Testing Simulation Platforms to Accelerate Optimal Military Decision-Making

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ABSTRACT

The training of complex military tasks such as the selection of proper infantry platoon formation is resource intensive and presents an opportunity for technology to offer greater efficiency through computer-aided experiential learning. The platoon formation decision task (PFDT) is a simulation that assesses an infantry officer's decision-making with the Cognitive Alignment with Performance Targeted Training Intervention Model (CAPTTIM), specifically ascertaining which subjects reached optimal decision-making and when it occurred.[1] Infantry training benefits from further development of high-capacity training on commonly available platforms. Therefore, our study builds upon previous work by refining and testing PFDT across two prevalent platforms. The PFDT includes 32 scenarios, each randomly presented four times for a total of 128 trials. Five factors were manipulated in the scenarios and SMEs confirmed the optimal, acceptable, and poor decision responses. Twenty-seven students and instructors 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). Results indicated that most participants adequately learned the task, but no platform effect nor experience level effect existed on the number of trials needed to reach optimal decision-making. Thus, the PFDT is a viable military training simulator regardless of technological platform utilized or amount of infantry-training.

ABOUT THE AUTHORS

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[1] Hanley, B. M. (2018). *TESTING A COGNITIVE ALIGNMENT-BASED TRAINING MODEL TO ACCELERATE OPTIMAL MILITARY DECISION-MAKING IN A PLATOON-FORMATION TASK*. Naval Postgraduate School.

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INTRODUCTION

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). 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 will obtain victory (Marine Corps Warfighting Lab, 2017). Multiple repetitions of tactical military decision-making in training, education, and combat are the critical requirement for victory and developing a bias of action amongst small unit leaders.

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 (USMC, 2020a). This process is detailed-oriented, requires additional time and a thorough understanding of planning processes. Thus, Marine leaders need intuition, informed by past experiences, to make decisions that are faster and less taxing (Klein, 1993). These processes of analysis and intuition are not mutually exclusive; they inform and strengthen one another, often simultaneously to make optimal decisions more capably (USMC, 2020a). Decisions that required analytical rigor simplify become amenable to intuitive decision-making through sufficient training and experiential gain.. Understanding the strengths and weaknesses of recognition-primed and analytical decision-making will allow Marine infantry small unit leaders to utilize training simulators for themselves, such as the platoon formation decision task (PFDT), to successfully transition from analytical to intuitive decision-making.

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. The new joins miss the basic-level training events accomplished early in the schedule prompting prioritization of assessment and mitigation of deficiencies with remaining resources. 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 period of instruction, pre-deployment workup, or deployment.

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 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. This research evaluated the usefulness of the PFDT, a simulated task of 0302-PAT-1001 (Lead a Unit in Patrolling Operations), which is an individual task within the Marine Corps Infantry Training and Readiness (T&R) Manual (USMC, 2020b), amongst students at TBS and the Naval Postgraduate School (NPS).

Platoon Formation Decision Task

In 2018, LTC Brian Hanley, USA, created a computer-based dynamic PFDT as a training aide for improving junior military leaders' decision-making abilities (Hanley, 2018). The PFDT consists of 32 scenarios, each randomly shown four times for a total of 128 trials. For each trial, users, who have no prior platoon formation experience, decide which of three platoon formations to use based on a 10-second first-person view video clip of terrain as well as written information regarding likelihood and direction of enemy attack (Figure 1). The primary goals behind the construction of the PFDT are to create a basic task that military users consider 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) is applied to the PFDT data to provide an understanding of when and why some participants pursue suboptimal decisions (Figure 2). CAPTTIM facilitates the detection of optimal decision-making by determining if a participant's cognitive state is aligned or misaligned with their decision performance (Kennedy et al., 2019). The results indicate the PFDT provides 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 indicates the participants learn from their experiences and show improvement as they progress through the task.

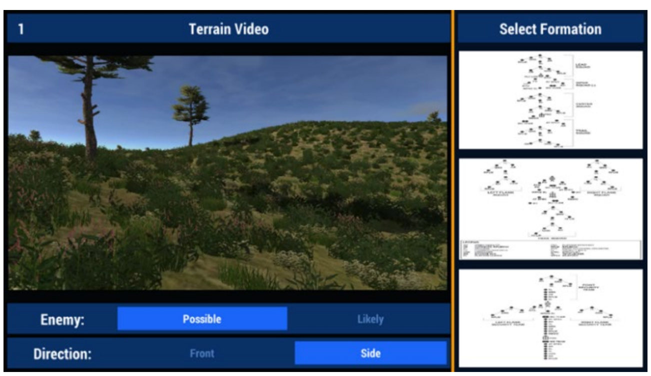

Figure 1. Sample trial of user interface from computer-based PFDT. Source: (Hanley, 2018).

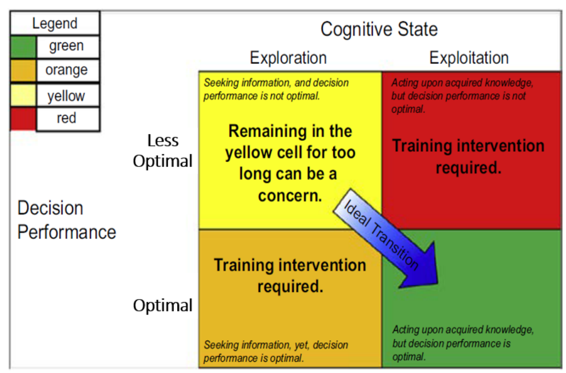

Figure 2. Illustration of the main components of CAPTTIM. Source: (Kennedy et al., 2019).

Cognitive Alignment with Performance Targeted Training Intervention Model

Training of effective rapid response decision-making is 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. Optimal decision-making occurs when a participant's cognitive state is consistently exploiting good decisions (see Figure 2). 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.

Training platforms

The PFDT demonstrates 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, we 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 examined was 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). We predicted that participants in the VR HMD 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).

Hypotheses

The guiding concepts from the USMC coupled with the literature review directed us to further Hanley's (2018) work and transfer the PFDT onto a tablet and VR to validate their usefulness as technology platforms for training simulators. The main research question was to what extent could training of platoon formation decisions be effectively utilized on a computer tablet and VR? We also explored the extent to which a participant's experience level affected their decision-making performance. The proposed hypotheses of the research were:

H1: 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?

H2: 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 2: To what extent does a participant's experience level affect their performance of achieving optimal decision-making?

METHODOLOGY

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. A total of 27 military personal (four female) with 4.5 mean years of service (*SD* = 3.9) and a mean age of 27 years old (*SD* = 4.1) took part in the study. There were 13 novice and 14 expert participants. 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. The research was approved by the NPS IRB and the USMC IRB.

Design

This study employed a between-participants, repeated measures design, so that the platform on which the PFDT was delivered was manipulated between participants. The independent variables were the three conditions the participants completed the PFDT: (1) Tablet, (2) VR HMD (VR only), (3) VR HMD with formations. The dependent variables were the time it took participants to make a choice and the outcome of each choice.

PFDT

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. These five characteristics were then utilized by infantry SMEs to confirm the optimal, acceptable, and poor decision responses for the PFDT scenarios. 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

The PFDT has three main requirements. First, it should incorporate the characteristics described in Table 1. 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. In the present study, PFDT scenarios were based on the factors of enemy, terrain, and time of day (See Table 2 for a description of the factors and their levels).

Table 2. Factor descriptions.

Factor		Description	Low	High
1	Time of Day	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

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.

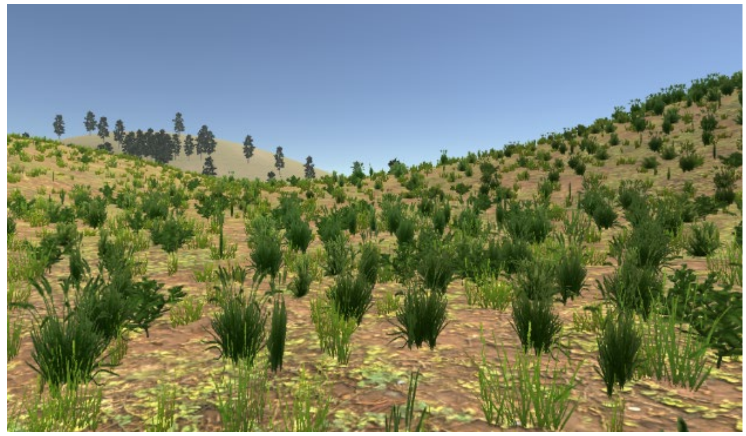

Figure 3. Example of hilly, sparsely vegetated terrain at day.

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.

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. These formations thus serve as the possible answers for each of the scenarios in the platoon formation task.

PFDT platforms

The PFDT was originally created for a desktop computer. It was adapted in this study to run on three different platforms – tablet, VR HMD, and VR HMD with formations. Figure 4 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.

In the VR-versions, 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: VR HMD and VR HMD with formations. In the former, the participant can see 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 5 shows the interface for the VR-version of the PFDT with the formations depicted. The virtual controller was shown within the virtual environment with a compass on top that also points in the intended direction of travel.

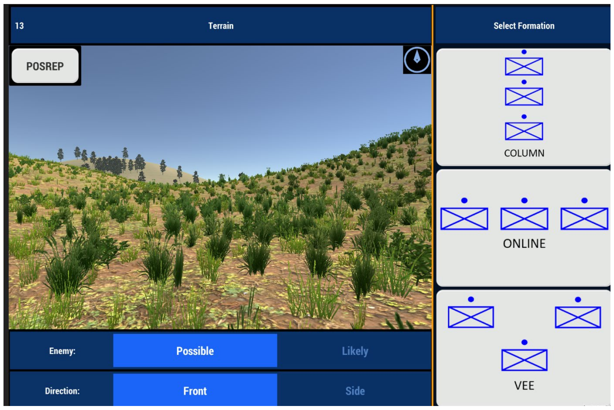

Figure 4. User interface for tablet-version PFDT.

Figure 5. User interface for VR-version PFDT.

Questionnaires

The study utilized two questionnaires: a demographic questionnaire and a post-task questionnaire. The demographic questionnaire collected basic data concerning the participants' age, gender, military service, and video game experience. This questionnaire 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. The post-task questionnaire focused on the participant's experience and on what information the participant used to make their formation choice. The questionnaire also asked about any strategy used during the task and if the strategy changed during the execution of the task. Finally, it assessed if the participants would use this as a training tool in the operating forces and to provide any additional comments.

Software and Equipment

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.

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 questionnaire and experiment data. The PFDT application required 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.

Procedure

Participants were randomly assigned to one of the three platform conditions. Each participant's visit included one visit to the research room typically lasting 30–45 minutes. Researchers used a script 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 questionnaire. After finishing the demographic questionnaire, participants completed a study session that consisted of reviewing a packet of information 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 questionnaire 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.

Data Analysis

This study used two data sources: the data recorded by the PFDT software and the questionnaire data. The PFDT software outputs a file with trial data that includes treatment, selection, and selection time. The questionnaire information that was filled out on paper was transcribed onto a Microsoft Excel 2016 spreadsheet by the research team. The research team used two software applications to analyze the quantitative data. The application of CAPTTIM and related graphs and charts used R. Statistical analysis was computed with JMP 16.

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. A participant was classified as reaching optimal exploitation if they made four optimal decisions in a row within a rolling window of ten scenarios. A two-tailed alpha level of .05 was used for all analyses.

CAPTTIM

CAPTTIM was utilized to ascertain when a participant's cognitive state properly aligns with their decision performance (Carlson, 2016; Critz, 2015; Hanley, 2018). Cognitive state is operationalized by 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. 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 (≤ or >) $S_{Baseline}$, 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

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. 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:

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

Results

Hypothesis 1 – Effective Training Simulator

Nineteen 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), $t(25) = 3.75$, $p < .0005$, $d = .71$. The mean percent of optimal decisions was less than 64% (SD = 0.09), $t(25) = -3.29$, $p < .9985$, $d = .67$. ANOVA indicated no platform effect existed across the three conditions when observing acceptable decisions or optimal decisions.

Table 3. ANOVA Test Results.

Data Comparison	Test	Results
Acceptable Decisions	ANOVA	$F(2, 23) = 1.39, p = .267, \eta_p^2 = .108$
Optimal Decisions	ANOVA	$F(2, 23) = .88, p = .425, \eta_p^2 = .072$

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. The mean optimal percentage was 65% for instructors and 64% for students. Furthermore, regression calculations using JMP did not indicate that years of experience predicted percent of acceptable or optimal decisions. These results indicated that years of service do not impact the percent of acceptable or optimal decisions.

Hypothesis 2 – Platform Effect

The trial number at which participants reached optimal decision-making ranged from 17 to 101 (M = 44.9, SD = 20.4) (see Table 4). There were seven participants (6 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. Although there was a trend for participants in the VR HMD with formation platform to attain optimal decision-making on an earlier trial than participants in the tablet platform (Tablet: M = 51.5, SD = 8.58; VR no formations: M = 44.6, SD = 9.39; VR with formations: M = 38.6, SD = 8.58), ANOVA indicated no significant platform effect existed, $F(2, 14) = .56$, $p = .583$, $\eta_p^2 = .074$.

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

Number of Trials	Number of Participants
0 – 20	1
21 – 40	5
41 – 60	7
61 – 80	1
81 – 100	0
101 – 128	1
129	7

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

This section used the CAPTTIM measure to identify if a participant's experience level affected 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 no significant difference between experts (M = 46.6, SD = 21.5) and novices (M = 42.6, SD = 20.2), $t(16) = -.39$, $p < .650$, $d = -4.03$. Additionally, regression calculations using JMP indicated that years of experience did not predict the trial number at which participants reached optimal decision-making. 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.

DISCUSSION

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). In Hanley's study, 30 participants who completed the PFDT on a computer reached 82.53% acceptable answers and 68.75% correct/optimal answers. In this study decision performance, either as defined via traditional methods as percent acceptable or as defined by when participants reached optimal decision-making via CAPTTIM, was consistent across the three platforms. Thus, these results demonstrated the versatility of the PFDT to be utilized on several technological platforms with no loss in training value. 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.

Recommendations

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 school houses, 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.

Limitations and Future Work

Increase Sample Size

Ability to collect data in the designated timeframe was challenging and we were unable to reach the expected sample size of 45 – 60 participants due to the COVID-19 pandemic. Future studies should ensure an appropriately sized sample.

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.

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.

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.

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.

CONCLUSION

Military leaders 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 more optimal 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 study 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.

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