Effects of Instructional Strategies within an Instructional Support System to Improve Knowledge Acquisition and Application

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Simulation based training requires skilled instructors to provide necessary training. Due to the limited numbers of instructors available, alternative methods of instruction are being investigated. This study replicated previous lab-based studies of instructional strategies (Metacognitive prompting and Contrasting Cases) as applied with military personnel, within the Deployable Virtual Training Environment (DVTE). Participants were randomly assigned to 3 groups, each group receiving either Metacognitive prompts, Contrasting Cases prompts or no prompts, respectively. Results showed 1) no difference between groups on declarative knowledge testing, 2) Contrasting Cases prompts scored highest on procedural knowledge testing, 3) Metacognitive prompts scored highest on conceptual knowledge testing, and 4) Metacognitive prompts scored highest on integrated knowledge testing. Recommendations and future research are discussed.

INTRODUCTION

Despite significant monetary investment and investigative research into the development of simulation-based training systems, most current systems lack the architecture to support embedded instructional interventions to aid learning, and therefore act only as practice and performance platforms. Consequently, skilled instructors are required to provide the necessary training components in order for these systems to be effective. In other words, simulation-based "training" systems can only be utilized as learning *tools* or *aids* rather than stand alone training programs.

Additionally, due to the limited number of instructional experts available to provide training, alternative methods for instruction should be considered. Specifically, it is necessary to investigate if instructional strategies can be embedded in stand-alone training systems and to what level they impact trainees' knowledge application.

Under the Office of Naval Research (ONR), Next-generation Expeditionary Warfare – Intelligent Training (NEW-IT) program, two generalizable strategies that significantly impact learning and could be instantiated into simulation based training environments were investigated: contrasting cases and metacognitive prompting. Vogel-Walcutt, et al. (2010) found that metacognitive prompting during simulation based training improved university students' ability to apply integrated knowledge. A review done by Fowlkes et al. (2009) found significant support in the literature for the use of contrasting cases. This study aimed to replicate these findings with military personnel.

Simulation Based Training

Simulation based training provides a virtual environment that models real-life situations. The goal of this type of training is to immerse the user in a virtual environment that mimics a situation closely enough to draw out real-time reactions (Gonzalez & Ingraham, 1994). Studies have shown that simulation based training (SBT) can facilitate learning better than traditional types of training (Steadman et al., 2006). Additionally, it has been shown to aid in the transfer of knowledge to closely related tasks (Oser, et. al., 1999), making it a natural training environment for the military.

However, the practice that most simulation based training systems currently provide is not generally effective in conveying higher levels of knowledge. In order to train a novice to react properly in a real-life, decision-making situation, conceptual and integrated knowledge must be conveyed. The military has therefore supported research aimed at improving current systems so they can provide a higher level of practice and training. However, with the amount of training necessary for each specific job in the field, the numbers of instructors are not sufficient. The military recognizes that current systems may be called upon to provide training that the instructors do not have time to relay fully. Without improving the instructional architecture of the current simulators, the effectiveness of this training and practice could be minimal. Instructional strategies, such as metacognitive prompting and contrasting cases, when added to the architecture, are hypothesized to improve training to a higher level of comprehension.

Contrasting Cases

Contrasting cases is an instructional strategy that brings attention to the differences between related cases (Loewenstein, Thompson & Gentner, 2003). Learners are asked to compare their solutions to those created by experts. The comparable cases are meant to highlight the differences and similarities that lead to identifying the underlying or specific details and concepts important for achieving expertise. Contrasting cases can be presented to the learner through means of video, text, or animations, and the cases selected are compared through means of lists, sorting, or discussions that identify differences/similarities within the selected cases. Due to the small differences between the cases presented, contrasting cases draws the learner's attention to the errors in procedural and integrated knowledge within the given situations.

Lab-based studies support these findings. Kluger and DeNisi support the argument that feedback during training improves learning (1996). Loewenstein, Thompson & Gentner, (2003) conducted three experiments to test the use of contrasting cases on the application of novel information. In all three experiments, this instructional strategy was shown to aid learners in acquiring and applying the provided information (more specifically, negotiation skills).

Metacognitive Prompting

Metacognition requires learners to be aware of and involved in their personal learning experience (Haller, Child, & Walberg, 1998). Specifically, metacognitive prompting during training encourages trainees to reflect upon how they are learning, identify the information with which they are familiar and which information requires additional attention, and adjust their cognitive resources accordingly (Solomon, Giberson, & Guterman, 1989; Wenden, 1998). In more basic terms, metacognitive prompting focuses the learner on what they already know and what else they need to learn. Thus, because students often have a difficult time distinguishing important information from extraneous noise, metacognitive prompting can improve their efficiency in synthesizing large amounts of information.

In laboratory studies, embedded metacognitive prompting has demonstrated significant improvement in training effectiveness and efficiency (Schraw, 1998; Fiore, Hoffman, & Salas, 2008; Garner & Alexander, 1989). Studies have shown that those who are encouraged to monitor their learning display an improved performance on transfer tasks (Solomon, Globerson, & Guterman, 1989). In a review of previous studies conducted by their lab, Pressley and Ghatala consistently found that students who were encouraged to monitor their comprehension while reading, acquired higher levels of knowledge than those who did not (1990). Further, prompting embedded specifically during training helps the trainee to focus on their proceeding performance and, thus, increase their awareness of misconceptions and incorrect knowledge (Vogel-Walcutt, Fiore, Bowers, & Nicholson, 2009). Together, these data suggest that when metacognitive prompts are utilized in a simulated field setting, higher level learning will be improved.

Current Study

The purpose of the current study was to replicate previous lab-based studies testing these two instructional strategies (contrasting cases and metacognitive prompting) on higher order knowledge and performance with a military sample. The two strategies were integrated into the Deployable Virtual Training Environment (DVTE). Knowledge acquisition and performance were assessed.

Hypotheses:
H1 (Acquisition of Knowledge): The control group (Group C) and experimental groups (metacognitive (M) and contrasting cases (CC)) will acquire similar levels of declarative knowledge, as evaluated by a declarative knowledge test. Group CC will acquire a higher level of procedural knowledge in comparison to the control and metacognitive group.

H2 (Synthesis of Knowledge): Group M will display greater knowledge application in higher level knowledge testing than Group C or Group CC.

H3 (Application of Knowledge): Groups M and CC will perform better in an application testing as measured by an integrated knowledge questionnaire and an assessment scenario in a simulation based training system. Group M is hypothesized to score the highest.

METHOD

Participants

20 individuals participated in the study (6 marine reservists, 7 cadets, and 7 university students; 4 female and 16 male). All were United States citizens and had varying levels of prior knowledge of the subject matter. Participants ranged from 18 to 50 years old, with a mean age of 28.1 (SD=2.5). The number of years served in the military ranged from zero to over ten years (7 participants with no military experience, 5 participants with 1-3 years, 2 participants with 4-6 years and 6 participants with 10+ years of military experience). Participants were recruited through cooperation with local military personnel and through an online recruiting program in the university's psychology department. No monetary compensation was provided to the participants, but the university students received class credit. Participants were randomly assigned to one of the three groups, receiving either metacognitive prompts during training (Group M), contrasting cases prompts following training (Group CC), or no prompts (Group C).

Training Materials

Computer-Based Materials:

- <u>Combined Arms Planning Tool (CAPT)</u> – The CAPT is part of the Deployable Virtual Training Environment (DVTE). The simulator provides a medium in which trainees practice planning the suppression of multiple enemy units using a selection of friendly units.
- <u>Training Tutorial</u> – A narrated PowerPoint presentation instructed participants on how to use the CAPT program. The training consisted of three parts: introduction (Cycle I), training/testing in two levels (Cycles 1 and 2), and assessment (Cycle 2A).

Paper-Based Materials:

- <u>Biographical Questionnaire (BQ)</u> – The BQ questionnaire was used to obtain the demographic information of participants, including gender, age, vision, degree of comfort working with computers, and military experience.

- Prior Knowledge Questionnaire (PKQ) – The PKQ consists of four, lab-developed, free-response questions to determine if participants know of Fire Support Teams (FiST) or the CAPT program.
- Cognitive Load Questionnaire (CLQ) – The CLQ is a self-report, 9-item Likert-scale used to measure perceived cognitive load, or subjective mental exertion, during a task or set of tasks (Paas, Tuovinen, Tabbers, & VanGerven, 2003).
- Declarative Knowledge Test (DKT) –The DKT is a lab-developed assessment, made up of 12 multiple choice questions designed to evaluate participants' knowledge of the FiST, friendly units, and battle situations.
- Procedural Knowledge Test (PKT) –The PKT is a lab-developed assessment that consists of 7 multiple choice questions, and ordering questions to determine participants' knowledge of the procedures for proper planning in a CAPT scenario.
- Conceptual Knowledge Test (CKT) –The CKT is a lab-developed multiple choice test that evaluates participants' comprehension of battle scenarios and planning.
- Integrated Knowledge Test (IKT) –The IKT is a lab-developed assessment, consisting of 8 free response questions about the FiST and the application of their knowledge in theoretical situations.
- Cue Recognition Test (CRT) – The CRT is a lab-developed, timed multiple-choice test that requires participants to identify the most correct plan of action based on images of battlefield situations.

Procedure

Introduction. Cycle I began with participants reading the informed consent, and then completing the BQ and the PKQ. Next, participants completed a pre-test packet, consisting of the DKT, PKT, CKT, IKT, and CRT. They were then asked to complete a CLQ based on the preceding tests. All participants, regardless of group assignment, watched an identical introductory training tutorial designed to introduce the background information for the scenarios as well as instruct participants in the usage of the CAPT program. Participants answered a CLQ after the tutorial and after completing a practice scenario that familiarized them with the CAPT program.

Training. Cycles 1 and 2 comprised the training phase. In each cycle, all groups received a PowerPoint training tutorial followed by a training scenario in CAPT. The experimental Groups' (M and CC) training cycle consisted of the training tutorial. Group M received metacognitive prompting during the training scenario and Group CC received contrasting cases prompting after the training scenario. The Control received no prompts. All groups completed CLQ's after the training tutorial and after the training scenarios.

Assessment. In Cycle 2a, all participants completed the same assessment scenario without prompts followed by a CLQ. Participants then answered a post-test packet identical to the pre-test packet and a final CLQ.

Results

H1 (Acquisition of Knowledge):

All groups will acquire similar levels of declarative knowledge. Group CC will acquire a higher level of procedural knowledge in comparison to the control and metacognitive group.

A 3 (group) x 2 (knowledge tests) multivariate analysis of variance (MANOVA) was conducted to determine the effects of prompting on knowledge acquisition. In support of Hypothesis 1, no significant differences were found between groups on the declarative knowledge test, [F (2, 17) = 2.251, p = .14]. Additionally, Group CC scored the highest on the procedural knowledge test regardless of participant type (student, novice military, experienced military), (see Table 1), but the difference was not significant, [F (2, 17) = 2.072, p = .16]. When comparing the amount of improvement each of the groups displayed from the pretest to the posttest, Group CC showed greater improvement on the procedural assessment in all separate participant types in comparison to the other two groups (see Figure 1).

H2 (Synthesis of Knowledge):

Group M will display greater knowledge application in higher level knowledge assessments than Group C or Group CC.

In support of Hypothesis 2, a one-way analysis of variance (ANOVA) showed a significant difference between groups on the conceptual knowledge test, [F (2, 17) = 4.986, p = .02]. Group M scored higher than Group CC and Group C, but Group CC still scored higher than Group C (see Table 1). This significant effect was still present when results from only cadet and reservist participant types were analyzed, [F (2, 10) = 4.935, p = .03] (see Figure 2).

H3 (Application of Knowledge):

Groups M and CC will perform better in an application assessment as measured by an integrated knowledge questionnaire and an assessment scenario in a simulation based training system. Group M is hypothesized to score the highest.

Including all participant types, Group M scored the highest on the integrated knowledge assessment, followed by Group CC then Group C (see Figure 3). The one-way analysis of variance (ANOVA) showed no significance in these differences [F (2, 17) = 1.36, p = .28]. When the university students were removed, Levene's test revealed that the variances weren't equal across groups; therefore Welch's F was used. No significant differences were found across the groups [F (2, 4.85) = 1.99, p = .24].

Overall, there were no significant differences in the performance in the decision-making assessment scenario. Group CC and Group M both averaged a higher performance than Group C on the assessment scenario in the CAPT/DVTE program (see Table 1). When only the cadet and reservist participants' data was included, this difference increased.

Table 1

Task	Group	Pre M	Pre SD	Post M	Post SD	p-value
Declarative Knowledge Test	Group C	5.50	1.773	9.75	1.165	.14
	Group M	4.75	2.121	8.38	1.408	
	Group CC	5.75	1.893	8.50	1.732	
Procedural Knowledge Test	Group C	10.38	2.875	10.50	4.175	.16
	Group M	11.63	2.669	11.87	2.696	
	Group CC	11.75	2.500	14.75	2.872	
Conceptual Knowledge Test	Group C	3.88	1.959	4.13	1.642	.02 (all)
	Group M	4.50	2.000	6.63	1.923	.03 (cadets only)
	Group CC	4.25	1.893	6.00	.000	
Integrated Knowledge Test	Group C	3.25	1.669	4.63	1.598	.28 (all)
	Group M	3.38	1.061	5.12	.991	.09 (military only)
	Group CC	3.50	1.291	3.75	1.500	

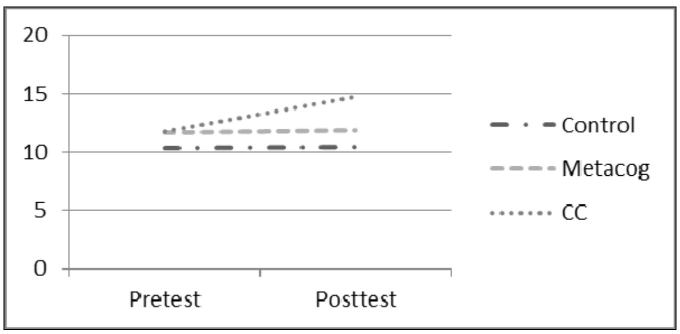

Figure 1. Procedural Knowledge Test (all participant types)

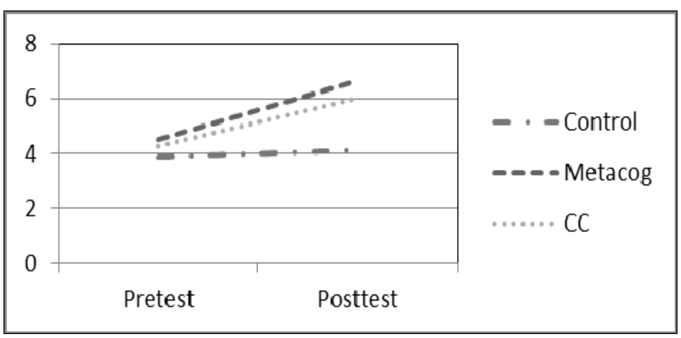

Figure 2. Conceptual Knowledge Test (all participant types)

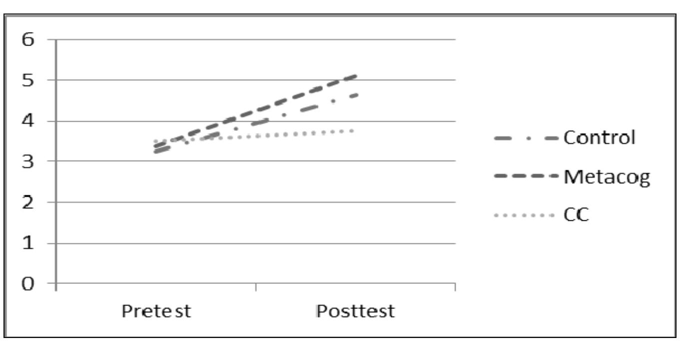

Figure 3. Integrated Knowledge Test (all participant types)

DISCUSSION

The intent of this experiment was to replicate lab based studies of instructional strategies, specifically metacognitive prompts and Contrasting Cases, that have been shown to be successful at increasing higher-order cognitive skills. The results indicate a positive replication of lab-based instructional strategies testing infield but not all results reached a high level of significance. Even when a separate analysis of results was conducted with regard to level of expertise in the domain (cadet/reservist), the same outcome occurred. Together, these data suggest that with military personnel, Metacognitive prompting and Contrasting Cases instructional strategies may be similarly impactful to lab based studies.

Recommendations

Based on this study and previous lab-based studies, it is recommended that when *procedural* knowledge is being taught, the instructional strategy of Contrasting Cases should be applied to facilitate a greater degree of learning. In cases where *conceptual* knowledge is being taught, the inclusion of Metacognitive prompting enables increased acquisition of learning.

Limitations and Future Research

Limitations of this study include a small sample size, variety of personnel, and strategy combinations. First, the low sample size may have limited the statistical significance of the data. It is recommended that a full-scale replication of this study be conducted to lend further support to the findings. Second, a lack of subject variability makes generalizability difficult. More research should investigate the possible differential impacts of these prompts on learners with different expertise levels. Finally, this study did not include both strategies simultaneously in the SBT, and therefore the combined effects of the instructional strategies on the learner should be further tested.

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