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The effect of metacognitive monitoring feedback on performance in a computer-based training simulation

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ABSTRACT

This laboratory experiment was designed to study the effect of metacognitive monitoring feedback on performance in a computer-based training simulation. According to prior research on metacognition, the accurate checking of learning is a critical part of improving the quality of human performance. However, only rarely have researchers studied the learning effects of the accurate checking of retrospective confidence judgments (RCJs) during a computer-based military training simulation. In this study, we provided participants feedback screens after they had completed a warning task and identification task in a radar monitoring simulation. There were two groups in this experiment. One group (group A) viewed the feedback screens with the flight path of all target aircraft and the triangular graphs of both RCJ scores and human performance together. The other group (group B) only watched the feedback screens with the flight path of all target aircraft. There was no significant difference in performance improvement between groups A and B for the warning task (Day 1: group A – 0.347, group B – 0.305; Day 2: group A – 0.488, group B – 0.413). However, the identification task yielded a significant difference in performance improvement between these groups (Day 1: group A – 0.174, group B – 0.1555; Day 2: group A – 0.324, group B – 0.199). The results show that debiasing self-judgment of the identification task produces a positive training effect on learners. The findings of this study will be beneficial for designing an advanced instructional strategy in a simulation-based training environment.

1. Introduction

Computer-based training simulation has become a prevalent instructional tool for military training (Bell and Kozlowski, 2007). Researchers have developed various instructional strategies to improve the efficiency of military training systems (Vogel-Walcutt et al., 2013). Providing metacognitive prompts is one of the recent training strategies within complex military contexts (Fiore et al., 2008; Fiorella et al., 2012). In this approach, trainees are provided with prompts that calibrate their understanding of materials related to conceptual and integrated knowledge. Metacognitive prompting is very effective for trainees at the novice and journeyman levels (Vogel-Walcutt et al., 2013). Although the results of previous research are encouraging, continuing studies on this new instructional strategy are needed to obtain further empirical evidence toward improving military training efficiency. To address this need, the present study was designed to identify the learning effects of viewing retrospective confidence judgment (RCJ) resulting from metacognitive prompting and operator action performance (OAP) feedback. After participants performed training scenarios and answered RCJ probes, a feedback screen was automatically displayed on a main monitor. The experiment tested two different feedback screens. One group (group A) viewed the feedback screens with the flight path of all target aircraft and the triangular graphs of both RCJ and OAP scores together. Another group (group B) only watched the feedback screens with the flight path of all target aircraft.

1.1. Metacognitive prompting and learning

Metacognition refers to thoughts about thoughts (Flavell, 1979) or the knowledge and regulation of one's own cognition (Nelson and Narens, 1994). It is related to the ability to monitor and control our knowing (Van Overschelde, 2008). Metacognition consists of three elements: metacognitive knowledge, metacognitive monitoring, and metacognitive control. Metacognitive knowledge is defined as people's declarative/procedural knowledge about cognitive processes. It plays an important role in selecting appropriate learning strategies and managing cognitive resources. The second element, metacognitive monitoring, is the ability to make accurate judgments at the metacognition (meta-level). According to Nelson and Narens (1990), metacognitive monitoring involves the flow of information from cognition (object-level) to metacognition (meta-level). The object-level is the

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view of the ongoing cognitive activities, such as attention, learning, and external objects (e.g., that thing I see is an aircraft). The meta-level is defined as the learners' understanding of the ongoing cognitive processes at the object-level. The last element, metacognitive control, can regulate the ongoing cognitive activities, such as a decision-making procedure regarding the use of new tactics to solve a difficult problem.

Metacognition helps learners develop an integrated learning process related to attention to one's own behaviors, current progress toward a goal, and evaluative response to one's own performance. Recently, the importance of metacognition has received considerable empirical attention in the literature (Boekaerts et al., 2005; Dunlosky and Bjork, 2013; Hacker et al., 2009). Although the definitions of metacognition vary, they focus on two primary dimensions: awareness and regulation (Schraw, 1998; Schraw and Dennison, 1994). According to prior research on metacognition, successful learning often results from participation in the specific awareness and regulation of cognition (Azevedo, 2005; Georghiades, 2004; Hattie et al., 1996; Wang et al., 1990). Learners who are equipped with a high level of metacognitive skills are aware of their current understanding of the training material as well as their own performance. Several studies have shown that a novice trainee's lack of skills reduces his or her ability not only to do a given task correctly but also to accurately judge future performance (Bol and Hacker, 2001; Dunning et al., 2003; Klassen, 2002). These results indicate that the calibration of metacognitive monitoring is a critical component in improving the quality of performance. Different experimental studies have focused on the calibration of metacognitive monitoring (Bol et al., 2012; Chiu and Klassen, 2010). Additionally, researchers have investigated the effects of the calibration of metacognitive monitoring on performance in a computer-based military training simulation (Cuevas et al., 2004; Fiore and Vogel-Walcutt, 2010; Fiorella and Vogel-Walcutt, 2011; Fiorella et al., 2012; Kim et al., 2012; Wiltshire et al., 2014). Although calibration is a major component of the metacognitive learning model (Winne and Hadwin, 1998), there is insufficient information on how to measure the gap between trainees' knowledge and their actions and performance.

1.2. Current study and rationale

The purpose of the present study is to investigate a training effect caused by debiasing learners' RCJs during a computer-based simulation. RCJs are the metamemory judgments that play a role in the regulation of memory. It is a metacognitive monitoring metric associated with retrieval that is commonly used to measure a participant's confidence level regarding responses before he or she knows a performance result (Dougherty et al., 2005). Researchers in metacognitive monitoring have found that most RCJs are either over- or under-confident (Dunlosky and Metcalfe, 2008). Over-confidence is observed when the RCJ score is higher than the task performance. In contrast, under-confidence is found when the RCJ score is lower than the performance. When the RCJ score is equal to the performance, the result is a perfect calibration (see Fig. 1).

People are often overconfident with general knowledge items (Tversky and Kahneman, 1975), a phenomenon called the overconfidence effect, or under-confident when they feel that the task is relatively easy (Gigerenzer et al., 1991).

According to the existing literature, there are two techniques for debiasing overconfidence in RCJs: response-oriented modification and process-oriented modification (Keren, 1990). The response-oriented technique involves providing feedback that informs the trainees about the overconfidence of their RCJs. On the other hand, in the process-oriented technique, the trainees are required to generate reasons for their answers before responding to RCJ probes (Dunlosky and Metcalfe, 2008). These debiasing techniques can affect the calibration in two different ways. First, they can influence the trainees' judgments of confidence. In this case, the trainees set an initial value and adjust from the anchor to develop a judgment of confidence. This is called the anchoring-and-adjustment heuristic (Tversky and Kahneman, 1975). Hacker et al. (2000) compared students' predicted performance before they took an exam and the postdiction after the exam. The results showed that the students' postdicted scores were lower and became less overconfident than the predicted scores. This indicated that the students began with an anchor near the predicted scores and adjusted their judgment downward after the exam. The findings of Hacker et al. showed that the anchoring-and-adjustment heuristic reflects the metacognitive process of debiasing overconfidence in RCJs. The other way that debiasing techniques affect calibration is by influencing not only the trainees' judgments but also their performances. Huff and Nietfeld (2009) found that students who made a habit of calibrating retrospective confidence judgments with test performance improved their calibration accuracy and showed higher confidence on test performance than other students. Nietfeld et al. (2006) also found that feedback improved both metacognitive monitoring accuracy and performance, because the students improved both their performance also showed enhanced calibration associated with self-efficacy. According to Coutinho (2008), the relationship between performance and metacognitive judgments could be regulated by self-efficacy. He found that a person's perceived ability to achieve a successful result and his or her metacognitive judgment influence human performance. Hence, in the present study, the response-oriented technique for debiasing RCJs is used to improve performance because giving feedback about the accuracy of the trainees' RCJs can direct their self-efficacy and attention to the discrepancies between performance and confidence.

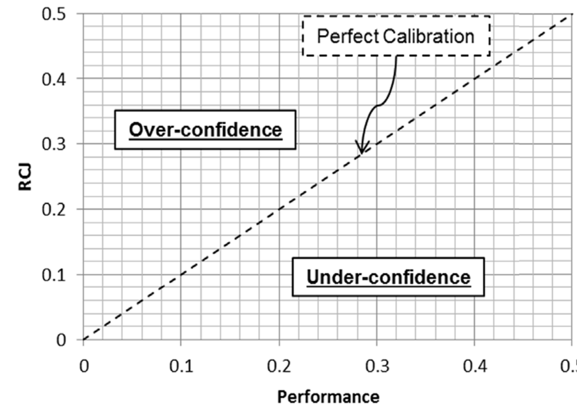

Fig. 1. Example of a perfect calibration.

The effects of RCJs have been previously tested in a computer-based training simulation. Sethumadhavan (2011) examined individuals' RCJs regarding their performance by using an air-traffic-control task. The results showed that the participants with higher confidence in their performance tended to have a better outcome and were faster in responding to system failures. However, other researchers have found that RCJs are accurate only in predicting search behavior (McCarley and Gosney, 2005; Mitchum and Kelley, 2010). For this reason, additional studies are needed to examine the relationship between RCJ and human performance. In the present work, a time-window-based human-in-the-loop (TWHITL) simulation representing an anti-air warfare coordinator (AAWC) was used as a tool to collect RCJ and human performance data in a computer-based training environment. During the experiment, the TWHITL simulation activates multiple task events, and each participant was required to carry out each event within a given time frame. The accuracy of on-time correct actions was used as a measure of the participant's performance, referred to as the operator action performance (OAP). There are two types of OAP: the first is for the warning task, and the second is for the identification task. Both tasks are discussed in detail in Section 2.2.

After each training session, the participants were provided with their RCJ and performance scores. Two groups participated in the