Empirically Derived Recommendations for Training Novices Using Virtual Worlds

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ABSTRACT

The U.S. Army Training and Doctrine Command's Army Learning Concept 2015 and Army Training Concept 2025 discuss the requirements for adaptive soldier learning models with flexible training delivery methods. Current Game-Based Virtual Environments (GBVEs) have the ability to provide Military Operations in Urban Terrain (MOUT) training based on the Army's requirements, but only for small unit operations. Existing GBVEs lack the capability to support large numbers of users in the same environment at one time or allow the users to engage in critical thinking. Virtual World (VW) technology offers viable solutions to flexibility and scalability challenges found in traditional simulation-based MOUT training such as room clearing tasks, as well as demonstrated the ability to impart valuable training for such tasks. Previous research indicates less experienced Soldiers benefit from VW training (Lackey, Salcedo, Matthews, & Maxwell, 2014). The evidence suggests a need to empirically explore the impact of VW training for operationally relevant tasks on inexperienced populations. This paper presents the results from the second study in a multi-year series of VW Training Effectiveness Evaluations (TEE). The present experiment investigates performance outcomes and user perceptions of 64 novice Soldiers (e.g., ROTC Cadets) using traditional and VW training methods for a room clearing task. Results indicate significant Pearson's product-movement correlation coefficients between the stress-state survey DSSQ and the workload survey NASA- TLX for each training condition and combined training. The survey results offer insight into performance outcomes for the room clearing task. Furthermore, the results reported herein contribute empirically-derived recommendations for the design, development, and implementation of VW training.

ABOUT THE AUTHORS

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INTRODUCTION

According to the Army Learning Concept 2015 and the Army Training Concept 2025, there is a need to develop adaptive Virtual World (VW) training for Soldiers to learn how to operate in complex, irregular combat situations. Current training environments, mostly traditional classroom-based settings, are typically limited in accessibility and require investing in personnel. Considering the current limitations in training budgets, the Army plans to address these training challenges by creating a new learning approach that includes virtual and gaming platforms with the already established classroom-based environments. Game-Based Virtual Environments (GBVEs) appear to offer viable options, having greater portability and scenario variability, but they do not support large numbers of simultaneous users (Lackey, Salcedo, Matthews, & Maxwell, 2014). Current GBVEs can support up to 40 users comfortably; however, any number larger than that may cause computer processing delays. Additionally, GBVEs do not provide the estimated flexibility and adaptability required by the Army. Scenario events are typically presented in a rigid and determinant manner, following a strict, pre-determined training sequence. This can lead to negative training in which the learner is unable to deconstruct information using critical thinking skills necessary to improve performance (Champion & Gallagher, 2003, Lackey, Salcedo, Matthews, & Maxwell, 2014). The use of VW training is meant to alleviate the limitations of current GBVEs by allowing a large number of simultaneous users from various locations to participate in scenario-based training. Furthermore, VWs permit the trainee to actively engage in critical thinking by providing the flexibility to adapt scenarios based on decisions made by the trainee. As the benefits of VW technology become more apparent, it has been adopted for use by the military, academia, and industry. This growing use of VW training contributed to the development and implementation of the MOSES training environment.

The MOSES (Military Open Simulator Enterprise Software) platform is an open source software that allows the construction of customizable environments within the VW based on task or user requirements. One key feature MOSES possesses is the capability to support a large number of users in a training scenario at one time. MOSES also allows the trainee the ability to exercise critical thinking by adapting to decisions made by the trainee rather than following a pre-determined sequence of events. The platform is persistent and allows users to enter the scenario at any time rather than waiting for a specified group to enter all at once.

To assess the viability of VW training programs, the training effectiveness evaluation (TEE) is performed. The most prevalent method for conducting a TEE is based on Kirkpatrick's (1994) four levels, reaction, learning, behavior, and results, for evaluating training (Alliger & Janak, 1989; Salas & Cannon-Bowers, 2001; Arthur Jr., Bennett Jr., Edens, & Bell, 2003; Lackey, Salcedo, Matthews, & Maxwell, 2014). The current research focuses on the first two levels, reaction (trainee reaction to training) and learning (increase in knowledge due to training). As part of a three-phase research investigation, this paper investigates the effectiveness of VW training for novices by measuring performance in relation to stress and workload. The results of this effort provide design recommendations for VW training technologies and strategies to enhance overall performance.

METHOD

Participants

The participants for this experiment consisted of 64 U.S. Army ROTC Cadets from the University of Central Florida (UCF). From these participants, 47 were male and 17 were female. Thirty-two participated in the traditional classroom training and 32 participated in the VW training. Participant ages ranged from 18 to 28 with M = 19.89, SD = 1.84. The requirements for participation included being a U.S. citizen, 18-40 age range, normal or corrected to normal vision, and full color vision. Participants received no monetary compensation or class credit for participation.

Experimental Design

The experiment employed a between-subjects design comprised of two groups of eight four-person teams split between traditional and VW training for room clearing. The independent variable was the training condition received (i.e., traditional classroom or VW training). The dependent variables included performance data (i.e., a rating of either "GO" or "NO GO" by the instructor) as well as survey data which assessed stress and workload.

Measurement Instruments

Several survey measures were administered to offer insight into performance outcomes for the room clearing task. The demographics questionnaire gathered biographical information (i.e., age, computer experience, years of military service, etc.). Other survey measures included the Dundee Stress State Questionnaire (DSSQ) (Matthews, Szalma, Panganiban, Neubauer, & Warm, 2013) and the National Aeronautics and Space Administration Task Load Index (NASA-TLX) (Hart & Staveland, 1988). The DSSQ measured stress experienced by a participant through rating 30 statements from 0 (Definitely false) to 4 (Definitely true). Each statement was categorized into three subscales: engagement, distress, and worry. The DSSQ Engagement subscale included attentiveness, enthusiasm to complete the task, motivation to succeed and improved concentration. The Distress subscale focused on mood states of increase tension, reduced hedonic tone, and loss of confidence. Finally, the Worry subscale considered cognitive thoughts on both task and personal concerns. The NASA-TLX measured the amount of workload experienced by participants related to six unweighted subscales: mental demand, physical demand, temporal demand, effort, frustration, and performance. Participants rated each subscale from very low (equivalent to zero) to very high (equivalent to 100).

Each participant was assessed individually on their performance by receiving a GO or NO-GO rating. Individual scores contributed to each team's overall performance. If there was no greater than 1 NO-GO, the team received an overall GO. If there were two or more NO-GOs, the team earned a NO-GO rating.

Materials

The traditional training condition was conducted in a UCF Army ROTC designated classroom, while the VW training condition was administered in a UCF Army ROTC Battle Lab. The classroom was an enclosed, air conditioned auditorium-style space assigned by the UCF Army ROTC Commanding Officer. In an adjacent room within the building, a 21ft. by 21ft. mock-up room was constructed for formal assessment of performance on the room-clearing task. Figure 1 provides a sketch of the assembled room. A 7ft. by 3ft. opening served as the door and the X represents the target.

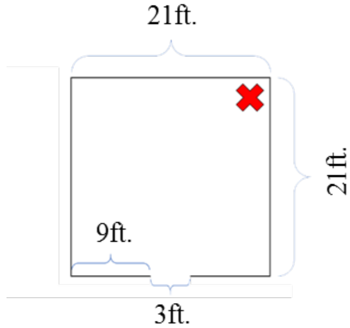

Figure 1. Evaluation Mock-up Room

The Battle Lab was comprised of 32 Hewlett Packard Pavilion 17-e118dx mobile computer workstations for participant use. Figure 2 provides an illustration of the ROTC Battle Lab set-up. Experimenters were provided with eight additional workstations to assist the participants if necessary. The software utilized for this experiment was a prototype VW training, known as the Military Open Simulator Enterprise Strategy (MOSES) from the U.S. Army Research Laboratory, Human Research Engineering Directorate, Simulation and Training Center (ARL HRED STTC).

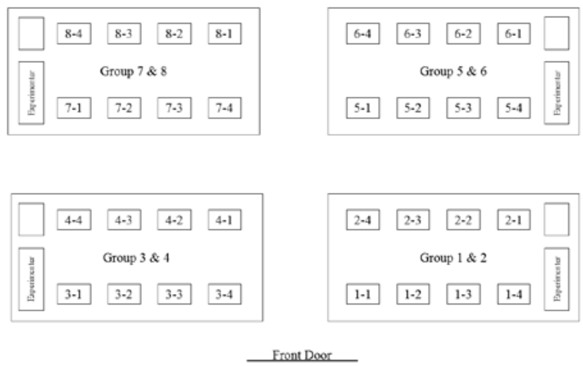

Figure 2. ROTC Battle Lab Set-up

Procedure

Each participant was randomly assigned to either the Traditional or VW condition prior to arrival.

Traditional Condition

Upon arriving at the UCF Army ROTC designated classroom, each of the 32 participants were assigned to one of eight four-person teams. Participants sat with their assigned teams facing the instructor. After receiving a welcome statement from the researchers, the participants were asked to sign the informed consent, giving voluntary consent to participate as well as permission to be photographed and videotaped. Next, each participant completed the demographics questionnaire and DSSQ pre-training questionnaire. Upon completion, the instructor presented, through PowerPoint, the procedure for a room clearing task, as well as provided clarification of the sectors of fire adopted from the formal U.S. Army doctrine. The instructor is a subject matter expert (SME) with extensive prior knowledge and experience completing room clearing tasks. Once the presentation concluded, each participant completed the NASA-TLX and the DSSQ post-training questionnaire. Following the questionnaires, the participants were provided the opportunity to practice the room clearing task in an open field with their four-person group for approximately 15 minutes prior to performing the room clearing task assessment. The participants performed the room clearing task in a mocked-up room two times and were assessed by the instructor.

Virtual Condition

VW training condition participants arrived to the UCF Army ROTC Battle Lab where each of the 32 participants were assigned to one of eight four-person teams prior to their arrival. Each team was seated at their designated workstation were each participant was asked to sign the informed consent and give consent to be photographed and videotaped. Following the informed consent, the participants were asked to complete the demographics questionnaire and the DSSQ pre-training questionnaire. Upon completion of the questionnaires, the participants watched a video simulating a room clearing task performed in the MOSES environment. Further clarification of the sectors of fire was provided by the SME based on the formal U.S. Army doctrine. After this presentation, the participants had the opportunity to practice the room clearing task (approximately 15-20 minutes) with their team members using the MOSES simulator software. Figures 1 and 2 provide two different views of the virtual environment. Once the practice was complete, participants were asked to fill out the NASA-TLX and the DSSQ post-training questionnaires. Upon completion of the questionnaires, the participants performed the room clearing task two times in a mocked-up room and were assessed by the instructor.

Figure 3. VW Room Clearing Scenario – Stacking

Figure 4. VW Room Clearing Scenario

RESULTS

Based on SME assessment, performance outcomes were as followed:

- During the Traditional condition, 25% (2/8) of teams received a GO rating during the first trial and 87.5% (7/8) received a GO rating during the second trial.
- During the VW condition, 37.5% (3/8) of teams received a GO rating during the first trail and 75% (6/8) of teams received a GO rating during the second trial.

Preliminary analyses were performed to ensure no violations of assumptions of normality, linearity, and homoscedasticity. An examination of the training type, virtual and traditional, using a one-way between-groups analysis of variance (ANOVA) revealed no significant difference on performance. To explain the lack of significant difference on performance (i.e., traditional and virtual) a series of Pearson product-movement correlation coefficients were conducted between the DSSQ and the NASA-TLX.

A Pearson product-movement correlation coefficient was conducted to assess whether or not a relationship exists between the subjective measures, DSSQ and NASA-TLX, for the VW training condition. The VW training condition produced a significant outcome in two cases (see Table 1). There was a moderate, positive relationship between DSSQ Post-training Engagement Difference and NASA-TLX Mental Demand, $r = .441$, $n = 32$, $p < .05$, as well as a moderate, positive relationship between DSSQ Post-training Worry Difference and NASA-TLX Physical Demand, $r = .375$, $n = 32$, $p < .05$.

Table 1. Significant Correlations for the Virtual World Training Condition

		DSSQ Subscales	
		Engagement	**Worry**
NASA-TLX Subscales	**Mental Demand**	.44*	
	Physical Demand		.38*

*Correlation is significant at the 0.05 level (2-tailed).

The traditional training condition produced significant results in three cases (see Table 2). There was a moderate, positive relationship between DSSQ Distress Difference and NASA-TLX Frustration, r =.568, n = 32, $p < .01$, a moderate, positive relationship between DSSQ Distress and NASA-TLX Global Workload, r =.475, n = 32, $p < .01$, and a moderate, positive relationship between DSSQ Worry and NASA-TLX Global Workload, r =.396, n = 32, $p <$ .05.

Table 2. Significant Correlations for the Traditional Training Condition

		DSSQ Subscales	
		Distress	**Worry**
NASA-TLX Subscales	**Frustration**	.57**	
	Global Workload	.48**	.40*

*Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed).

When analyzing the training conditions together, three significant outcomes occurred (see Table 3). Overall, DSSQ Distress and NASA-TLX Frustration had a weak, positive correlation, r =.277, n = 64, $p < .05$, DSSQ Engagement and NASA-TLX Mental Demand had a moderate, positive relationship, r =.348, n = 64, $p < .01$, and DSSQ Worry and NASA-TLX Physical Demand had a weak, positive correlation, r =.250, n = 64, $p < .05$.

Table 3. Significant Correlations for Combined Training

		DSSQ Subscales		
		Distress	**Engagement**	**Worry**
NASA-TLX Subscales	**Frustration**	.28*		
	Mental Demand		.35**	
	Physical Demand			.25*

*Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed).

Negative weak correlations were found to be significant between Video Game Use and NASA-TLX Temporal Demand $r = -0.326$, $n = 64$, $p < .01$, Video Game Use and Performance $r = -0.313$, $n = 64$, $p < .05$, as well as Video Game Use and Global Workload $r = -0.260$, $n = 64$, $p < .05$. (See Table 4)

Table 4. Significant Correlations for Overall Video Game Use and Workload

		Demographics
		Video Game Use
NASA-TLX Subscales	**Temporal**	-0.326**
	Performance	-0.313*
	Global Workload	-0.260*

*Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed).

DISCUSSION

The results of this paper provide insight into the performance outcomes and the effectiveness of implementing VW training for a room clearing task. The positive correlations from Table 1 depict the NASA-TLX Mental and Physical Demand subscales having a moderate, positive relationship with the DSSQ Engagement and Worry subscales. This may be a consequence of the participants' desire to perform well. Having no previous exposure or experience with VWs may have increased their levels of stress and workload, impacting their trial one performance on the room clearing task. VW training requiring higher complexity skills involve some level of previous experience or familiarity of the operational environment. In this experiment, the complexity of the task and the participants' inexperience may have contributed to greater Mental Demand, while the novelty of the VW training environment may have increased task Engagement. This can be attributed to the novelty effect associated with using the new VW technology. In relation to the Traditional training condition, the correlations found in Table 2 appear to be consistent with what one would expect with training highly complex tasks to novices. High frustration and overall workload can be associated with increased levels of stress, particularly Distress, over the difficulty level and concerning performance.

Next, the correlations from Table 3 revealed low to moderate positive correlations between the DSSQ subscales and NASA-TLX subscales. Notably, the DSSQ Worry subscale is apparent not only in the combined training but also experienced in the VW training condition and Traditional training condition. It appears that participants' state of worry may have been impacted by workload. As a consequence, participants may have experienced increased stress levels. Increased stressed levels may be explained by the lack of military experience as well as VW training for room clearing tasks. The lack of experience may have contributed to reduced self-efficacy and in turn impacted performance outcomes for the first trials (see Results section). Past research has shown that self-efficacy is strongly correlated with performance (Locke, Frederick, Lee, & Bobko, 1984; Bandura, 1982; Feltz, 1982). These results also holds true for current research results. Due to perceived low efficacy, the novices experienced an increase in stress resulting in higher workload for Mental and Physical Demand as well as Frustration. While the results hold true for this phase of the experiment, the results appear contrary to previous findings from the initial field study (Salcedo, Lackey, Matthews, & Maxwell, 2014). Previous finding suggest that VW training mitigate levels of Worry and Distress amongst the novice group. The inconsistencies in the current results may be attributed to participants increased stress levels, lack of military experience, and VW exposure.

Finally, the correlation between Video Game Use and NASA-TLX Temporal Demand, Global Demand, and Performance revealed a low to moderate negative correlation for all participants. Individuals with increase video gaming experience reported a decrease in workload for Temporal Demand, Global Demand, and Performance (see Table 4). These results appear to be consistent with previous findings for VW training associated with reduced workload (Salcedo, Lackey, Matthews, & Maxwell, 2014) due to the "game-like experience" while using the VW. A trend appears to emerge from having video game experience that correlates with reduced workload offering opportunities to enhance training skills. The results do not hold true for NASA-TLX Performance which was negatively impacted. This may be a result of the lack of in-world feedback indicating if the team completed the room clearing task sufficiently. Generally, most gameplay experiences provide the user with challenging activities, choices, and competition while the game elements comprise of goals, rules, and fantasy elements (Charsky, 2010). To further enhance the "game-like experience," introducing game elements (e.g., goals, rules, etc.) may cultivate intrinsic motivation for learning the room clearing task. Furthermore, spending more time practicing the desired task should amplify the learning potential and ultimately impact overall performance.

CONCLUSION

The present experiment is part of a multi-year research initiative for assessment of two training methods, traditional and VW. The focus of this phase captured data from novices conducting a room clearing task. Based on the research findings, there are several unexplored areas warranting further investigation. These focus on after-action-review (AAR), feedback, larger sample size, and time constraints. To address these gaps, the following recommendations are provided. First, the participants received limited exposure to the VW environment (approximately 15 minutes) as well as minimal to no feedback at the conclusion of the VW training. Therefore, future research may want to consider increasing the exposure time to the VE, engaging in AARs, and incorporating a VW instructor during scenario training to provide feedback when needed. Second, the results from the first year research experiment on VW room clearing indicated decreasing worry and distress among novices using a VW for training (Lackey, Salcedo, Matthews, & Maxwell, 2014). However, the results from the present study offer differing results in this area. To alleviate this, a larger sample size is suggested as this research initiative continues to expand. Finally, to assess whether or not time constraints affected the results, a longitudinal study is proposed to assess what impact, if any, long term exposure to the VW training would have on future performance. By addressing these recommendations, this research can begin to develop strategies for enhancing virtual world training.

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