Differential impact of two types of metacognitive prompting provided during simulation-based training

Logan Fiorella *, Jennifer J. Vogel-Walcutt, Stephen Fiore

University of Central Florida, Institute for Simulation and Training, 3100 Technology Parkway, Orlando, FL 32828, United States

A R T I C L E   I N F O

Article history:
Available online 10 December 2011

Keywords:
Metacognitive prompting
Simulation-based training

A B S T R A C T

The purpose of the current study was to test the differential impact of two forms of metacognitive prompts on knowledge acquisition and application during simulation-based training. Participants in the experimental conditions were prompted to construct sentences by connecting declarative words (Words Group) or conceptual phrases (Phrases Group) related to the training material from two columns. Performance was then compared across conditions during an assessment scenario that did not include prompting. Overall, results provide support for the effectiveness of metacognitive prompting generally, when compared to the Control Group that did not receive prompting. Further, some support was found for providing word-based prompts over more conceptual phrase-based prompts, suggesting that the phrases may have distracted or overloaded learners. Implications for further investigation into the effects of different types of metacognitive support are discussed.

© 2011 Elsevier Ltd. All rights reserved.

1. Introduction

Simulation-based training (SBT) has become one of the most popular modes of instruction for training complex military tasks, due in part because SBT systems are typically more cost-effective and allow training to occur within a safe, but realistic context. However, in terms of training outcomes, the effectiveness of such systems is much less clear (Bell, Kanar, & Kozlowski, 2008; Salas & Cannon-Bowers, 2001). Further, much of the current research on the effectiveness of SBT has focused on the systems as a whole, rather than the specific individual features that may impact learning (Cannon-Bowers & Bowers, 2009). Thus, in order to optimize training outcomes, SBT development efforts should focus on identifying effective guidance and support strategies that can be embedded within the systems themselves (Bell & Kanar, 2008; Bell & Kozlowski, 2007; Cannon-Bowers & Bowers, 2009). Unfortunately, the current literature regarding SBT does little to identify such features, and consequently, specific guidelines for the development of SBT systems are limited (Bell & Kanar, 2008). Mayer and Johnson (2010) recently recognized this problem within the educational games literature, citing several studies that involve comparing media (e.g., game versus PowerPoint), rather than the value of adding individual features to games that are intended to promote learning. According to Mayer and Johnson (2010), this ‘value-added’ approach is the most effective method for identifying which instructional features are most beneficial to learning, and ultimately, the most useful for establishing research-based guidelines for instructional design. Specifically, this approach involves empirically testing the value of adding a particular instructional feature to an existing media (e.g., simulation and game) by comparing its impact to a control Group that does not receive the feature. Ultimately, this will allow researchers to pinpoint which components of training systems are most effective in order to make practical recommendations to developers.

The purpose of the current article is to apply this ‘value-added’ approach toward investigating the impact of providing varying methods of metacognitive support within a SBT context. For example, metacognitive prompting techniques have been shown to improve learning outcomes within many educational contexts, including questioning, monitoring, reflection, and inference making (Hoffman & Spatariu, 2008). These studies have found that learners who elaborate on learning material may enhance their comprehension monitoring, and result in a greater understanding of the domain (e.g., Chi, de Leeuw, Chiu, & Lavancher, 1994; Chi, Bassok, Lewis, Reimann, & Glaser, 1989; Cuevas, Fiore, Bowers, & Salas, 2004a; Weinstein & Mayer, 1986). The purpose of these interventions was to prompt learners to become aware of their own learning processes and to help them select and implement strategies for acquiring and integrating knowledge.

While these strategies appear to be useful, little research has examined them during complex decision-making contexts within SBT (Georgiades, 2004; Hattie, Biggs, & Purdie, 1996). We build upon prior work that has found evidence for the beneficial effects...
of self-generated elaboration on learning (Cuevas, 2005; Cuevas, Fiore, Bowers & Salas, 2004b; King, 1992; Rosenshine, Meister, & Chapman, 1996; Weinstein & Mayer, 1986) in the context of SBT. As such, the goal of this article is to fill two primary gaps: (1) developing a better understanding of the relationship between metacognition and learning within SBT; and (2) testing the differential impact of two types of metacognitive support within SBT.

1.1. Metacognition and learning

Metacognition has long been studied in the learning and cognitive sciences. At its most general level it is argued to consist of knowledge of cognition and the regulation of cognition (Cuevas, Fiore, & Oser, 2002; Cuevas et al., 2004a; Flavell, 1979; Schraw, 1998; Schraw & Dennison, 1994). Contemporary definitions vary, but they generally revolve around two primary dimensions of metacognition: awareness and regulation (Haller, Child, & Walberg, 1988; Schraw & Dennison, 1994). Contemporary definitions vary, but they generally revolve around two primary dimensions of metacognition: awareness and regulation (Haller, Child, & Walberg, 1988; Schraw & Dennison, 1994). Metacognitive awareness involves monitoring the cognitive processes related to learning, while metacognitive regulation involves continual assessment of one’s current understanding or performance in order to identify and select appropriate strategies needed to maximize learning. In other words, learners high in metacognitive skills are aware of their current understanding of the training material, as well as any relevant skills and abilities they possess, and are able to use this information to regulate cognitive resources toward strategies appropriate for maximizing learning.

Research has shown that these processes are essential for optimal learning and the development of expertise (Hattie et al., 1996; Smith, Ford, & Kozlowski, 1997; Sternberg, 1990). Additionally, metacognition is also considered a domain-independent skill that can be applied across a wide range of domains (Schraw, 1998). For example, positive relationships between metacognition and learning exist across a wide range of domains, including reading comprehension (Haller et al., 1988), language learning (Wenden, 1998) and math and science (Davis & Linn, 2000; Schraw, Crippen, & Hartley, 2006). Metacognition has also been related to measures of general intelligence (Garner & Alexander, 1989). Fortunately, there is evidence that metacognitive skills can be improved, regardless of an individual’s intellectual or achievement level (Schraw, 1998; Swanson, 1990). This has led researchers to investigate methods of promoting metacognitive skills through the use of instructional interventions. And, from the standpoint of SBT, metatheoriticians have noted that such regulatory processes are flexible enough to be applied in preparation for, during the execution of, and in reflection upon, a specific learning event (Fiore, Hoffman, & Salas, 2008; Fiore & Vogel-Walcutt, 2010).

1.2. Metacognitive prompting

A variety of methods for promoting metacognition have been studied, and, although focusing on either awareness or monitoring, they often are described using different terms. For example, such methods include metacognitive cueing (Veenman, Kenseboom, & Ilmthorn, 2000), reflective prompting (Davis, 2003), questioning (King, 1994; Kramarski & Gutman, 2006), self-generated inferences (Wittrock, 1990); self-monitoring or reflection (Kauffman, 2004; Lin & Lehman, 1997), and self-explanations (Chi et al., 1989). Many of these strategies can be grouped within the broader category of metacognitive prompting, which Hoffman and Spatariu (2008) define as “… an externally generated stimulus that activates reflective cognition or evokes strategy use with the objective of enhancing learning” (p. 878). The purpose of metacognitive prompting is to guide learners in the process of identifying the structure of problems, creating connections with prior knowledge, and selecting learning strategies (Mevarech & Kramarski, 1997). It differs from other forms of instructional support, such as feedback, in that it intends to promote self-regulated learning, rather than simply providing information regarding an individual’s understanding or performance (i.e., feedback) Butler, 1995; Mory, 2004. In other words, unlike feedback mechanisms, metacognitive prompting is meant to promote learners’ regulation of their knowledge and skills during training (Cuevas et al., 2004a) rather than awareness of performance alone.

Different forms of metacognitive prompting have been effective across many educational contexts, including math (Kramarski & Gutman, 2006), science (Davis, 2003), and writing (Schardamalia, Bereiter, & Steinbach, 1984). In general, teaching students cognitive strategies for elaborating upon the learning material (e.g., generating questions), leads to gains in comprehension, as measured by standardized and experimenter-generated tests following the interventions (Rosenshine et al., 1996). For example, Cuevas et al. (2004b) found that incorporating queries into computer-based training can improve integration and application of task-relevant knowledge and led to more accurate comprehension monitoring (see also Cuevas, 2005).

However, despite the apparent benefits of metacognitive prompting within educational domains, its applicability to the acquisition of higher-order cognitive skills during SBT has remained relatively unexplored. Further, while effective strategies have been identified, the differential impact of these methods has not been sufficiently distinguished. In other words, the value of adding metacognitive support within various learning environments generally appears to be high; however, it is much less clear which types of this support hold the most instructional value. Thus, research is needed to explore possible factors that may cause differential training outcomes dependent on the type of metacognitive prompting implemented.

Researchers have identified a number of challenges and assumptions associated with providing instructional prompting during training. For example, trainees must first register the cues provided (Butler, 1995). This can be a problem when prompts are viewed as unnecessary or intrusive (Lin & Lehman, 1997), or if the message is distorted due to trainees’ existing beliefs (Butler, 1995). Prompting provided during training also has the potential to distract learners from the primary task (Cannon-Bowers & Bowers, 2009). Therefore, to address these concerns, it is important to consider how best to present metacognitive prompting within SBT so that it is viewed by trainees as useful rather than distracting, and so that it fosters cognitive processing related to learning rather than overloading trainees with too much additional information.

1.3. Learning efficiency

Because metacognitive processes may alter the amount of workload experienced by the learner, we also take into account how our interventions may impact cognitive processes. We utilize measures derived from Cognitive Load Theory (CLT) to examine the interaction between metacognition and workload. According to CLT, the amount of cognitive effort required to acquire information is a function of the learner’s level of expertise and/or the nature of the training intervention and can consequently affect learning (for a full discussion of CLT, see Sweller (1994), Sweller and Chandler (1994)). In the learning sciences, this is often referred to as measures of learning efficiency.

Learning efficiency consists of a composite score of instructional effectiveness and cognitive load (Paas, Van Merriënboer, & Adam, 1994; Tuovinen & Paas, 2004). Instructional effectiveness is operationally defined in terms of performance or the application of knowledge, while cognitive load is defined as the amount of effort required to complete a task. Combining performance and cognitive
load data, a mathematically derived learning efficiency score can be derived that describes how much effort is required for a learner to demonstrate a particular level of performance. For example, Cuevas et al. (2002) showed how the incorporation of diagrams into training materials improves instructional efficiency. In particular, participants presented with task relevant diagrams, not only performed at a higher level on knowledge assessment measures, they did so with less mental effort exerted.

In sum, according to Cognitive Load Theory (CLT), the amount of cognitive load imposed on learners through instructional design can alter their performance level and learning, regardless of previous knowledge (Veenman et al., 2000; Vogel-Walcutt & Nicholson, 2009). Proponents of CLT suggest that analyzing instructional efficiency will improve our understanding of instructional design and support the development of more useful recommendations for training systems (Vogel-Walcutt et al., 2008). This information can help drive instructional strategies aimed at, not only improving knowledge acquisition within SBT, but also to improve cognitive efficiency.

2. Current study

The current study examined the impact of providing two types of metacognitive prompting during SBT. Participants played the role of a military Fire Support Team (FiST) member and were trained on how to execute Call for Fire tasks within a computer-based simulator. Those assigned to one of the experimental conditions were provided with a metacognitive prompt following each decision made during two SBT scenarios. Specifically, they were asked to create sentences related to their training by selecting either declarative words (Words Group) or conceptual phrases (Phrases Group) from two columns. Participants in the Control Group received no prompting. Following training, performance was compared across groups during a simulation-based assessment scenario (that did not provide prompting) and paper-based knowledge tests. To calculate learning efficiency, perceived cognitive load was also measured throughout the experiment.

2.1. Hypotheses

For our hypotheses, the overarching question is how metacognitive processing, operationalized at a general level as prompting driven regulatory processes, influences learning. To examine this question, we replicate and extend the work of Cuevas et al. (2002, 2004b) where metacognitive processes were examined in the context of complex task training. This study intended to test the effects of two forms of metacognitive support on knowledge acquisition and application during SBT: declarative word-based prompts and conceptual phrase-based prompts. Overall, it is expected that providing conceptual-level prompts will better activate the reflective processes required for selecting and implementing strategies during decision making than providing declarative-level prompts. The specific hypotheses tested in this study are presented below:

2.1.1. Hypothesis 1: Knowledge acquisition

Participants in the Phrases Group will perform better on paper-based knowledge assessments than those in the Words Group. Further, those receiving either form of metacognitive prompting will outperform the Control Group.

2.1.2. Hypothesis 2: Knowledge application

Participants in the Phrases Group will demonstrate higher decision-making performance during a simulation-based assessment scenario than those in the Words Group. Further, those receiving either form of metacognitive prompting will outperform the Control Group.

2.1.3. Hypothesis 3: Learning efficiency

Participants in the Phrase Group will demonstrate greater learning efficiency than those in the Words Group. Further, those receiving either form of metacognitive prompting will demonstrate greater learning efficiency than the Control Group.

3. Method

3.1. Participants

Forty-five college students (15 male and 30 female) from a large southeastern university served as participants for the current study. Participants were required to be United States citizens, due to the protected nature of the assessment material, and to have no prior knowledge of the subject matter. The participants ranged in age from 18 to 23, with a mean age of 19.4. Participants were recruited from the psychology department’s on-line participant database and received class credit for their participation.

Participants were randomly assigned to one of three groups. The Control Group received no instructional interventions during SBT. The two experimental conditions received metacognitive prompting during SBT involving either declarative-level, word prompts (Words Group) or conceptual-level, phrase-based prompts (Phrase Group).

3.2. Computer-based materials

3.2.1. Training tutorial

The Threat-Assessment Training System (ThreATS) tutorial is a narrated video presentation that consists of three parts: an introduction and two parts focused on explaining the decisions participants would make while using the USMC’s Deployable Virtual Training Environment (DVTE) simulator. The introductory presentation is approximately ten minutes in duration and begins by describing background information regarding Fire Support Teams (FiSTs), including their purpose and the roles of their specific team members. It then explains the participant’s role in the experiment as the Forward Observer, one member of the FiST. Finally, the presentation demonstrates how the participant is to execute Call for Fire (CFF) tasks within the DVTE, specifically, by using the GPS, rangefinder, and radio sheet features of the simulator. The GPS and rangefinder are used to gather coordinates regarding the participant’s location and the location of targets within the environment. The radio sheet is then used to communicate this information to the FiST leader and call for the engagement of a target.

Part 1 of the training presentation is approximately five minutes in duration and describes the first two decisions that participants make during the simulation-based scenarios. Participants are told they must distinguish between friendly and enemy targets and identify the closest enemy target to their location. These are considered the most threatening targets and must be destroyed first.

Part 2 of the training presentation is approximately 5 min in duration and describes additional, more complex decisions that participants are required to make. First, they are told that targets in their environment may be moving and that they should destroy the closest, moving enemy target. Additionally, participants are told that they should consider specific characteristics of the targets to determine the appropriate ammunition to use. Specifically, they were required to choose the appropriate method of engagement and warning order for each target they decided to destroy.
Participants could choose from two methods of engagement that varied in their cost and level of destruction. Correctly determining which method of engagement to use consisted of choosing the less destructive and less expensive type to destroy vehicles, while saving the more destructive and expensive type to destroy tanks.

Participants also had to choose between two warning order options that varied in their cost and the amount of area the ammunition could cover. Correctly determining which warning order to use consisted of choosing the less expensive ammunition that covered a smaller area to destroy static targets, while saving the more expensive ammunition that could cover a wider area to destroy moving targets.

3.2.2. Decision-Making Assessment Scenarios (DMAS)

The DMAS (Vogel-Walcutt et al., 2008) was used for participants to engage in simulated CFF scenarios. Four scenarios were used in this experiment: a practice scenario, two training scenarios, and an assessment scenario. Each scenario presented participants with a battlefield that contained friendly and enemy targets that were either static (Level 1) or both static and dynamic (Level 2). During the training scenarios, participants received declarative, word-based prompts (Word Group), conceptual, phrase-based prompts (Phrases Group), or no prompting (Control Group) after each time they decided to destroy a target. The prompts asked participants to form sentences using words or phrases from two columns consisting of information related to the training material. For example, participants in the Word Group could choose to form a sentence between the words “FIST Leader” and “Battle Plan” (e.g., “The FIST leader coordinates the battle plan”). Those in the Phrase Group could choose to connect “Destroy closer enemies first” and “bigger threat” (e.g., “Destroy closer enemies first because they represent a bigger threat”). This exercise was repeated by participants after each decision they made during the scenario. Finally, in the assessment scenario, the same format as the Level 2 training scenario was used, but the scenario did not provide prompting to any group.

3.3. Measures

3.3.1. Cognitive Load Questionnaire (CLQ)

The CLQ (Swanson, 1990) is a single-item measure of perceived cognitive load during a task or set of tasks. Participants rate subjective impressions of mental exertion on a 9-point Likert-type scale, ranging from 1, “very very low”, to 9, “very very high”, mental effort.

3.3.2. Procedural Knowledge Test (PKT)

Developed for use in the current study, the PKT consists of seven multiple-choice items designed to assess the extent to which the participant understands the proper execution of a CFF task. One point is assigned for each correct response, with a higher score indicating greater procedural knowledge about the task.

3.3.3. Conceptual Knowledge Test (CKT)

Developed for use in the current study, the CKT is comprised of 18 multiple-choice items designed to assess conceptual knowledge regarding the relationships among members of the FIST, such as which support team each FIST member communicates with and how the tasks are divided among the different members of the FiST. One point is assigned for each correct response, with a higher score indicating greater comprehension of the task.

3.3.4. Integrated Knowledge Test (IKT)

Developed for use in the current study, the IKT is comprised of nine free-response items designed to assess participants’ ability to make accurate inferences by applying their knowledge of the FiST. The questions present situations a FiST member might encounter that are not explicitly mentioned in the training presentations, requiring participants to apply their conceptual knowledge to novel situations. Trained raters using a coding rubric score the IKT. Each item is worth a maximum of three points, with intermediate credit assigned for partial or incomplete answers.

3.3.5. Decision Making (DM)

Decision-making scores were based on performance in DMAS and calculated to indicate overall decision-making skills across the full assessment. Targets were rank-ordered a priori to indicate the best neutralization sequence. This ranking was based on the differential levels of threat of each target (as described in ThreATS). Decisions were scored with increasingly higher penalty points according to this ranking, with the best decisions (i.e., destroying the right enemy target at the right time) acquiring no points, and the worst decisions (i.e., destroying a friendly target) losing as many as sixteen points. These individual scores were then averaged across the number of decisions made. Decision-making was also assessed with regards to how well participants were able to determine the appropriate method for destroying targets. Specifically, participants were required to determine the appropriate Warning Order and Method of Engagement, based on specific characteristics of targets during the Level 2 training scenario and the assessment scenario. One point was assigned for each correct selection out of eight possible correct selections (i.e., both scenarios consist of eight enemy targets).

3.3.6. Learning efficiency

The Paas and Van Merriënboer (1993) method of calculating learning efficiency was used. This measure combines perceived cognitive effort (as measured by the CLQ) with assessments of knowledge application (as measured by the paper-based knowledge tests and assessment scenario). In the equation below, $P$ represents a standardized performance score, while $L$ represents a standardized score of cognitive load:

$$E = \frac{(P - L)}{\sqrt{2}}$$

3.4. Procedure

After providing informed consent, participants completed a biographical and prior knowledge surveys. Participants then watched the introductory ThreATS video and completed the practice DMAS to familiarize themselves with the simulator and CFF task. After the introductory training cycle, participants completed training on the specific decisions required for successfully completing the Level 1 and Level 2 training scenarios. Participants first watched Part 1 of the training tutorial and then completed the Level 1 training scenario. They then watched Part 2 of the training tutorial, followed by completion of the Level 2 training scenario. Participants were given fifteen minutes to complete each training scenario, and the respective metacognitive prompting was provided to those assigned to one of the experimental conditions.

Following training, participants completed the procedural, conceptual, and integrated knowledge questionnaires. They were then
given fifteen minutes to complete the assessment scenario (during which no prompting was provided). The CLQ was administered upon completion of the knowledge tests, and again following completion of the assessment scenario. The total duration of the experiment was approximately ninety minutes.

4. Results

Analyses for all hypotheses consisted of comparisons across conditions (Words Group, Phrases Group, Control Group) using a one-way analysis of variance (ANOVA) and comparisons between the Control Group and both experimental conditions combined (Prompting Group) using independent samples t-tests.

4.1. Hypothesis 1

No significant differences across conditions were found regarding the acquisition of declarative knowledge, $F(2, 42) = .711, p = .50$. However, significant differences were found across groups regarding the acquisition of procedural knowledge, $F(2, 24.60) = 7.73, p < .01$. Post-hoc tests revealed that the Words Group outperformed both the Phrase Group ($p = .05$) and the Control Group ($p = .01$). No differences were found across conditions or between the Prompting and Control groups regarding higher-level conceptual or integrated knowledge acquisition.

These findings suggest that prompting did not impact the acquisition of declarative, general knowledge regarding FiSTs, but significantly influenced the acquisition of procedural knowledge relevant to executing CFF tasks in the simulator. Further, providing declarative, word-based prompts was superior to providing conceptual, phrase-based prompts, suggesting that the Phrase Group may have been overloaded or distracted by the type or amount of additional information present in the prompts. Finally, conceptual knowledge of FiSTs and CFF tasks, as well as the integration of this knowledge to novel situations, did not appear to be influenced by prompting (see Table 1).

4.2. Hypothesis 2

Regarding overall decision making performance during the assessment scenario, significant differences were found across conditions, $F(2, 42) = 4.52, p = .02$. Post-hoc tests revealed that both

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Knowledge acquisition.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measure</td>
<td>Group</td>
</tr>
<tr>
<td>Declarative test</td>
<td>Prompting</td>
</tr>
<tr>
<td></td>
<td>Control</td>
</tr>
<tr>
<td></td>
<td>Phrases</td>
</tr>
<tr>
<td></td>
<td>Words</td>
</tr>
<tr>
<td>Procedural</td>
<td>Prompting</td>
</tr>
<tr>
<td></td>
<td>Control</td>
</tr>
<tr>
<td></td>
<td>Phrases</td>
</tr>
<tr>
<td></td>
<td>Words</td>
</tr>
<tr>
<td>Conceptual</td>
<td>Prompting</td>
</tr>
<tr>
<td></td>
<td>Control</td>
</tr>
<tr>
<td></td>
<td>Phrases</td>
</tr>
<tr>
<td></td>
<td>Words</td>
</tr>
<tr>
<td>Integrated</td>
<td>Prompting</td>
</tr>
<tr>
<td></td>
<td>Control</td>
</tr>
<tr>
<td></td>
<td>Phrases</td>
</tr>
<tr>
<td></td>
<td>Words</td>
</tr>
<tr>
<td></td>
<td>Control</td>
</tr>
</tbody>
</table>

Note: Welch’s F was used due to heterogeneity of variances.

4.3. Hypothesis 3

No significant differences were found across conditions or between the Prompting Group and Control Group regarding learning efficiency (combined performance and cognitive load scores) during the paper-based knowledge assessments or decision making during the assessment scenario (see Table 3).

5. Discussion

This study took a ‘value-added’ approach to investigate the differential impact of two types of metacognitive prompting provided during SBT. First, it was expected that adding metacognitive prompting during training of a complex decision-making task would result in improved knowledge acquisition and application. Second, it was expected that providing conceptual, phrase-based prompts would result in greater decision-making performance than declarative, word-based prompts. The results of this study appear to have confirmed the overall hypothesis that adding
metacognitive prompting, in general, results in greater decision-making performance. However, there was little evidence of a differential effect of prompting type. On two measures of performance (i.e., procedural knowledge acquisition and warning order decisions), those receiving word-based prompts outperformed those receiving phrase-based prompts. This could be because the word-based prompts were less cognitively demanding (i.e., presented less information) and were targeted at lower-level knowledge (i.e., declarative, rather than conceptual), compared to the phrase-based prompts. However, the type of prompting provided did not influence overall decision-making performance or higher-level knowledge acquisition (i.e., conceptual and integrated). Thus, the findings of this study suggest that the method of prompting used (i.e., connecting words or phrases to create sentences) effectively enhanced metacognition and learning, while the type of prompting (i.e., declarative words or conceptual phrases) was much less impactful. In other words, simply creating sentences related to training content appears to be sufficient for activating reflective cognitive processes, regardless of the specific content of those sentences.

However, due to the relatively low sample size, the current study should be considered an exploratory investigation into the potential value of two forms of metacognitive prompting. As such, its findings indicate one potentially effective strategy that is in need of further empirical support in order to verify its instructional impact. Further research is also needed to investigate the instructional value of alternative methods of metacognitive prompting. Writing a sentence during a scenario can be time-consuming and risks learners being distracted from the primary task or overloaded with too much information. Nonetheless, these results are similar to that of Cuevas (2005) who found that incorporating low-level elaboration queries into training resulted in improved integration and application of task-relevant knowledge. But the more complex high-level elaboration queries failed to produce significantly better post-training outcomes. Cuevas argued that this might be due to increased cognitive load imposed on learners during training. Perhaps simply having participants match provided training concepts (rather than generating their own sentences) is enough to activate metacognitive processes related to learning. Finally, research on metacognitive prompting should be conducted across a wide range of domains and training environments to identify the breadth of its impact and any potential limitations of its use.

Acknowledgements
This work is supported in part by the Office of Naval Research Grant N0001408C0186. The views and conclusions contained in this document are those of the authors and should not be interpreted as representing the official policies, either expressed or implied, of the ONR or the US Government. The US Government is authorized to reproduce and distribute reprints for Government purposes notwithstanding any copyright notation hereon.

References


