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TESTING SIMULATION PLATFORMS TO ACCELERATE OPTIMAL MILITARY DECISION-MAKING IN A PLATOON-FORMATION TASK

by

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Training an infantry officer to select the proper platoon formation during a military operation traditionally requires a large dedication of training assets. Infantry training would benefit from further development of high-capacity training on commonly available platforms. In 2018, a computer-based simulated platoon-formation decision task (PFDT) was created and the Cognitive Alignment with Performance Targeted Training Intervention Model (CAPTTIM) was utilized to ascertain which participants reached optimal decision-making and when it occurred. This study built upon that work by refining and testing PFDT across two prevalent platforms. The PFDT included 32 scenarios, each randomly presented four times for a total of 128 trials. Five factors were manipulated in the scenarios and a SME confirmed the optimal, acceptable, and poor decision responses. Twenty-seven students at The Basic School and Naval Postgraduate School completed the PFDT in one of three platforms: tablet, virtual reality (VR), or VR with formations (which provided participants the ability to depict formations onto virtual backgrounds). CAPTTIM indicated no platform effect existed on the number of trials needed to reach optimal decision-making. Additionally, participants' experience levels did not impact whether experts or novices reached optimal decision-making prior to the other. The PFDT is thus a viable military training simulator regardless of technological platform utilized or amount of infantry training.

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Training an infantry officer to select the proper platoon formation during a military operation traditionally requires a large dedication of training assets. Infantry training would benefit from further development of high-capacity training on commonly available platforms. In 2018, a computer-based simulated platoon-formation decision task (PFDT) was created and the Cognitive Alignment with Performance Targeted Training Intervention Model (CAPTTIM) was utilized to ascertain which participants reached optimal decision-making and when it occurred. This study built upon that work by refining and testing PFDT across two prevalent platforms. The PFDT included 32 scenarios, each randomly presented four times for a total of 128 trials. Five factors were manipulated in the scenarios and a SME confirmed the optimal, acceptable, and poor decision responses. Twenty-seven students at The Basic School and Naval Postgraduate School completed the PFDT in one of three platforms: tablet, virtual reality (VR), or VR with formations (which provided participants the ability to depict formations onto virtual backgrounds). CAPTTIM indicated no platform effect existed on the number of trials needed to reach optimal decision-making. Additionally, participants' experience levels did not impact whether experts or novices reached optimal decision-making prior to the other. The PFDT is thus a viable military training simulator regardless of technological platform utilized or amount of infantry training.

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LIST OF ACRONYMS AND ABBREVIATIONS

.csv	comma separated value file
AAR	After Action Review
ANOVA	analysis of variance
CAPTTIM	Cognitive Alignment with Performance Targeted Training Intervention Model
CMC	Commandant of the Marine Corps
COA	course of action
CPG	Commandant’s Planning Guidance
CRA	Charles River Analytics
DOD	Department of Defense
H0	Null Hypothesis
HA	Alternate Hypothesis
HMD	head mounted display
HPT&E	Human Performance, Training and Education
IRB	Institutional Review Board
LVC-TE	Live, Virtual, and Constructive Training Environment
MAGTF	Marine Air Ground Task Force
MCSTE	Marine Corps Synthetic Training Environment
METT-TC	Mission, Enemy, Terrain, Troops, Time, Civilians
MOS	military occupational specialty
MOVES	Modeling, Virtual Environments, and Simulation
NPS	Naval Postgraduate School
ONR	Office of Naval Research
OODA	Observe-Orient-Decide-Act
PFDT	Platoon Formation Decision Task
PM TRASYS	Program Manager Training Systems
PTP	pre-deployment training programs
PTSD	post-traumatic stress disorder
RPD	Recognition-Primed decision
STO	Science and Technology Objective

TBS	The Basic School
T&E	Test and Evaluation
T&R	Training and Readiness
TMT	Training Management Tools
TTPs	tactics, techniques, and procedures
USMC	United States Marine Corps
VR	virtual reality
WML	working memory load

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I. INTRODUCTION

A. BACKGROUND

Over the past two decades, the Marine Corps has primarily focused on specific, prescribed pre-deployment training programs (PTP) for the twenty-four infantry battalions deploying to Iraq, Afghanistan, or in support of Marine Expeditionary Unit operations. PTP rightfully focused on preparing Marines and Sailors for success during deployments that conducted counterinsurgency or amphibious contingency operations. In July 2019, however, the Commandant of the Marine Corps (CMC), issued his planning guidance tasking leaders to focus on "force design, warfighting, education and training, core values, and command and leadership" (Berger, 2019, p. 1). Essential to achieving his vision is a deliberate and focused effort on developing the best tactical decision-makers in the world, with a bias for action and a drive to maintain superior tempo on the future battlefield. Despite American technological advantages, uncertainty, chaos, and friction will continue to rule future battlefields. Only experienced professionals, who exercise sound judgment and make effective and timely decisions, without awaiting further detailed and specific orders, will obtain victory (Marine Corps Warfighting Lab [MCWL], 2017). The critical requirement for victory and developing such a bias is a depth of small unit leader experience that can only be honed through repetition in training, education, and combat.

Recognition-Primed decision-making is the Marine Corps' choice decision-making model which focuses on individuals completing numerous repetitions of a task to utilize the gained experience in identifying patterns with present situations (Cohen et al., 1996; Klein, 1993). Pattern recognition allows individuals to identify satisfactory options and quickly react instead of conducting further analysis to pursue more optimal solutions. The alternative to intuitive decision-making is analytical decision-making (Cohen et al., 1996; Klein, 1993). An "analysis is fundamental to decision-making and involves scheduling, coordination, logic, organization, translation, interpretation, calculation, and prediction" (United States Marine Corps [USMC], 2020a, p. 4). This process is detailed-oriented, requires time and a thorough understanding of planning processes. Marine leaders need a requisite base of knowledge of doctrine and experiences to foster faster and less taxing decision-making. “These processes of analysis and intuition are not mutually exclusive; they inform and strengthen one another, often simultaneously” (USMC, 2020a, p. 4). Therefore, it is an imperative that Marine leaders have tools available to develop these skills.

In 2018, LTC Brian Hanley, USA, created a computer-based dynamic platoon formation decision task (PFDT) and the associated software to be used as a training aide for improving junior military leaders’ decision-making abilities (Hanley, 2018). The PFDT consisted of 32 scenarios, each randomly shown four times for a total of 128 trials. For each trial, users, who had no prior platoon formation experience, decided which platoon formation should be used based on a 10-second first-person view video clip of terrain as well as written information regarding likelihood and direction of enemy attack (see Figure 1). The primary goals behind the construction of the PFDT were to create a basic task that military users considered realistic, offer an appropriate level of difficulty, and provide the user the ability to learn from the task through repetition. Additionally, Cognitive Alignment with Performance Targeted Training Intervention Model (CAPTTIM) was applied to the PFDT data to provide an understanding of when and why some participants pursued suboptimal decisions (see Figure 2). As described below, CAPTTIM facilitates the detection of optimal decision-making by comparing a participant’s cognitive state with their decision performance (Kennedy et al., 2019). The results indicated the PFDT provided an appropriate level of difficulty while also demonstrating the utility of mimicking real-world behavior in which some decisions, while not optimal, are acceptable. Additionally, the CAPTTIM data indicated the participants learned from their experiences and showed improvement as they progressed through the task.

Figure 1. Sample trial of user interface from PFDT.
Source: Hanley (2018).

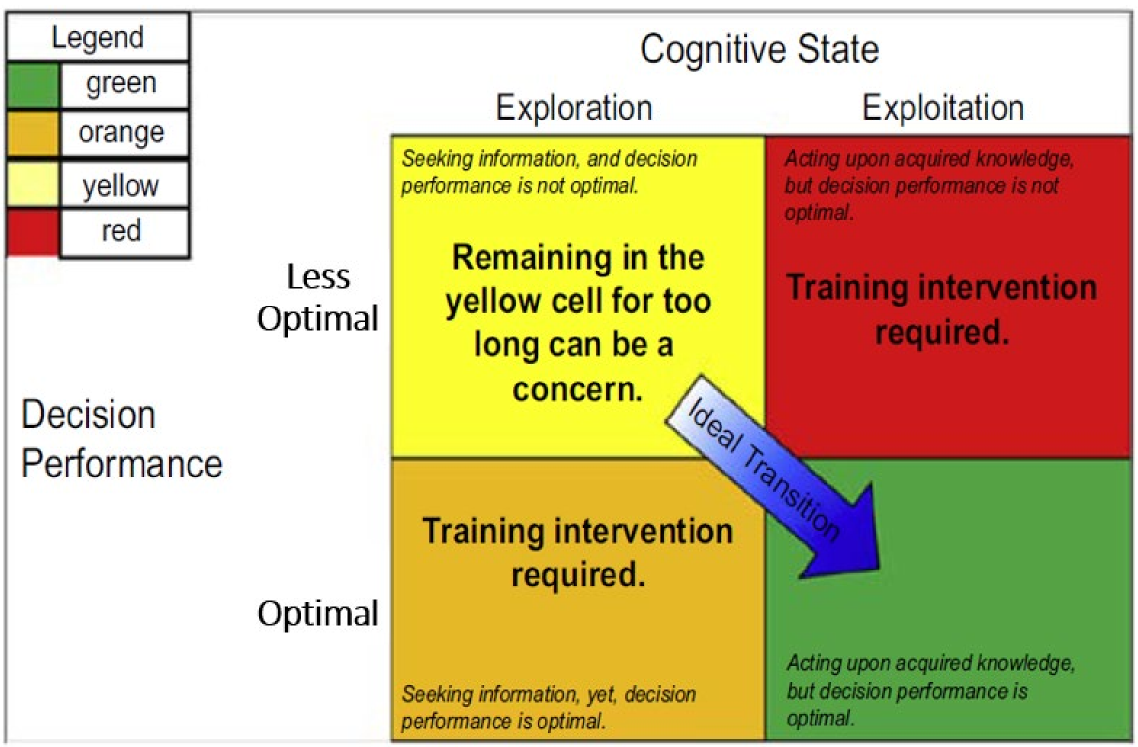

Figure 2. Illustration of the main components of CAPTTIM.
Source: Kennedy et al. (2019).

Training of effective rapid response decision-making can be accelerated by embedding decision assessment tools such as CAPTTIM into the simulated training task (Kennedy et al., 2019). CAPTTIM offers a method to determine when the trainee has reached optimal decision-making and provides feedback to the trainee or instructor based on the alignment of their cognitive state and their decision performance (Carlson, 2016; Critz, 2015; Hanley, 2018; Kennedy et al., 2015, 2019). This tool distinguishes between two participant cognitive states—exploration and exploitation—and two levels of decision performance—optimal and less optimal. The combination of cognitive state and decision performance are utilized to identify in real-time how a participant progressed through the task (see Chapter IV, Section B for a detailed description for the calculations underlying the CAPTTIM classification process). Optimal decision-making occurs when a participant's cognitive state is consistently exploiting good decisions. Because CAPTTIM data is recorded at the trial-by-trial level, it can describe an individual's transition from exploration to optimal decision-making and when that transition occurs.

The PFDT demonstrated the feasibility of using relatively simple software applications to provide military training opportunities (Hanley, 2018). It is important to exploit the success of the PFDT by ensuring it can be transferred onto emerging technology that is common to military servicemembers. The laptop, smartphone, game console, and Internet connection are the most commonly owned digital resources by military servicemembers (Sadagic and Yates, 2015). Additionally, the virtual reality (VR) head mounted display (HMD) is an emerging technology that when used as a pedagogical tool can bridge the divide between improving an individual's learning experience and their performance (Grivokostopoulou et al., 2020). The military should focus on large-scale adoption of placing training simulators on these readily available devices and improve the individual servicemember's decision-making abilities. In this study, I progressed this goal by determining how well the computer-based task such as the PFDT transfers to the tablet and virtual environment.

The present-day capabilities of VR provide a myriad of functions to include sports training, early-education pedagogical tools, and architectural design (Ahir et al., 2019; Grivokostopoulou et al., 2020; Su & Wang, 2012). This study focused on incorporating

VR in a military simulation. The specific feature I examined is how a VR HMD can display images not capable of being shown on other electronic devices. In this study, a group of the participants who conducted the PFDT on a VR HMD were able to view the platoon formations overlaid on the generated terrain. Participants completed the PFDT under one of three conditions: (1) Tablet, (2) VR HMD (VR only), (3) VR HMD with formations displayed on the terrain video (VR with formations). My prediction was participants in the VR with formations condition, who viewed the formations on the terrain within VR, would be able to reach optimal decision-making faster compared to those that had to mentally picture the formation on the terrain (Tablet and VR only conditions).

B. RESEARCH QUESTIONS

Research Question 1: To what extent can training of platoon formation decisions be effectively utilized on a computer tablet and VR?

HA_1: Effective training of PFDT will be demonstrated by participants, on average, selecting acceptable or optimal decisions on at least 70% of the trials on the PFDT, $\mu > .70$.

Exploratory Question 1: To what extent does a participant's experience level affect their performance of making acceptable and optimal decisions?

Research Question 2: To what extent will participants reach optimal decision-making when completing the PFDT across the three conditions?

HA_1: Application of CAPTTIM to the PFDT data will reveal that, on average, participants in the VR with overlay condition take fewer trials to reach optimal decision-making than participants in the other conditions, $\mu_{\text{VR overlay}} < \mu_{\text{VR}}, \mu_{\text{tablet}}$.

Exploratory Question 1: To what extent does a participant's experience level affect their performance of achieving optimal decision-making?

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II. LITERATURE REVIEW

A. TACTICAL MILITARY DECISION-MAKING

The Basic School (TBS), an introductory-level schoolhouse for all Marine Corps officers, teaches "success in combat becomes determined by a leader's ability to make time competitive decisions, communicate them clearly to subordinates, and impose their will to turn decisions into action" (USMC, 2020a, p. 4). The nature of war makes simple tasks complex and must not be entered by amateurs. Thus, the battlefield commander that is capable of rapidly completing this orient-observe-decide–act process will mentally out cycle their opponent. Therefore, it is critical military leaders sharpen their decision-making abilities to ensure success on the future battlefield. The following review of decision-making theories, training simulators, and CAPTTIM is pertinent to this thesis research and not meant to be all-inclusive.

1. Recognition-Primed Decision Model

In 1985, the Recognition-Primed Decision (RPD) model was created by psychologist Gary Klein after observing experienced decision-makers utilize mental simulations to quickly choose a satisfactory decision. It identifies two methods of decision-making that involve intuitive and analytical thinking. This model is comparative to the System 1 (decision-making operates automatically) and System 2 (effortful mental activities) modes of thinking with similar components: "a fast, non-conscious, intuitive pattern-matching and a slower, deliberate, conscious mental simulation to do the analysis/evaluation" (Kahneman, 2011; Klein, 2021). The RPD model relies upon one's judgment and experience to use intuition to recognize the essence of a given situation and rapidly create effective solutions to complex problems through pattern analysis (Schmitt, 1995). Alternatively, analytical decision-making is based on a comparison of quantitative options which seeks the most ideal solution at the cost of time and mental focus. This thesis uses Klein's definition of RPD, as a naturalistic method of "recognizing the plausible course of action (COA) as the first one to consider" (Klein et al., 1986).

Military leaders rely on RPD in planning operations and making decisions because of its speed and success at satisficing. Herbert Simon, a Nobel Prize winner in economics, proposed the idea of satisficing as a cognitive heuristic that involves someone choosing to adopt the first acceptable option they come across (Boella et al., 2011). His theory stated experienced decision-makers would choose satisfactory, over optimal, outcomes because they understand achieving perfect solutions is impracticable. Klein et al. (1993) stated the key to satisficing is through the establishment of a baseline within one's natural environment to associate current problems with previous situations by detecting patterns, conducting mental simulations, and determining suitable solutions. Additionally, Orasanu & Connolly discovered eight factors that influence decision-makers observing and orienting to their natural surroundings. These 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 (Orasanu and Connolly, 1993)

Therefore, it is paramount for military leaders to understand these factors as well as cognitive heuristics, such as satisficing, and how they influence decision-making. These leaders must build experience making satisfactory decisions within any combination of the above factors to hone their mental acumen.

2. Learning Tactical Military Decision-Making

RPD is the primary decision-making model taught to Marine Corps lieutenants at TBS. These future leaders spend six months learning basic infantry tactics despite their preferred military occupational specialty (MOS) because of the realization that any of them may be presented with a situation in which they must lead a small unit against enemy combatants. Each student's performance at learning and implementing small unit infantry tactics is analyzed by the instructor staff and largely determines their future assignments. Students do not receive notification of their assigned MOS until after months of observation and evaluation by the instructor staff. Individual students have minimal opportunities to gain experience within a leadership billet and thus are encouraged to develop additional methods to sharpen their intuition. Student's limited exposure to making decisions in tactical situations is a primary reason TBS prefers RPD as theorized by Klein.

Decision-makers typically apply RPD in the following four situations:

- When time pressure for a decision is great because only one COA is analyzed at a time and an optimum solution is not necessarily sought.
- When the decision situation is more dynamic and changes before an analytical decision analysis can be performed.
- When goals are ill-defined, which makes it difficult for the decision-maker to determine solution evaluation criteria.
- When the decision-maker is experienced in the decision domain. He has more life experiences to match against to recognize the situation and to choose a satisfactory COA. (Sokolowski, 2003, p. 21)

The first three situations are prevalent with students at TBS; the fourth situation generally does not apply because of their limited military experience at this point in their careers. This situation may apply to officers who were prior enlisted with multiple years of service; however, the additional experience does not automatically determine classification as an expert in tactical decision-making. Therefore, a student's limited experience within an environment defined by the first three situations results in RPD often being applied analytically vice subconsciously and inherently assumes more risk because decisions are made by novices that do not understand the decision-making process (USMC, 2020a). Thus, the importance of training and experience are lynchpins to mitigating risk and are instilled early in Marines' careers. The next section will explain how TBS curriculum identifies the issue of how novices are trained to intuitively make decisions based on limited experience.

3. Training and Evaluating Tactical Military Decision-Making

The primary decision-making learning objective at TBS is for students to understand and execute analytical decision-making through rigorous planning; which ultimately leads to RPD by honing one's intuition through experience in detailed planning (USMC, 2020a). Students are taught and trained that expert, intuitive decision-making does not occur naturally and must be developed through the deliberate practice of analytical decision-making. Similarly, researchers investigated decision-making strategies amongst handball players that ranged from novice to expert and found that expert athletes who developed their intuition were quicker at decision-making than novice athletes who classified as deliberative decision-makers (Raab & Laborde, 2011). The results showed that expert handball players who adopted a take-the-first option heuristic were quickly able to mentally process that option through simulations, determine predictable outcomes, and modify courses of action as needed to the current situation. Like these athletes, TBS students are given the goal of completing numerous iterations of analytical decision-making to transition to intuitive decision-making.

This mental process that Raab and Laborde (2011) researched directly aligns with Klein's (1989) RPD model, as shown in Figure 3, in that there are three critical components: feature matching, analogical reasoning, and mental simulation (Klein & Klinger, 1991). Feature matching is a comparison of a current situation to previous personal experience whether obtained through past actions, training, or rehearsals. Analogical reasoning is the process of identifying patterns from a similar event the individual has previously observed or studied. Mental simulation is a heuristic that allows an individual to recreate a sequence of events to explain the current environment. These three steps condition individuals to effectively recognize meaningful patterns by comparing the current environment to previous experiences. This will allow them to select a satisfactory option and assess its validity. However, this mental process in its current state does not directly benefit novices with limited experience.

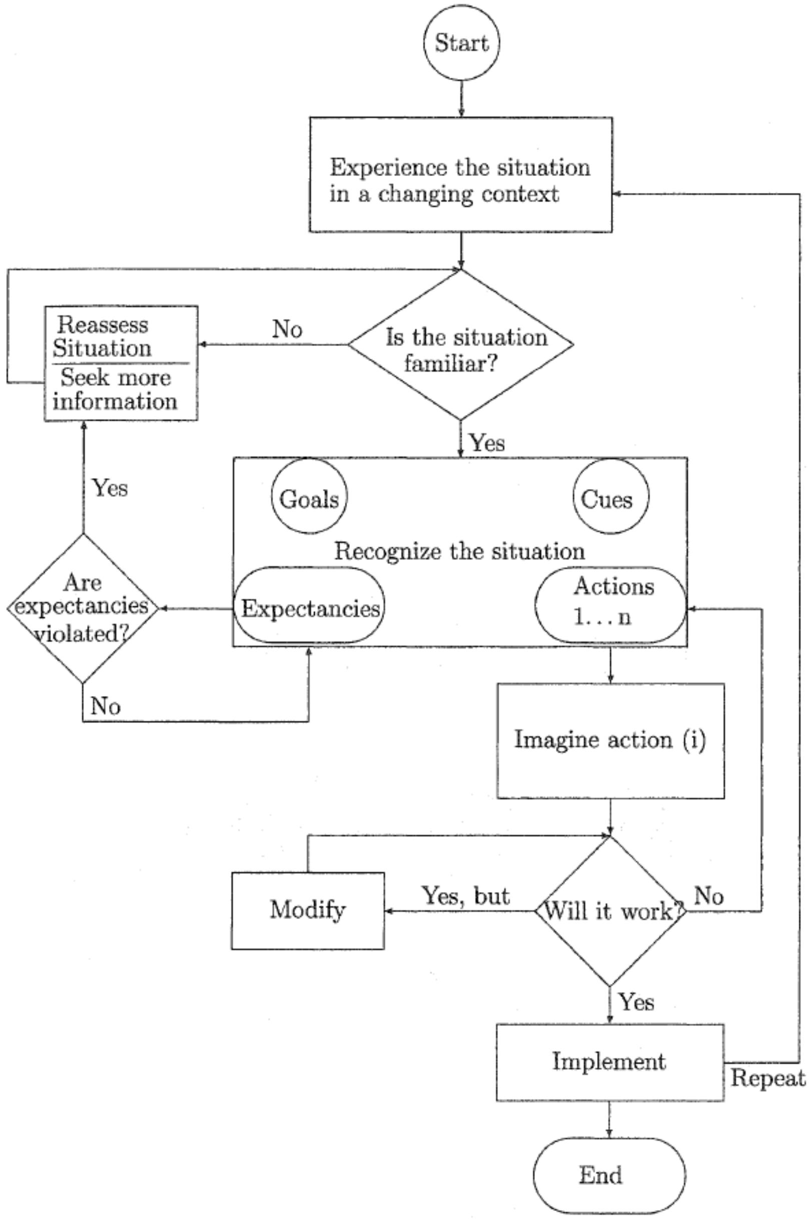


Figure 3. Recognition-Primed Decision Model. Source: Klein (1989).

Thus, the Marine Corps relies on satisficing for novices to begin developing their analytical decision-making. This technique of choosing the first satisfactory course of action is colloquially referred to as the 70% Solution. The name implies to the student that their decision is not perfect, nor is it expected to be. Novice decision-makers often suffer from mental paralysis through analysis in their attempt to interrupt the uncertain, vague, and contradictory information found on the battlefield. This ambiguous environment drives the decision-makers to identify the first satisfactory solution to avoid getting themselves and their subordinates mentally bogged down. Military research (USMC, 2020a) has identified seven factors in this environment that degrade an individual's ability to analyze data. These factors are:

- Chance—the absence of any cause of events that can be predicted, understood, or controlled.
- Risk—the expectation that the future holds the possibility of more than one result.
- Information—the sum of all the inputs, often from multiple sources, in a given situation.
- Time—a constraint imposed either by the mission or the enemy, requiring action to occur at a certain instant,
- Uncertainty—decisions will never be made with complete protection from error and there must be a balance between attempting to acquire the most precise information with given time constraints.
- Experience—knowledge gained through exposure to an event or idea that has been stored in your memory.
- Human Factors—external factors that influence decision-making, often without the reconceived realization it is happening. (USMC, 2020a, p. 8)

Knowledge of these factors can help novices develop techniques on how to mitigate them. One such technique, the OODA Loop, is another decision-making method taught at TBS that directly relates to RPD.

The Boyd Cycle, colloquially referred to as "The OODA Loop," is a concept presented in 1986 by Col. John R. Boyd (USAF, ret.) in his brief "Patterns of Conflict" (Brown, 2018). It consists of four activities: observe, orient, decide, and act (see Figure 4). The cycle is initiated by an individual observing their environment through sensory reception which provides the basis for orientation (Boyd, 1976). Once the situation is observed, an individual processes and analyzes the information based on their experiences, biases, and background. This knowledge of the situation allows the individual to decide on an acceptable course of action to respond to the environment. Orientation is the most important activity as an incorrect assessment of the situation will result in an action on a misaligned decision ultimately providing an advantage to an opponent. This cycle is then continuously repeated while an individual observes the changes to the environment based on their own actions as well as others.

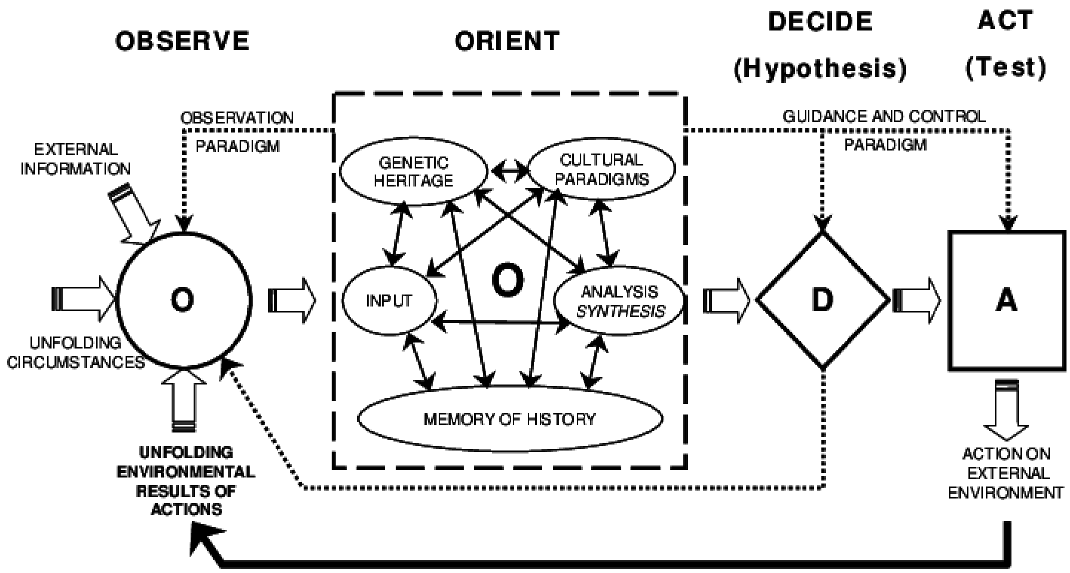


Figure 4. OODA Loop Model. Source: Ullman (2007).

The OODA Loop is an accurate depiction of naturalistic decision-making, can be applied within most life experiences, and directly relates to RPD (Ullman, 2007). The speed at which this cycle is conducted is improved as an individual becomes more effective at completing each step. Additionally, Hick's Law states an individual's response time improves by increasing the number of known responses available during unknown situations (Roberts et al., 1988; Schneider and Anderson, 2011). Therefore, evaluations of TBS students assigned to leadership billets during training exercises are assessed in their ability to mission plan and execute their plan. An individual's process is expectedly slow and problematic in the beginning; however, they are expected to improve throughout the six months of instruction after completion of numerous training exercises. My hypothesis is the utilization of a decision-making training simulator can improve an individual's response time and success rate of selecting optimal decisions by allowing them to complete multiple iterations of a task. This new experience will facilitate a greater understanding of available options allowing an individual to become more familiar with unknown stimuli when cycling through the OODA Loop and conducting RPD.

B. MILITARY TRAINING SIMULATORS

Gen. David Berger elevated the importance of utilizing simulators in training environments in his 2019 Commandant's Planning Guidance (CPG). He stated, "Our training facilities and ranges are antiquated, and the force lacks the necessary modern simulators to sustain training readiness" (Berger, 2019, p.6). The Program Manager Training Systems (PM TRASYS), a branch within Marine Corps Systems Command, is tasked to provide the Marine Corps with training support as well as developing and sustaining training systems and devices. Examples of various training products they facilitate include simulators, mock weapons, range targets, range instrumentation, training technology research and development, distributed learning capabilities, training observation capabilities, and after-action review systems (USMC, 2019). PM TRASYS defines Individual Training Systems (ITS) as, "support to the individual Marine, crew, section, and platoon in familiarity, function, and sustainment of warfighting and pre-deployment skills" (USMC, 2019, p. 18). This organization is leading the effort of improving the Marine Corps' use of military training simulators; however, the heightened need for improvement requires a bottom-up refinement in addition to established programs of record.

Each Marine Corps base is unique in its capabilities to train Marines. Unfortunately, state-of-the-art simulators capable of improving an individual's decision-making and combat proficiency vary in availability. For example, the Gunfighter's Gym, designed to replicate the physical and visual challenges of combat is currently only available at Camp Lejeune, North Carolina. A unit's limited exposure to adequate training simulators is compounded by complex schedules, fiscal budgets, and individual leader's priorities. LtCol (ret.) Brendan McBreen, USMC, a proponent of tactical decision games, addressed repetition with feedback as the most important factor in developing an individual's decision-making ability (O'Connell, 2020). The CPG emphasizes the necessity to utilize simulators to maximize learning opportunities in garrison before training in the field. Having training simulators readily available will allow tactical decision-makers to get the repetitions required to improve their RPD and discuss this experience with their training staff to instill learning.

The PFDT is the simulated task of 0302-PAT-1001 (Lead a Unit in Patrolling Operations) an individual task within the Marine Corps Infantry Training and Readiness (T&R) Manual (USMC, 2020b). A primary benefit of utilizing simulators to conduct simple training events during different phases of a training cycle is the ability to validate individual deficiencies. Additionally, a unit will receive new Marines and Sailors at various times throughout a pre-deployment workup which compounds the issue as basic-level training events are accomplished early in the training schedule and there is rarely time allotted to retrain an event. Training simulators allow small unit leaders to validate their unit's proficiency in particular individual and collective training tasks (USMC, 2020b) to address weaknesses before executing a large-scale field training exercise and evaluate new joins proficiency. The primary benefit of using training simulators to support these individual training tasks is availability. Each event within the T&R Manual has an associated sustainment interval mandating when an individual or collective unit must be reevaluated. The accessibility of easy-to-use training simulators, such as the PFDT, on widely owned electronic platforms, will facilitate units to maintain proficiency throughout a pre-deployment workup and deployment.

C. VIRTUAL REALITY AND MILITARY TRAINING SIMULATORS

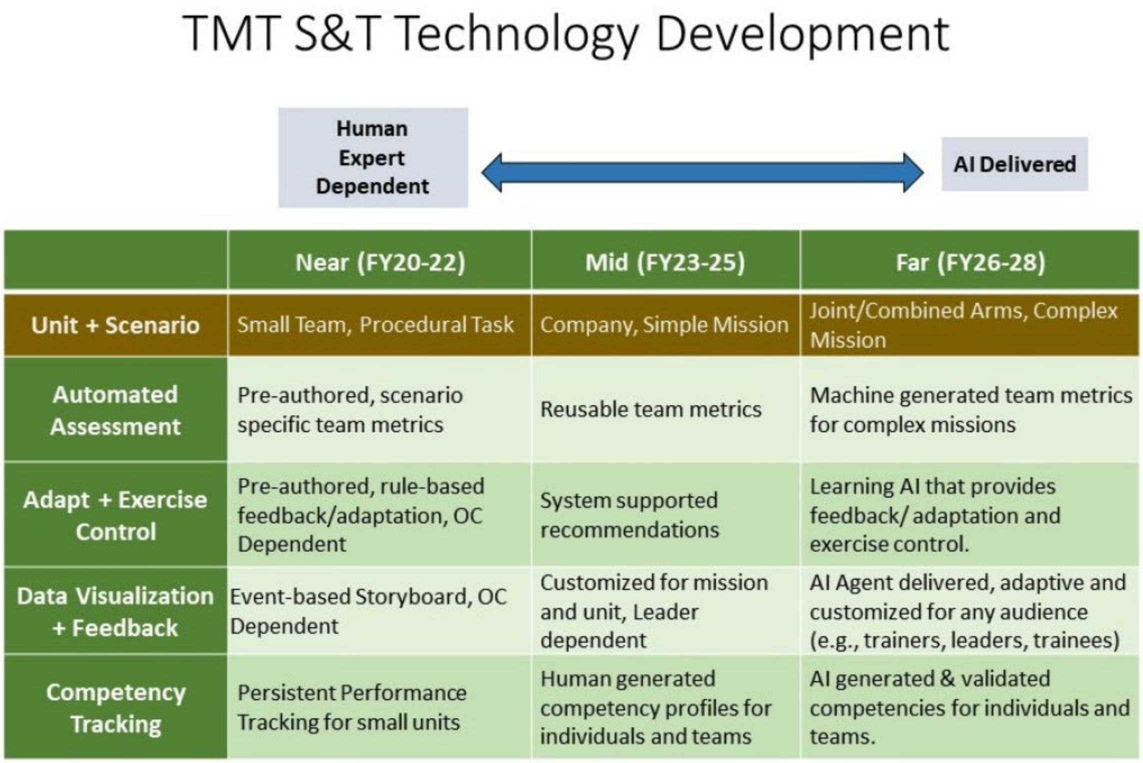
In 1966, virtual reality was first introduced to the U.S. military by Thomas Furness, a military engineer, who created a helmet-mounted display flight simulator for the U.S. Air Force. Since then, virtual simulated environments have become a mainstay for presenting military decision-makers with unique experiences to improve their cognitive attributes. The Marine Corps, through the PM TRASYS, is currently in the process of creating the Marine Corps Synthetic Training Environment (MCSTE) through the Live, Virtual, and Constructive Training Environment (LVC-TE) which combines real-world exercises, virtual reality, and computer-generated entities into one environment (Goodwin & Hoffman, 2020). The implications of this technology, projected for initial operating capability in 2026, may lead to a paradigm shift in training methodology and modernization. Additionally, the U.S. Army is working on its version of a Synthetic Training Environment to pursue similar goals. Academia, private business, and the military are mutually endeavored to advance the capabilities of virtual reality and benefit from its development (Hamilton et al., 2020; Wong et al., 2019).

The primary benefit of utilizing a VR HMD for military training simulators within the LVC-TE is the concept of presence. Presence refers to the phenomenon of believing you are a part of a virtual environment and making the experience more real (Sanchez-Vives & Slater, 2005). This heightened level of immersion has created new opportunities for training simulators that previously were not capable (Hamilton et al., 2020). The MCSTE is attempting to capitalize from this benefit by creating simulated battlefield environments for units to train. This simulated training environment has the potential to foster unit cohesion while drastically reducing the cost and time of live training events. The military also has benefited from presence through successful clinical trials to treat active duty and former military service members suffering from posttraumatic stress disorder (PTSD); by identifying the precise event from a patients' traumatic experiences, recreating that event in a virtual environment, and treating the specific incident rather than attempting to recall the events through numerous therapy sessions (Rizzo et al., 2015).

The MCSTE's Training Management Tools (TMT), one of three major components, incorporates an intelligent tutoring capability that will support the planning, preparation, execution, and assessment of training events (Goodwin & Hoffman, 2020). This capability will provide the generation of tailored scenarios, real-time feedback and adaptation, and rapid assessment and after-action reviews (AAR). Most importantly, the development of automated assessment as well as competency tracking at both the individual and collective levels is directly relevant to the focus of this thesis (see Figure 5).

> Virtual and constructive training capabilities provide more repetitions for certain tasks than live training, and they allow training in conditions that would not be safe or feasible on live ranges. However, live training is the essential test of readiness. Virtual training, when used as a precursor to live training, enhances its benefits. The LVC-TE will support more repetitions and more integrated training, which will result in a more agile and lethal Marine Air Ground Task Force (MAGTF). (USMC, 2021)

The ultimate objective is to deliver simulators, capable of adaptive training and providing valuable feedback, to small unit leaders to effectively train their units in military tactical decision-making they would not receive otherwise.



	Near (FY20-22)	Mid (FY23-25)	Far (FY26-28)
Unit + Scenario	Small Team, Procedural Task	Company, Simple Mission	Joint/Combined Arms, Complex Mission
Automated Assessment	Pre-authored, scenario specific team metrics	Reusable team metrics	Machine generated team metrics for complex missions
Adapt + Exercise Control	Pre-authored, rule-based feedback/adaptation, OC Dependent	System supported recommendations	Learning AI that provides feedback/ adaptation and exercise control.
Data Visualization + Feedback	Event-based Storyboard, OC Dependent	Customized for mission and unit, Leader dependent	AI Agent delivered, adaptive and customized for any audience (e.g., trainers, leaders, trainees)
Competency Tracking	Persistent Performance Tracking for small units	Human generated competency profiles for individuals and teams	AI generated & validated competencies for individuals and teams.

Figure 5. Technology challenges for TMT.
Source: Goodwin and Hoffman (2020).

D. ANALYZING OPTIMAL DECISION-MAKING USING CAPTTIM

CAPTTIM has been utilized to ascertain when a participant's cognitive state properly aligns with their decision performance throughout multiple Naval Postgraduate School (NPS) theses' experiments (Carlson, 2016; Critz, 2015; Hanley, 2018). A participant's cognitive state refers to their ability to explore or exploit knowledge of their environment. Whereas decision performance is measured by regret, which is determined by comparing a participant's single trial performance to the best possible outcome for that trial (Kennedy et al., 2015). As revealed in chapter 21 of *Neuroergonomics: The Brain at Work and in Everyday Lif*e, "effective adaptive tactical training requires assessing whether a trainee is in a cognitive state of exploration or exploitation, and how far their decision performance deviates from optimal decision-making throughout a training event" (Kennedy et al., 2019, p. 127). Through their CAPTTIM research, Kennedy et al. distinguished "between two participant cognitive states: exploration (the participant has not figured out the task and needs to explore the environment) and exploitation (the participant evaluates that they have mastered the task and is acting upon acquired knowledge)" (Kennedy et al., 2019, p. 127). Their model allows a researcher to properly identify if a participant's cognitive state matches observed decision performance (see Figure 2).

This decision-making assessment model provides the critical ability to analyze the results of users of military training simulators. "CAPTTIM utilizes simple behavioral measures to characterize cognitive state and decision performance. It uses variability in latency between each decision to determine whether the trainee's cognitive state is exploration (large latency variability) or exploitation (small latency variability)" (Kennedy et al., 2019, p. 127). As a participant begins a decision task, the expectation is they spend some time in the yellow area (Exploration and Less Optimal) of the model before transitioning to the green area (Exploitation and Optimal). These established cognitive states were applied in Hanley's PFDT to each participant's results to identify their decision-making process. The following transition demonstrates the ideal progression of learning through exploration (see Figure 6).

Figure 6. Participant 230 shows the successful transition from exploration to exploitation. Source: Hanley (2018).

Concern arises when a participant strays to the red or orange regions of the model for a substantial period (see Figures 7 and 8); this pattern was an indication the participant's cognitive state was no longer aligned with their decision performance and may require intervention (Carlson, 2016; Hanley, 2018; Kennedy et al., 2015). In Figure 7, the participant spends the last third of the task in the orange zone, in which the participant is making correct decisions, but is unaware the decisions are correct. Figure 8 depicts a more alarming pattern in which the participant regularly is in the red zone by making incorrect decisions but believing they are making the correct choice. In this case, the participant has not correctly learned the appropriate cues to make correct decisions and should be reminded of the cues (Carlson, 2016; Hanley, 2018; Kennedy et al., 2015). CAPTTIM is utilized within this research to determine a participant's ability to learn and to measure the effectiveness of the PFDT as a training simulator. The goal of this research team was to create a credible training aide with high cognitive affordance that could be utilized on commonly owned digital platforms.

Figure 7. Participant 164 fluctuated between exploration and exploitation.
Source: Hanley (2018).

Figure 8. Participant 159 continued to exploit poor decision-making.
Source: Hanley (2018).

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III. METHODS

This chapter explains the steps the research team took to design and develop the study. First, the discussion focuses on the target population of the participants and the design of the PFDT. The second section explains the design and development of the PFDT. The third section discusses the materials required to operate the program. The final section of this chapter discusses the procedure we implemented to conduct the experiment. Both the NPS and USMC Human Research Protection Program Institutional Review Boards (IRBs) reviewed and approved the study.

A. PARTICIPANTS

The target population for this experiment were students at TBS and NPS; personnel within the military who have received introductory tactical infantry training to include platoon-level tactics and formations. Hanley's study utilized participants who were primarily non-infantry trained personnel, which differs from this target population who are individuals currently receiving or previously received infantry tactical training. However, both test groups would ideally utilize a similar simulator for the anticipated stated purposes. Novice students at TBS, who would have a familiarity with the military but not have a detailed knowledge of infantry tactics, could use the PFDT to develop their RPD if the platoon formation task were adopted as a training tool. Whereas experienced students at NPS could use the PFDT to maintain proficiency in making tactical-level decisions regarding formation selection. Participant recruiting efforts included a bulk email to TBS students and instructors, an announcement posted on bulletin boards, and word of mouth. All participants volunteered to take part, and the research team provided no compensation to the participants.

B. DESIGN

This study employed a between-participants, repeated measures design, so that the delivery of the PFDT was manipulated between participants. Hanley developed the PFDT to aide platoon commanders who had to determine the most optimal formation for their units conducting patrolling operations (USMC, 2020a). This simulator attempts to replicate real-world settings where novice leaders would find themselves; albeit, with significantly fewer available pieces of information. 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. Both the Army and Marine Corps evaluate formations based on five characteristics: control, flexibility, fire capabilities and restrictions, security, and movement (USMC, 2014). Leaders determine which formation is most appropriate for the situation based on the strengths and weaknesses of these characteristics. Table 1 describes the five characteristics.

Table 1. Characteristics defined.

Characteristics	**Description**
Control	The ease with which the leader can 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	The 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 (USMC, 2021). Second, the task should help the participant transition from analytical to recognition decision-making. Finally, the task must provide positive/negative feedback to the participant for each trial.

2. Design of Study

Application of CAPTTIM across multiple studies has revealed three distinct decision performance profiles: successfully transitioned, consistent poor exploiters, and fluctuating (Carlson, 2016; Critz, 2015; Hanley, 2018). The successfully transitioned profile is those participants that transition from exploration to optimal exploitation (see Figure 6). Consistent poor exploiters are those that predominately use suboptimal exploitation throughout the task (see Figure 8). The fluctuating classification is participants that fluctuate between exploration and exploitation without successfully transitioning to optimal exploitation (see Figure 7). These established decision performance profiles were applied to this study's data to assess how participants perform across the three conditions. This research team chose the three conditions in which participants will complete the PFDT as the independent variables: (1) Phone, (2) VR HMD (VR only), (3) VR HMD with formations. The dependent variables are the time it takes participants to make a choice and the outcome of each choice.

3. Design of Platoon Formation Decision Task

For this study, the METT-TC factors of enemy, terrain, and time were employed to develop scenarios to present to the participant. 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 the amount of light	Daylight	Night
2	Terrain Height	Degree of variation in the height of the terrain	Flat	Hilly
3	Terrain Vegetation	The 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

a. Terrain Generation

To convey each of the 32 situations to the participant, the research team created eight different terrain scenes. Charles River Analytics (CRA) developed a computer application capable of procedurally generating terrain (Charles River Analytics, 2020). 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 Terrain Generation Tool (TGT), for use in this project. TGT uses four variables (time of day, weather, terrain height, and terrain vegetation) to manipulate the terrain. These four variables facilitate the manipulation of three of the five PFDT factors: time of day, terrain height, and terrain vegetation. TGT has a built-in capability to manipulate the field of view through the generated terrain. Viewing the terrain occurs using a scripted location for placement of the individual within the TGT to then look around the environment as they need. A magnetic compass is placed on the screen that indicates to the participant the required direction of travel. Three examples of the created scenes are shown in Figures 9–11.

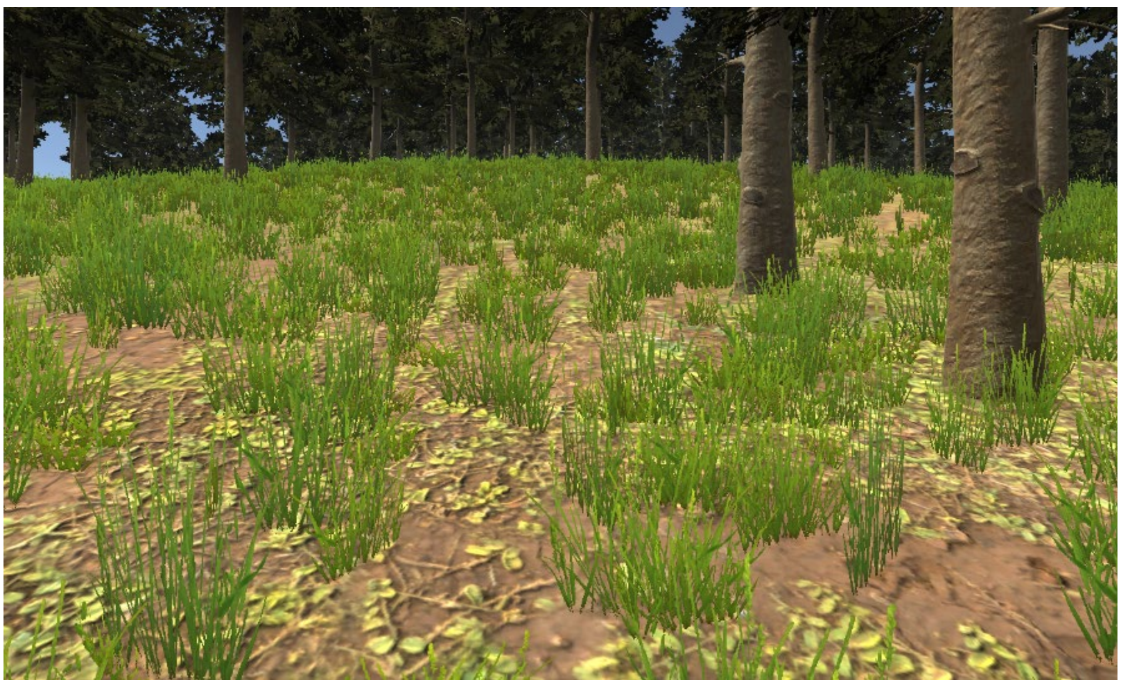

Figure 9. Example of hilly, densely vegetated terrain at day by Charles River Analytics.

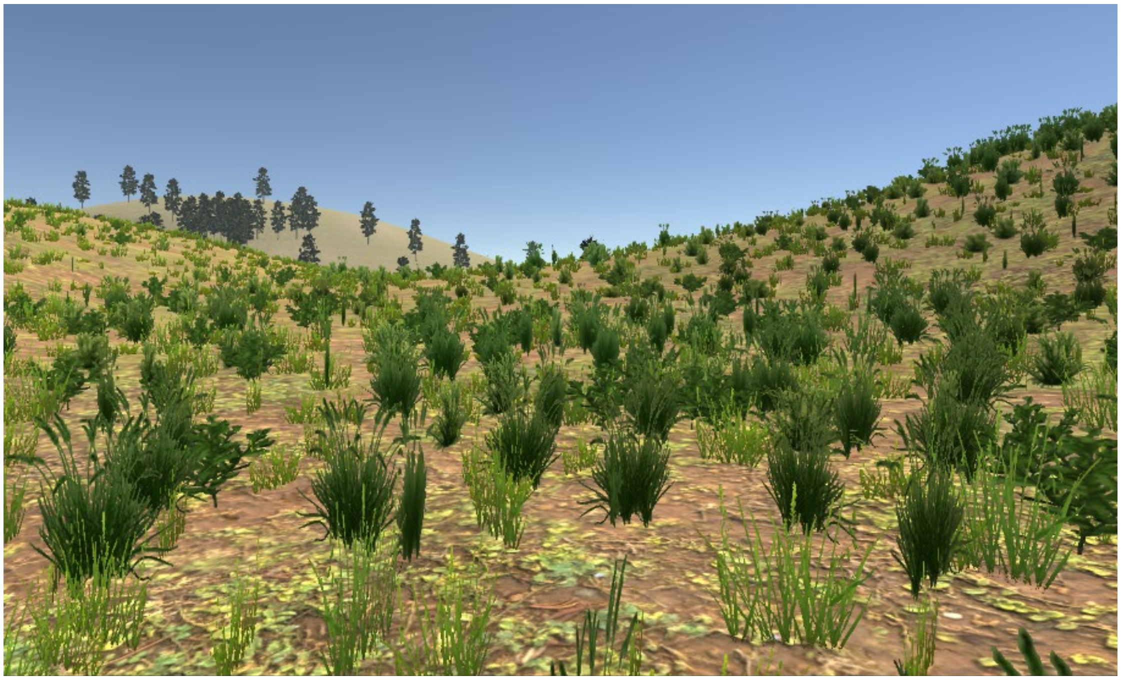

Figure 10. Example of hilly, sparsely vegetated terrain at day by Charles River Analytics.

Figure 11. Example of flat, densely vegetated terrain at night by Charles River Analytics.

b. Inclusion of the Enemy

The remaining two PFDT factors involve the direction of attack and the probability of taking contact from the enemy situation. 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 in each scenario of the PFDT provide the participant an overly simplified enemy situation that would be in an operations order.

c. Formation Options

As previously stated, one of the dependent variables in this task is which platoon formation the participant selects during each trial. Marine Corps doctrine describes five platoon-level dismounted formations; in this task, participants select from only three of these formations. The determination to use only three of the five formations facilitates a more focused study period before commencing the task. Additionally, limiting the PFDT to three formations ensures fewer scenarios to be tested while preserving an acceptable amount of time to complete the task.

The research team worked with two infantry officers as the subject matter experts (SMEs) to determine which three formations are the most common options for 32 treatment scenarios based on the doctrinal characteristics listed in the Marine Corps' *MCWP 3-11.1 Infantry Company Operations* (USMC, 2014) and the Army's *ATP 3-21.8 Infantry Platoon and Squad* (Department of the Army, 2016). These publications have similar content regarding each formation; however, the Army publication is more detailed and consequently was chosen to create the study guide. The three selected formations are the platoon column, platoon line, and platoon vee (see Figures 12–17). These formations thus serve as the possible answers for each of the scenarios in the platoon formation task.

Additionally, the SMEs validated the selection of correct formations to ensure the most optimal formations per each trial were selected. This measure of validity was taken to minimize the subjective nature of determining which formation is most optimal in a certain situation. It is considered subjective because although this simulator utilizes five factors to make one formation more optimal than the rest; a small unit leader might prefer another formation that functions better for their unit. The SMEs discussed the most optimal decision for each scenario based on the five factors of the experiment, their professional experience, and Army and Marine Corps doctrine: ATP 3-21.8 and MCWP 3-11.1.

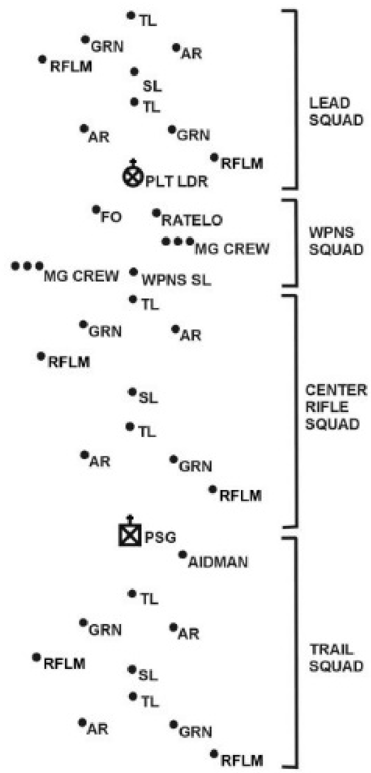

Figure 12. Platoon column with each platoon member displayed. Source: Department of the Army (2016).

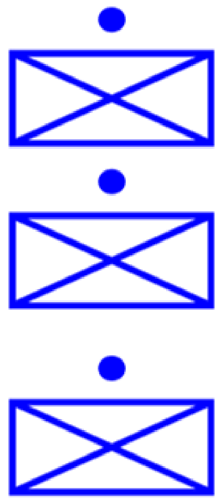

Figure 13. Platoon column displayed in the Operations, Terms, and Graphics format as shown in the PFDT.

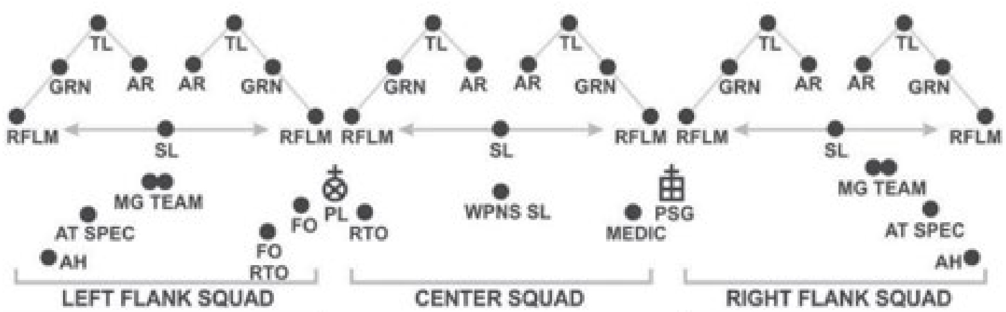

Figure 14. Platoon line with each platoon member displayed. Source: Department of the Army (2016).

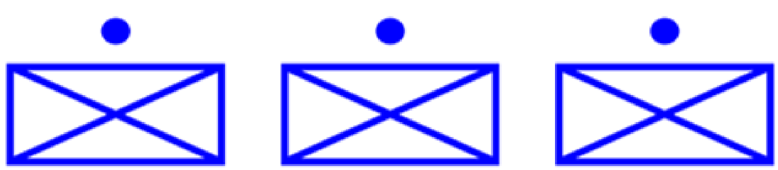

Figure 15. Platoon line displayed in the Operations, Terms, and Graphics format as shown in the PFDT.

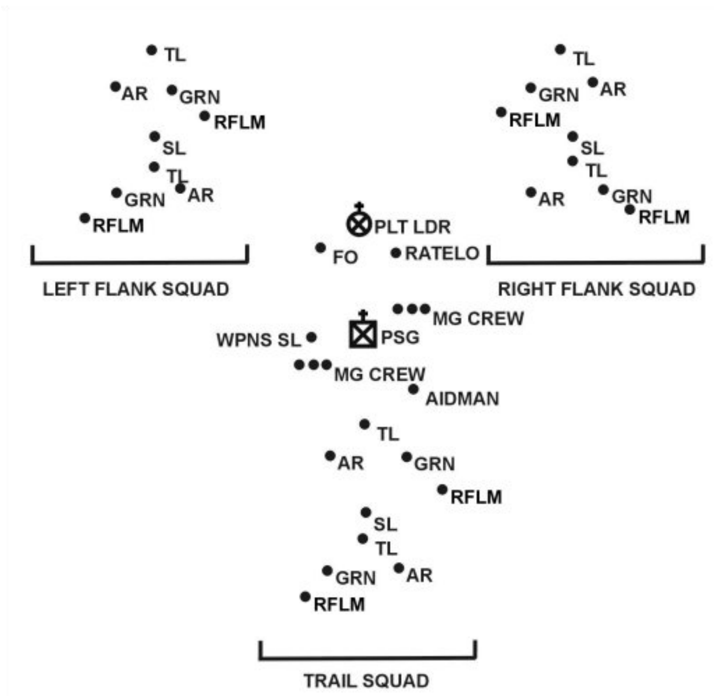

Figure 16. Platoon vee with each platoon member displayed. Source: Department of the Army (2016).

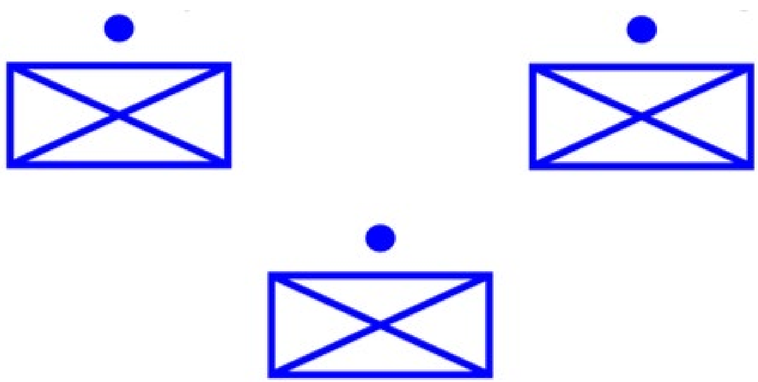

Figure 17. Platoon vee displayed in the Operations, Terms, and Graphics format as shown in the PFDT.

For each scenario, there is an optimal, less-than-optimal, and non-optimal response. Using this method of acceptable answers instead of only correct or optimal more closely represents the realities of combat (Hanley, 2018). Additionally, although doctrine provides clear tactics, techniques, and procedures (TTPs) for certain situations it is the on-scene battlefield commander to utilize RPD to determine the most optimal solution based upon available information. Therefore, formations being classified as most optimal is subjective in nature dependent on the individual commander in exact situations. Thus, the research team worked with several infantry officers to identify the most optimal solution for each trial.

4. Development of the Platoon Formation Decision Task

This thesis differs from Hanley's thesis in the platforms on which the PFDT is completed—tablet and VR. For each platform, features of the PFDT were adapted. Figure 18 shows the interface for the tablet-version of the PFDT. In the tablet-version, the participant sees the TGT in the upper left portion of the screen while the enemy situation is displayed in the lower left. The 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 participant to read the situation for each scenario presented. Along the right side of the screen are the three formation options for the participant to choose from.

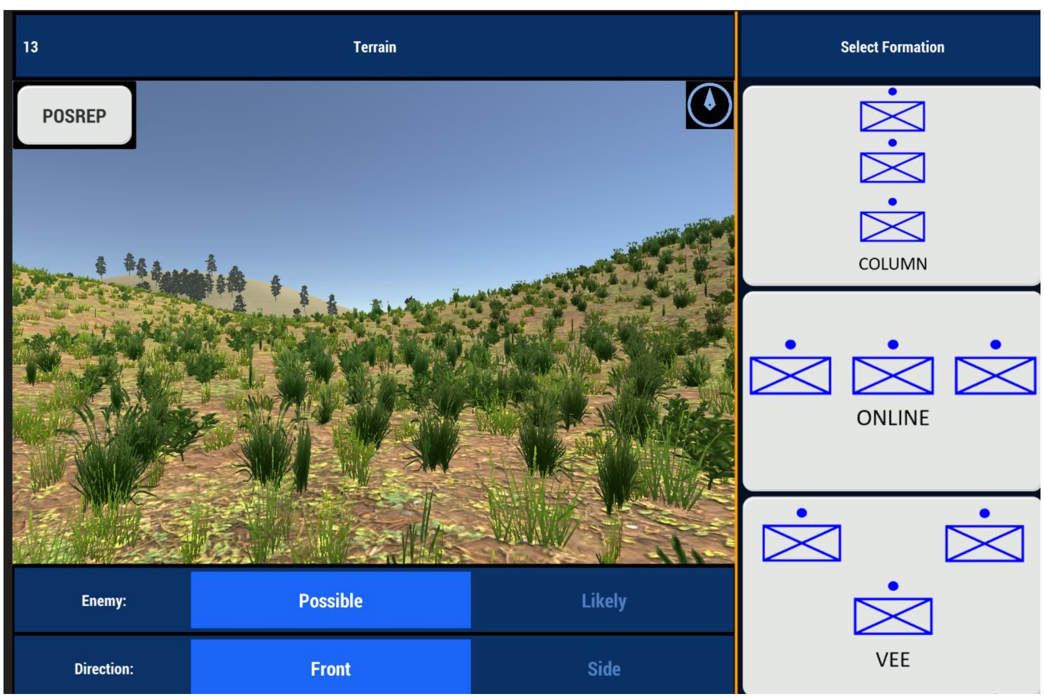

Figure 18. User interface for the tablet-version PFDT.

In the VR-version, the participant sees the TGT throughout the entire field of view while the enemy situation and formations are in a static box superimposed on the TGT. There are two variations to the VR-version: formations depicted and formations not depicted. In the former, the participant can visualize the platoon formation on the TGT to assist in making their decision. The user interface allows the participant to tap the VR controller on a formation to depict that formation on the TGT. The individuals within the platoon appeared as they would if conducting patrolling operations while facing the direction of travel. Figure 19 shows the interface for the VR-version of the PFDT with the formations depicted. Figure 20 shows the VR-version without formations overlaid on the TGT. The virtual controller was shown within the virtual environment with a compass on top that also points in the intended direction of travel.

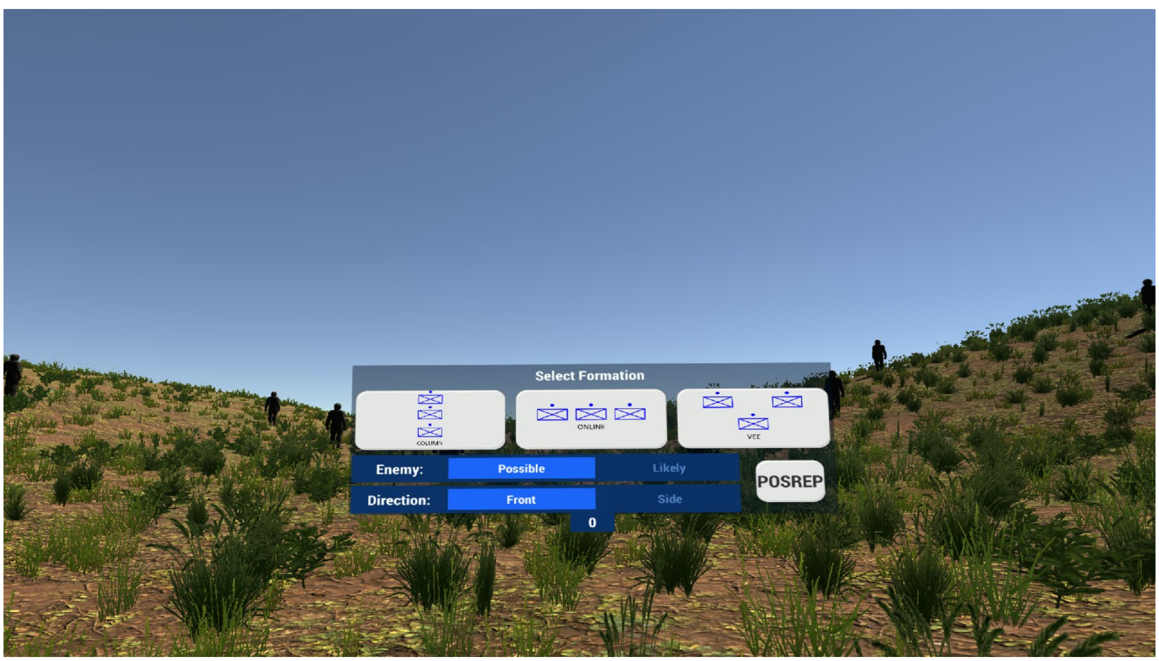

Figure 19. User interface for the VR-version PFDT with formations depicted.

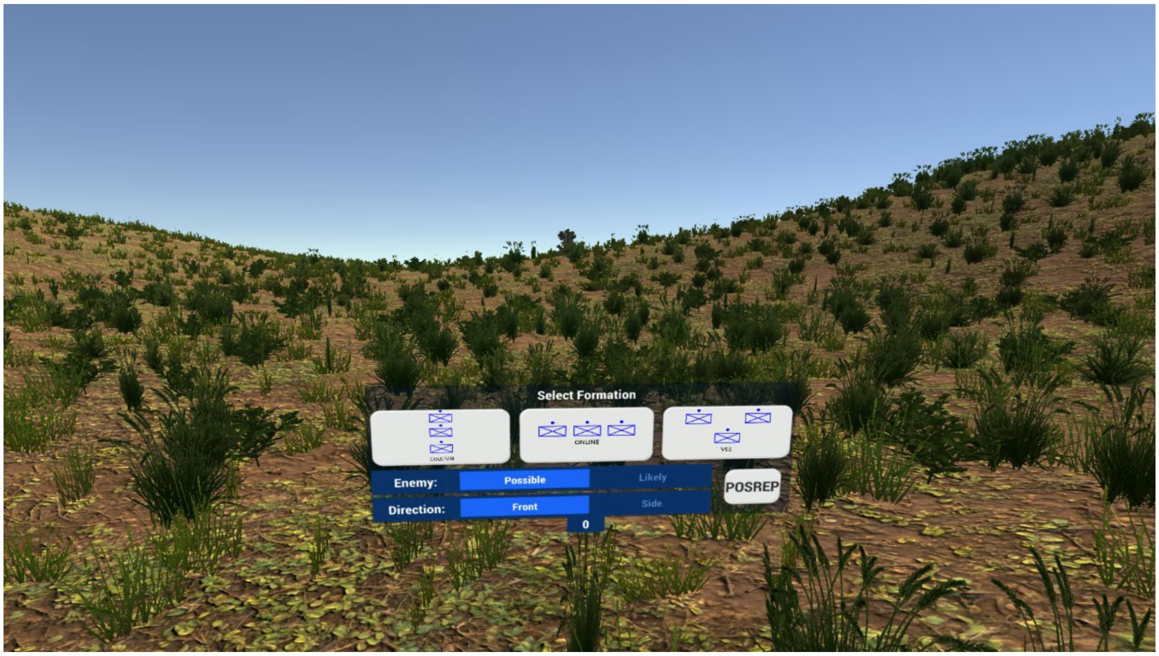

Figure 20. User interface for the VR-version PFDT without formations depicted.

5. Task Summary

The resulting final task design included 32 scenarios presented four times for a total of 128 trials. The 128 trials were subdivided into four blocks with each block randomly presenting the 32 scenarios to the participant. The presentation of the 128 trials is the same for each participant. The participant sees the TGT 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. The participant may make the formation selection at any time upon being presented the scenario. The amount of time it takes the participant to make a decision is the second dependent variable for this study. Following the selection of the formation, the participant receives one of two messages: "You made the optimal choice" or "You did not make the optimal choice." The message remains on the screen until the participant selects the "NEXT" button and the next trial begins. Appendix A contains a list of the 32 scenarios with the optimal formation and the associated regret levels. Appendix B shows the sequence of the 128 trials with the optimal formation and regret levels.

C. MATERIALS

1. Program

The PFDT software was created by the NPS Modeling Virtual Environments and Simulation (MOVES) Institute's FutureTech team and was developed using Unity. The application reads from a reference file to identify the correct TGT and enemy factor levels to play for each scenario. Additionally, the application records the participant's selections and times of selection. The application compares the participant's response to the correct response contained in the reference file and provides the participant feedback. The feedback tells the participant if they selected the optimal formation or a non-optimal formation. When a participant completes their session, the application creates an output file that contains the participant's responses and decision times for the application of CAPTTIM.

2. Surveys

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

a. Demographic Survey

The demographic survey collected basic data concerning the participants' age, gender, military service, and video game experience (see Appendix C). This survey allowed the research team to describe the demographic characteristics of the sample and determine if individual experience and skill level affected the results of the experiment. Participants recorded their answers on a hardcopy print out and the results were manually input into a computer by a member of the research team.

b. Post-Task Survey

The post-task survey focused on the participant's experience and thought process (see Appendix C). The survey focused on what information the participant used to make their formation choice. The survey also asked about any strategy used during the task and if the strategy changed during the execution of the task. Finally, the survey asked if they would use this as a training tool in the operating forces and to provide any additional comments. The participant also completed this survey on a hardcopy print out and the results were manually input into a computer by a member of the research team.

3. Equipment

This study used three laptop computers, two Vive Pro virtual reality headsets, and one Microsoft Surface tablet. One laptop was a typical office computer capable of running the standard applications used for office and student work hosted the survey and experiment data. The PFDT application requires a computer with a separate graphics processor to support the playing of the software. The two gaming laptops used for this study were an Origin EVO16-S and an MSI GS75 Stealth 9SG, both had NVIDIA GeForce RTX 2080 video cards. Each Vive Pro set came with a headset, link box, two controllers, and two base stations. The PFDT software worked through SteamVR on each laptop. The Microsoft Surface 3 tablet operated on Windows 10 Pro with an Intel HD graphics card.

D. PROCEDURE

Each participant's visit included one visit to the research room typically lasting 30–45 minutes. Researchers used a script (see Appendix E for study script) to guide each participant's session to standardize the sessions. When a participant arrived for their session, the researcher welcomed them, and provided an explanation of the session process followed by the informed consent. After consenting to participate, the participant filled out the demographic survey. After completing the demographic survey, participants completed a study session that consisted of reviewing a packet of information (see Appendix F for study packet) on each formation with information extracted from ATP 3-21.8 and MCWP 3-11.1.

Participants had five minutes to review and study the three formations they would encounter during the execution of the platoon formation task. Researchers only answered questions clarifying the information of the study sheet (e.g., the meaning of words, the distance markers). Researchers did not answer any question about the employment of a formation (e.g., when appropriate, how, why). Following the study session, participants executed the PFDT consisting of one familiarization scenario; during which 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. After the familiarization scenario, participants started the experimental trials, consisting of 128 scenarios.

Participation concluded with the post-task survey and debrief. The debrief 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 five minutes or more discussing the discriminators for the optimal formations as well as training simulators. The equipment and workstations were sanitized upon the completion of each participants' involvement with the experiment.

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IV. PILOT TEST

Pilot testing was conducted to validate the software application, verify the CAPTTIM calculations, and solidify the procedure for conducting this experiment. Nine individuals volunteered to help the research team with pilot testing. They varied in experience of performing a billet as a combat-arms small unit leader: one infantry officer with one combat deployment in support of Operation Enduring Freedom, two infantry officers with no combat deployment experiences, three officers with combat-arms MOSs, and three officers with non-combat MOSs

A. PFDT SOFTWARE APPLICATION

The PFDT software application functioned very well; the users found the interface intuitive, and the application performed as intended. The research team did identify one item to adjust. Pilot test participants utilizing VR with formation overlay experienced slight confusion as to which formation was being depicted on the TGT. Two participants with no combat-arms experience were unable to ascertain which formation was being observed after selecting a formation to view on the terrain. They knew they had selected a formation to observe but were unsure which one was displayed. To address this issue, the research team requested the FutureTech team modify the user interface to allow individual formation boxes to become highlighted after a participant selected to observe (see Figure 21). The FutureTech team made this adjustment in less than a day. This change allowed participants in the experiment to correctly identify the depicted formation by observing the information box as well as recognizing it on the terrain.

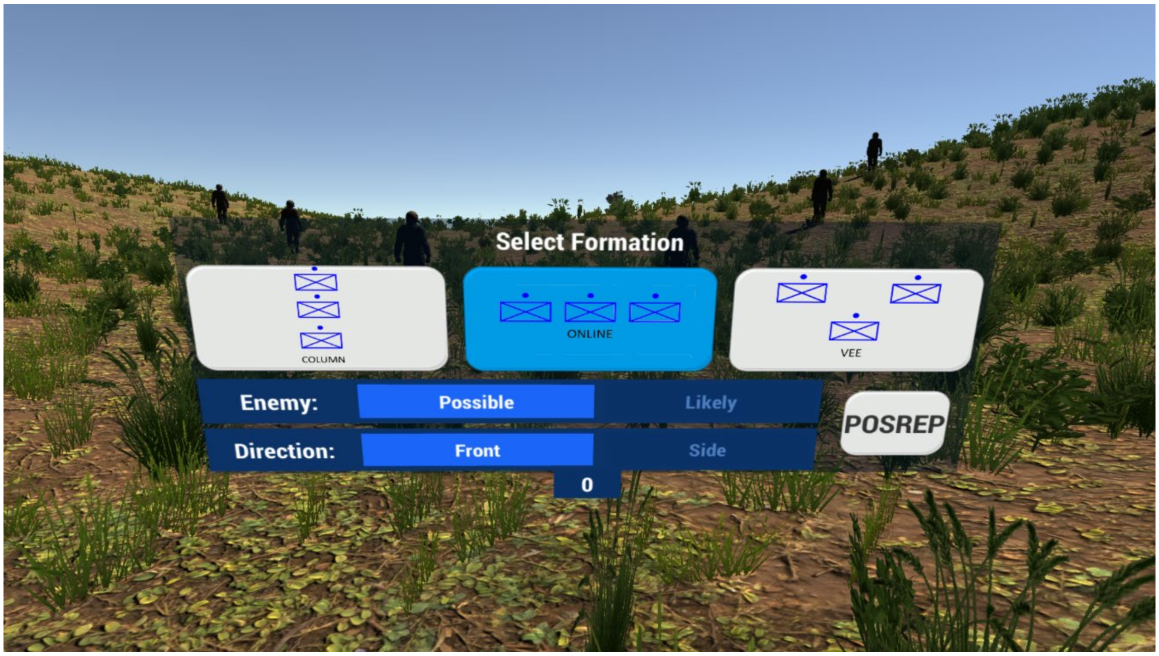


Figure 21. Modification to user interface.

B. VERIFICATION OF CAPTTIM FORMULA

We verified the data from the pilot tests with the same CAPTTIM calculations developed by Hanley to distinguish the two levels of cognitive state, exploration and exploitation, and two levels of decision performance, optimal and non-optimal (Hanley, 2018). See Chapter II, Section D for a thorough discussion on the method Hanley utilized to determine how a participant transitions between the CAPTTIM levels. This verification of the formulas ensured no unintended issues appeared after transferring the PFDT from one technological platform to another.

1. Cognitive State

Hanley calculated cognitive state by computing each participant's intra-individual variability in decision time from trial to trial: large intra-individual variability indicated exploration; relatively stable decision times indicated exploitation. This process consisted of three steps: identify a participant's intrinsic processing speed by establishing their baseline mean and standard deviation of decision times, utilize a moving standard deviation to determine intra-individual variability in decision times, and compare the moving standard deviation to the established baseline mean and standard deviation of decision times. A participant's processing speed was calculated by establishing the baseline mean ($\overline{x}_{Baseline}$) and standard deviation ($s_{Baseline}$) of decision times for a given trial (t_i). The time immediately following a non-optimal decision was not included in these calculations to account for any hesitation from the participant. to the formula for the moving standard deviation (s_{Moving}) is: abased on the previous 16 scenarios.

$$s_{Moving} = \sqrt{\frac{\sum_{i-16}^{i}\left(t_i - \overline{t}_{i-16,i}\right)^2}{n-1}}$$

Finally, an even comparison of decision time, t_t, to baseline standard deviation, $t_t\left(\leq or >\right)s_{Baseline}$, was utilized to ascertain whether participants were exploring or exploiting their environment.

If $t_t \leq s_{baseline}$ the cognitive state for that trial was categorized as exploitation.

If $t_t > s_{baseline}$, the cognitive state for that trial was categorized as exploration.

2. Decision Performance

Decision performance was identified through three steps: classify separate levels of regret for each decision, calculate the total acceptable amount of regret, and delineate whether a participant had high or low regret. Regret was delineated into one of two levels: low, indicating that the person was making optimal decisions; and high, indicating that the person was making non-optimal decisions. Hanley assigned regret values for each scenario determined by the severity of a non-optimal decision and the given situation. An optimal decision would result in zero regret while an extremely non-optimal decision would score 10. Next, a continuous exponentially weighted moving average (EWMA) is compared it to three. Finally, a participant's most recent scenario was weighted as 75% of the EWMA. Thus, the following equations were created to delineate high versus low regret where RL was the regret level, R_t was regret received for trial t, and RE was the EWMA of regret.

$$RL = High \text{ if } (0.75)R_t + (0.25)RE, t - 1 > 3$$

$$RL = Low\ if\ (0.75)R_t + (0.25)RE,\ t - 1 < 3$$

This research team successfully applied CAPTTIM to the pilot data. CAPTTIM results from each pilot session included all four CAPTTIM categories. Additionally, the inexperienced team members improved their decision performance as they progressed through their session (see Figure 22 for one example). These two outcomes indicated that the CAPTTIM model was functioning as expected.

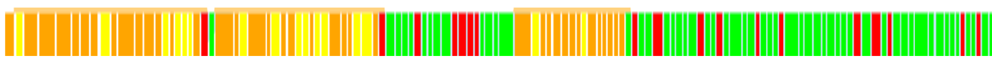


Figure 22. Pilot Test 4 shows improvement and transitions from exploration to exploitation.

V. RESULTS

This chapter is organized into five sections. The first section discusses data preparation. The second and third sections discuss statistical methods and preliminary analysis of the data collected during the PFDT and the application of CAPTTIM. The final two sections provide the results from 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 paper that was transcribed onto a Microsoft Excel 2016 spreadsheet by the research team. The research team used two software applications to analyze the data. The application of CAPTTIM and related graphs and charts used R. Statistical analysis was computed with JMP 16.

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 an R workbook that computed regret, cognitive state, and performance values, as well as applying the CAPTTIM categorization. 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 via hardcopy and the data was input into Microsoft Excel. The research team combined this data with the overall performance values of the participants. The overall performance values included percent optimal answers, percent acceptable answers, accumulated regret, and percent of trials classified as yellow, orange, red, or green CAPTTIM categories.

3. Participant Analysis

The participant pool for this study included the students and instructors of TBS and students of NPS. A total of 27 participants volunteered to take part in this study. Table 3 shows the descriptive statistics for the participants. One participant had experience leading troops in dismounted infantry operations during a combat deployment, and all participants had received a basic level of training on infantry tactics while going through initial military training.

Table 3. Demographic descriptors.

Age	$M = 27$, $SD = 4.1$
Gender	Male: 23, Female: 4
Service	USMC: 25, USN: 2
Years of Service	$M = 4.5$, $SD = 3.9$
Participants with a Combat Deployment	5

B. STATISTICAL ANALYSIS

Statistical methods used for hypotheses testing include one-sample *t*–test, two-sample *t*–test, analysis of variance (ANOVA), and regression. To test Research Question 1, Hypothesis 1, the percent of acceptable and optimal decisions selected by each participant was calculated to see whether on average, participants had at least 70% acceptable and/or optimal decisions. Acceptable decisions were defined as answers that result in regret values ranging from 0 to 4. Optimal decisions were decisions that resulted in a regret of 0. Then, ANOVA was used to determine if there was a platform effect (i.e., a difference tablet, VR, and VR with formations) on the percent of acceptable and optimal decisions.

To test Research Question 2, Hypothesis 1, CAPTTIM categorization was applied to each participant's trial by trial PFDT data at the individual trial level. This categorization indicated when a participant had reached optimal decision-making. ANOVA was used to determine if the average trial number to reach optimal decision-making differs across the three platforms.

Assumptions and conditions for each statistical method were met: independence, normal distribution, a 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. Two-tailed alpha levels of .05 were used.

C. PRELIMINARY RESULTS

Descriptive analysis was conducted on the main performance measures to identify the percent of acceptable decisions and regret. During the preliminary analysis, one outlier (see Figure 23) stood out in the overall percent of acceptable decisions. The outlier was influential given the relatively small sample size; thus, their data was removed from further analysis. The remainder of the analysis did not include the outlier's data (see Figure 24). Further analysis was conducted to observe the descriptive statistics of only optimal decisions (see Figure 25).

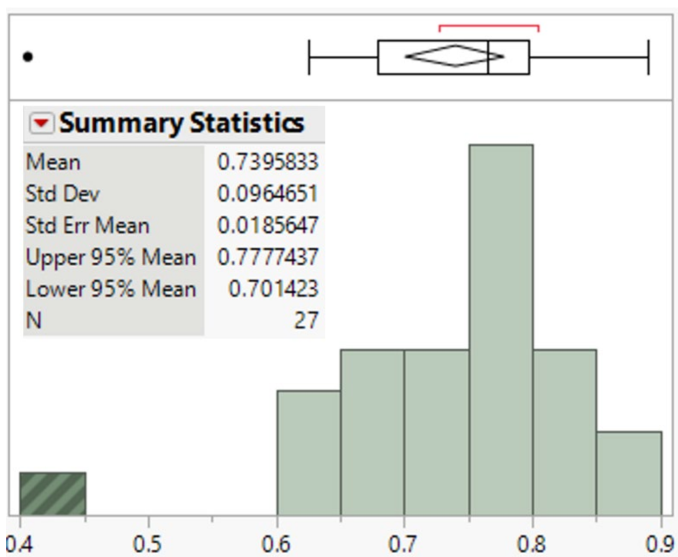


Figure 23. Distribution of percent of overall acceptable answers.

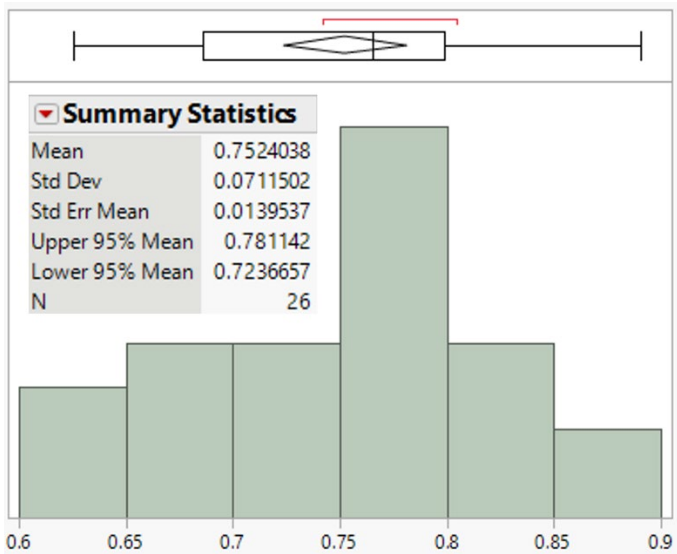


Figure 24. Distribution of percent of overall acceptable answers without outlier.

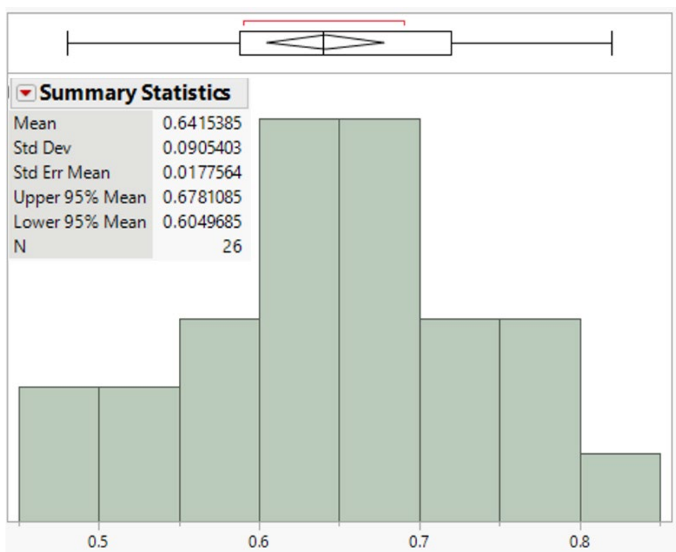


Figure 25. Distribution of percent of optimal answers.

D. RESULTS ON RESEARCH QUESTION 1: TO WHAT EXTENT CAN TRAINING OF PLATOON FORMATION DECISIONS BE EFFECTIVELY UTILIZED ON A COMPUTER TABLET AND VR?

This section examines the results of the participants who completed the PFDT study. The objective behind this examination was to determine if the task was able to successfully transfer to additional electronic platforms and remain an effective training aide to the user of the PFDT task.

1. Hypothesis 1: Effective training of PFDT will be demonstrated by participants, on average, selecting acceptable or optimal decisions on at least 70% of the trials on the PFDT, $\mu > .70$

This hypothesis indicates the effectiveness of conducting the PFDT on the new technology platforms as well as the difficulty of the task. If the percentage of acceptable results are too high that indicates an easy task while too low of a percent indicates too difficult of a task. Figure 26 shows the distribution of acceptable decisions across the 26 participants. 19 of the 26 participants exceeded 70% acceptable decisions. Additionally, a one-sample t-test indicated the mean percent of acceptable decisions was greater than 70% (M = 0.75, SD = 0.07), $t(25) = 3.75$, $p < .0005$, $d = .71$. Thus, the null hypothesis was rejected, providing support that the percent of acceptable decisions is greater than 70% for the PFDT.

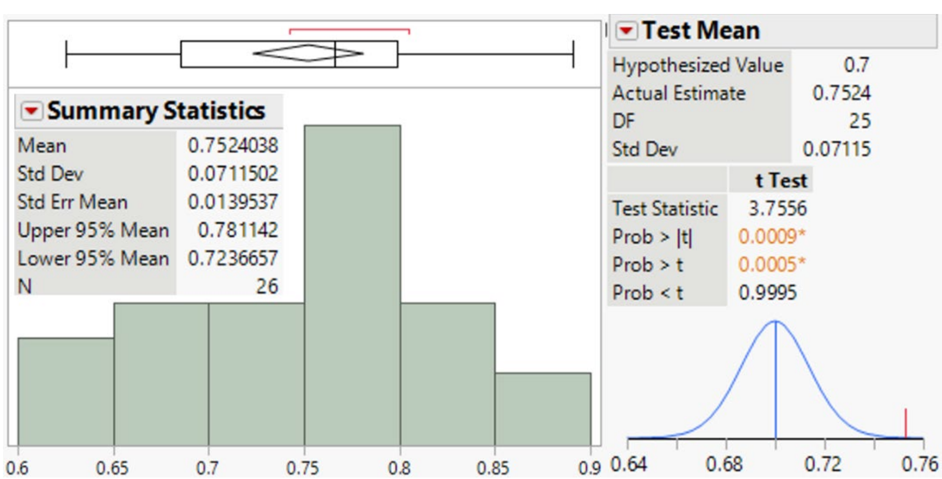
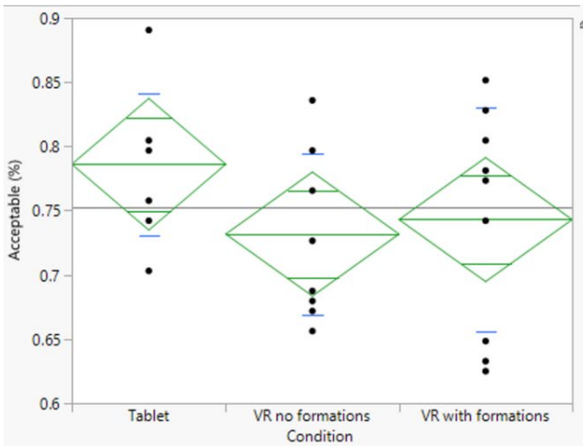


Figure 26. Descriptive statistics on the percent of acceptable decisions and t-test results.

Figure 27 shows the distribution of acceptable decisions across the three conditions and Figure 28 shows the distribution of optimal decisions. Analysis of variation indicated no platform effect existed across the three conditions when observing acceptable decisions, $F(2, 23) = 1.39$, $p = .267$, $\eta_p^2 = .108$. Similarly, analysis of variation indicated no platform effect existed when observing only optimal decisions, $F(2, 23) = .88$, $p = .425$, $\eta_p^2 = .072$.



Oneway Anova

Summary of Fit

Rsquare	0.108401
Adj Rsquare	0.030871
Root Mean Square Error	0.070043
Mean of Response	0.752404
Observations (or Sum Wgts)	26

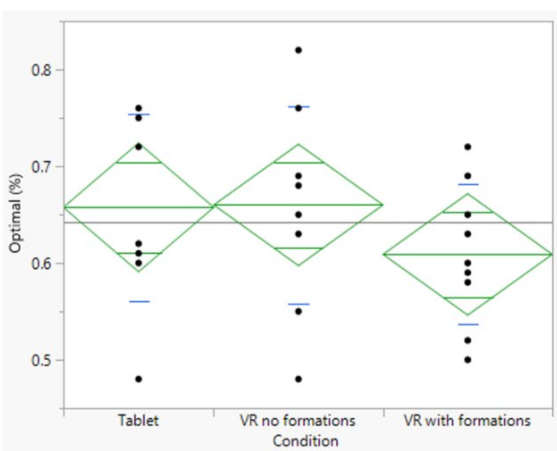
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Condition	2	0.01371915	0.006860	1.3982	0.2673
Error	23	0.11283959	0.004906		
C. Total	25	0.12655874			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Tablet	8	0.786133	0.02476	0.73490	0.83736
VR no formations	9	0.731771	0.02335	0.68347	0.78007
VR with formations	9	0.743056	0.02335	0.69476	0.79135

Figure 27. Distribution and ANOVA results on the percent of acceptable decisions across the three platforms.



Oneway Anova

Summary of Fit

Rsquare	0.071727
Adj Rsquare	-0.00899
Root Mean Square Error	0.090946
Mean of Response	0.641538
Observations (or Sum Wgts)	26

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Condition	2	0.01469957	0.007350	0.8886	0.4249
Error	23	0.19023889	0.008271		
C. Total	25	0.20493846			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Tablet	8	0.657500	0.03215	0.59098	0.72402
VR no formations	9	0.660000	0.03032	0.59729	0.72271
VR with formations	9	0.608889	0.03032	0.54618	0.67160

Figure 28. Distribution and ANOVA results on the percent of optimal decisions across the three platforms.

2. Exploratory Question 1: To what extent does a participant's experience level affect their performance of making acceptable and optimal decisions?

This question was examined with two methods: one in which participants were simply classified as novice or experienced, the second by years of military service. The mean acceptable percentages and mean optimal percentages between instructors and students were almost equal. The mean acceptable percentage was 74% for instructors and 76% for students (see Figure 29). The mean optimal percentage was 65% for instructors and 64% for students (see Figure 30).

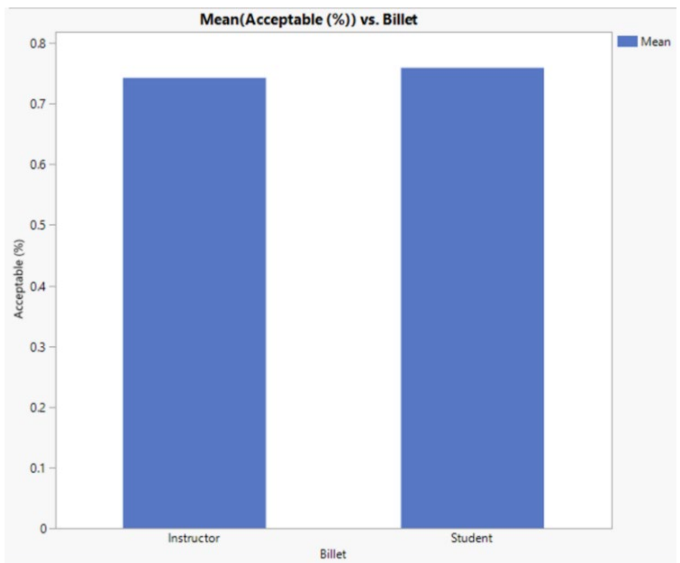


Figure 29. Bar chart displaying the mean acceptable percentages between instructors and students.

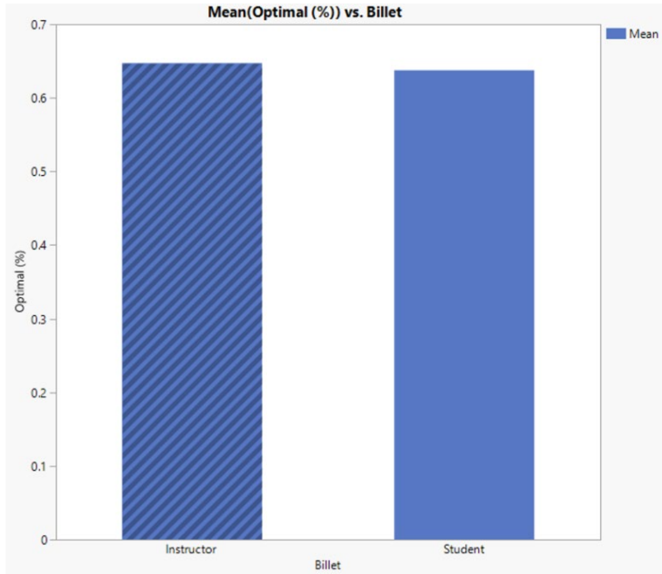


Figure 30. Bar chart displaying the mean optimal percentages between instructors and students.

Regression calculations using JMP did not indicate that years of experience predicted percent of acceptable or optimal decisions (see Figures 31 and 32). These results indicate that years of service do not impact the percent of acceptable or optimal decisions.

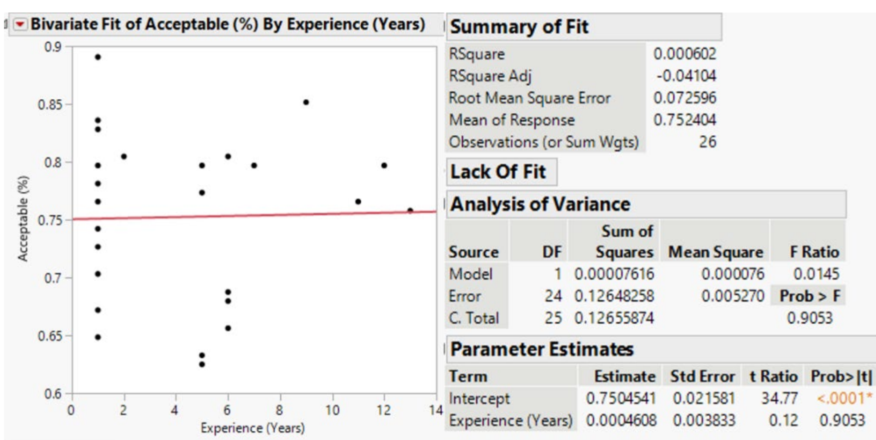


Figure 31. Linear regression results testing percentage of acceptable decisions to amount of experience.

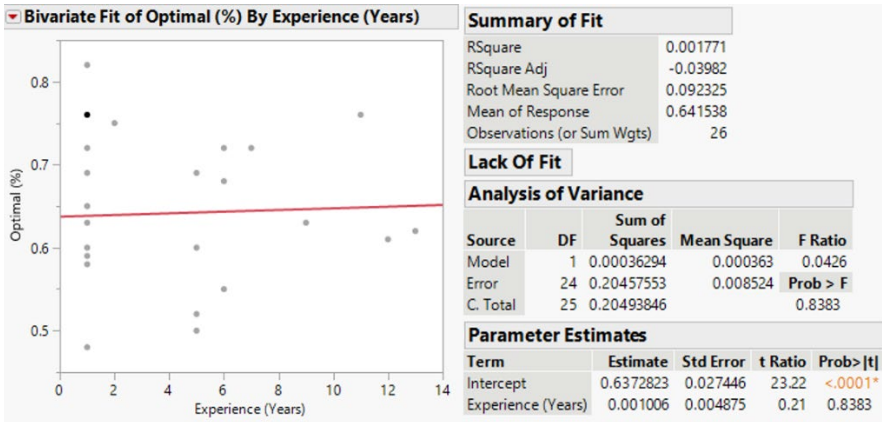


Figure 32. Linear regression results testing percentage of optimal decisions to amount of experience.

E. RESULTS ON RESEARCH QUESTION 2: TO WHAT EXTENT WILL PARTICIPANTS REACH OPTIMAL DECISION-MAKING WHEN COMPLETING THE PFDT ACROSS THE THREE CONDITIONS?

1. Hypothesis 1: Application of CAPTTIM to the PFDT data will reveal that, on average, participants in the VR with overlay condition take fewer trials to reach optimal decision-making than participants in the other conditions, $\mu_{\text{VR overlay}} < \mu_{\text{VR}}, \mu_{\text{tablet}}$

This section examines if participants were able to reach optimal decision-making earlier within one condition in comparison to the others. The objective behind this examination was to identify if a platform effect existed to allow future users of the PFDT to benefit by conducting it on a specific technological platform. A participant was classified as reaching optimal exploitation if they made four optimal decisions in a row within a rolling window of ten scenarios. This definition of optimal decision-making allowed the research team to identify the exact trial number a participant reached this state of exploitation (see Table 4).

Table 4. Trial number participants reached optimal decision-making.

Participant Number	Trial Number
1I-001	101
1I-002	62
1S-001	129
1S-002	36
1S-003	129
1S-004	17
1S-005	57
1S-006	36
2I-001	129
2I-002	41
2I-003	43
2I-004	129
2S-001	24
2S-002	57
2S-003	58
2S-004	129
2S-005	129
3I-001	41
3I-002	33
3I-003	48
3I-004	37
3I-005	129

The trial number participants reached optimal decision-making ranged from 17 to 101 (M = 44.9, SD = 20.4). There were seven participants (4 novices and 3 experts) that never obtained optimal exploitation decision-making which is indicated with a trial number of 129. They were removed from the following analysis to not skew the data. Figure 33 shows the distribution of what trial number participants reached optimal decision-making across the three conditions. Although there was a trend for participants in the VR with formation platform to attain optimal decision making on an earlier trial than participants in the tablet platform, ANOVA indicated no significant platform effect existed, $F(2, 14) = .56$, $p = .583$, $\eta_p^2 = .074$.

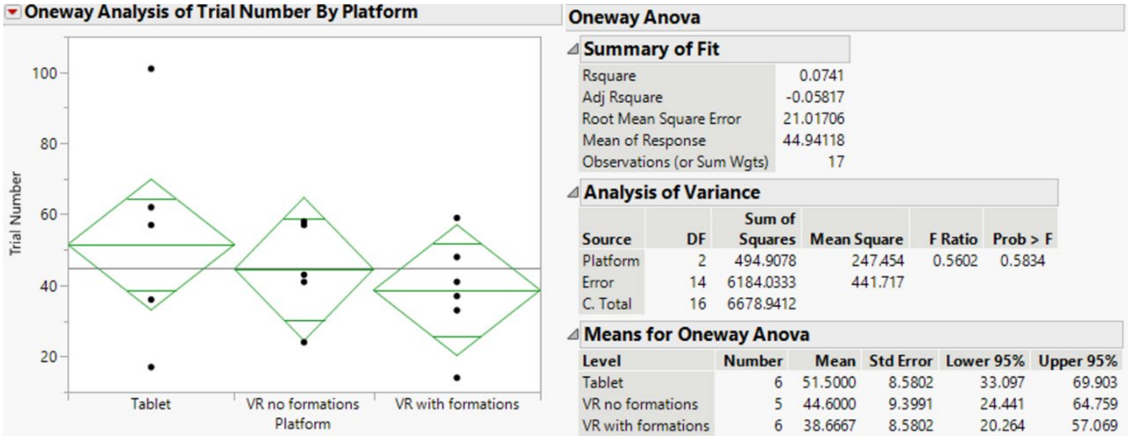


Figure 33. Distribution and ANOVA results on what trial number optimal decisions were reached across the three platforms.

2. Exploratory Question 1: To what extent does a participant's experience level affect their performance of achieving optimal decision-making?

This section will use the CAPTTIM measure discussed in the previous section to identify if a participant's experience level affects the trial number optimal decision-making was achieved. The methods of two-sample *t*-test and regression were utilized to distinguish between novices and experts. A two-sample *t*-test indicated there was no significant difference between experts ($M = 46.6$, $SD = 21.5$) and novices ($M = 42.6$, $SD = 20.2$), $t(16) = -.39$, $p < .650$, $d = -4.03$ (see Figure 34).

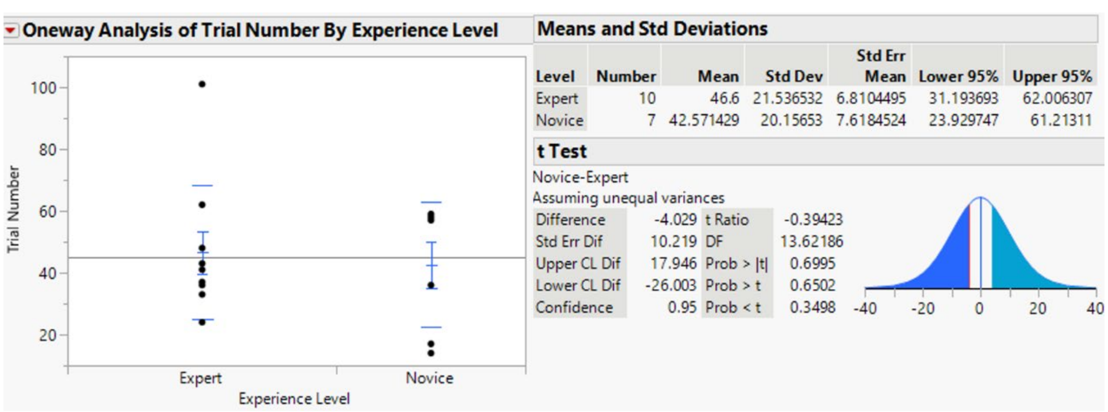


Figure 34. Two-sample t-test results testing trial number optimal decision-making was reached to years of experience.

Additionally, regression calculations using JMP indicated that years of experience did not predict the trial number at which participants reached optimal decision making (see Figure 35). These results indicate that novices, entry-level servicemembers who recently received doctrinal training on tactical decision-making, were able to reach optimal decision-making similarly to experts who were able to utilize doctrinal training coupled with experience in the PFDT.

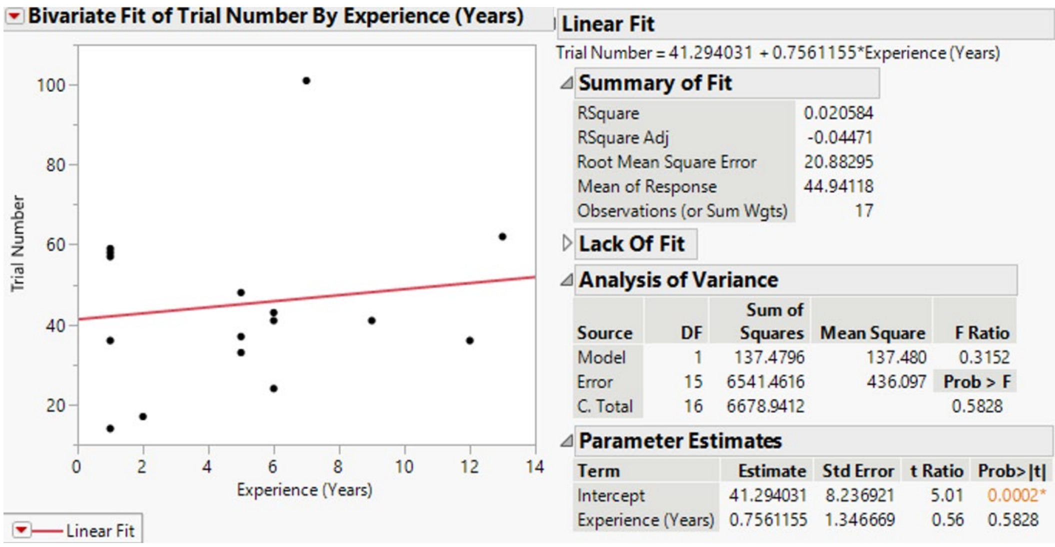


Figure 35. Linear regression results testing trial number optimal decision-making was reached to years of experience.

VI. CONCLUSIONS

This chapter is organized into five sections. The first section discusses a summary of the research results. The second and third sections discuss the implications and limitations of the PFDT. The fourth section discusses potential future work which provides a way ahead for this research. The final section discusses the importance of training tactical military decision-making and concludes this research.

A. SUMMARY OF RESULTS

This thesis focused on two primary areas: the transfer of the PFDT onto commonly available technological devices and if participants performed better on one device compared to the other. The first area focused on validating if the PFDT was effective as a training aide on a computer tablet and virtual reality. The software applications were developed by the FutureTech team to replicate Brian Hanley's thesis work from 2018 onto these new platforms. The manipulations of the five factors (time, terrain height and vegetation, and enemy likelihood and direction) produced a relatively complex task which could be repeated numerous times and facilitated a quality assessment of an individual's knowledge-level pertaining a certain task. These results were compared to Hanley's research to determine the effectiveness of transferring the PFDT onto other platforms. The second area of this thesis focused on identifying if a specific platform allowed a participant to reach optimal decision-making over the other.

1. Platoon Formation Decision Task

The concept behind this research was to take a well-established military training aide and determine if its effectiveness would transition to modern technological devices. The PFDT placed the participants into thirty-two different scenarios four times each (for a total of 128 scenarios) and asked them to choose the most optimal formation for that scenario. This task was initially conducted on a computer and this research team moved it to a computer tablet and VR. Analysis of the data indicated that participants of this study were able to achieve similar results to Hanley's research. The 27 participants in this study achieved a mean of 75.24% acceptable answers (regret level of 0 or 4) and 64.15% of correct/optimal answers (regret level of 0). Hanley's results displayed 30 participants of the PFDT on a computer reached 82.53% acceptable answers and 68.75% correct/optimal answers. Thus, these results demonstrated the viability of the PFDT to be utilized on numerous platforms.

Additionally, CAPTTIM was utilized during post-task analysis to determine a participant's decision-making state. Previous work demonstrated that CAPTTIM could determine participants' cognitive states and correlate those states to decision-making performance (Cohen et al., 1996; Critz, 2015; Hanley, 2018; Kennedy et al., 2019). Applying this model concluded that only 17 of the 27 participants, or 62.9%, reached optimal decision-making. However, nothing more could be concluded because of the small sample size that conducted the task.

2. Platform Effect

The PFDT was transferred from a computer onto a tablet and VR HMD. The results indicated a significant platform effect did not exist across the three conditions: tablet, VR, and VR with formations depicted. As discussed in the previous section, 75.24% of the participants were able to select acceptable answers to the 128 trials. This result indicated the versatility of the PFDT to be utilized on several technological platforms with no loss in training value. Additionally, the trial number at which participants reached optimal decision-making ranged from 17 to 101 with no significant platform effect (although, see Section C, 2). These results indicate the usefulness the PFDT has for both novices and experts, alike. Finally, the research team's definition of optimal decision-making may provide more information to instructors as to when and why decision-makers deviate from optimal decision-making than simply looking at overall percent correct. Thus, the application of CAPTTIM to a decision training tool has the potential to make decision-making training more efficient and effective.

B. IMPLICATIONS

This experiment validated the usefulness of the PFDT on tablet-based and VR-based simulators when utilized for military training applications. The benefits of presence in virtual environments could provide the additional experience required to "mentally prepare forces for strain, sensory overload, and unexpected conditions" (Helfstein, 2018). Having simulators available on VR would provide leaders and trainees the opportunity to work them into their schedules as needed as well as repeatedly practice them for learning reinforcement. By providing easy to use military training simulators on readily available technological platforms to the operational forces would significantly improve the number of tactical decisions a small unit leader could conduct. This increase in repetitions of decision-making would allow novices to reach the level of expert decision-maker in a reduced amount of time. The PFDT and other similar realistic training simulators can provide this function for military entry-level schoolhouses, advanced training schools, and the operating forces. Additionally, this tool could be made available on military educational internet websites such as MarineNet and anyone with access could gain repetitions whenever they desired. Leaders could incentivize the completion of military training aides on MarineNet such as the PFDT to improve subordinate leader's tactical decision-making.

C. LIMITATIONS

1. CAPTTIM Limitations

In the PFDT, 32 scenarios are randomly presented four times. One limitation of applying CAPTTIM to the PFDT was that it examines trial by trial behavior and does not indicate whether subjects learn from previous exposure to specific scenarios. It would be beneficial if specific knowledge deficiencies were able to be identified post-task to assist instructors in designing an individualized remediation plan. Therefore, the research team identified a theoretical complementary method to examine learning at the scenario level.

This complementary method assumes perfect memory for a scenario, the previous selections to that scenario, and the feedback on those selections. This analysis of the entire trial was accomplished by observing how a participant explored or exploited their environment (see Figure 36). As a participant began the PFDT, their assessed mental state was located at Start on the flowchart. Each time they observed a scenario they could either select the optimal decision or one of the two non-optimal decisions. Non-optimal decisions were not penalized with regret the first time a participant experienced a scenario as they were considered optimally exploring.

The second time a participant experienced a scenario they had one of three choices: choose the other non-optimal solution and remain in sustained exploration (light green), choose the previously selected non-optimal decision and move to regressive exploration (yellow), or select the optimal decision and move to optimal behavior (dark green). The third time a participant experienced the same scenario they could either select the optimal decision and move to optimal behavior (dark green) or continue exploring the non-optimal decision (yellow). Once a participant was informed of the optimal decision, they could either continue making that decision to sustain optimal behavior (dark green) or make a non-optimal decision and regress from the optimal path (red).

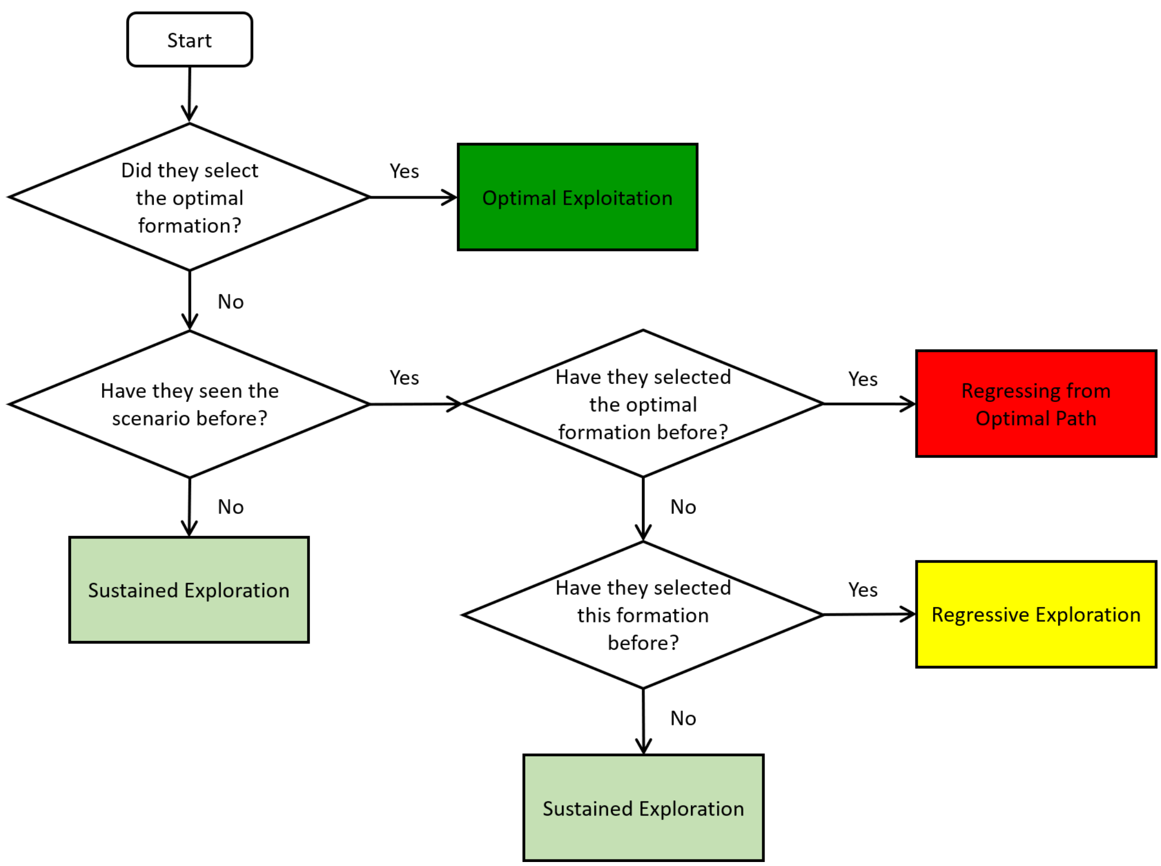


Figure 36. Individual Decision-Making Assessment Tool Flowchart.

Regret was only assigned after a participant chose a decision they were previously informed was non-optimal. Individual non-optimal decision regret values were determined by the research team based on the perceived negative outcome which would occur if a participant had made that decision in a real scenario. For example, if a participant had previously selected Platoon Line when the enemy situation was likely to the side, they would incur a regret value of 10 as that would place the enemy in enfilade of their formation. Whereas the more optimal decision of the remaining two formations now depended on the remaining factors such as terrain and time of day; therefore, the lesser non-optimal decision did not incur as much regret since the participant was not placing their unit in such a precarious situation. This analysis could benefit entry-level military schools with assessing students on certain skill sets, identifying deficiencies, and knowing where remediation is required.

2. Small Sample Size

The initial plan was to obtain approximately 60 volunteers from TBS to participate in the PFDT. However, due to COVID-19, the research team was only able to receive 20 students and instructors to volunteer from TBS to participant in the experiment. This small sample size necessitated further testing on Marine Corps students at NPS, as a second trip to TBS was not possible. The NPS Marine Corps students were classified as experts, similarly to the instructors, as their time in service was comparable. Additionally, two of the TBS students were prior enlisted Marines and thus were also categorized as experts based on their time in service. This mixture of populations may have affected the resulting data but further analysis was unable to be conducted.

Additionally, the smaller sample size of 27 participants, with one removed outlier for a total of 26, may account for the lack of significant amount of data displayed within the results. Specifically, there is potential for a platform effect to exist when analyzing the mean values of the participants in the VR with formation platform compared to the other platforms to determine who would reach optimal decision making at an earlier trial; however, ANOVA indicated no significant platform effect existed. This potential was interesting as it aligned with the initial hypothesis of the research team. It would be interesting to further study the potential benefits and capabilities of conducting military training of tactical scenarios, such as the PFDT, within VR and immersive environments.

D. FUTURE WORK

1. Modifying Feedback

This study was specifically designed to provide limited feedback to the participants to simplify a post-task assessment of their CAPTTIM level. However, the common recommendation amongst all the participants was to improve the level of feedback to improve a participant's ability to learn while conducting the task. As Hanley recommended, a comparison of performance amongst a group receiving additional feedback and a group using the traditional optimal/non-optimal feedback would be the logical next phase. This additional feedback would be provided when a participant made a non-optimal decision which might facilitate participants quickly transitioning to the green CAPTTIM state.

2. Expand the Task

This task would significantly improve as a training simulator by providing more variety for a user to experience. Hanley's recommendations of adding more formations, scenarios, and enemy forces to the task remain valid. These additions would increase the difficulty of the task; however, they would provide more realism to users by presenting more scenarios they might encounter. This realism would increase a user's experience level while potentially preventing users from memorizing a limited number of scenarios.

3. Utilizing Eye Tracking to Determine Decision-Making Factors

Virtual reality headsets with eye tracking could provide the data needed to understand which factors are prioritized to make optimal decisions. The PFDT had five factors it manipulated to develop each scenario. The ability to subtly track which factors participants most often utilized to inform decision-making would provide researchers the knowledge of where emphasis would need to be placed in training simulators. Future iterations of military training simulators could be drastically improved by placing an emphasis on these critical factors.

4. Transfer of Training

This study collects no data on assessing the effectiveness of this training simulator through the transfer of training of practical exercises. Methods should be designed to have users of the PFDT conduct a similar test during actual training events that replicate the PFDT. Ultimately, the purpose of the PFDT as a training simulator is for users to obtain virtual experience to then be utilized during training events. Thus, comparative analysis should be conducted to determine a participant's CAPTTIM state during the PFDT and their performance during a training event.

E. CONCLUSION

Military leaders are paid to make decisions, clearly communicate orders, and develop subordinates to be critical thinkers. These leaders rely on knowledge and experience to complete these difficult tasks. A common task to all junior Marine leaders is to determine which platoon formation to use during training. Yet, current military training on this topic is designed for unit-level audiences instead of being modified for an individual's current abilities. Tactical military "decision-making must be understood as a continuous cycle of analysis and intuition" (USMC, 2020a, p. 4). Analysis is essential to decision-making; however, it is time-intensive and requires intuition to make faster, less taxing decisions. Therefore, it is essential to build an individual's intuition by providing meaningful experience through a deliberate training plan. Training simulators can assist military servicemembers in gaining experience and further developing the cognitive skills required to solve emerging, complex problems. Simulators that provide an appropriate level of realism can skillfully be utilized to create master decision-makers. However, there is a lack of cross-platform training simulators that are accessible and provide realistic training. Furthermore, it is unclear if simulators across platforms provide the training needed to reach optimal decision-making while minimizing working memory load.

This thesis used a PFDT accessible on multiple electronic platforms to assess platform viability and effectiveness in training optimal decision-making. The development of a tablet- and VR-based PFDT demonstrated the utility of a training aid capable of providing a simpler method of evaluating specific training and readiness tasks. The availability of simulated tactical tasks across numerous, commonly owned digital platforms offers service members the ability to complete multiple iterations of a task to gain the experience needed to improve their intuitive decision-making. Although this study focuses specifically on deciding platoon formations, future work could develop a multitude of training tasks completed on the same electronic platforms. This study assessed the extent to which utilizing training tools can improve military decision makers' ability to observe a situation, gain awareness, and perform pattern recognition to solve problems. This improvement to military training simulators could advance the training of individuals across every military occupational specialty in every branch of the Department of Defense.

APPENDIX A. SCENARIOS

Table 5 shows the 32 scenarios created by varying the five factors of the PFDT. The table also matches the scenario to the correct terrain and the optimal formation.

Table 5. List of scenarios for the platoon formation decision task.

Scenario Number	Factor Level					Optimal Formation
	Height	Vegetation	Light	Enemy Probability	Enemy Direction	
11111	Flat	Sparse	Day	Possible	Front	3
11112	Flat	Sparse	Day	Possible	Side	3
11121	Flat	Sparse	Day	Likely	Front	2
11122	Flat	Sparse	Day	Likely	Side	3
11211	Flat	Sparse	Night	Possible	Front	3
11212	Flat	Sparse	Night	Possible	Side	3
11221	Flat	Sparse	Night	Likely	Front	2
11222	Flat	Sparse	Night	Likely	Side	1
12111	Flat	Dense	Day	Possible	Front	3
12112	Flat	Dense	Day	Possible	Side	1
12121	Flat	Dense	Day	Likely	Front	2
12122	Flat	Dense	Day	Likely	Side	1
12211	Flat	Dense	Night	Possible	Front	1
12212	Flat	Dense	Night	Possible	Side	1
12221	Flat	Dense	Night	Likely	Front	2
12222	Flat	Dense	Night	Likely	Side	1
21111	Hills	Sparse	Day	Possible	Front	3
21112	Hills	Sparse	Day	Possible	Side	3
21121	Hills	Sparse	Day	Likely	Front	3
21122	Hills	Sparse	Day	Likely	Side	3
21211	Hills	Sparse	Night	Possible	Front	1
21212	Hills	Sparse	Night	Possible	Side	3
21221	Hills	Sparse	Night	Likely	Front	2
21222	Hills	Sparse	Night	Likely	Side	3
22111	Hills	Dense	Day	Possible	Front	1
22112	Hills	Dense	Day	Possible	Side	1
22121	Hills	Dense	Day	Likely	Front	3
22122	Hills	Dense	Day	Likely	Side	1
22211	Hills	Dense	Night	Possible	Front	1
22212	Hills	Dense	Night	Possible	Side	1
22221	Hills	Dense	Night	Likely	Front	2
22222	Hills	Dense	Night	Likely	Side	1

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APPENDIX B. TRIALS WITH REGRET

Tables 6 and 7 show each treatment for the 128 trials with regret for each formation.

Table 6. Treatment by trial (trials 1–64).

Trial #	Scenario	Optimal Answer	Regret Column	Regret Line	Regret Vee		Trial #	Scenario	Optimal Answer	Regret Column	Regret Line	Regret Vee
1	12122	1	0	10	5		33	12111	3	7	5	0
2	11122	3	3	10	0		34	21222	3	3	10	0
3	21121	3	10	3	0		35	22221	2	7	0	5
4	12222	1	0	10	7		36	11111	3	7	5	0
5	11112	3	5	10	0		37	22222	1	0	10	7
6	21122	3	3	10	0		38	12122	1	0	10	5
7	22221	2	7	0	5		39	11122	3	3	10	0
8	12111	3	7	5	0		40	11222	1	0	10	5
9	21111	3	10	5	0		41	21212	3	5	10	0
10	12112	1	0	10	5		42	11221	2	10	0	5
11	21212	3	5	10	0		43	21211	1	0	7	3
12	12211	1	0	7	3		44	11211	3	8	5	0
13	22112	1	0	10	7		45	12221	2	7	0	5
14	21211	1	0	7	3		46	12212	1	0	10	7
15	21112	3	3	10	0		47	12121	2	10	0	5
16	22122	1	0	10	7		48	22211	1	0	5	7
17	22121	3	7	3	0		49	11121	2	10	0	3
18	22222	1	0	10	7		50	21221	2	10	0	3
19	12221	2	7	0	5		51	12112	1	0	10	5
20	22211	1	0	5	7		52	22111	1	0	5	3
21	21222	3	3	10	0		53	12211	1	0	7	3
22	11222	1	0	10	5		54	21111	3	10	5	0
23	12121	2	10	0	5		55	21112	3	3	10	0
24	11212	3	5	10	0		56	22112	1	0	10	7
25	11121	2	10	0	3		57	21121	3	10	3	0
26	11111	3	7	5	0		58	11212	3	5	10	0
27	11211	3	8	5	0		59	12222	1	0	10	7
28	11221	2	10	0	5		60	22121	3	7	3	0
29	22212	1	0	10	7		61	22212	1	0	10	7
30	12212	1	0	10	7		62	11112	3	5	10	0
31	21221	2	10	0	3		63	22122	1	0	10	7
32	22111	1	0	5	3		64	21122	3	3	10	0

Table 7. Treatment by trial (trials 65–128).

Trial #	Scenario	Optimal Answer	Regret Column	Regret Line	Regret Vee	Trial #	Scenario	Optimal Answer	Regret Column	Regret Line	Regret Vee
65	11111	3	7	5	0	97	12212	1	0	10	7
66	12111	3	7	5	0	98	22211	1	0	5	7
67	11112	3	5	10	0	99	21112	3	3	10	0
68	21221	2	10	0	3	100	21212	3	5	10	0
69	22112	1	0	10	7	101	22112	1	0	10	7
70	22111	1	0	5	3	102	21211	1	0	7	3
71	21112	3	3	10	0	103	12122	1	0	10	5
72	22121	3	7	3	0	104	21111	3	10	5	0
73	12112	1	0	10	5	105	11221	2	10	0	5
74	12121	2	10	0	5	106	21222	3	3	10	0
75	22122	1	0	10	7	107	11121	2	10	0	3
76	21212	3	5	10	0	108	22221	2	7	0	5
77	12212	1	0	10	7	109	11111	3	7	5	0
78	21111	3	10	5	0	110	11112	3	5	10	0
79	11211	3	8	5	0	111	22222	1	0	10	7
80	22211	1	0	5	7	112	11222	1	0	10	5
81	21122	3	3	10	0	113	21221	2	10	0	3
82	12222	1	0	10	7	114	21122	3	3	10	0
83	11221	2	10	0	5	115	12111	3	7	5	0
84	11122	3	3	10	0	116	11211	3	8	5	0
85	21211	1	0	7	3	117	12112	1	0	10	5
86	22221	2	10	0	5	118	21121	3	10	3	0
87	12221	2	7	0	5	119	22212	1	0	10	7
88	12122	1	0	10	5	120	11122	3	3	10	0
89	11212	3	5	10	0	121	12222	1	0	10	7
90	11121	2	10	0	3	122	22122	1	0	10	7
91	22212	1	0	10	7	123	12221	2	7	0	5
92	22222	1	0	10	7	124	12121	2	10	0	5
93	12211	1	0	7	3	125	11212	3	5	10	0
94	11222	1	0	10	5	126	12211	1	0	7	3
95	21121	3	10	3	0	127	22121	3	7	3	0
96	21222	3	3	10	0	128	22111	1	0	5	3

APPENDIX C. SURVEYS

Demographic Survey

Participant Number: _____________ Date: ______________

1. Age:

2. Gender: Male Female

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 (circle one):

Maneuver Intelligence Fires Sustainment Communications Aviation

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

        i. If so, what was your billet while deployed?

        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, TBS, 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

Post-Task Survey

Participant 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 decision task? Yes No

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

c. Do you feel your choices improved after your strategy changed? Yes No

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

6. Would you use this as a training tool in the operating forces? Yes No

7. We appreciate any comments you may have.

APPENDIX D. PFDT SESSION SCRIPT

Overview and Consent Form (5 minutes)

Welcome to my thesis research study, my name is Shane Robinette. Thank you for volunteering to participate in this study, it will take about 30–45 minutes of your time. This simulator is called the Platoon Formation Decision Task. In the simulator, your role is a rifle platoon commander and I will be asking you to make tactical decisions to determine what platoon formation is the most optimal while you're on a patrol. After you finish, if you are interested, I will provide an explanation of what I am trying to do with the study.

I have a couple documents for you to review and sign prior to beginning the experiment. Before we start, I want you to know your participation is strictly voluntary and there is no penalty if you decline to participate at any time throughout this experiment.

The first document regards providing consent to participate in the research. Please take some time to review the consent form and let me know if you have any questions.

Demographic Survey (5 minutes)

This second document is a demographic survey for you to fill out.

Review Platoon Formation Study Materials (5 minutes)

I have selected three platoon-level formations that will be utilized throughout this study. This packet contains information on each formation and is to be used for you to review during the next five minutes; however, you will not be able to reference them during the execution of the task. The information is from the Army Technique Publication 3–21.8 "Infantry Platoon and Squad." Once you have finished reviewing the packet, I will answer any questions before explaining the conduct of the experiment.

Complete the Platoon Formation Task (25-35 minutes)

You will be conducting the Platoon Formation Decision Task on the XX (choose either tablet, VR w/o formations, VR w/ formations). I sanitize the equipment and work space after each participant has completed the experiment, and also provided wipes and hand sanitizer if needed.

Secondary Task

You will hear your higher headquarters (callsign Warrior) requesting position reports (POSREPs) from numerous units throughout the PFDT. Your unit's callsign is Valkyrie. When you hear Valkyrie's callsign called requesting a POSREP you will need to respond by pressing the POSREP button on the screen. Nothing else is required other than clicking the POSREP button once per Valkyrie POSREP request. Lastly, this task is secondary to your primary task of selecting the most appropriate formation.

Tablet

This is a Microsoft Surface which you will be using to complete the experiment with today. I am typing in your subject number and then you may begin. The first task you encounter is meant to familiarize you with the user interface of the PFDT. You will see the terrain in the upper left side of the interface along with a compass indicating your direction of travel. You are able to look around the terrain by swiping your finger in the direction you would like to look. An enemy situation is provided below the terrain. 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 tapping the formation.

Now you will begin the trials; there are 128. These will be similar to the familiarization you just completed, but your selection will be recorded. If you think you see the same task repeated, it has nothing to do with your performance of the task, it is simply by chance, everyone will see them in the same order regardless of performance. You may begin when ready.

Virtual Reality (without formations)

This is a Vive Pro which you will be using to complete the experiment with today. In a moment I will have you fit the headset and allow you to move within the taped area. There is a small possibility that immersion in a virtual environment can induce minor nausea or motion sickness. If you start to feel uncomfortable let me know and I will have you sit down or remove the headset.

The first task you encounter is meant to familiarize you with the user interface of the PFDT. You will see the terrain in every direction along with your controller and the information board. A compass indicating your direction of travel is located on the top of the controller. The information board is static and will not move; however, you are free to move around the area. If you near an obstacle a boundary will appear to show you not to walk into it. An enemy situation is provided on the bottom of the information board. Above the 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 formation with the trigger button.

Now you will begin the trials; there are 128. These will be similar to the familiarization you just completed, but your selection will be recorded. If you think you see the same task repeated, it has nothing to do with your performance of the task, it is simply by chance, everyone will see them in the same order regardless of performance. You may begin when ready.

Virtual Reality (with formations)

This is a Vive Pro which you will be using to complete the experiment with today. In a moment I will have you fit the headset and allow you to move within the taped area. There is a small possibility that immersion in a virtual environment can induce minor nausea or motion sickness. If you start to feel uncomfortable let me know and I will have you sit down or remove the headset.

The first task you encounter is meant to familiarize you with the user interface of the PFDT and will not be timed. You will see the terrain in every direction along with your controller and the information board. A compass indicating your direction of travel is located on the top of the controller. The information board is static and will not move; however, you are free to move around the area. If you near an obstacle a boundary will appear to show you not to walk into it. An enemy situation is provided on the bottom of the information board. Above the cues, you will see the same three formations you just studied. If you use your controller to tap a formation you will see it depicted on the terrain.

Please select the formation you feel is most appropriate for the scenario by clicking the formation with the trigger button.

Now you will begin the trials; there are 128. These will be similar to the familiarization you just completed, but your selection will be recorded. If you think you see the same task repeated, it has nothing to do with your performance of the task, it is simply by chance, everyone will see them in the same order regardless of performance. You may begin when ready.

Complete Post-Task Survey (5 minutes)

This final document is a post-task survey to ask some questions about the tasks and any additional comments are much appreciated. After you complete the survey, if you are interested, I can provide you with your overall performance information.

Debrief (5 minutes)

Explanation of Study

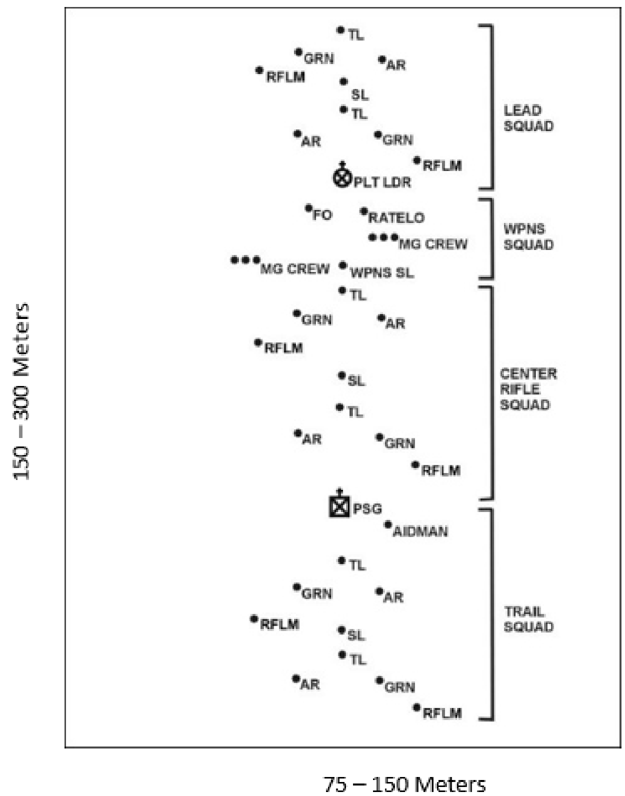
I am attempting to verify the usefulness of military training aides on easy-to-use, readily available platforms such as tablets and virtual reality headsets. My thesis is to demonstrate that an individual's recognition primed decision-making can be improved through the completion of numerous repetitions of a training aide such as the Platoon Formation Decision Task. Ultimately, my intent is that this will prepare military leaders to make faster, more optimal decisions by increasing their experience and honing their intuition.

Questions & Answers

APPENDIX E. PLATOON FORMATION REFERENCE SHEET

PLATOON COLUMN

The platoon column provides the best speed and control, and is ideal when conducting night operations or moving through thick vegetation and canalizing terrain. Column provides the best security and deployability to the flanks, but the worst to the front.



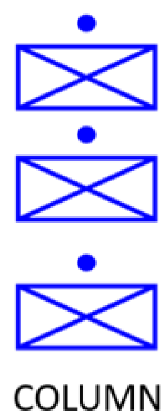


Figure 37. Platoon Formation Reference Sheet 1.

PLATOON LINE

The platoon line, squads on line may be used in the assault to maximize the firepower and shock effect of the platoon. This normally is done when there is no intervening terrain between the unit and the enemy or when the unit is exposed to artillery fire and must move rapidly. The platoon line with squads on line is the most difficult formation from which to make the transition to other formations.

In the platoon line, squads on line formation, or when two or more platoons are attacking, the company commander chooses one of them as the base platoon. The base platoon's center squad is its base squad. When the platoon is not acting as the base platoon, its base squad is its flank squad nearest the base platoon. The weapons squad may move with the platoon or it can provide the support by fire position. This is the basic platoon assault formation.

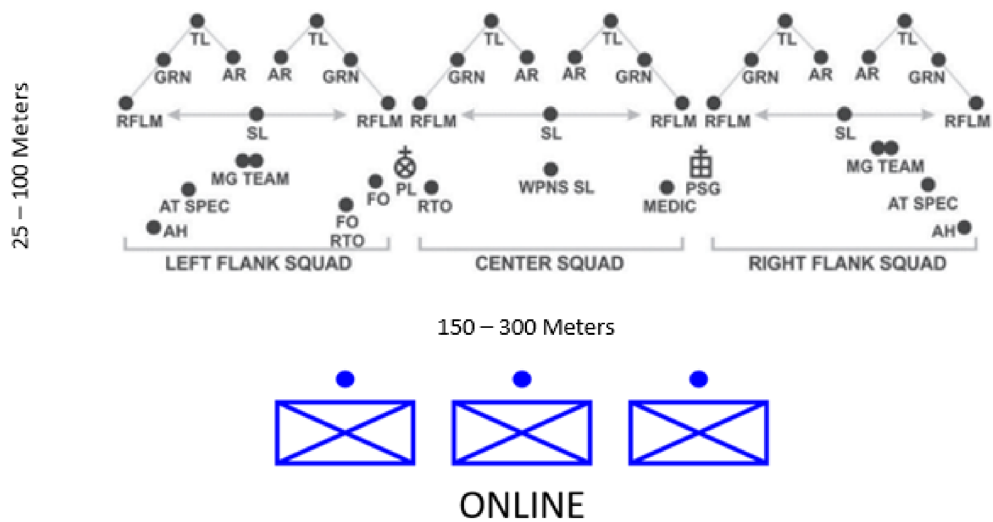


Figure 38. Platoon Formation Reference Sheet 2.

PLATOON VEE

The platoon vee has two squads up front to provide a heavy volume of fire on contact. It also has one squad in the rear either overwatching or trailing the other squads. The platoon commander designates one of the front squads as the platoon's base squad. The platoon vee is slow and difficult to control since there are two lead elements. Security is excellent to the front and good to the flanks. The vee is typically used when the enemy is to the front or when crossing a large open danger area.

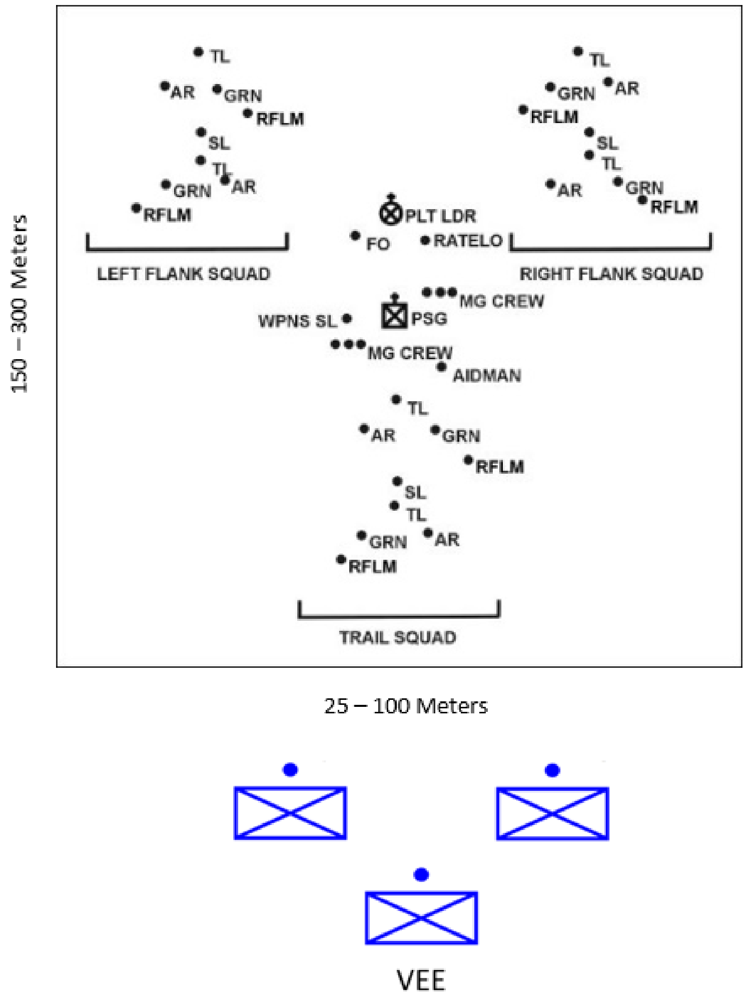


Figure 39. Platoon Formation Reference Sheet 3.

MOVEMENT FORMATION	WHEN MOST OFTEN USED	Movement Characteristics				
		CONTROL	FLEXIBILITY	FIRE CAPABILITIES AND RESTRICTIONS	SECURITY	MOVEMENT
Platoon Column	Platoon primary movement formation	Good for maneuver (fire and movement)	Provides good dispersion laterally and in depth	Allows limited firepower to the front and rear, but high volume to the flanks	Extremely limited overall security	Good
Platoon Line, Squads on line	When the commander wants all personnel forward for maximum firepower to the front and the enemy situation is known	Difficult	Minimal	Allows maximum firepower to the front, little to the flanks and rear	Less secure than other formation because of the lack of depth, but provides excellent security for the higher formation in the direction of the echelon	Slow
Platoon Vee	When the enemy is to the front or when crossing a large open danger area	Difficult	Adequate	Allows good overall security	Excellent to the front and good to the flanks	Slow

Figure 40. Platoon Formation Reference Sheet 4.

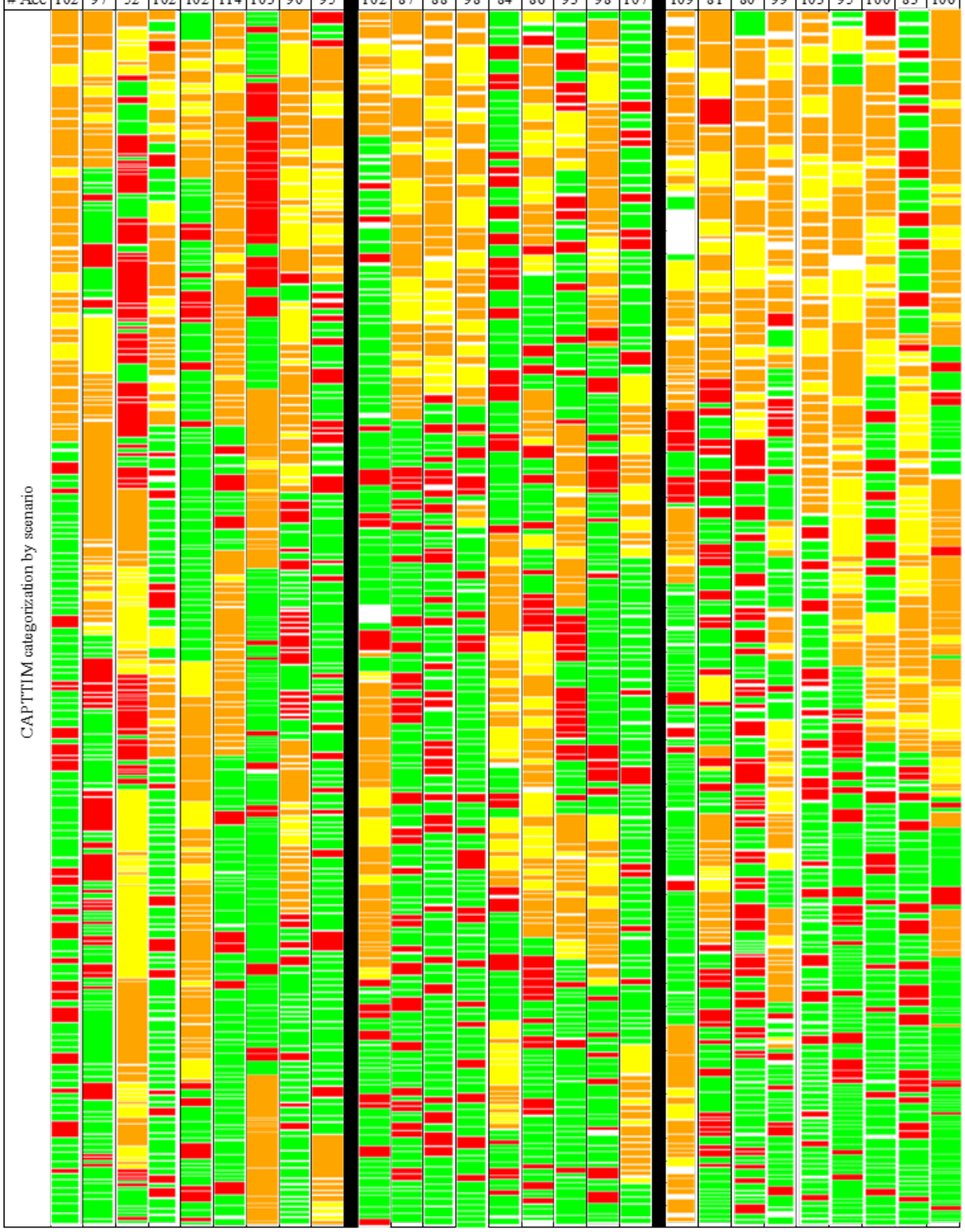
APPENDIX F. OVERALL PERFORMANCE DATA

Table 8. CAPTTIM categorization by trial.

Participant #	1I-001	1I-002	1I-003	1S-001	1S-002	1S-003	1S-004	1S-005	1S-006
# Opt	72	62	25	72	61	60	75	48	76
# Acc	102	97	52	102	102	114	103	90	95

Participant #	2I-001	2I-002	2I-003	2I-004	2S-001	2S-002	2S-003	2S-004	2S-005
# Opt	69	68	68	76	55	48	63	65	82
# Acc	102	87	88	98	84	86	93	98	107

Participant #	3I-001	3I-002	3I-003	3I-004	3I-005	3S-001	3S-002	3S-003	3S-004
# Opt	63	50	60	52	72	65	69	58	59
# Acc	109	81	80	99	103	95	100	83	106



This table shows all 27 participants' CAPTTIM categorization for each trial. The chart divides the participants across the three conditions and subdivides them by students and instructors.

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