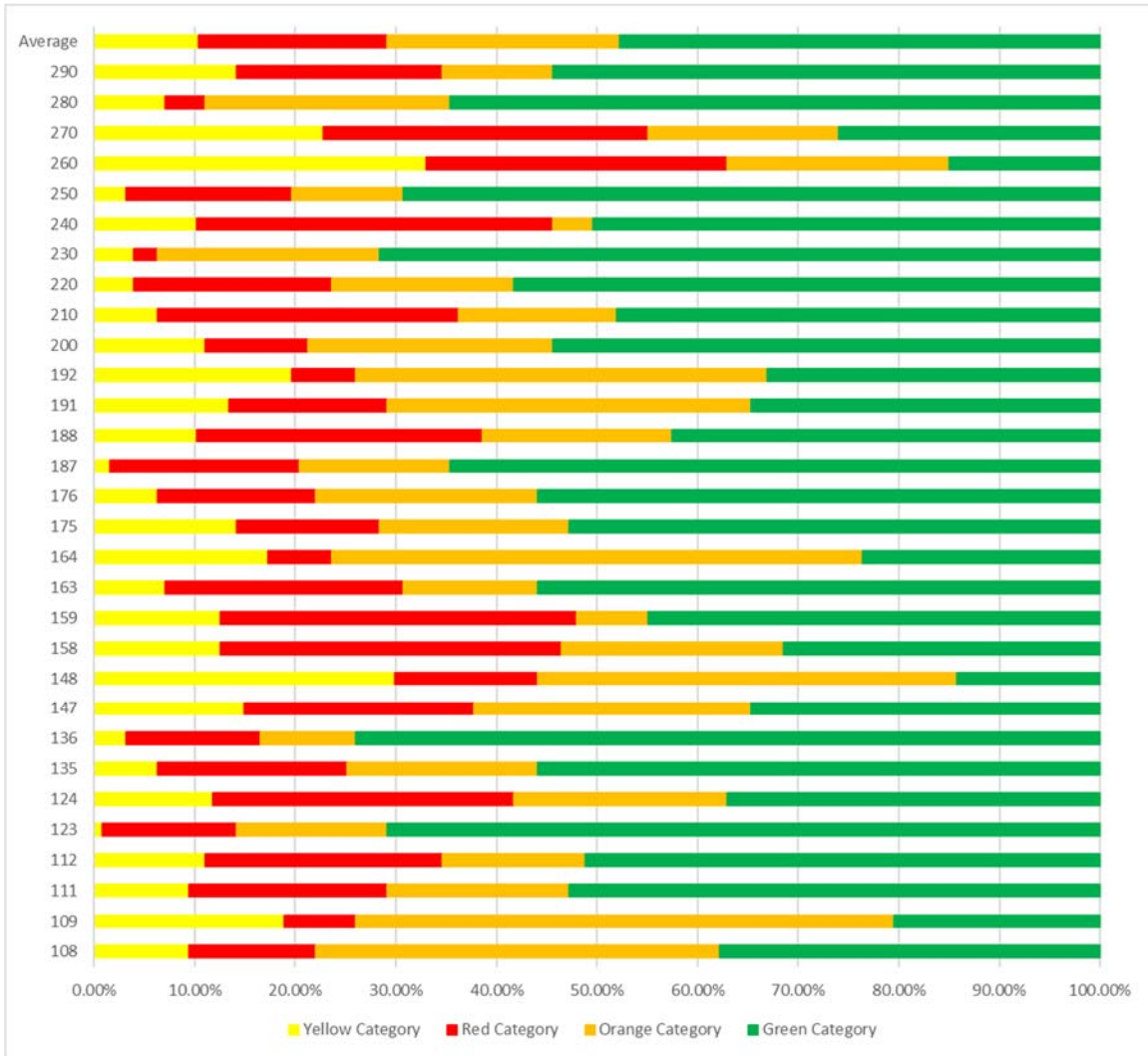
Figure 21.   Comparison of participants overall CAPTTIM categorizations

1. Exploratory Question: CAPTTIM classification will reveal three distinct decision performance profiles

Based on previous work (Critz 2015; Carlson 2016), the research team expected to find the participants' CAPTTIM patterns to fall into three groups. After applying CAPTTIM to the PFDT data, groups similar to those seen in Critz's 2015 research became evident:

1. <u>Successfully transitioned</u>: Those that transition from exploration (yellow and orange categories) to optimal exploitation (green category), as illustrated by participant 230.

Figure 22. Participant 230 shows the successful transition from exploration to exploitation

2. <u>Consistent poor exploiters</u>: Those that predominantly use suboptimal exploitation (red category) throughout the task, as illustrated by participant 159

Figure 23. Participant 159 continued to exploit poor decision-making

3. <u>Fluctuating</u>: Those that fluctuate between exploration and exploitation without successfully transitioning to optimal exploitation (green category), as illustrated by participant 164.

Figure 24. Participant 164 fluctuated between exploration and exploitation

The distribution among Critz's participants equaled 26% successfully transitioned, 62% consistent poor exploiters, and 12% fluctuating respectively. The distribution among the PDFT participants equals 57% successfully transitioned, 27% consistent poor exploiters, and 16% fluctuating (see Appendix J for CAPTTIM categorization for all PFDT participants by trial).

2.   **Exploratory Question: CAPTTIM classification will provide a more accurate depiction of which participants satisfactorily progressed within the platoon formation decision task**

CAPTTIM intends to provide a clearer understanding of an individual's performance than the traditional performance measures of total score or percent correct. The delineation between the orange and green categories distinguishes those who are making optimal decisions but do not think they have figured it out (orange) and those who know they are making optimal decisions (green).   Participants who are categorized as in the green for the majority of their optimal decisions (referred to as green optimal decisions) would be considered to have successfully learned the task. Participants who are categorized as in the orange for many of their optimal decisions (referred to as orange optimal decisions) would be considered on the cusp of successfully learning the task. To determine if CAPTTIM provides this insight with the PFDT, the research team examined the percent of green optimal decisions and orange optimal decisions for the 17 participants who made optimal decisions on more than 70% of the trials.

The research team examined the last 50 trials when most of these 17 participants were consistently making optimal decisions (average number of optimal decisions = 41.00, $s = 5.2$, range = 32, 49). Of these 17 participants, the average percent of green optimal decisions was 80%, $s = 25\%$, range = 16, 100%.   On those last 50 trials in which the optimal decision was selected, those participants with a greater than two-thirds categorization of green are considered to have figured out the task and achieved a satisfactory level of proficiency. Using this metric, 11 of the 17 participants would meet this criterion (see Table 5).   This result suggests that CAPTTIM may provide a finer grain determination of which users truly meet proficiency standards.

Table 5. CAPTTIM successful transition metric

Subject	108	109	111	123	135	136	164	175	175
Count Optimal	43	38	36	47	35	49	37	41	40
% Optimal	86%	76%	72%	94%	70%	98%	74%	82%	80%
Count Green	35	23	36	47	35	49	6	30	40
% Green	81%	61%	100%	100%	100%	100%	16%	73%	100%
Subject	187	191	192	200	220	230	250	280	
Count Optimal	40	32	46	45	38	48	41	49	
% Optimal	80%	64%	92%	90%	76%	96%	82%	98%	
Count Green	26	18	29	45	19	48	41	49	
% Green	65%	56%	63%	100%	50%	100%	100%	100%	

Highlighted orange cells indicate those participants who did not meet the two-thirds green optimal decision criterion.

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V. CONCLUSIONS

This thesis focused on two primary areas: the design of a platoon formation task and the application of CAPTTIM to that task. The first area focused on the development of a task that met several criteria: (1) it must incorporate the doctrinal mission factors of METT-TC; (2) the task should help the user transition from analytical to recognition decision-making; and (3) the task must provide positive/negative feedback for each trial. A video representation of a landscape was determined to provide the best means of providing the user with relevant information to drive their decision. A software application, developed by the Future Tech team of the MOVES Institute at NPS, played these stimuli and recorded the user's performance. This effort resulted in a first of its kind military relevant task that is grounded in doctrine. The manipulation of five factors (time, terrain height and vegetation, and enemy direction and likelihood) produce a relatively complex task that provides a reasonable approximation of reality.

The second area of this thesis focused on applying CAPTTIM to the data collected by the software application. Previous work with CAPTTIM focused on a fairly simplistic and static decision task; the objective of this research explored whether CAPTTIM could be applied to a more complex and dynamic decision task. Retrospective application of CAPTTIM provided the opportunity to test different threshold values to find the values that produced the best-fit model.

A. SUMMARY OF RESULTS

1. Platoon Formation Decision Task

The concept behind the construction of the PFDT and the scenarios used for this study was to create a task that military users consider realistic in both the basic task and level of difficulty as well as provide the user an opportunity to learn from the task. In the PFDT, study participants make tactical decisions that every platoon leader must make multiple times during a single mission. The PFDT placed the participants into thirty-two different scenarios four times each (for a total of 128 trials), and asked them to choose the most appropriate formation for the given scenario.

To evaluate the difficulty of the task design, the study used a threshold of $\mu = 70\%$ acceptable answers across all participants. The thirty participants in the PFDT study achieved a mean of 82.53% acceptable answers (regret level of 0 or 4) and 68.75% of correct/optimal answers (regret level of 0). These results indicate the task provides an appropriate level of difficulty. They also demonstrate the utility of mimicking real world behavior in which some decisions, while not optimal, are acceptable. All participants selected both acceptable and optimal options.

To evaluate the second goal of the PFDT, the research team looked at the performance from the first quarter of the trials to the performance during the last quarter of the trials. The difference in the percent of acceptable answers between the two periods provides the measure of performance for this goal. Both the *t*-test and linear regression results indicate the participants learned from their experience and showed improvement as they progressed through the task. Of the 32 scenarios, participants tended to improve their decision-making in all but two. However, the scenarios that had low light levels with low vegetation were associated with lower percentages of optimal decisions (higher average regret levels) indicating the participants had more difficulty with this combination of factors than other combinations. Conversely, scenarios with high light and enemy direction of contact from the side had four of the five highest percentages of optimal decisions.

In summary, the PFDT achieved both goals of being appropriately challenging and providing an opportunity to learn. During analysis of the data, the research team identified several areas in which to make adjustments to improve the PFDT through expansion and execution design. (See limitations and future work for further discussion.)

2.   CAPTTIM

Previous use of CAPTTIM focused on its application to the Convoy Task, a military version of the Iowa Gambling Task (Bechara, Damasio, Damasio, & Anderson, 1994; Kennedy et al., 2015; Critz, 2015; Carlson 2016). This study sought to apply CAPTTIM to a more complex task with more realistic decision outcomes (optimal and acceptable). The research team explored two questions: (1) would similar groupings of decision

performance be found as in Critz (2015) and (2) does CAPTTIM provide a more accurate assessment of which participants gained proficiency?

As in Critz's study (2015), participants fell into three decision performance groups: those that successfully transitioned from naïve decision_making to optimal decision_making (57%), those that consistently exploited poor decisions (27 %), or those who fluctuated between the exploration and exploitation cognitive states (16%). That about half the participants successfully transitioned to optimal decision_making indicates the intended instructional design of the PFDT succeeded. These values also differ from those found in Critz (2015) (successful transition: 26%, consistent poor decisions: 62%, fluctuaters: 12%), suggesting that CAPTTIM is sensitive to task difficulty.

The participants' CAPTTIM categorization for trials in which they provided an optimal answer (regret level of 0) showed which participants transitioned to an exploitive state with a clear understanding of the platoon formations. Seventeen of the 30 participants made optimal decisions on greater than 70% of their trials. In CAPTTIM, optimal decisions can be further distinguished by participants' cognitive state -- classified as either orange (making good decisions but not knowing why) or green (knowingly making good decisions). To truly show task proficiency, a large proportion of a participant's optimal decisions should be categorized as green. Of the 17 participants, 11 received green categorization on more than two-thirds of their optimal answers. This result indicates CAPTTIM may provide a clearer understanding of which participants truly understand the PFDT and meet the proficiency standard than relying solely on typical performance measures.

In summary, the CAPTTIM goals for this study were achieved. Patterns of decision performance were consistent with previous work (Critz, 2015. Results also demonstrated that synthesizing cognitive state with decision performance provides feedback that is more specific and illustrates which participants successfully transitioned from naïve platoon formation decision-makers to proficient ones.

B.   IMPLICATIONS

The results have several implications for platoon formation training and the further use of CAPTTIM. First, this study validated the PFDT as a relevant military decision task. Additionally, the study showed the PFDT facilitates the learning of a basic tactical decision made by junior leaders. Results also demonstrate that CAPTTIM works with a more advanced decision task than used previously (Critz, 2016; Carlson, 2016). It also pinpoints if and when optimal decision_making occurred for each participant.

The success of the PFDT in improving the participants' performance implies the PFDT concept is a viable training tool. The finding that participants with little to no exposure with infantry tactics were able to improve their performance by 5.5% over 128 trials after only five minutes of study time implies the PFDT concept may work for other basic level tasks. Increased repetitions in making decisions with varied scenarios provides personnel the opportunity to improve their awareness of which factors are important to consider and understanding which aspects of each factor drive the decision (Klein, et al., 1993). The PFDT concept provides a framework by which an individual has the opportunity to experience varied scenarios and make multiple decisions in a short period of time. The proliferation of portable technology in the form of smart phones and tablets throughout society provides new opportunities to expand short duration, low overhead training to the domain of mobile applications.

The PFDT shows potential to move basic tactical decision_making from the traditional 20th Century industrial methods into the 21st century's digital age. This is not to say the PFDT can replace the traditional methods, however it is a way to provide more repetitions to future leaders. Table 6 provides a rough comparison of the traditional methods to the PFDT based on the experience of several U.S. Army officers at their pre-commissioning training.

Table 6.   Comparison of traditional training methods to the PFDT

Traditional methods	PFDT
Time Consuming	Little time to execute
Resource intensive • Instructor/Assistant instructor • Land • Squad/Platoon members	Low overhead • Computing device w/ application
Per Year • 5-7 repetitions as a leader • 20-30 repetitions as a squad or platoon member	Per 15 Minutes • 128 repetitions

The validation of the PFDT means a new tool is available for those looking to use a military relevant task in their research. The PFDT has the potential for modifications to provide researchers additional flexibility in their studies. The PFDT provides a dynamic task with multiple scenarios, which can be modified to provide varying levels of difficulty. These features make it a relevant research tool for studies of decision-making, human performance, and other areas of cognitive science research.

CAPTTIM's successful integration with the PFDT illustrates its potential for use with real time application to assess decision performance. While this study did not apply CAPTTIM in real time as the participants completed each trial, it became evident to the research team that real time application would be feasible. Real time application of CAPTTIM into an adaptive training system would provide feedback to the user and instructor and assess the user's performance to the next level of difficulty. This application would be especially useful in distinguishing between users who are unwittingly making

optimal decisions (the orange category) and those who are consciously exploiting optimal decisions (the green category).

C. LIMITATIONS

1. Treatment Distribution

During data analysis, the research team recognized the random order generated for the 128 trials did not evenly spread the four instances of each scenario. Several scenarios appeared three times in spans of less than thirty trials. This frequency of repetition may have affected the participants' ability to recall the scenario and their previous responses, facilitating an improved response on the later repetitions. In hindsight, the research team should have randomized the thirty-two scenarios four times and combined those four series to create the order for the 128 trials. This method would ensure the PFDT presents each scenario during each quarter of the session. The benefit of spreading each appearance for a particular scenario is to gain better insight into a participant's progression and to assess more accurately the participant's learning.

2. Population

The sample used for this study abstractly models the target audience if the PFDT were modified into a training tool. Cadets and junior non-commissioned officers that make up the target audience generally range in age from 18–22. This study sample consisted of 30 military officers, across five services U.S. and allied, and civilians. Their mean age of 38.2 (s = 10.04) years nearly doubles the age of the target audience for the training tool. Additionally, the target audience would have more recent exposure to the platoon formations and infantry tactics used in the PFDT. Future studies should attempt to use a sample that more closely resembles the target audience to further validate the PFDT.

D. FUTURE WORK

1. Real Time CAPTTIM Application

In this study, the application of CAPTTIM occurred retrospectively as part of the data preparation process. The real value of CAPTTIM comes from real-time application to support training tools. Incorporating an initial baseline period, i.e., the first 32 trials of the

PDFT, to establish each user's natural processing speed and intra-individual variability in decision time for the computation of cognitive state is one possibility for achieving this goal. Incorporating this baseline period would facilitate feedback focused on an individual's performance during execution. Additionally, it would facilitate modification of the PFDT into an adaptive training system through the inclusion of different levels of difficulty, managed by the CAPTTIM categorization/performance. For example, achieving 70% green categorization over 20 trials could serve as the criterion for entering the next level of difficulty, adapting to the user's level of proficiency.

2. Modifying Feedback

Feedback to the user during this study included only an assessment of correct or incorrect for each trial. Two possible modifications to feedback exist.

First, provide feedback based on the level of regret. Providing regret-based feedback would allow the user to know the degree to which their selection was non-optimal. An interesting next step would be to compare performance between a group receiving regret-based feedback and a group using the traditional optimal/non-optimal feedback.

Second, provide feedback based on the selected formation/scenario. When a user makes a non-optimal selection, providing feedback based on the scenario and/or selected formation might speed up the time it takes participants to transition to the green CAPTTIM category. Including key factors to consider for the given scenario or the optimal formation would provide clarity to the user why his selection was not optimal.

3. Expand the Task

Many ways to expand the task exist. To make the PFDT a viable training tool, more variety would provide a higher level of fidelity.

a. *More/Varying Formations*

Changing the possible formation options available for the scenarios would force the users to weigh the advantages and disadvantages of more formations than the three

presented in this version of the PFDT. A possible expansion might be to provide options to the user that do not include the optimal formation for the scenario so that they need to select the best option available. This expansion would increase the ecological validity of the PFDT.

b. More Scenarios

Adding more scenarios and factors/factor levels would increase the variety of the scenarios. Different types of environments and additional factors such as weather would provide more factors for the user must consider in their selection. The additional scenarios would increase the range of the PFDT. This would aid in retention of the user's interest as well as the creation of varying difficulty levels in the PFDT.

c. Add Enemy Forces

Inserting a visible enemy force into the scene to replace or augment the written cues below the video would provide additional visual cues for the user. An indicator of the direction of travel would need to be included in the video to orient the user with the intended direction of movement or relative position of the enemy to that direction.

4. User Responses

This study collected limited data regarding which factors the participants considered when making a platoon formation selection. More detail on what information factored into the participants' formation selections could provide additional insight on overall performance. Aggregating the user responses to the post-task survey would also enable the modification of the PFDT to provide feedback that is more effective to the user during execution of the PFDT.

E. CONCLUSION

Decision-making is at the core of being a leader. Understanding how to accelerate the learning process to make the optimal decision is necessary to efficiently train our leaders. In a world in which leaders have little time to make some decisions, we must develop technology to help train our leaders to make decisions quickly. The most powerful

tool we have in the military is the mind of our leaders. Across DoD, this need for mental agility has been recognized, as seen in: the Army's Operating Concept 2020–2040 (Department of the Army, 2014), The Human Dimension White Paper (United States Army Combined Arms Center, 2014); the Navy's Navy Leader Development Framework (Department of the Navy, 2018); the Marine Corps' The Marine Operating Concept: How An Expeditionary Force Operates in the 21st Century (United States Marine Corps, 2016); and the Air Force's Air Force Future Operating Concept (Department of the Air Force, 2015). At the root of developing the skills necessary to make complex decisions, we must first focus on teaching our young leaders how to make simple decisions.

The research team feels leveraging the combination of CAPTTIM and rapid response decision task training applications can reduce the time it takes users to gain task proficiency. CAPTTIM offers a tool to evaluate individuals' decision performance and provide feedback based on the alignment of their cognitive state and their decisions. This study illustrates the usefulness of CAPTTIM to assess these basic cognitive tasks, and the PFDT demonstrates the feasibility of using relatively simple software applications to provide training opportunities.

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APPENDIX A. VIDEO ANALYSIS

(1)   Purpose:

Video clips provide three of the factors subjects participating in this study need to use to make a decision on the correct platoon formation. Through the video clips, subjects will observe the level of light available, the vegetation, and the ruggedness of the terrain. The analysis was conducted to determine what movement through the terrain provides the best opportunity to understand the terrain.

(2)   Method:

The factors that most effect how much terrain/area the subject views during the video clip are turn rate, movement speed, and video length. The number of trials required for the study (128 trials) and the desire to limit the time taken for a subject not to exceed one hour, therefore this analysis focused on movement speed and turning rate through the terrain, limits the video length to 10 seconds.

A basic piece of terrain with only ground vegetation and limited rolling hills was used to test different movement configurations. The two main movement concepts tested include move-turn-move and turn-while-moving. After attempting both concepts, the turn-while-moving caused the terrain generator to freeze, and the remaining effort focused on move-turn-move method.

The move-turn-move concept creates a zigzag movement pattern through the terrain. The factors manipulated during tests included periods and speed of movement and the duration and rate of turns. After several trials and errors, a movement period of 2–3 seconds and turn duration of 1 second yielded the most "natural" feel to the movement. Several videos using these times and changing the movement speed and turn rates were then tried. Movement speeds tested ranges from 1–4 in increments of 0.5. The tested turn rates ranged from 2–6 in increment of 0.5. Speeds of less than 3.0 felt slow to the testers and speeds over 4.0 blurred the terrain. The turn rates did not create as much blurring issue as the speed, however it either limited the terrain seen (when too slow) or made the tester

feel unsteady. After several trials, the tester identified 3.5 as the optimal speed for movement and a turn rate of 5 as the most comfortable turning rate.

Figure 25 shows several sets of sample of parameters tested for movement through the terrain. Figure 26 provides a description for each part of the parameter.

Figure 25.   Sample parameters tested for movement through the terrain
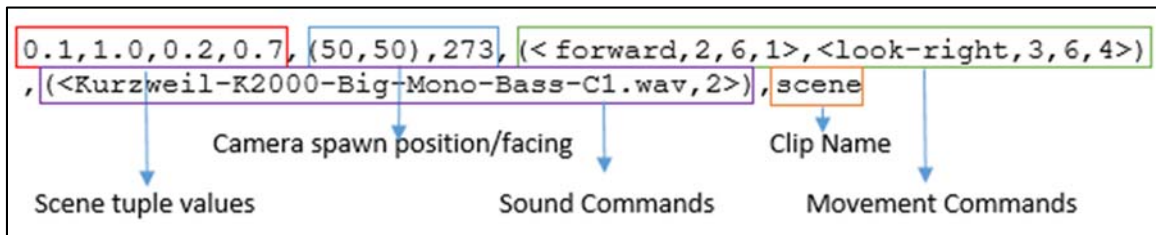
Figure 26.   Video parameters explained (Charles River Analytics, 2017, p. 2)

APPENDIX B. SCENARIOS

Table 7 shows the 32 scenarios/treatments created by varying the five factors of the PFDT. The table also matches the scenario to the correct video and the optimal formation.

Table 7. List of treatments for the platoon formation decision task

Treatment Number	Factor Level					Video	Optimal Formation
	Height	Vegetation	Light	Enemy Probablity	Enemy Direction		
11111	Flat	Sparse	High	Possible	Front	1	Vee
11112	Flat	Sparse	High	Possible	Side	1	Column
11121	Flat	Sparse	High	Likely	Front	1	Vee
11122	Flat	Sparse	High	Likely	Side	1	Column
11211	Flat	Sparse	Low	Possible	Front	3	Column
11212	Flat	Sparse	Low	Possible	Side	3	Column
11221	Flat	Sparse	Low	Likely	Front	3	Column
11222	Flat	Sparse	Low	Likely	Side	3	Column
12111	Flat	Dense	High	Possible	Front	2	Vee
12112	Flat	Dense	High	Possible	Side	2	Column
12121	Flat	Dense	High	Likely	Front	2	Vee
12122	Flat	Dense	High	Likely	Side	2	Column
12211	Flat	Dense	Low	Possible	Front	4	File
12212	Flat	Dense	Low	Possible	Side	4	File
12221	Flat	Dense	Low	Likely	Front	4	File
12222	Flat	Dense	Low	Likely	Side	4	File
21111	Hill	Sparse	High	Possible	Front	5	Vee
21112	Hill	Sparse	High	Possible	Side	5	Column
21121	Hill	Sparse	High	Likely	Front	5	Vee
21122	Hill	Sparse	High	Likely	Side	5	Column
21211	Hill	Sparse	Low	Possible	Front	7	Column
21212	Hill	Sparse	Low	Possible	Side	7	Column
21221	Hill	Sparse	Low	Likely	Front	7	Column
21222	Hill	Sparse	Low	Likely	Side	7	Column
22111	Hill	Dense	High	Possible	Front	6	Vee
22112	Hill	Dense	High	Possible	Side	6	Column
22121	Hill	Dense	High	Likely	Front	6	Vee
22122	Hill	Dense	High	Likely	Side	6	Column
22211	Hill	Dense	Low	Possible	Front	8	File
22212	Hill	Dense	Low	Possible	Side	8	File
22221	Hill	Dense	Low	Likely	Front	8	File
22222	Hill	Dense	Low	Likely	Side	8	File

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APPENDIX C. TRIALS WITH REGRET

Tables 8 and 9 show each treatment for the 128 trials with regret for each formation.

Table 8. Treatment by trial (trials 1–64)

Trial #	Treatment	Correct Answer	Regret Column	Regret Vee	Regret File	Trial #	Treatment	Correct Answer	Regret Column	Regret Vee	Regret File
1	21112	Column	0	7	4	33	22111	Vee	4	0	7
2	12212	File	4	9	0	34	21122	Column	0	7	4
3	11211	Column	0	4	4	35	11121	Vee	4	0	7
4	11111	Vee	4	0	7	36	12121	Vee	4	0	7
5	21111	Vee	4	0	7	37	22121	Vee	4	0	7
6	12211	File	4	7	0	38	22111	Vee	4	0	7
7	12222	File	6	9	0	39	21122	Column	0	7	4
8	11122	Column	0	7	4	40	22122	Column	0	6	5
9	12212	File	4	9	0	41	22212	File	5	8	0
10	12221	File	4	7	0	42	22221	File	4	7	0
11	21221	Column	0	6	5	43	22211	File	5	7	0
12	12112	Column	0	7	4	44	22122	Column	0	6	5
13	11111	Vee	4	0	7	45	11211	Column	0	4	4
14	11112	Column	0	4	7	46	21112	Column	0	7	4
15	12112	Column	0	7	4	47	11122	Column	0	7	4
16	21112	Column	0	7	4	48	22222	File	5	8	0
17	22211	File	5	7	0	49	11112	Column	0	4	7
18	22112	Column	0	7	4	50	11212	Column	0	7	4
19	11212	Column	0	7	4	51	22111	Vee	4	0	7
20	21222	Column	0	7	4	52	21221	Column	0	6	5
21	12121	Vee	4	0	7	53	21222	Column	0	7	4
22	11222	Column	0	7	4	54	22121	Vee	4	0	7
23	22222	File	5	8	0	55	11212	Column	0	7	4
24	22221	File	4	7	0	56	21221	Column	0	6	5
25	21121	Vee	4	0	7	57	12211	File	4	7	0
26	11221	Column	0	5	6	58	22112	Column	0	7	4
27	12111	Vee	4	0	7	59	22221	File	4	7	0
28	21221	Column	0	6	5	60	12211	File	4	7	0
29	22212	File	5	8	0	61	21121	Vee	4	0	7
30	11211	Column	0	4	4	62	11212	Column	0	7	4
31	22121	Vee	4	0	7	63	12221	File	4	7	0
32	12122	Column	0	7	4	64	12111	Vee	4	0	7

Table 9.   Treatment by trial (trials 65–128)

Trial #	Treatment	Correct Answer	Regret Column	Regret Vee	Regret File	Trial #	Treatment	Correct Answer	Regret Column	Regret Vee	Regret File
65	21111	Vee	4	0	7	97	21222	Column	0	7	4
66	22212	File	5	8	0	98	11112	Column	0	4	7
67	12121	Vee	4	0	7	99	21211	Column	0	6	5
68	22211	File	5	7	0	100	22121	Vee	4	0	7
69	22222	File	5	8	0	101	11111	Vee	4	0	7
70	12122	Column	0	7	4	102	12212	File	4	9	0
71	22122	Column	0	6	5	103	12111	Vee	4	0	7
72	21211	Column	0	6	5	104	21122	Column	0	7	4
73	22112	Column	0	7	4	105	11111	Vee	4	0	7
74	21212	Column	0	7	4	106	11222	Column	0	7	4
75	12111	Vee	4	0	7	107	12221	File	4	7	0
76	21111	Vee	4	0	7	108	22111	Vee	4	0	7
77	12121	Vee	4	0	7	109	21211	Column	0	6	5
78	22211	File	5	7	0	110	12222	File	6	9	0
79	11221	Column	0	5	6	111	11121	Vee	4	0	7
80	11211	Column	0	4	4	112	12112	Column	0	7	4
81	11222	Column	0	7	4	113	21211	Column	0	6	5
82	12212	File	4	9	0	114	22112	Column	0	7	4
83	12122	Column	0	7	4	115	11121	Vee	4	0	7
84	22122	Column	0	6	5	116	21212	Column	0	7	4
85	11222	Column	0	7	4	117	12221	File	4	7	0
86	22221	File	4	7	0	118	22222	File	5	8	0
87	21212	Column	0	7	4	119	21112	Column	0	7	4
88	12222	File	6	9	0	120	11122	Column	0	7	4
89	12122	Column	0	7	4	121	11121	Vee	4	0	7
90	11122	Column	0	7	4	122	21122	Column	0	7	4
91	21222	Column	0	7	4	123	21111	Vee	4	0	7
92	21212	Column	0	7	4	124	21121	Vee	4	0	7
93	11112	Column	0	4	7	125	12211	File	4	7	0
94	21121	Vee	4	0	7	126	12222	File	6	9	0
95	11221	Column	0	5	6	127	22212	File	5	8	0
96	12112	Column	0	7	4	128	11221	Column	0	5	6

APPENDIX D. SURVEYS

A. DEMOGRAPHIC SURVEY

Platoon Formation Task

Demographic Survey

Subject Number: _____   Date: _____

1. Age:

2. Gender: Female   Male

3. Preferred writing hand: Left   Right

4. Are you currently serving in the Armed Forces: Yes   No

    a. Which branch: USA   USN   USMC   USAF

       USCG

    b. Years of Service: _____

    c. Highest Rank: _____

    d. Functional Area/Specialty:

       Maneuver   Intelligence   Sustainment

                           Communications   Fires   Protection

    e. Have you ever deployed to a combat zone?   Yes   No

        i. If so what was your duty position while deployed? (i.e. Platoon leader, staff position, commander, department head,…) Please be specific.

        ii. Did you ever lead troops in a dismounted operation while deployed?

    f. Have you ever received training in dismounted infantry operations/tactics?

               Yes   No

        i. If yes, what kind; ROTC, The Basic School, AIT, BCT, etc…?

           _____

5. Do you play tactical video games?   Yes   No

   If Yes…

    a. How often?   < 2 hrs/wk   2-4 hrs/wk   4-8 hrs/wk   >8 hrs/wk

    b. What Kind?   single player multi player   first-person   third person

B. POST-TASK SURVEY

Platoon Formation Task

Post-Task Survey

Subject Number: _____   Date: _____

1. What did you use to base your decisions?

    Vegetation   Hills   Light

    Enemy likelihood   Enemy Direction

2. Did you use a strategy to make your selections? Yes   No

    a. Did your strategy change during the platoon formation task?

       Yes   No

    b. If yes, what made you change your strategy?

    c. Do you feel your choices improved after your strategy change?

       Yes   No

3. Do you feel your choices improved as the number of repetitions improved?

       Yes   No

4. What percentage of choices do you feel you made the most optimal decision? _____

5. How confident are you in your overall performance? Low   Med   High

APPENDIX E. INSTITUTIONAL REVIEW BOARD APPROVALS

A.   NPS APPROVAL

Naval Postgraduate School
Human Research Protection Program

From: President, Naval Postgraduate School (NPS)
To: Dr. Quinn Kennedy, Operation Research Department (OR)
        Ms. Rabia Khan, System Engineering Department (SE)
        LTC Brian Hanley, USA
Via: Chairman, Institutional Review Board (IRB)

SUBJ: TESTING A COGNITIVE ALIGNMENT-BASED TRAINING MODEL TO
        ACCELERATE OPTIMAL MILITARY DECISION-MAKING IN A PLATOON
        FORMATION TASK

Encl: (1) Approved IRB Initial Review

1.   The NPS IRB is pleased to inform you that the NPS President
has approved your initial review protocol (NPS IRB#
NPS.2018.0027-IR-EP7-A). The approved IRB Protocol is found in
enclosure (1). Completion of the CITI Research Ethics Training
has been confirmed.

2.   This approval expires on 30 June 2018. If additional time
is required to complete the research, a continuing review report
must be approved by the IRB and NPS President prior to the
expiration of approval. At expiration all research (subject
recruitment, data collection, analysis of data containing PII)
must cease.

3.   You are required to obtain consent according to the
procedure provided in the approved protocol.

4.   You are required to report to the IRB any unanticipated
problems or serious adverse events to the NPS IRB within 24
hours of the occurrence.

5.   Any proposed changes in IRB approved research must be
reviewed and approved by the NPS IRB and NPS President prior to
implementation except where necessary to eliminate apparent
immediate hazards to research participants and subjects.

6.   As the Principal Investigator (PI) it is your responsibility
to ensure that the research and the actions of all project
personnel involved in conducting this study will conform with
the IRB approved protocol and IRB requirements/policies.

Figure 27.   NPS IRB approval page 1

Subj: TESTING A COGNITIVE ALIGNMENT-BASED TRAINING MODEL TO
ACCELERATE OPTIMAL MILITARY DECISION-MAKING IN A PLATOON
FORMATION TASK

7. At completion of the research, no later than expiration of
approval, the PI will close the protocol by submitting an End of
Experiment Report.

Lawrence G. Shattuck, PhD
Chair
Institutional Review Board

Ronald A. Route
Vice Admiral, U.S. Navy (Ret.)
President, Naval Postgraduate School

Date: ___FEB 0 9 2018___

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Figure 28.   NPS IRB approval page 2

B.   USMC APPROVAL

DEPARTMENT OF THE NAVY
HEADQUARTERS UNITED STATES MARINE CORPS
3300 RUSSELL ROAD
QUANTICO, VA 22134-5001

3900
C 4623
24 Mar 18

From: Human Research Protection Official, U.S. Marine Corps (Attention:
        Ms. Leah Watson), 1019 Elliott Road, Quantico, VA 22134

To: Dr. Quinn Kennedy, Operation Research Department, Naval Postgraduate
        School, Monterey, CA
        LTC Brian Hanley, USA, Student Researcher, Naval Postgraduate School,
        Monterey, CA

Subj: U.S. MARINE CORPS HUMAN RESEARCH PROTECTION PROGRAM ADMINISTRATIVE
        REVIEW OF PROPOSED STUDY: "TESTING A COGNITIVE ALIGNMENT-BASED
        TRAINING MODEL TO ACCELARATE OPTIMAL MILITARY DECISION-MAKING IN A
        PLATOON FORMATION TASK"

Ref: (a) DoDI 3216.02
        (b) SECNAVINST 3900.16E
        (c) MCO 3900.18
        (d) U.S. Marine Corps Human Research Protection Program (HRPP) Policy
            and Procedures (28 September 2016)
        (e) DoD N-40042 Naval Post Graduate School DoD-Navy Assurance
        (f) MCO 5300.18 USMC Survey Order

Encl: (1) NPS.2018.0011-IR-EP7-A
        (2) President, Marine Corps University ltr 1000 CG of 16 Mar 18

1.   Per references (a) through (d), I have conducted an Administrative
Review, on behalf of the Marine Corps, of the research titled "Testing a
Cognitive Alignment-Based Training Model to Accelerate Optimal Military
Decision-Making in a Platoon Formation Task." This research has two main
objectives: (1) Assess whether a computer based platoon formation decision
task can provide adequate stimuli to participants with enough clarity the
participants choices improve as they progress through 128 trials (2) To
assess the validity of using the Cognitive Alignment with Performance-
Targeted Training Intervention Model (CAPTTTM) with a complex task. This
research is being conducted in partial fulfillment of academic requirements
for LTC Brian Hanley, a student assigned at Naval Postgraduate School (NPS).

2.   The research protocol at enclosure (1), and supporting documentation at
enclosure (2), as submitted to the NPS IRB, have been reviewed by this office
to ensure compliance with requirements the U.S. Marine Corps Human Research
Protection Program.

3.   As outlined in the enclosures, subjects will complete the decision-making
'platoon formation task.' Over the course of 128 trials, subjects will view
brief video clips moving through a piece of terrain. Based on the video and
information regarding likelihood and direction of enemy contact, subjects
will select what they think is the best formation for that scenario. After
making their selection, subjects receive immediate feedback letting them know
if they made an optimal of sub-optimal decision. Through multiple trials,
participants use experience with the three formations to attempt to make the
most optimal selections. Subjects will complete a demographic survey and a
post-task survey. The target population is employees and students at NPS, to
include Marines, who have not received formal tactical ground combat training
outside of initial entry training or their commissioning source.
Participation will be solicited via posted fliers, e-mail and in-person

Figure 29.   USMC IRB approval page 1

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Subj: U.S. MARINE CORPS HUMAN RESEARCH PROTECTION PROGRAM ADMINISTRATIVE
REVIEW OF PROPOSED STUDY: "TESTING A COGNITIVE ALIGNMENT-BASED
TRAINING MODEL TO ACCELARATE OPTIMAL MILITARY DECISION-MAKING IN A
PLATOON FORMATION TASK"

recruitment. The protocol package includes the proposed surveys, informed
consent forms, fliers, recruitment script and the recruitment e-mail.
Enclosure (2), from the research sponsor, requests approval from the Navy
Survey Office. Enclosure (3) provides the required cost analysis for the
survey.

4. Reference (e) is the DoD Institutional Assurance for Naval Post Graduate
School. As reflected at enclosure (1)) the NPS IRB reviewed and approved
your research proposal and found that it met criteria for Expedited Review
under Category 7: "Research on individual or group characteristics or
behavior (including, but not limited to, research on perception, cognition,
motivation, identity, language, communication, cultural beliefs or practices,
and social behavior) or research employing survey, interview, oral history,
focus groups, program evaluation, human factors evaluation, or quality
assurance methodologies."

5. Enclosure (2) provides the General Officer level letter of support from
the President, Marine Corps University/Commanding General Education Command,
as required under reference (d).

6. Review by the NPS IRB and the General Officer letter of support satisfy
Marine Corps review requirements for this study. I concur with the
determination of the NPS IRB. Approval by the NPS IRB assures that the
members of the research team have completed the required research ethics
training. You are required to inform this office, as well as your approving
IRB, if there are any changes or amendments to your protocol. No further
review or approval from this office is required.

7. Review and approval by the Marine Corps Survey Officer is required under
reference (f) for this research prior to execution.

8. If you have any questions or require further information, please don't
hesitate to contact me at (703) 432-2566, e-mail leah.watson@usmc.mil. I
wish you success with your study and appreciate the prior coordination to
ensure compliance with the USMC HRPP review and approval process.

L. B. WATSON
Chair, Institutional Review Board

Copy to:
USMC Survey Officer
NPS HRPP Specialist

Figure 30.   USMC IRB approval page 2

APPENDIX F. PFDT SESSION SCRIPT

a. *Welcome*

(1)   Script for Subjects

Welcome to my thesis research study. Thank you for volunteering to participate in this study, it will take about 30–45 minutes of your time. During your time, I will ask you to make some tactical decisions based on brief video clips you will see on the computer. The decision I am going to ask you to make is what infantry platoon formation is most appropriate for the given scenario. After you complete the study, if you are interested, I will provide you an explanation of what I am trying to do with the study.

After we complete this initial welcome, I will review the informed consent documents, and ask you to sign those acknowledging your consent to participate in the study. Following that, I will ask you to fill out a short demographic survey, and then you will have 5 minutes to review the three platoon formations and their characteristics. You may ask questions during that time if you desire. Following the review period, you will complete the Platoon Formation Task by selecting the most appropriate formation for the scenario given. You do not need to wait for the video to finish playing before making a selection, and there is no time limit on how long you have to make the decision. Once you complete the Platoon Formation task, I will ask you to fill out a brief post-task survey. If you desire, I can also provide you an explanation of my research and the methodologies used in the development of the task.

If you get thirsty or hungry, I have a bottle of water and some snacks here for you. Again, I would like to thank you for volunteering to participate in this study.

(2)   Script for Validation Subjects

Welcome to my thesis research study. Thank you for volunteering to participate in this study, it will take about 30–45 minutes of your time. During your time, I will ask you to make some tactical decisions based on brief video clips you will see on the computer, and also rate your confidence level. The decision I am going to ask you to make is what

infantry platoon formation is most appropriate for the given scenario. After you complete the study, if you are interested, I will provide you an explanation of what I am trying to do with the study.

After we complete this initial welcome, I will review the informed consent documents, and ask you to sign those acknowledging your consent to participate in the study. Following that, I will ask you to fill out a short demographic survey, and then you will have 5 minutes to review the three platoon formations and their characteristics. You may ask questions during that time if you desire. Following the review period, you will complete the Platoon Formation Task by selecting the most appropriate formation for the scenario given. You do not need to wait for the video to finish playing before making a selection, and there is no time limit on how long you have to make the decision. Once you complete the Platoon Formation task, I will ask you to fill out a brief post-task survey. If you desire, I can also provide you an explanation of my research and the methodologies used in the development of the task.

If you get thirsty or hungry, I have a bottle of water and some snacks here for you. Again, I would like to thank you for volunteering to participate in this study.

b.   *Consent*

All Subjects

Please take some time to review the consent form. We will not use your name or any other PII for this study. All references to individuals will be done through subject number and aggregation of demographic groups, i.e., males over 30, intelligence officers, or active gamers, etc…

The only connection of your name to this study is on the subject ledger which aligns your name to a subject number. One we have completed the data analysis portion of the study, we will then destroy the ledger, and all connection of your name to the study will be gone.

Subject signs consent form

c. Demo Survey

All Subjects

Please fill out the survey on this computer. It asks some basic information about your military background and training and about how often you play video games.

Researcher writes name and contact information of subject on the ledger assigning a subject number and places the consent form in the file.

d. Study Period

All Subjects

You will now have five minutes to study the three platoon formations from which you will choose during the study. The information provided on the study sheet is directly taken from the Army Technique Publication 3–21.8 "Infantry Platoon and Squad." You are able to take notes on the sheet or on scratch paper if you would like, but during the execution of the task you will not be able to use any references.

If you have any questions please feel free to ask, and I will do my best to answer the question, but I can only try to clarify the information on the sheet.

e. Task Execution

Non-Validation Subjects

Now we will begin the task. There is one scenario to allow you to familiarize yourself with the interface. You will see a video play in the upper left side of the interface with additional cues written below the video. To the right of the video and cues, you will see the same three formations you just studied. Please select the formation you feel is most appropriate for the scenario by clicking the picture, you do not need to wait for the video to stop before you make a selection. The familiarization is untimed and you may ask questions about the interface and the execution of the task, no questions about the formations at this time.

Validation Subjects

Now we will begin the task. There is one scenario to allow you to familiarize yourself with the interface. You will see a video play in the upper left side of the interface with additional cues written below the video. To the right of the video and cues, you will see the same three formations you just studied. Please select the formation you feel is most appropriate for the scenario by clicking the picture, you do not need to wait for the video to stop before you make a selection. After you make your selection, you will be asked to rate your confidence level on a scale of 0–100. The familiarization is untimed and you may ask questions about the interface and the execution of the task, no questions about the formations at this time.

EXECUTE FAMILIARIZATION

ALL Subjects

Now you will begin the trials. These will be similar to the familiarization you just completed, but your selection will be recorded. If you think you see the same video play back to back, it has nothing to do with your performance of the task, it is simply by chance, everyone will see all of the videos in the same order regardless of performance.

EXECUTE TASK

Researcher reviews demographic survey and monitors the application, record any clarifying points needed for the survey and any bugs encountered with the application.

f.   *Post-Task Survey/Close out*

All Subjects

Thank you. Now I just need you to complete a short survey asking you some questions about the trials. Feel free to ask questions if needed. After you complete the survey, if you are interested I can provided you with your overall performance information if you would like.

Subject fills out survey on left computer. Researcher pulls up output file on the right computer confirms data and finds overall performance stats.

After subject fills out survey researcher quickly reviews answers and then asks any clarifying statements.

Free flowing conversation to answer any questions.

Thank you for participating in our study. We greatly appreciate the time you have spent with us and helping us with our research.

Close out tasks for researcher

- lock the subject ledger in the file cabinet

- confirm the output file is saved with the correct subject number

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Platoon Column

Movement Characteristics	When most often used	Platoon primary movement formation
	Control	Good for maneuver (fire and movement)
	Flexibility	Provides good dispersion laterally and in depth
	Fire Capabilities and Restrictions	Allows limited firepower to the front and rear, but high volume to the flanks
	Security	Extremely limited overall security
	Movement	Good

25 – 50 Meters
150 – 300 Meters

Platoon Vee
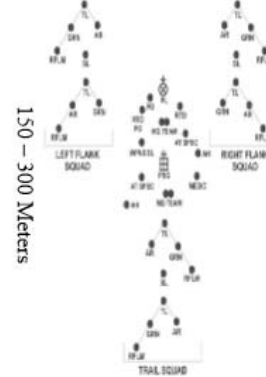
Movement Characteristics	When most often used	When the enemy situation is vague, but contact is expected from the front
	Control	Difficult
	Flexibility	Provides two squads up front for immediate firepower and one squad to the rea for movement (fire and movement) upon contact from the flank
	Fire Capabilities and Restrictions	Immediate heavy volume of firepower to the front or flanks, but minimum fires to the rear
	Security	Good security to the front
	Movement	Slow

75 – 150 Meters
150 – 300 Meters

Platoon File

Movement Characteristics	When most often used	When visibility is poor due to terrain, vegetation, or light
	Control	Easiest
	Flexibility	Most difficult formation from which to maneuver
	Fire Capabilities and Restrictions	Allows immediate fires to the flanks, masks most fires to front and rear
	Security	Extremely limited overall security
	Movement	Fastest for dismounted movement

25 – 100 Meters
75 – 300 Meters

Figure 31.   Platoon Formation Reference Sheet This is the sheet subjects used to study the three platoon formations before beginning the PFDT.

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APPENDIX H. CAPTTIM WORKSHEET EXPLAINED

(1)　　Summary of Code/Formulas Used to Compute CAPTTIM Data for Final Study

This summary is meant to explain the processes used to calculate the subject's regret, cognitive state, and CAPTTIM category. The image below is a view of the Microsoft Excel worksheet template used for the calculations. Below the image is a breakdown of the data contained in each column and how that data was collected or computed.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Trial Number	Correct Answer	Regret Col	Regret Vee	Regret File	Subject Answer	Subject Regret	Subje ▾ Time	EWMA Regret	Time Calculations Median	STD DEV	Cognitive State	CAPTTIM Cat				
1	1	0	7	4		error		error	#NUM!					Baseline mean	#DIV/0!	
2	3	4	9	0		error		#VALUE!	#NUM!	#DIV/0!	#DIV/0!	#DIV/0!		Baseline SD	#DIV/0!	
3	1	0	4	4		error		#VALUE!	#NUM!	#DIV/0!	#DIV/0!	#DIV/0!		Count Yellow	0	#DIV/0!
4	2	4	0	7		error		#VALUE!	#NUM!	#DIV/0!	#DIV/0!	#DIV/0!		Count Red	0	#DIV/0!
5	2	4	0	7		error		#VALUE!	#NUM!	#DIV/0!	#DIV/0!	#DIV/0!		Count Orange	0	#DIV/0!
6	3	4	7	0		error		#VALUE!	#NUM!	#DIV/0!	#DIV/0!	#DIV/0!		Count Green	0	#DIV/0!
7	3	6	9	0		error		#VALUE!	#NUM!	#DIV/0!	#DIV/0!	#DIV/0!		Cat Check	0	#DIV/0!
8	1	0	7	4		error		#VALUE!	#NUM!	#DIV/0!	#DIV/0!	#DIV/0!		Baseline Times		
9	3	4	9	0		error		#VALUE!	#NUM!	#DIV/0!	#DIV/0!	#DIV/0!				
10	3	4	7	0		error		#VALUE!	#NUM!	#DIV/0!	#DIV/0!	#DIV/0!				
11	1	0	6	5		error		#VALUE!	#NUM!	#DIV/0!	#DIV/0!	#DIV/0!				
12	1	0	7	4		error		#VALUE!	#NUM!	#DIV/0!	#DIV/0!	#DIV/0!				
13	2	4	0	7		error		#VALUE!	#NUM!	#DIV/0!	#DIV/0!	#DIV/0!				

Figure 32.　Screen shot of the Microsoft Excel worksheet template used for data computation.

Columns A-E contain reference data. Column A and B are the trial number and the correct answer for the trial. Columns C, D, and E hold the regret value for the formation choices. Regret values are based on a scale of 0 – 10. A regret value of 0 means the formation is the most appropriate option for the given scenario of that trial. The higher the regret value the less appropriate the formation for given scenario. A team of infantry and armor United Sates Army officers with experience leading platoons in combat collaborated to determine the regret values for each of the 32 scenarios of this task.

Column F is the subject's selection for the trial. This data is transferred from the output of the Platoon Formation Task application.

Column G is the subject's regret for the trial. This column uses Excel's logical "IF" formula to place the correct regret value in the cell. The formula references the subject's answer in column F, and then chooses the regret value for the corresponding formation column; answers of 1, 2, and 3 correspond to Column, Vee, and File, respectively.

Column H is the subject's selection for the trial. This data is transferred from the output of the Platoon Formation Task application.

Columns I is the exponentially weighted moving average (EWMA) (I) subject's regret. The research team used Excel's "Exponential Smoothing" tool from the Data Analysis tools. The previous trials provided 25% influence while the current trial provided 75% of the value.

Columns J and K are time calculations needed for the application of CAPTTIM. Colum J is the median time through trial n. Column K calculates the standard deviation of all trials to that point for the subject's time to choose a formation

Column L computes the subject's cognitive state for the trail. This column uses Excel's logical "IF" formula to fill in the state. The formula compares the subject's standard deviation time for the trail to the baseline standard deviation (baseline computations explained below). If the subject's response time is greater than the baseline standard deviation, the formula fills in "Explor" and otherwise "Exploit."

Column M classifies the subject's performance into one of the four CAPTTIM categories. This column uses conditional formatting rules to color the cell to the corresponding color for the CPTTIM category. It uses the value of Column L (Cognitive State) and then compares the subject's EWMA regret to 3. A higher EWMA regret than 3 results in a high regret determination and less than 3 is a low regret.

Columns O, P, and Q contain information required for other computations and a summary of the CAPTTIM results. The baseline mean was mentioned earlier, here it will be fully explained. To identify the cognitive state, a mean time and its standard deviation is required. To compute the baseline any trial following an incorrect response is discounted, as most people will take more time to consider their response following an incorrect answer. Column H colors the cell of any time that comes after an incorrect response red,

these cells are then filtered out, and only the remaining times are transferred to Column P for inclusion into the "Baseline Times." The Baseline times are used to compute the mean and standard deviations. The remaining section of these columns include a summary of the subjects CAPTTIM categorizations. Using Excel's "COUNTIF" formula, each category's number of occurrences in Column M is counted and a percentage is calculated. These pieces of information allow the research to confirm the data was properly copied into the worksheet.

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APPENDIX I. OVERALL PERFORMANCE DATA

Subject ID	# Red	# Orange	# Green	# Accept	# Corr	% Yellow	% Red	% Orange	% Green	% Accept	% Corr	Total Regret	Time (sec)	% Improve
108	16	51	48	107	99	9.4%	12.6%	40.2%	37.8%	83.6%	77.3%	151	910.1	12.5%
109	9	68	26	107	94	18.9%	7.1%	53.5%	20.5%	83.6%	73.4%	184	711.1	6.3%
111	25	23	67	100	90	9.4%	19.7%	18.1%	52.8%	78.1%	70.3%	213	981.7	3.1%
112	30	18	65	104	83	11.0%	23.6%	14.2%	51.2%	81.3%	64.8%	227	906.5	9.4%
123	17	19	90	119	109	0.8%	13.4%	15.0%	70.9%	93.0%	85.2%	91	839.4	9.4%
124	38	27	47	116	74	11.8%	29.9%	21.3%	37.0%	90.6%	57.8%	239	1121.3	-3.1%
135	24	24	71	105	95	6.3%	18.9%	18.9%	55.9%	82.0%	74.2%	167	951.3	-6.3%
136	17	12	94	120	105	3.1%	13.4%	9.4%	74.0%	93.8%	82.0%	108	1313.3	12.5%
147	29	35	44	110	79	15.0%	22.8%	27.6%	34.6%	85.9%	61.7%	223	957.0	6.3%
148	18	53	18	106	71	29.9%	14.2%	41.7%	14.2%	82.8%	55.5%	275	592.7	-3.1%
158	43	28	40	82	68	12.6%	33.9%	22.0%	31.5%	64.1%	53.1%	356	530.4	-12.5%
159	45	9	57	90	66	12.6%	35.4%	7.1%	44.9%	70.3%	51.6%	341	817.5	-9.4%
163	30	17	71	96	88	7.1%	23.6%	13.4%	55.9%	75.0%	68.8%	232	784.1	9.4%
164	8	67	30	107	97	17.3%	6.3%	52.8%	23.6%	83.6%	75.8%	164	1124.2	18.8%
175	18	24	67	109	91	14.2%	14.2%	18.9%	52.8%	85.2%	71.1%	183	947.2	12.5%
176	20	28	71	116	99	6.3%	15.7%	22.0%	55.9%	90.6%	77.3%	133	689.5	0.0%
187	24	19	82	113	101	1.6%	18.9%	15.0%	64.6%	88.3%	78.9%	131	367.7	0.0%
188	36	24	54	94	78	10.2%	28.3%	18.9%	42.5%	73.4%	60.9%	270	405.2	0.0%
191	20	46	44	102	90	13.4%	15.7%	36.2%	34.6%	79.7%	70.3%	210	448.9	-18.8%
192	8	52	42	111	94	19.7%	6.3%	40.9%	33.1%	86.7%	73.4%	170	648.7	31.3%
200	13	31	69	118	100	11.0%	10.2%	24.4%	54.3%	92.2%	78.1%	132	644.3	12.5%
210	38	20	61	102	82	6.3%	29.9%	15.7%	48.0%	79.7%	64.1%	249	684.2	15.6%
220	25	23	74	110	97	3.9%	19.7%	18.1%	58.3%	85.9%	75.8%	154	544.1	3.1%
230	3	28	91	124	119	3.9%	2.4%	22.0%	71.7%	96.9%	93.0%	43	398.7	9.4%
240	45	5	64	106	69	10.2%	35.4%	3.9%	50.4%	82.8%	53.9%	294	1259.0	15.6%
250	21	14	88	109	102	3.1%	16.5%	11.0%	69.3%	85.2%	79.7%	144	497.2	6.3%
260	38	28	19	74	48	33.1%	29.9%	22.0%	15.0%	57.8%	37.5%	472	688.6	-3.1%
270	41	24	33	84	57	22.8%	32.3%	18.9%	26.0%	65.6%	44.5%	384	3431.9	3.1%
280	5	31	82	119	112	7.1%	3.9%	24.4%	64.6%	93.0%	87.5%	83	642.4	15.6%
290	26	14	69	109	83	14.2%	20.5%	11.0%	54.3%	85.2%	64.8%	212	610.4	9.4%

Figure 33. Consolidated performance data for all 30 PFDT participants.

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APPENDIX J. CAPTTIM CATEGORIZATION BY TRIAL

Table 10.   CAPTTIM categorization by trial.

	108	109	111	112	123	135	136	163	175	176	200	230	250	280	290	124	158	159	188	210	240	260	270	147	148	164	187	191	192	220
# Opt	99	94	90	83	109	95	105	88	91	99	100	119	102	112	83	74	68	66	78	82	69	48	57	79	71	97	101	90	94	97
# Acc	107	107	100	104	119	105	120	96	109	116	118	124	109	119	109	116	82	90	94	102	106	74	84	110	106	107	113	102	111	110
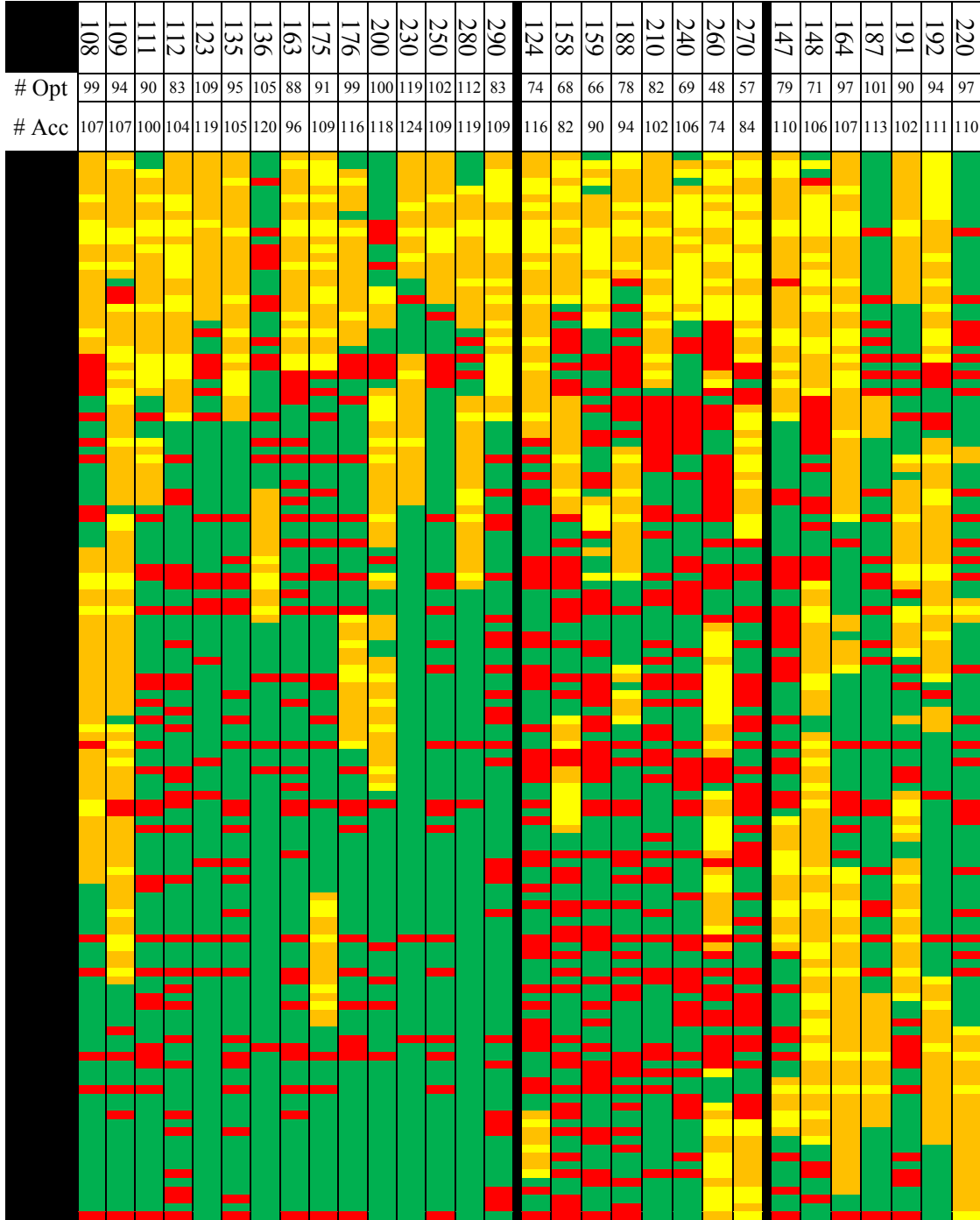
This table shows all 30 subjects CAPTTIM categorization for each trail. The chart breaks the subjects into the three groups (labeled at the top of the chart) and shows each subjects CAPTTIM categorization starting with trial 2 at the top through trial 128 at the bottom.

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APPENDIX K. PERFORMANCE BY TREATMENT

A.   MEAN REGRET BY TRIAL

This section shows the means and 95% confidence interval for each treatment by trial of appearance. Each of the 32 treatments appears four times in the 128 trials. These charts allowed the research team to observe which treatments the study subjects were able to improve the most on as they progressed through the PFDT.

Treatment 11111



Treatment 11122

Treatment 111112

Treatment 11211

Treatment 11121
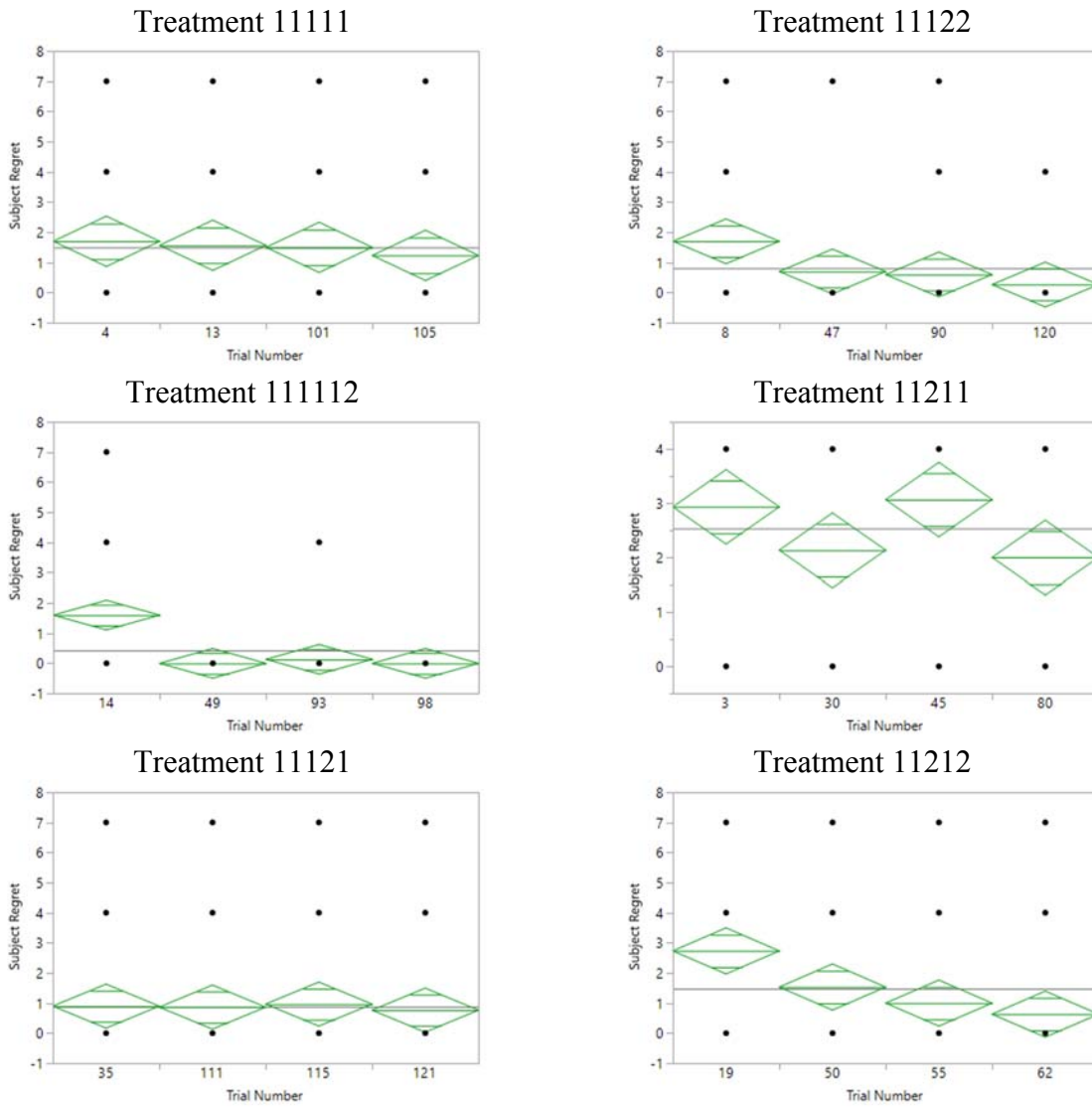
Treatment 11212
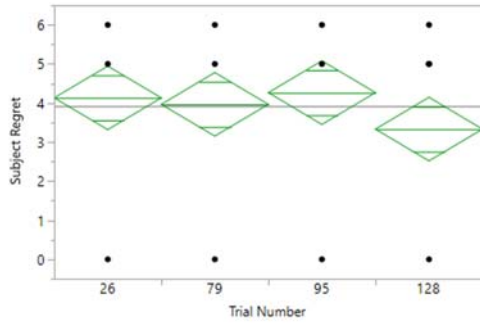
Treatment 11221

Treatment 12121
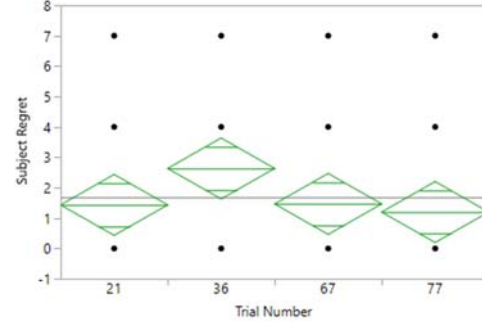
Treatment 11222
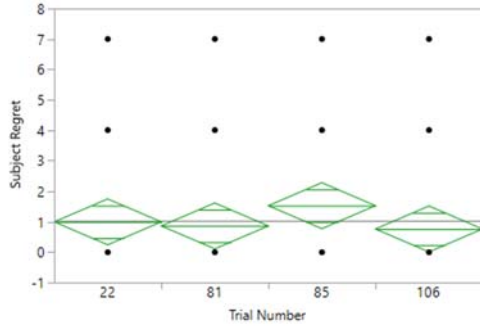
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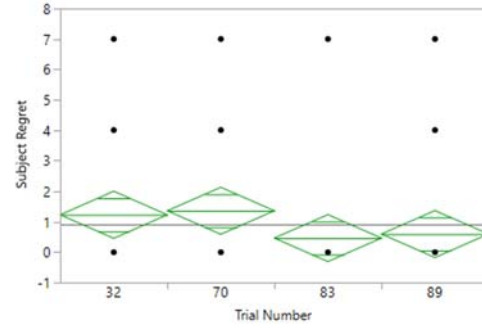
Treatment 12111
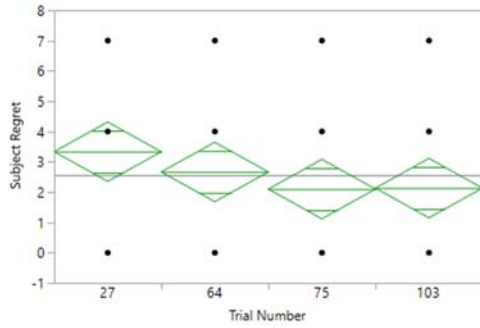
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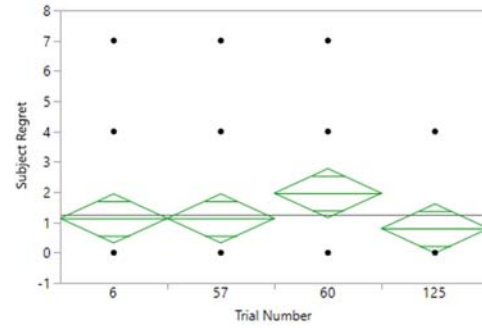
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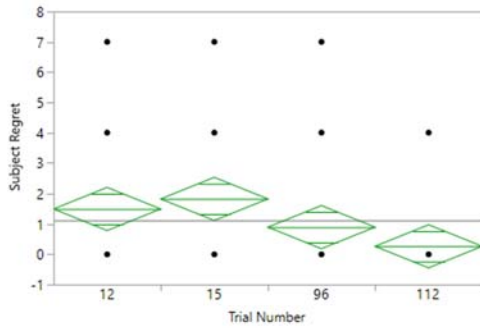
Treatment 12212

92
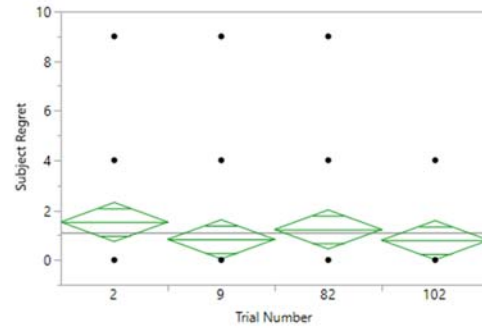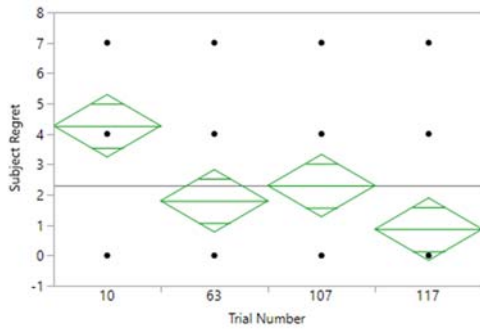
Treatment 12221

Treatment 21121
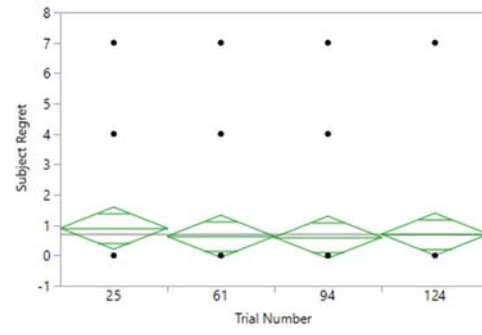
Treatment 12222
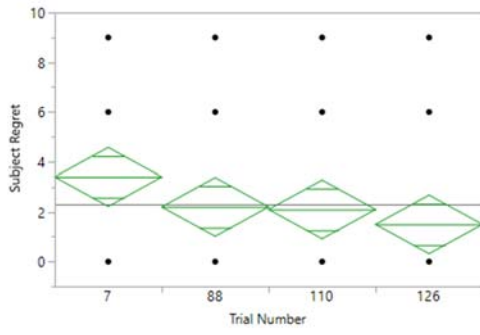
Treatment 21122
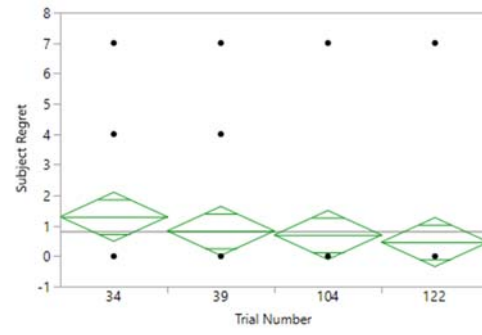
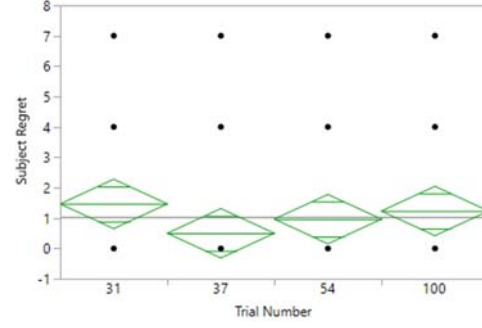## Treatment 21111
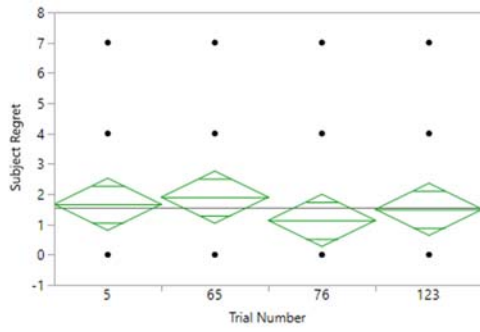
Treatment 21211
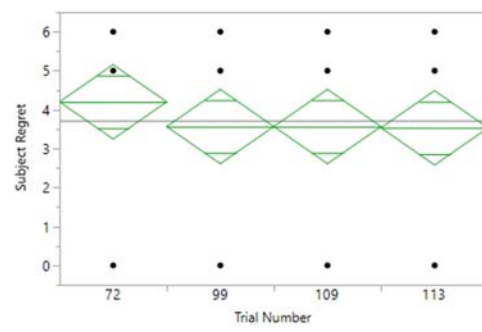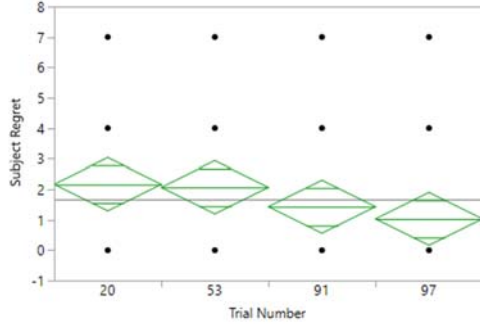

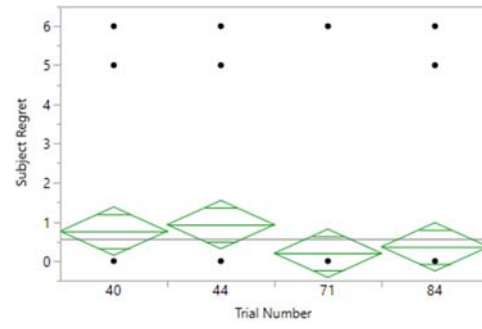## Treatment 21112
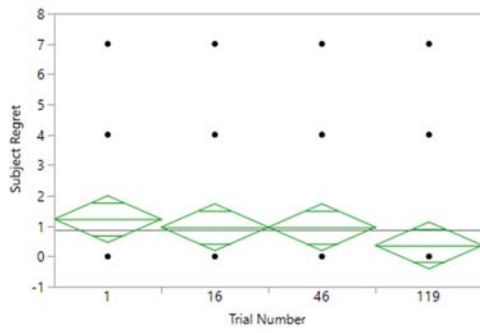
Treatment 21212
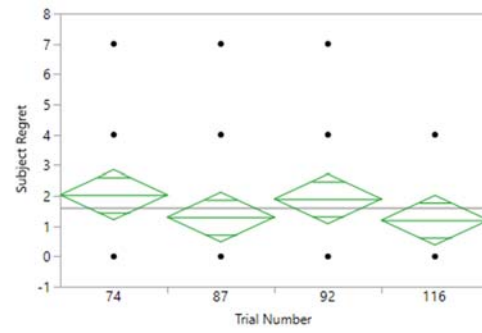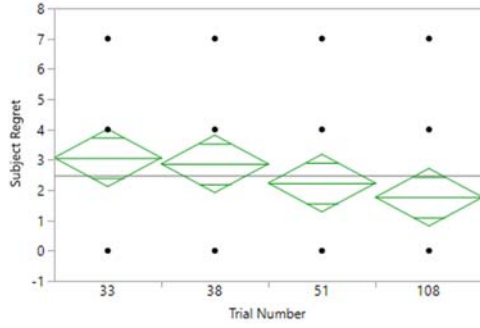
Treatment 21221
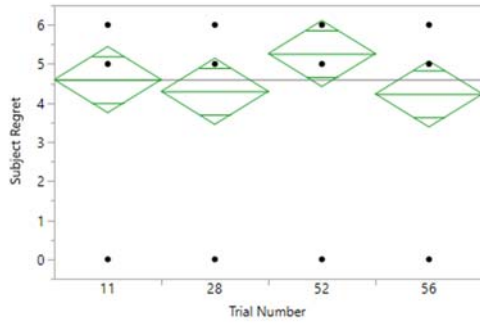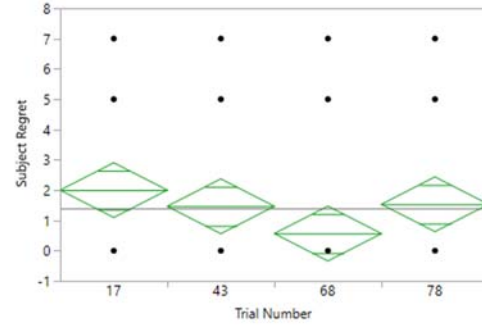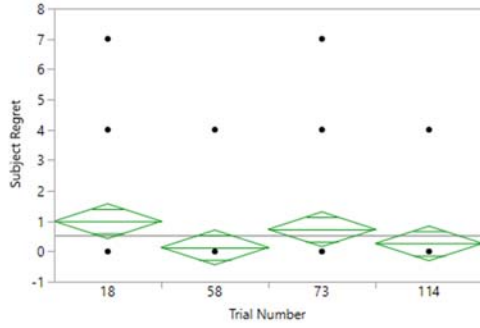

Treatment 22121

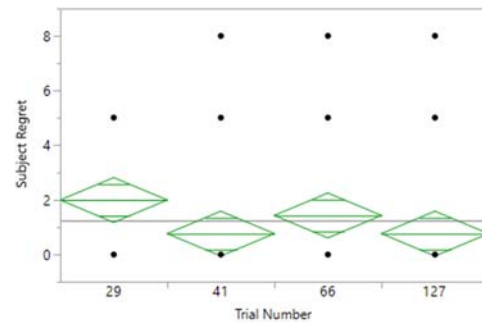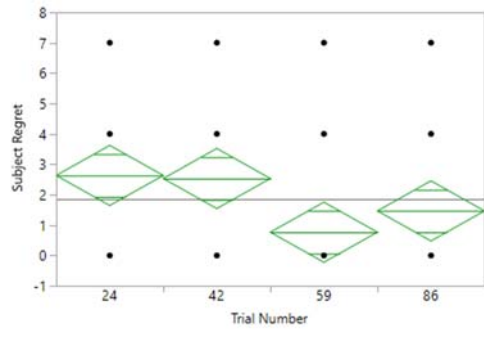Treatment 21222

Treatment 22122
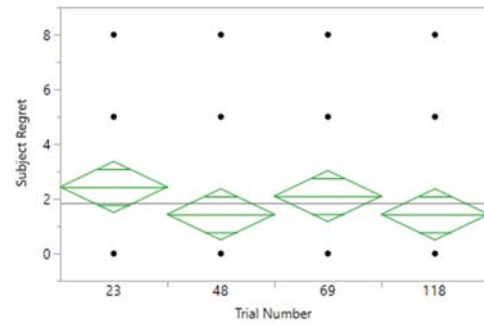

Treatment 22111

Treatment 22211

Treatment 22112

Treatment 22212

94

Treatment 22221

Treatment 22222

B.   TREATMENT MEAN REGRET OVERALL

Table 11 shows the overall mean regret and confidence intervals for each of the 32 treatments presented in the PFDT.

Table 11.   Mean regret for each treatment

| Treatment Number	Factor Level					Number	Mean	Std Error	Lower 95%	Upper 95%
	Height	Vegetation	Light	Enemy Probablity	Enemy Direction					
11111	Flat	Sparse	High	Possible	Front	120	1.50	0.21	1.08	1.92
11112	Flat	Sparse	High	Possible	Side	120	0.43	0.21	0.02	0.85
11121	Flat	Sparse	High	Likely	Front	120	0.88	0.21	0.46	1.29
11122	Flat	Sparse	High	Likely	Side	120	0.82	0.21	0.40	1.23
11211	Flat	Sparse	Low	Possible	Front	120	2.53	0.21	2.12	2.95
11212	Flat	Sparse	Low	Possible	Side	120	1.48	0.21	1.06	1.89
11221	Flat	Sparse	Low	Likely	Front	120	3.93	0.21	3.51	4.34
11222	Flat	Sparse	Low	Likely	Side	120	1.04	0.21	0.62	1.46
12111	Flat	Dense	High	Possible	Front	120	2.56	0.21	2.14	2.98
12112	Flat	Dense	High	Possible	Side	120	1.13	0.21	0.71	1.54
12121	Flat	Dense	High	Likely	Front	120	1.68	0.21	1.27	2.10
12122	Flat	Dense	High	Likely	Side	120	0.92	0.21	0.50	1.33
12211	Flat	Dense	Low	Possible	Front	120	1.26	0.21	0.84	1.68
12212	Flat	Dense	Low	Possible	Side	120	1.10	0.21	0.68	1.52
12221	Flat	Dense	Low	Likely	Front	120	2.31	0.21	1.89	2.73
12222	Flat	Dense	Low	Likely	Side	120	2.30	0.21	1.88	2.72
21111	Hill	Sparse	High	Possible	Front	120	1.55	0.21	1.13	1.97
21112	Hill	Sparse	High	Possible	Side	120	0.88	0.21	0.47	1.30
21121	Hill	Sparse	High	Likely	Front	120	0.71	0.21	0.29	1.13
21122	Hill	Sparse	High	Likely	Side	120	0.83	0.21	0.41	1.24
21211	Hill	Sparse	Low	Possible	Front	120	3.72	0.21	3.30	4.13
21212	Hill	Sparse	Low	Possible	Side	120	1.61	0.21	1.19	2.03
21221	Hill	Sparse	Low	Likely	Front	120	4.60	0.21	4.18	5.02
21222	Hill	Sparse	Low	Likely	Side	120	1.68	0.21	1.26	2.09
22111	Hill	Dense	High	Possible	Front	120	2.48	0.21	2.07	2.90
22112	Hill	Dense	High	Possible	Side	120	0.53	0.21	0.12	0.95
22121	Hill	Dense	High	Likely	Front	120	1.04	0.21	0.62	1.46
22122	Hill	Dense	High	Likely	Side	120	0.57	0.21	0.15	0.98
22211	Hill	Dense	Low	Possible	Front	120	1.39	0.21	0.97	1.81
22212	Hill	Dense	Low	Possible	Side	120	1.24	0.21	0.82	1.66
22221	Hill	Dense	Low	Likely	Front	120	1.85	0.21	1.43	2.27
22222	Hill	Dense	Low	Likely	Side	120	1.85	0.21	1.43	2.27

C.   REGRET LEVEL BY TREATMENT
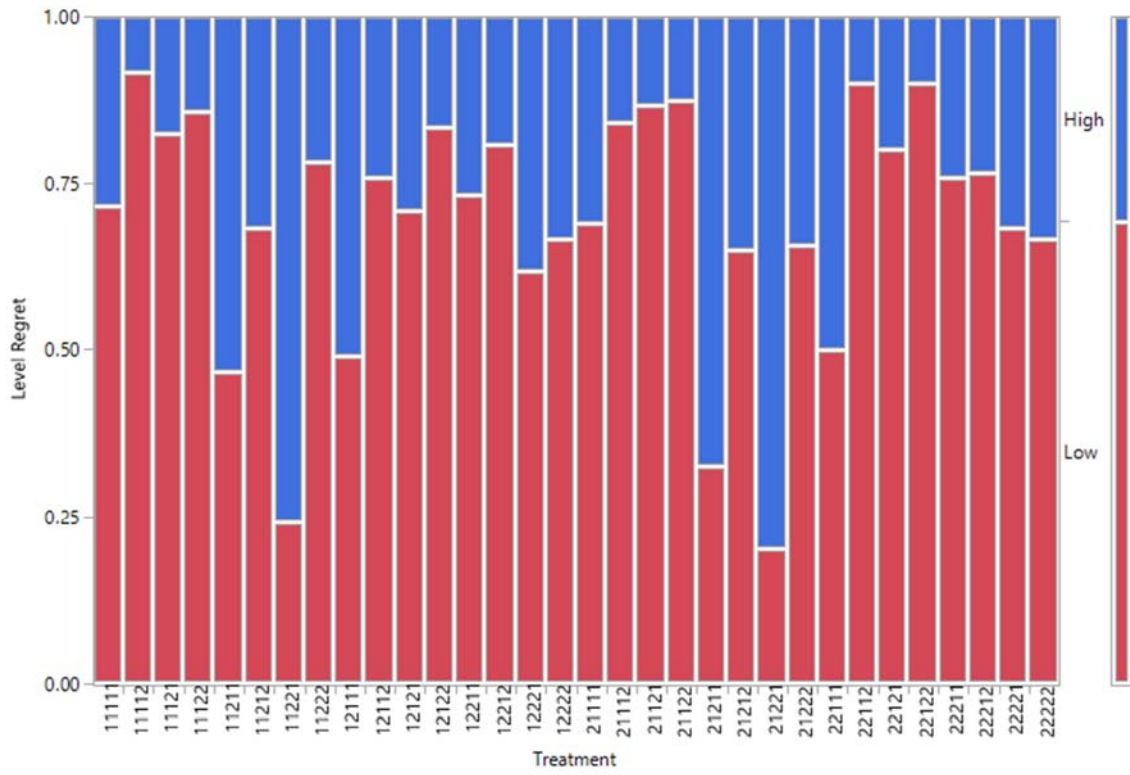
Figure 34.   Low vs. High regret by treatment This chart shows the percentage of low regret and high regret for each treatment in the PFDT.

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