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Motivation matters: Interactions between achievement goals and agent scaffolding for self-regulated learning within an intelligent tutoring system

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ABSTRACT

In this study, we examined the influence of achievement goals and scaffolding on self-regulated learning (SRL) and achievement within MetaTutor, a multi-agent intelligent tutoring system. Eighty-three ($N = 83$) undergraduate students were randomly assigned to either a *control* or *prompt and feedback* condition and engaged in a 1-h learning session with MetaTutor to learn about the human circulatory system. Process and product data were collected from all participants prior to, during, and following the session. MANCOVA analyses revealed that students in the *prompt and feedback* condition deployed more SRL strategies and spent more time viewing relevant science material compared to students in the *control* condition. Results also revealed a significant interaction between achievement goals and condition on achievement outcomes, such that learners adopting a dominant performance-approach demonstrated higher achievement in the *prompt and feedback* condition. Findings are discussed in relation to the role of motivation in self-regulated learning within computer-based learning environments. Implications for the design of pedagogical agents are also discussed.

1. Introduction

Do pedagogical agents foster self-regulated learning processes and achievement? What role does motivation play in the effectiveness of agent scaffolding? Should instructional supports adapt to learners' achievement goals? Despite the potential advantages of embedding prompts and feedback within hypermedia environments to foster self-regulated learning (Azevedo, 2009, 2015; Azevedo, Feyzi-Behnagh, Duffy, Harley, & Trevors, 2012), there is a need for research to examine the impact on students' learning processes and achievement using both process and product data (Azevedo et al., 2013; Bannert, Reimann, & Sonnenber, 2014). Moreover, few studies have explored the interactions between motivation and instructional supports within these types of computer-based learning environments (Moos, 2014; Moos & Marroquin, 2010).

Although models of self-regulated learning (e.g., Boekaerts, 2011; Efklides, 2011; Pintrich, 2000, 2004; Winne & Hadwin, 2008; Zimmerman, 2011) and interactive tutoring feedback (e.g., Narciss, 2008) indicate that motivational orientation is a critical factor in learners' use of self-regulatory strategies and responsiveness to scaffolding, these theoretical claims have not received empirical scrutiny within computer-based learning environments. For example, it may be the case that agent scaffolding and learners' achievement goals both relate directly to self-regulated learning and achievement. It may also be the case the there is an interaction between the two; that is, that the effectiveness of scaffolding will vary according to the type of achievement goal adopted. For instance, it is not clear whether learners who aim to improve their personal competence (i.e., mastery-approach) benefit differently from scaffolding compared to learners who strive to outperform their peers (i.e., performance-approach) or how this impacts their achievement within computer-based learning environments.

In the present study, we aim to address these gaps by drawing on frameworks of self-regulated learning (e.g., Winne & Hadwin, 2008) and achievement motivation (e.g., Elliot & Murayama, 2008) to examine the impact and interactions between pedagogical agent scaffolding and achievement goals within MetaTutor, a multi-agent hypermedia-based intelligent tutoring system designed to help students learn about the human circulatory system. This study extends previous work by responding to calls to: (1) collect trace data in real-time to examine the deployment of self-regulatory strategies (Azevedo et al., 2013; Winne &

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Azevedo, 2014); (2) examine the effectiveness of pedagogical agent scaffolding on learning outcomes using an experimental design (Heidig & Clarebout, 2011); and (3) investigate motivational facets of self-regulated learning in addition to cognitive and metacognitive processes within computer-based learning environments (Moos, 2014; Moos & Marroquin, 2010; Moos & Stewart, 2013).

Findings from this research have important implications for the advancement of self-regulated learning models and the design of computer-based learning environments by providing insights into the role of learner characteristics, such as achievement goals. In the following sections, we provide theoretical background and a review of the literature on self-regulated learning, instructional scaffolding, and achievement motivation within computer-based learning environments. The introduction closes with the goals of the current study.[1]

1.1. Self-regulated learning

Theories of self-regulated learning (e.g., Boekaerts, 2011; Pintrich, 2000; Winne & Hadwin, 2008; Zimmerman & Schunk, 2011) are commonly employed as a guiding framework to understand the nature of student learning. Broadly speaking, self-regulated learning (SRL) refers to the self-initiated management of thoughts, feelings, and behaviors, which are used to achieve specific learning goals (Zimmerman, 2001, 2011). Research has demonstrated that in order to achieve positive learning outcomes, students must engage in effective SRL processes, such as planning and setting goals, selecting and monitoring learning strategies, and evaluating comprehension of the material (e.g., Azevedo & Feyzi-Behnagh, 2010; Azevedo et al., 2012, 2013; Greene & Azevedo, 2010; Winne & Perry, 2000).

These SRL processes are particularly important within computer-based learning environments where students must carefully regulate several aspects of their learning given the potential of these environments to be open-ended, non-linear, and information-rich (Azevedo et al., 2013; Bannert & Mengelkamp, 2013; Opfermann, Scheiter, Gerjets, & Schmeck, 2013). For example, within hypermedia environments, information is presented in multiple formats (e.g., texts, diagrams, animations) and contains hypertexts that allow learners to self-direct the sequencing and duration of content viewed. As such, learners must make decisions about which information to attend to, for how long, and in what order.

As Moos (2009) has argued, the nature of these environments can place high demands on limited cognitive resources, which may thwart learning. Indeed, research has demonstrated that students typically do not self-initiate a high degree of SRL processes and often struggle when learning about complex topics or ill-structured problems (Azevedo et al., 2012; Kinnebrew, Biswas, Sulcer, & Taylor, 2013; Opfermann et al., 2013). This lack of effective regulation limits the potential learning gains of educational tools aimed at promoting deep comprehension of complex topics, such as science (Graesser & McNamara, 2010). As a result, researchers have developed a variety of computer-based learning environments, including hypertext, multi-media, hypermedia, and intelligent tutoring systems, that are designed to promote, support, and detect SRL (e.g., Azevedo & Aleven, 2013; Azevedo et al., 2012; Biswas, Jeong, Kinnebrew, Sulcer, & Roscoe, 2010; Graesser, Chipman, King, McDaniel, & D'Mello, 2007; Lajoie et al., 2013; Lester, Mott, Robinson, & Rowe, 2013; Winne & Nesbit, 2009). In the following section we discuss how scaffolding embedded within these systems can influence SRL and achievement.

1.2. Instructional scaffolds

Instructional scaffolding refers to support or guidance provided by an agent or tool that allows learners to participate in a task that would otherwise be too challenging to effectively complete (Belland, 2014). In the context of computer-based learning environments designed to promote self-regulated learning for science education, scaffolds have typically focused on promoting regulation of cognitive processes (Devolder, van Braak, & Tondeur, 2012). Recently, these systems have also integrated scaffolds and design features to promote metacognition (e.g., Azevedo et al., 2012) and motivation (D'Mello, Chauncey-Strain, Olney, & Graesser, 2013; D'Mello, Lehman, & Graesser, 2011; Mayer, 2014). Scaffolding can take several forms, including: hints, prompts, feedback, illustrations, or interactive features (Devolder et al., 2012). For example, within MetaTutor (Azevedo et al., 2012, 2013), learners have access to an embedded SRL palette that contains a number of strategies that can be selected to self-initiate self-regulatory processes Taub, Azevedo, Bouchet, & Khosravifar, 2014). These include cognitive strategies (e.g., taking notes, writing a summary, making an inference) and metacognitive strategies (e.g., activating prior knowledge, evaluating content relevancy, assessing understanding and knowing).

To further promote effective learning, researchers have embedded pedagogical agents within computer-based environments to adaptively scaffold SRL by providing timely instructional prompts and or feedback (e.g., Azevedo et al., 2012, 2013; Biswas et al., 2010; D'Mello et al., 2013; Graesser & McNamara, 2010; Lester et al., 2013; Poitras & Lajoie, 2014).[2] Within MetaTutor (Azevedo et al., 2013), agents are designed to scaffold cognitive and metacognitive processes by providing prompts and feedback in response to learners' goals, behaviors, self-evaluations, and progress. For instance, learners receive prompts at various points to set sub-goals for learning, monitor understanding and feelings of knowing, activate prior knowledge, and deploy learning strategies. Learners also receive feedback as they create sub-goals (e.g., too broad or too narrow), write summaries (e.g., too long or too short), view content (e.g., relevant or irrelevant to sub-goal), progress toward their goals (e.g., sufficiency of content coverage), and assess understanding (e.g., calibration between quiz result and self-evaluation).

These types of environments are garnering evidence that pedagogical agents can effectively promote self-regulated learning (Azevedo et al., 2012, 2013). For example, Trevors, Duffy, and Azevedo (2014) found that within MetaTutor, agents significantly reduced shallow-level note-taking (e.g., verbatim copying) for low prior knowledge learners, which was found to be a maladaptive learning strategy. Despite these potential benefits, limited research has directly examined the effectiveness of agent scaffolding for SRL to promote achievement. One major limitation in research examining the impact of pedagogical agents is the lack of experimental design and control groups (Heidig & Clarebout, 2011). In addition, there is a need for research to attend to the role of learner characteristics, which likely impact the effectiveness of scaffolding (Devolder et al., 2012). Although research has demonstrated that prior knowledge has an influential role within agent-based environments (e.g., Taub et al., 2014; Trevors, Duffy, & Azevedo, 2014), one learner characteristic that has received inadequate attention within computer-based learning environments is achievement goal motivation (Moos & Marroquin, 2010).

[1] Given the diversity of research on computer-based learning environments, we focus our review on scaffolding and motivation within CBLEs designed to promote self-regulated learning.

[2] For further information regarding variations in agent features and scaffolding design, see Azevedo, 2014; Azevedo & Hadwin, 2005; Graesser & McNamara, 2010; Heidig & Clarebout, 2011; Tien & Osman, 2010).