Instructional Intervention Effectiveness for Task Activities in Virtual Environment Training

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ABSTRACT

Virtual Environments (VE) afford numerous benefits over "real world" training, including greater instructional flexibility and performance assessment. VE simulations allow instructors to enhance environmental stimuli and provide specific immediate feedback in teaching specific skills or patterns of behavior. The U.S. Army Research Institute has established a research program in VE technology in order to investigate the wide range of potential approaches and application contexts. Different *Instructional Strategies* can provide combinations of different classes of examples, and cuing tactics can provide graphic cues, auditory or textual information. These strategies are implemented through the use of *Instructional Features*. This paper expands the instructional features conceptual framework in VE, and tests specific instructional features for inclusion in future VE-based training programs. Finding the optimal way to impart skill and knowledge in an explicit and directed manner is the major research focus. This initial experiment addressed learning terrain assessment and understanding for movement and positioning, through the use of an attention-direction graphic and a specific within-mission interrogative coaching style, applied during entry-level learning exercises in a completely crossed experiment. The results from the post-training test exercise found that with one of the cognitive-based evaluative activities the interrogative coaching was significantly better than the no-coaching condition. The attention-direction graphic did not provide significant improvement over the no-graphic presentation condition, during the test exercise. This indicates that for initial learning of different types of complex activities, different instructional tactics and features can provide significant advantages, but much remains to be learned about the optimal use of different strategies, tactics, and instructional features. A follow-on experiment using a different graphic, a different coaching style, and different presentation tactics will also be described. The results of these experiments will provide information for training guidelines incorporating instructional features in the wide range of training environments envisioned for the Future Force.

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INTRODUCTION

U.S. Army soldiers are tasked with a growing number of different, and difficult, requirements. Dismounted soldiers, in particular, must possess knowledge and skills that can be applied almost instantly to survive and excel in warfare operations today. Improved training for dismounted soldiers is therefore a main thrust of the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI). One approach that has already proven effective for training is the use of virtual environment (VE) simulations to teach new skills and allow soldiers to practice these skills in an interactive, dynamic fashion. VE simulations afford numerous benefits over traditional, "real world" training programs. These include greater flexibility to alter environments and mission conditions, and superior performance assessment abilities as VE systems are well suited to capture and store performance data. An example is the Virtual Sand Table; a computer-generated version of the traditional sand table exercise which gives personnel the opportunity to practice military doctrine in a hands-on manner (Wisher, Macpherson, Abramson, Thornton, & Dees, 2001). VE simulations also allow for the use of instructional strategies and features that are unavailable, or difficult to implement, in a real-world setting. For instance, instructors can enhance environmental stimuli with computer-generated images in order to teach specific skills or patterns of behavior.

ARI's Simulator Systems Research Unit (SSRU), supported by the University of Central Florida Institute for Simulation and Training (IST), has established a research program in VE technology in order to investigate a wide range of potential training applications. The program goals are to "improve the Army's capability to provide effective, low cost training for Special Operation Forces and Dismounted Infantry through the use of VE technology and ICS [Individual Combatant Simulation]" (Knerr et al., 1994, pp.10-12).

One current focus in this program of research is to find specific ways to enhance the training effectiveness of VE systems for dismounted soldiers and small-unit leaders. The goal is to address VE-specific capabilities that can enhance learning and skill levels for important or critical dismounted small unit leader tasks. This approach is particularly important because of the increasing cognitive loads being imposed on the squad and platoon leaders through the Land Warrior and Objective Force Warrior programs (National Research Council, 1997). Learning to execute activities that are repetitive within the most significant infantry missions is key to the success of those missions, and will be even more important as the information load of the small unit leader increases. One way to keep technology-based increases in information flow within the cognitive resource bounds of the small unit leader is to reduce the load required for successful performance of other, ubiquitous activities through improved training. Serendipitously, the best way to research improved training within the increased technology context is also through the use of VE systems that can represent unfielded equipment configurations. The purpose of this paper is to present an initial outline of our research rationale, initial experiment, and first results. The rationale for investigating VE-based directed learning is presented next.

Instructional Interventions in Training

VE-based training is constrained by many factors. Because VE-based instruction will continue to be relatively expensive for the foreseeable future, the focus in this effort is on initial skill training. The goal is to efficiently move someone from declarative knowledge (being able to answer questions about the rules or concepts) through slow and minimally competent, essentially correct performance to faster, more competent, and less effortful performance. In psychological terms, this means moving the learner from the declarative knowledge state into a procedural knowledge state, and from more effortful and error-ridden controlled processes toward automaticity in a perceptual-motor based decision-making task.

The approach is to identify instructional strategies and features, used in non-VE domains like academia, industry, and certain military training programs and then examine their potential for use in VE training systems. The first step was to identify a group of common small group leader tasks, based on an assessment of activities necessary for US Army operations, as likely candidates for enhanced VE-based training with instructional features. Second, informed by empirical findings and theoretical work, define and categorize instructional strategies and features to provide a reasonable degree of order and clarity to literature in the research. That overall review is not presented in this paper, although elements are briefly introduced. Third, we identified several instructional features that were judged by developers and researchers to be promising for improving the effectiveness of VE-based training within an instructional strategy. Finally, we implemented one of these features and tested the instructional feature, within the constraints of a commonly used instructional strategy, as applied to several small-group leader planning tasks.

Based on Jacobs et al.(1994) comprehensive review of military tasks amenable to representation in VE systems, we abstracted a number of tasks and activities into three, higher-order groups of critical functions. These three groups are collectively referred to as Position/Maneuver expertise (PME) and are integral to the critical missions identified in the National Research Council report (1997). The three groups incorporate both perceptual-psychomotor and cognitive aspects, as identified below.

1. <u>Enemy Position</u>: refers to knowledge and awareness of enemy locations and firepower capabilities (type, range, threat zone, etc.).

2. <u>Own Position</u>: refers to knowledge and awareness of trainee's fellow soldiers, troops, and other assets (artillery, tanks, etc.).

3. <u>Access Identification</u>: refers to knowledge and awareness of avenues for logistics support (MEDEVAC, supply vehicles, other troops). For example, evaluating if a helicopter could land in the area and identifying events that could prevent or threaten access.

These types of tasks are complex, require visual and auditory stimuli based on terrain and environmental effects, and can involve dynamic interaction with other forces and personnel. The development of expertise in these areas requires interaction in performing the tasks within varying scenarios that foster efficient repetition of complex skills. These characteristics are well suited for VE-based training. There are three tasks that require a small unit leader to plan and direct collective performance that are solidly based in these expertise groups. They are: planning a bounding overwatch movement, positioning a helicopter landing zone, and selecting observation/fire post positions.

Two knowledge types are utilized in each of the above areas and our proposed tasks: declarative and procedural knowledge. In brief, declarative knowledge refers to knowledge of facts, schemata and propositions, or the *what* of the task, whereas procedural knowledge concerns *how* to do the task. For example, a soldier learns the basic procedures of securing a building, such as search patterns and movement protocols, through textbooks and coaching instruction. This declarative knowledge is then called on when the soldier converts the declarative into procedural knowledge by physically practicing searching and securing a building, for example during standard field training exercises. Although Bounding Overwatch (BO), positioning a helicopter landing zone (LZ) and positioning observation/fire posts (OFPs) are relatively easy to present in declarative form, they are much more difficult in terms of reaching procedural performance proficiency. These tasks clearly fall into the three PME groups presented above.

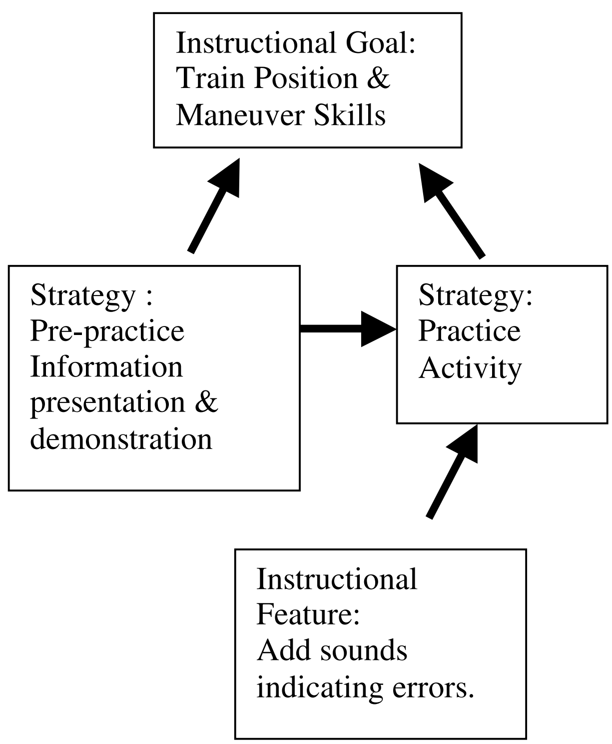
The distinction between declarative and procedural knowledge is important because different training approaches are needed for each type. Wickens (1992) argued that study and rehearsal are best suited for teaching declarative knowledge. Furthermore, successful students, like successful soldiers, generally use procedural knowledge almost immediately with little thought or diversion of attentional resources. The situationally-correct rapid and non-effortful application of procedural knowledge, or *procedural automaticity*, should therefore be the ultimate goal for any procedural training program. Soldiers must be able to collect information from the environment, assess the meaning and importance of the information, and immediately choose the optimal course of action.

Unfortunately, reaching procedural automaticity is a challenge. Although extended practice is necessary to produce automaticity for most tasks (Logan & Klapp, 1991; Palmeri, 1997), simply increasing practice duration is not sufficient (Fisk, Ackerman, & Schneider, 1987). For practice to be effective, stimuli from the environment, and rules governing responses, must be *consistently* mapped to a response (Fisk, Hodge, Lee, & Rogers, 1990; Logan, 1988). In cases when rules or procedures vary from one practice session to the next, automaticity will develop more slowly, if at all.

Training and mission rehearsal in a relatively complex VE system fits the requirements outlined above, and can help train soldiers to achieve procedural automaticity of the important skills. However, given the obstacles to achieving automaticity, doing so will require the use of strategies and techniques that both optimize the learning environment and ensure that procedural knowledge is consistently mapped, or related to, appropriate actions. We therefore examined literature related to instructional strategies and features used to support such strategies, to identify several promising approaches that could be used in future VE-based training programs.

Relationship Between Instructional Goals, Strategies, & Features

In order to frame our research approach and initial experiment, a few concept definitions must be established. However, a complete review of the



literature, and development of a

Figure 1. Example Relationship of Instructional Features and Instructional Strategies in supporting Instructional Goals

taxonomic structure is beyond the scope of this paper and therefore will not be presented. Directed learning is the purposeful transfer of information, knowledge, skills, abilities, and/or attitudes from one source (e.g., instructor, computer software, simulation, or other system) to an individual or group (Hays, 2001). For almost all directed learning approaches, there are three main components, as shown conceptually in Figure 1. First, there is the overall objective, or the *instructional goal*. Second, to achieve a specific instructional goal, directed learning programs must have one or more explicit approaches, or instructional strategies — organized method(s) or tactic(s) for conveying information, knowledge or skill to an individual or group. Finally, there are the tools and techniques that instructors can use to support and implement the instructional strategy. Methods for altering the normal experiential flow are identified as the *instructional features* (IF).

A number of IFs can be used to support or aid specific instructional strategies. These features can be categorized based on their characteristics. The categories are most relevant and useful when addressing simulations, whether for training or skill maintenance. The categories are **Adjunct Stimuli** and **Naturalistic Augmentation**, and are based on whether the stimuli are inherent in the task or event information presentation (based on Boldovici, 1992). Practice with actual equipment in the real environment or in high fidelity simulations will present the critical initiating, guiding, and correct-performance reinforcing stimuli for every required activity. Declarative presentations should identify these stimuli so that the learner can correctly attend to and use them. **Adjunct** cues or stimuli are those that do not normally belong in the target task environment. The insertion of something new into the stimulus flow, which calls attention to or makes more salient the important initiating, guiding, or reinforcing stimuli is classified as an adjunct instructional feature. In general, this category relates to stimuli or IFs implemented during performance of a training task. The **Naturalistic Augmentation** category concerns to what degree the feature imitates or has the appearance of naturally occurring stimuli within the real world task. **Augmenting** an initiating, guiding, or reinforcing cue means manipulating the normal sensory characteristics to make them more or less noticeable or salient (Boldovici, 1992). Note that changing the time course of a stimulus would place the stimulus in the Naturalistic Augmentation category, because there is a natural pace to stimulus events in reality. Most IFs are classified as adjunct because, by their very nature, the features add to the natural environment in order to improve training.

There is also a **Temporal** aspect to IFs, which concerns *when* the IF is applied; before, during, or after a training task or subtask event. For example, Park and

Gittleman (1995) compared Dynamic Visual Displays (DVD) with Static Visual Displays (SVD) to help students form mental models of electronic circuits. In using either display as an instructional feature, the display could be presented before, during, or after the presentation of the declarative information. As an example, an adjunct tone IF could be presented just prior to detected error commission, concurrently with commission of an error, immediately after an error is committed, or even later when the activity during which an error was committed runs to completion.

Task Activities & Instructional Interventions

Exercising the three selected tasks (BO, LZ, and OFP) requires several environments in which to practice non-repetitious environment inspection and decision-making. The VE simulations of McKenna and Shugart-Gordon Military Operations in Urban Terrain (MOUT) sites were used to provide these differing exercise scenarios. Using the VE system allows implementation of a candidate adjunct IF, as discussed above and illustrated in Figure 2. As the primary aspect of the three expertise groups and the three selected tasks concern evaluations of the environment for potential enemy positions, and the placement of positions in response to those evaluations, an attention-direction feature was judged appropriate. While there are many

Figure 2. Example of ARROW IF in Shugart-Gordon MOUT VE

ways to add stimuli to an environment in order to attract or direct attention, one of the easiest to implement for experimental purposes was a simple arrow, as shown in Figure 2.

The Arrow IF (see Figure 2) was designed to always appear at the bottom of the visual field in a helmet-mounted display, and point toward the position selected by the Experimenter / Instructor. This is a generically applicable instructional feature, and since instructional features are always applied within some instructional strategy context, the strategy applied in the experiment was used as the other factor in the investigation. The instructional strategy (IS) was also chosen to be relatively generic, and easy to implement. One of the most ubiquitous strategies is individual coaching feedback (an indication that an error was committed, with information about the type of error and rule for correct performance). Even within this strategy of coaching feedback, there are time- and performance-linked aspects. Given the wide variety and conditions in which coaching could be used, it seemed least confounding to use the most basic approaches possible. The most obvious control condition is no coaching at all, and when no IF is presented this provides a pure control condition. This design also allows the arrow feature to be used without coaching, for a direct measure of possible training effect. Following this line of argument, the coaching condition was designed as a performance error linked interrogative protocol. The provision of coaching was limited to the initial error in each of the three mission phases (BO, LZ, or OFP placement). The coaching feedback was also used during the After Action Reviews (AARs) that followed each mission, in addressing only the most critical error detected in each phase. In this way, even the control condition participants received critical feedback for each phase of the mission following each of the three training missions. The fourth mission in the sequence was used as the test mission, and no training manipulations were applied during that mission.

METHODS

Thirty-two participants were recruited from the University of Central Florida student population, and paid or given class credit for participation. The average age of participants was 20.59, and there were 9 females and 23 males.

Apparatus

The VE scenarios were rendered on a computer-based system consisting of linked PCs. MotionStar[tm] sensors were used to track participant's physical movements, and Virtual Reality VR8[tm] head mounted displays (HMD) presented head-slaved, computer-generated, stereoscopic color imagery to the participants. Stereo sound for object collision and gun shot noises (paint and small arms) was provided through earphones attached to the HMD. The software was written by IST using Performer, C++, and Java.

The Arrow IF, designed by programmers at IST, was controlled by the experimenter. After an adequate time during which participants failed to look at a critical locations, the experimenter would select the location by using a mouse-arrow and menu, causing the IF arrow to appear in the lower portion of the participant's Field of View, with a changing orientation always pointing toward the selected location of interest. The arrow remained in the FOV until the participant shifted their gaze to within a minimum deviation from the target location and maintained gaze for approximately one second.

Procedures

Background information about the participants was collected using a simple biographical questionnaire. Within the SSRU research program, there are two ongoing themes of investigation that are normally pursued through questionnaires that are administered before, during, and after the experimental procedures. The questionnaires include the Simulator Sickness Questionnaire (Kennedy, Lane, Berbaum, & Lilienthal, 1993), along with the Immersive Tendencies and Presence questionnaires (Witmer & Singer, 1998). As is required for ethical treatment of experimental participants, the purposes of the research was explained to each participant, their questions were answered to their satisfaction, and their agreement to participate in the research was recorded on standard experimental permission sheets before the experiment training and exercises begin.

Each participant was trained to a test criterion on the requisite VE and military tasks. The training began with simple movement techniques in the VE, and the use of a virtual paint gun for marking placements in the VE. The U.S. Army rules and doctrine for movement, posting, and selection of a landing zone were also taught. Participants were also taught how to read topographical maps; interpreting the markings for roads, clearings, flowing water, and other obstacles from the maps of the virtual databases. Participants were tested on correct knowledge of features, and application of rules, before being allowed to participate in the VE exercises.

The map and VE exercises were the central episodes in the experiment. First, the mission goal was briefed to the participant, and a map of the exercise area presented. The participant was then allowed approximately five minutes to use the map for planning the platoon's bounding overwatch positions, rally points, etc. to a selected landing zone. The landing zone was marked on the map, and a required minimum of two observation/fire posts (OFPs) were identified for protecting the landing zone. No additional instruction or feedback was provided during the map portion of each mission. After completing an SSQ, the participant entered the VE and moved through the database in order to perform the same planning tasks as those performed on the map. The time allowed in the VE was limited to twelve minutes, in order to insure minimal potential for simulator sickness by the participants. As a result, not all participants finished all phases of the planning exercises during the VE exercises. After exiting the VE, the participant completed another SSQ (monitoring for debilitating effects of VE exposure), and an after action review (AAR) of approximately five minutes duration was provided (see discussion above for general guidelines). During the AAR only previously uncorrected errors (to prevent repetitive discussion of errors already noted during the mission) were called out, and the participant was asked to explain the decisions or actions made. Only the most critical of these errors from the three mission tasks were presented for discussion, one for each task during each AAR. The AAR of critical errors with coaching is the only "instructional feedback" that the no-coaching and no IF group experienced.

Each participant proceeded through four map and VE exercises during the experiment (with the scenarios being presented in counter-balanced order), following the same process and protocol. After the initial VE training, as well as the first and last experimental exercises, the participant completed a Presence Questionnaire. No AAR was administered after the last VE mission, as there was no succeeding mission on which to gauge learning. Participants were kept onsite for at least 20 minutes after the final exercise, and a final SSQ was then administered to insure that there were no lingering effects from the VE experience.

RESULTS

Repeated measures analysis of variance (ANOVA) of the four repeated missions found significant improvements in Bounding Overwatch performance over the four missions, but no other significant effects. As this only confirms that humans learn with repetition, no further analyses over all the missions will be presented in this paper.

A Multiple ANOVA was conducted on the overall performance ratings for the three mission phases conducted during the fourth (test) mission, and the percentage of building inspection time during the test mission. Results indicated that participants given Coaching (m=34.902) performed significantly better on the overall bounding overwatch performance than No-Coaching participants (m=33.474,) $F(1,28)=7.506$, $p=.011$). No significant results were found for the overall LZ or OFP performance, nor for the total building inspection time during the mission.

CONCLUSIONS

The primary goal of this research was to assess the benefits of two VE-based instructional features; interrogative coaching and a simple, direction-indicating arrow. The coaching feedback condition was intended to provide a framing context for any significant effect found from use of the Arrow IF. A decrease in errors and increase in accuracy can be taken as evidence of learning, when found over the repeated exercises. Increased support for the IF and/or IS would be provided if one or more of the instructional treatments demonstrated a more rapid learning process than the "control" condition of no coaching and no instructional feature. This was not found, and the initial conclusion must be that the Arrow IF did not increase the effectiveness of the training. Reasons for this may include: (a) the feature itself did not assist as anticipated; (b) there was a presentation weakness that prevented the expected improvement, (c) there were methodological weaknesses.

Finding a significant effect on BO performance for the Coaching approach during the test mission suggests that the experimental method was appropriate. Not finding this difference in the other two tasks, nor finding a difference with the Arrow IF, led to inspection of those procedures for possible errors. The raw data seems to indicate that more time and effort was expended during the training missions on the BO task, relative to the LZ and OFP tasks, which could bias the performance during the test mission. This would lead to improvement in the BO tasks which was not matched for the other two tasks. The possibility also exists that the application of the Arrow IF was only marginally understood by the participants. It may have been that although the participants most often looked in the arrow indicated direction as they were instructed, that the emphasized need for additional visual inspection during their tasks may not have been completely clear. Finally, it seemed that the time required for the Coaching and Arrow IF interventions during the training missions could have actively taken time and cognitive resources away from the trainees, relative to those in the control condition. This would have left those with the highest level of intervention with less time and resources for actually learning to perform the task, although they could have had improved mental models of the required task performance parameters.

A second instructional feature experiment is being conducted to extend the findings for this first experiment. The design and variables will change as little of the original experiment as possible in order to leverage insights across experiments. However, the following presentation and methodological changes have been made.

1. An additional independent variable will be added to the experimental design - a text window with the appropriate coaching feedback message. Like the other instructional features, the text window appears on command in the field of view immediately after the first error of each mission phase. Similar approaches have proven successful in simulator-based flight training (Skitka, Mosier, & Burdick, 1999; Loftin, Wang, Baffes, & Hua, 1992).

2. The form of coaching feedback to participants will change from an interrogative format, to specific directive feedback in the following format: (a) you have done something wrong; (b) here are the parameters on how to do it right, and; (c) do the task activity again.

3. Strict time limits will be used for each of the three mission phases.

4. The experimenter standardized auditory directive coaching will be recorded and played back in order to provide consistent feedback and instructions. These same directive coaching will be presented in the text window coaching condition (see above) and during the AAR in response to identical critical errors.

5. The length and format of the Arrow IF will change a short arrow in front of the participant to converging lines that extend to the area of interest marked by the experimenter.

6. During the AAR, 5- and 50-meter circles will surround participant marks for BO, LZ, and OFP positions for feedback on distances.

The initial results of this line of research confirm that injecting more information into the virtual training environment does not necessarily translate into better learning performance. The results also indicate that interrogative-style coaching can be beneficial in the initial acquisition of an important environment-evaluation based decision activity. Obviously, care must be taken in using instructional features or performance decrements may result. The results of this and future research will be used to provide implementation and use guidelines for simulation-based training.

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