Workload Analysis of Virtual World Simulation for Military Training

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ABSTRACT

This research examined the training effectiveness of utilizing a virtual world simulation within an operationally relevant task domain and environment. Virtual world simulation-based training is becoming more common for military training due to recent simulation technological advancements. However, there remains a paucity of research examining this class of simulation's training effectiveness. In this paper, we examined the effect that virtual world simulation had on soldiers' workload, in comparison to live simulation's effect. Soldiers, participating as members of their assigned rifle squads, were randomly assigned to one of two training treatments (virtual world or live simulation) and performed four collective tasks. The independent variable was training condition and the dependent variable was workload, as measured by the NASA-TLX survey. Workload analysis revealed that training treatment had a significant main effect on the degree of workload perceived by Soldiers, in five of the six NASA-TLX sub-scales. This indicated that virtual world simulation stimulated greater perceived workload than the control treatment, live simulation. These results may challenge the notion that virtual world simulation cannot approximate the perceived workload of live simulation.

ABOUT THE AUTHORS

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INTRODUCTION

This research examined the training effectiveness of utilizing a virtual world simulation within an operationally relevant task domain and environment. The results of this study will provide the Army's research, acquisition and training communities with empirical, data-driven results that measure the training effectiveness of virtual world simulation. In this paper, we explore the effect that virtual world simulation had on soldiers' workload, in comparison to live simulation's effect. Specifically, the experimental objective discoursed in this paper was to empirically assess the training effectiveness of the Army's Program of Record (PoR) for virtual world simulation training using a qualified population of Soldiers, specifically focused on an individual's workload.

There are three classes of simulation used for training: live, virtual and constructive (Hodson & Hill, 2013). In the past decade, a fourth class has been added: gaming (Roman & Brown, 2008). Live simulations comprise real people operating real systems while virtual simulations encompass real people operating simulated systems in simulated environments. Constructive simulations involve simulated people operating simulated systems. The term gaming refers to the employment of interactive, computer-based applications used for training purposes (Bergeron, 2006), generally characterized by their low overhead and cost. When the four classes overlap each other in training (i.e. employment of more than one class in a training exercise), this is referred to as "blended training".

One of the major advantages of employing virtual, constructive and game-based simulation for training are their associated cost advantages (Orlansky, et al., 1994; Riecken, et al., 2013) especially when compared to live training. In the current fiscal environment, this is of paramount importance as budgets for training continue to decline. Furthermore, the United States Army continues to employ simulation-based training (SBT) in novel ways (Mishkind M. C., Boyd, Kramer, Ayers, & Miller, 2013). This is largely due to its proven effectiveness in training (Sotomayor & Proctor, 2009; Lisk, Kaplancali, & Riggio, 2011; Blow, 2012) and the need to decrease the cost of that training. In recognition of the effectiveness of SBT, the Army's Learning Model explicitly calls for the increased use of virtual training, as this class of simulation allows the Army to maintain Soldier proficiency in critical skills at reduced cost (Stafford & Thornhill II, 2012).

While the current employment of SBT is typically conducted in a stand-alone manner, a relatively new approach the Army is adopting uses persistent virtual environments for training, where these environments are defined as "persistent immersive simulated environments in which a participant uses an avatar (a digital representation of oneself) to interact with digital agents, artifacts, and contexts" (Dawley & Dede). One of the unique qualities of employing virtual worlds for training is the true distributive nature of the training for Soldiers. Distributed training represents a potential major cost reduction to military training as users may train together without having to be physically co-located (Dutta, 2013; Stafford & Thornhill II, 2012). This in turn has attracted intense interest from the Department of Defense (DoD) and has led the Army to be an early adopter of virtual worlds for training (Schulzke, 2013), even as the technology is still relatively immature and evolving (Lele, 2013).

As previously described, virtual world training is still an emerging technology for military training. This is evidenced by the absence of any embedded instructional strategy (Vogel-Walcutt, Fiorella, & Malone, 2013) and training effectiveness framework (Landers & Callan, 2012) for this domain. However, recent advancements in simulation technology have enabled the rendering of sufficiently realistic virtual world environments that may support effective training (Wong, Nguyen, & Ogren, 2012). In light of the state of technological maturation for virtual worlds, and the associated paucity of research examining its training effectiveness, this research effort initiates a systematic examination of virtual world simulation's training effectiveness.

BACKGROUND

MOSES Project

The Human Research and Engineering Directorate (HRED) of the U.S. Army Research Laboratory (ARL) has established the Military OpenSimulator Enterprise Strategy (MOSES) project to identify key features, strategies, and conditions that comprise effective virtual world SBTs. The goal of the project is to influence the design of future SBTs with lessons uncovered from research that will maximize the efficacy of military training in simulated environments. To accomplish this goal, the MOSES project has focused on two main objectives: to both analyze and extend the development of an open-sourced virtual world and to examine the training effectiveness of virtual worlds. These objectives introduce and assess novel technological innovations in virtual environments (VE) for feasibility, appropriateness, and accuracy.

The purpose of the MOSES project is to explore alternate SBT applications and architectures. The virtual world research performed by the MOSES project employs a number of different VEs to study training effectiveness. MOSES is used to study and respond to U.S. Army training capability gaps and requirements, outlined in the U.S. Army's Capstone Concept 2012 (TRADOC PAM 525-3-0), which describes a need for a future, home-station training system that emphasizes the criticality of dismounted infantry soldier skills.

The overall MOSES project goal is to determine if SBT is more or less effective than traditional live training methods. While it may not be reasonable to expect virtual training methods to completely replace live training, it is possible that augmenting live training with virtual may reap tremendous benefits. This paper discusses a data collection activity which took place over a period of five months at the Florida Army National Guard’s 211th Regional Training Institute (RTI), located at Camp Blanding, Florida. The SBT platform utilized in this study was the U.S. Army’s VE program of record, Virtual Battle Space 3. The RTI’s Warrior Leader Course already utilized existing VBS3 content and training material, so it was appropriate to use their existing apparatus in this study.

To date, the MOSES project has produced several noteworthy contributions to the SBT community. These contributions include a standard method for measuring simulator performance (Mondesire, Stevens, & Maxwell, 2015), techniques that increased supported echelon-levels in virtual world simulation (Mondesire, Stevens, & Maxwell, 2015), and a mechanism that introduced state-of-the-art software components that enhance the realism of VEs (Maxwell, Geil, Rivera, & Liu, 2014). With these contributions and ongoing research, the project continues towards satisfying its goal of seeding future SBTs with valuable lessons and effective features.

Virtual BattleSpace 3/Game-based Training Effectiveness

Virtual Battlespace 3 (VBS3) is a flexible gaming simulation platform currently utilized by the U.S. Army for training Soldiers on tactics, techniques, and procedures prior to entering the operational environment. Game-based training (GBT) simulations, such as VBS3, have been recognized by The U.S. Army Training and Doctrine Command (TRADOC) as viable training solutions for both individual and collective military tasks. As budget constraints continue to arise, GBT becomes a low-cost alternative to traditional classroom-based instruction. In addition to reducing costs, these environments have numerous training benefits, such as scenario variability, ease of deployment, and after-action-review capabilities. They also offer a high degree of realism, necessary to create the appropriate level of fidelity for learning (Chalmers & Debattista, 2009; Lukosch, van Nuland, van Ruijven, van Veen, & Verbraeck, 2014). Despite the value of GBT, there still remains a lack of research investigating the effectiveness of GBT and VBS3 for training.

Live Simulation Training Effectiveness

The DoD has historically relied upon live training to train its servicemembers, leaders and formations. However, technological advancements made in this century have improved the realism of training simulation such that the optimal balance between live and virtual simulation training is being analyzed continuously (Schank, Thie, Graf, Beel, & Sollinger, 2002). In many instances, live training is simply not feasible due to safety, cost and other resource constraints (Boese, 2013). However, when possible, live training supplemented with simulator-based training, has generally been found to be effective in the transfer of training (Boese, 2013).

Live simulation training has been found to be effective in the transfer of learning and training. Mishkind et al. (2013) empirically demonstrated live simulation's training effectiveness in the medical domain through the use of a simulated medical clinic whereby a deploying unit successfully prepared for their deployment mission by executing live simulation scenarios they would face in theater. The authors determined one of the strengths of live training is the hands-on component to task training associated with this class of simulation. Hamstra et al. (2014) analyzed recent simulation best practices and determined that the method of training may have more of an effect than the degree of simulator fidelity in the optimization of the transfer of training and learning. Whitney, Temby and Stephens (2013) found live training to be more effective than virtual training in infantry fire team attack training, when performance was measured in a live transfer condition. The authors also determined live training resulted in improved performance within condition; in addition to significantly better performance when compared between conditions.

Increasingly, the literature supports the notion that blended simulation training may be more effective than conducting training in one singular class of simulation. Reitz and Richards (2013) determined that dismounted squads rehearsing a collective urban mission in a virtual training condition performed as well as squads that rehearsed in a live training condition, but had better communication and situational awareness skills. Fautua et al.'s (2014) longitudinal study empirically demonstrated higher learning was achieved using a blended (i.e. virtual and live) experimental condition when compared to a control condition (live only) in a classroom-type setting. Blended simulation, in the form of live, virtual and constructive (LVC) simulation technologies has also become increasingly common in the test and analysis of various military concepts, weapons systems and other platforms (Hodson & Hill, 2014).

Workload

The use of LVC technologies can increase the effectiveness of training by measuring human performance. Human performance assessment quantifies perceptual survey data such as situational awareness, decision making and workload. Past studies evaluating workload measures have been limited to lab-based experimentation and rely even less on live simulation (Hill, et al., 1992; Cao, Chintamanj, Pandya, & Ellis, 2009). The significance of measuring workload using live simulations promotes a realistic, operationally relevant environment for performance assessment. This research initiative differs from previous studies because it assesses workload in both virtual and live simulation. Specifically, this paper examines the comparison between the two conditions (i.e., virtual and live) in order to explain the effects of the simulation on perceived workload. The measurement survey selected to assess workload analysis was the NASA-TLX survey.

NASA-TLX

The NASA-TLX survey rates perceived workload experienced by an individual or team across six dimensions to assess effectiveness, performance, or task results. The six dimensions of the NASA-TLX include mental demand, physical demand, temporal demand, effort, performance and frustration (Hart & Staveland, 1988; Stanton, Salmon, & Walker , 2005). Mental demand refers to the amount of mental and perceptual activity required to complete the task. Physical demand focuses on the intensity of the physical exertion necessary to complete the task. Temporal demand examines the time pressure for accomplishing the required task. Effort refers to the amount of work needed to sustain the level of performance during the task. Performance indicates the level of success in accomplishing the task. Frustration determines the level of insecurity, discouragement versus security, or contentment experienced during the task. The NASA-TLX can be administered using a pencil and paper or via computer. Due to the dynamic nature of the experiment, the NASA-TLX pencil and paper version was administered to the participants.

METHODOLOGY

Participants

98 U.S. Soldiers, in the rank of Specialist or Sergeant, participated in this experiment. Each participant was an enrolled student in the U.S. Army's WLC located at Camp, Blanding, FL. The WLC is a 22-day experiential learning course that serves as the Army's junior, non-commissioned officer (NCO) leader preparatory course. Graduation of the WLC is mandatory for aspiring Soldiers to become permanent NCOs. Participants were randomly assigned to one of two treatment groups and had an average age (n = 98, M = 27.7, SD = 4.7) and years in service (n = 98, M = 6.0, SD = 2.6).

Research Objective

The purpose of this research was to examine the training effectiveness of a virtual world framework within an operationally relevant task domain and environment. The method employed was an empirical assessment of the degree of training transfer of the experimental (virtual world simulation) condition in comparison to a control (live simulation) treatment. We evaluated the simulation using Kirkpatrick's model for evaluating training programs. This research examined both Level I (Reaction Criteria), which is an evaluation of the participant's reaction to the training program as well as Level II (Learning Criteria), which is whether or not there was an increase or decrease in the student's knowledge or capability as a consequence of using the simulation. For this study, Level I assessment was conducted using a variety of individual-level, validated questionnaires and surveys, representing the focus of this paper. Level II analysis examined whether or not there was a quantitative difference discovered in collective performance, as measured in a transfer condition, between treatment groups. Our Level II analysis examined collective performance at the squad echelon, results of which will be published in the future. The evaluation approach taken is congruent with Kirkpatrick's model, and allows us to comprehensively measure the training effectiveness of a virtual world simulation in comparison to a live control treatment, using both objective and subjective measurements of performance. Results of this study will be used in the future to guide simulation practitioners in the optimization of human performance using training simulation.

Design of Experiment

The experiment was conducted at the WLC located at Camp Blanding, FL using course participants as our sample. Data collection occurred over a period of five months, representing results from five discrete rotations of the WLC. The experiment utilized one independent variable - "walk-phase" training condition. Students were assigned to one of two treatment groups in the walk-phase: the experimental condition (virtual world simulation) or the control condition (live simulation). In both conditions, Soldiers executed four collective tasks as a member of a rifle squad. Participants performed these collective tasks in the "walk-phase", with their assigned squad, either using the Army's VBS3 software (experimental condition) or in a local training area (control condition); both conditions supervised by a team of WLC Small Group Leaders (SGLs). The WLC's situational training exercise (STX) lanes represented the "run phase" of the experiment and served as the transfer condition. The "walk-phase" of training occurred on Day 18 of the course and was immediately followed by the "run-phase", executed during Days 19 and 20. Dependent variables included squad performance and individual survey responses. Squad performance (Level II) was measured by the WLC cadre's evaluation and assessment of the squad's execution of the same four collective tasks during the STX lane, using the SGL Evaluation Survey, which we developed for this experiment. The SGL Evaluation Survey consisted of a rubric for each of the four collective tasks, decomposed into sub-performance measures, each of which were scored on a 4-point Likert scale. Survey responses (Level I) included the individual's completion of a Trainee Feedback Survey as well as questionnaires assessing the individual's immersive tendency, presence, simulator sickness, stress and workload experienced.

The four collective tasks employed for this experiment were: React to an Improvised Explosive Device (IED), React to Indirect Fire, React to Near Ambush and React to Far Ambush. These tasks were selected primarily because they composed the majority of the WLC STX lane, could be supported in both treatment conditions and were executable at the squad echelon. The control treatment (Figure 1), consisted of a wooded environment whereby the squads rehearsed the four collective tasks under the supervision of a SGL team. Soldiers donned all of their personal tactical equipment, but this treatment did not utilize opposing forces (OPFOR) or ammunition. The experimental treatment (Figure 2) was conducted using VBS3 as the apparatus; a platoon's worth of gaming stations was located at the post's simulation training center. VBS3 scenarios were constructed by the SGLs and facilitated the rehearsal of the four collective tasks, in a content-rich, dynamic, VE. Virtual OPFOR, ammunition and communications were utilized in this treatment. Finally, performance was measured in the transfer condition (Figure 3) using the rubric developed for this experiment, previously described. The STX lane represented the culminating exercise of the WLC, was a requirement for course graduation and utilized live OPFOR and blank ammunition.

Figure 1: Control Condition (Live Simulation)

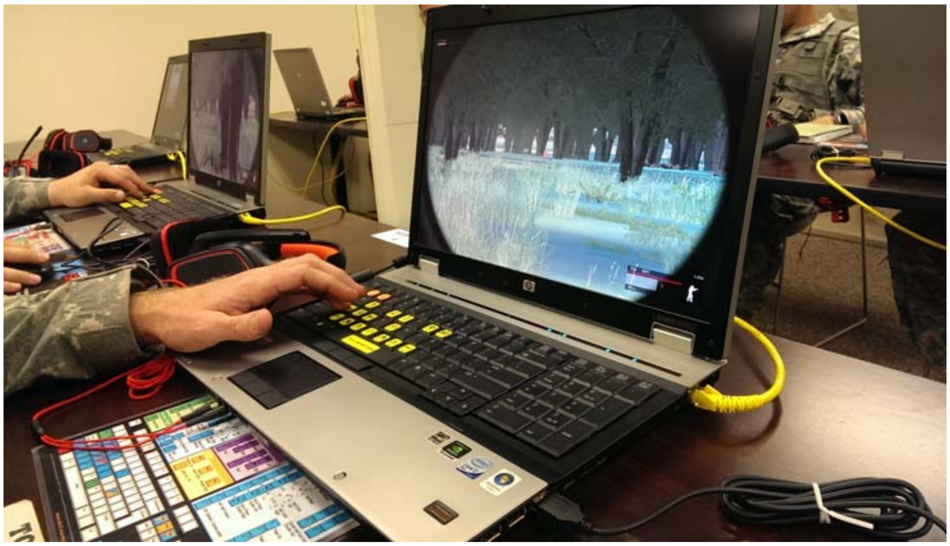

Figure 2: Experimental Condition (Virtual World Simulation)

Figure 3: Transfer Condition (Live Simulation)

This experiment was conducted over a three-day period, repeated every month for five months. On the first day (Day 18), all participants completed their consent forms and demographics survey prior to training. Participants were then assigned to squads, which were in turn randomly assigned to either the control or experimental condition. Squads were then issued a tactical operations order (OPORD) by the WLC SGLs, providing them with direction and guidance on the four collective tasks to be rehearsed in their respective treatments. Once at their assigned treatments' physical location, participants were administered a variety of pre- and post-treatment surveys and questionnaires by research personnel; the results of which will provide us with a solid, comprehensive foundation in which to measure the training effectiveness of both treatments. All squads then converged on the following day (Day 19) to execute the WLC's two-day long STX lane, which tasked all squads to execute the four collective tasks in a live, "run-phase" training setting. The STX lane employed live OPFOR and blank ammunition, similar to an Army Combat Training Center (CTC) rotation.

The focus of this paper are the results of the NASA-TLX survey, which measures an individual's perceived workload. The NASA-Task Load Index (TLX) questionnaire contains six subscales of perceived workload including: mental demand, physical demand, temporal demand, and effort, performance, and frustration levels. The responses were rated in 5-point increments on a 100-point scale (Hart & Staveland, 1988). The NASA-TLX provides an established standard to measure workload that is recognized by many human performance domains.

RESULTS

The purpose of this research was to examine the training effectiveness of a virtual world framework within an operationally relevant task domain and environment. We specifically examined the effect that virtual world simulation had on soldiers' workload, in comparison to live simulation's effect. Perceived workload was analyzed using the NASA-TLX survey, which was administered to all Soldiers, in both treatments, after their "walk-phase" training was completed.

Workload analysis results are depicted in Figure 4. Initial data analysis using the Anderson-Darling goodness-of-fit test confirmed normality in nine of the twelve samples obtained, with the other three samples closely approximating normality. Two-tailed hypothesis testing discovered significant differences in five of the six subscales that compose the NASA-TLX, by treatment. Hypothesis testing indicated a significant difference in Soldiers' Mental Demand scores [$t(93) = 3.05$, $p = 0.003$], Physical Demand scores [$t(95) = -11.27$, $p < 0.0001$], Temporal Demand scores [$t(87) = 2.12$, $p = 0.04$], Performance scores [$t(80) = 4.36$, $p < 0.0001$] and Frustration scores [$t(86) = 4.85$,

$p<0.0001$]. Hypothesis testing found no significant differences in Soldiers' Effort scores [t(88) = 1.08, $p = 0.28$]. Statistical analysis was conducted at $\alpha = 0.05$.

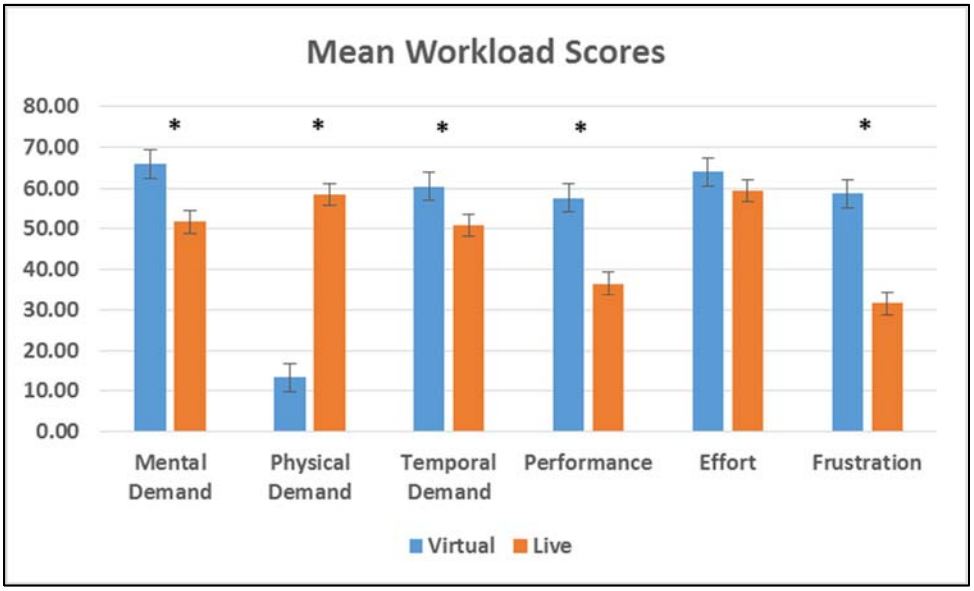

Figure 4: Mean NASA-TLX Workload Scores

Statistical analysis revealed that perceived workload was higher in the experimental condition than the control condition, for five of the six NASA-TLX subscales. No significant difference was discovered for the Effort subscale, by treatment. Workload analysis also revealed overall low to moderate workload scores across all subscales, to include the global workload scale, which is an average value of all six subscales.

DISCUSSION

The purpose of this paper was to initiate our examination and analysis of the training effectiveness of a virtual world framework within an operationally relevant task domain and environment. Virtual world simulation for training represents a novel employment of SBT. The military faces a daunting challenge to both increase the quality of training while at the same time reduce its cost. In order to support this goal, this research specifically examined the effect that simulation class had on perceived workload. Once completed, our comprehensive analysis of the training effectiveness of virtual world simulation (Kirkpatrick Level I & II analyses) will hopefully support DoD's objective to create training that is qualitatively better, easier, cheaper and quicker than it is currently.

Our results were noteworthy. We discovered a significant main effect of simulation class on perceived workload, as evidenced by five of the six subscale results that compose the NASA-TLX survey. Soldiers reported higher perceived mental demand, temporal demand, performance, effort and frustration levels in the virtual world simulation, as compared to the live condition. The only exception were the physical demand results, whereby Soldiers rated live simulation as physically more demanding than virtual world simulation, a not unexpected result. Thus, our results indicate that Soldiers perceived higher required mental exertion, felt more time pressure, expended more effort and had higher task frustration in the virtual condition than the live condition. These results may challenge the notion that virtual world simulation cannot approximate the perceived workload of live simulation.

The Army's declining training budget is forcing the institution to examine whether there are more efficient, effective and cheaper methods to train its Soldiers. While virtual simulation training has proven to be an economical and effective class of simulation, there are still perceptions that must be overcome in order for the force to truly adopt this class of simulation for training. Live simulation will never be truly replaced by the Army; nor are we advocating that position. However, we believe, in part due to the results presented in this paper, that when live training is supplemented with virtual world simulation training, that this technique offers greater benefits than the use of just one class of simulation. While lowering the cost of training is a noble endeavor, this objective requires empirical analyses that examine the effect that different simulation classes have on training effectiveness. This paper initiates a series of training effectiveness analyses the MOSES project will conduct.

This study represents the first of many efforts that will compose our comprehensive examination of the training effectiveness of virtual world simulation. With the Army's fiscal uncertainty, the proper allocation of training resources is a critical issue and thus the correct design decisions must be made for the next generation of SBT devices. Those design decisions must be guided by empirical results that examine SBT's effect on performance, the goal of the MOSES project.

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