Does the Frequency of Pedagogical Agent Intervention Relate to Learners' Self-Reported Boredom while using Multiagent Intelligent Tutoring Systems?

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Abstract

Pedagogical agents (PAs) have the ability to scaffold and regulate students' learning about complex topics while using intelligent tutoring systems (ITSs). Research on ITSs predominantly focuses on the impact that these systems have on overall learning, while the specific components of human-ITS interaction, such as student-PA dialogue within the system, are given little attention. One hundred undergraduate students interacted with MetaTutor, a multiagent hypermedia ITS, to learn about the human circulatory system. Data from these interactions were drawn from questionnaires and log-files to determine the extent to which a specific agent from MetaTutor, Sam the Strategizer, impacted students' overall emotions while using the system. Results indicated that Sam negatively impacted students' experiences of enjoyment, in relation to the other agents of MetaTutor, and the frequency of Sam's interactions with students significantly predicted their reports of boredom while using the system. Implications for the design of affect-sensitive multiagent ITSs are discussed.

Keywords: affect; metacognition; self-regulated learning; intelligent tutoring systems; pedagogical agents; self-reports

Introduction

Research on multiagent intelligent tutoring systems (ITSs) has traditionally focused on their impact on learning and performance (Azevedo & Aleven, 2013). The incorporation of pedagogical agents (PAs) within ITSs has been demonstrated to be beneficial in the promotion of students' effective use of various cognitive, affective, metacognitive, and motivational (CAMM) processes while learning about complex topics (Azevedo et al., 2013; D'Mello & Graesser, 2012a; Kim & Wei, 2011; Kramer & Bente, 2010; Lusk & Atkinson, 2007). Researchers include PAs within ITSs in an attempt to facilitate students' self-regulatory learning (SRL) processes. Specifically, SRL is based on the premise that successful learning involves students' ability to accurately regulate their cognitive and metacognitive processes through planning, monitoring, and using learning strategies (Winne & Azevedo, 2014). It is a fundamental educational construct that has been shown to be effective in students' ability to learn (Azevedo et al., 2013; Winne & Hadwin, 2008). As such, the impact of PAs on SRL processes has been studied extensively (Azevedo et al., 2013; Kinnebrew et al., 2013; Veletsianos & Russell, 2014). For PAs to be successful, there is a key question to be addressed first—that is, the impact PAs have on learners' emotions. Specifically, it is imperative to focus on the impact of agents' prompting and feedback on students' emotions as well as how these prompts and feedback may interfere with the ability to self-regulate (by deploying SRL processes) and overall learning.

We have begun examining the impact of PAs on students' emotions during learning with an ITS using MetaTutor. MetaTutor is an intelligent multiagent hypermedia-based learning environment, designed to promote the effective use of SRL processes as students learn about complex science topics (Azevedo et al. 2010, 2013). MetaTutor uses four PAs designed to externally regulate and foster students' cognitive (e.g., summarizing) and metacognitive (e.g., judgment of learning) SRL processes while learning about various human body systems. Fundamentally, the aim of MetaTutor is to facilitate the acquisition, use, and transfer of SRL processes by enhancing learning gains and performance across various science topics. Each of the four embedded PAs represents a specific component of SRL and is embedded within MetaTutor, including cognitive and metacognitive processes: Gavin the Guide assists the student in navigating through the learning environment; Pam the Planner aids in the creation of subgoals and prior knowledge activation (planning); Mary the Monitor helps monitor progress toward the established subgoals and prompts the use of metacognitive monitoring strategies, such as content evaluation; and Sam the Strategizer facilitates the selection and use of cognitive learning strategies, such as summarizing and taking notes. The inclusion of these PAs is an attempt to encourage the deployment of SRL processes, which have been shown to be effective for learning and performance.

The majority of past research with ITSs has focused predominantly on students' cognitive and metacognitive processes while interacting with these PAs (Azevedo et al., 2013; Kinnebrew et al., 2013). Other research has focused on the impact of students' affective states and motivational processes while using multiagent ITSs, but to a smaller extent (Craig et al., 2004; D'Mello & Graesser, 2011; Kort et al., 2001). Findings have demonstrated that affective states of engagement significantly and positively impact learning (Baker et al., 2010; Craig et al., 2004; Woolf, 2009), whereas affective states such as boredom have been demonstrated as deleterious to students' overall learning gains (Baker et al., 2010; D'Mello et al., 2014; D'Mello & Graesser; 2012b; Mudrick et al., 2014). Particularly, the negative affective state of boredom has been shown to negatively correlate with students' overall learning gains (Baker et al., 2010; Craig et al., 2004; D'Mello & Graesser, 2011, 2012b; Mudrick et al., 2014; Schutz & Pekrun, 2007).

The ability of ITSs to elicit emotions has been studied extensively. However, little attention has been paid to the PAs within these systems and their abilities to differentially provoke and impact students' affective responses. Previous investigations have demonstrated that agent-directed affective responses, specifically negative affect, have a deleterious impact on students' overall learning gains (Mudrick et al., 2014). As such, it is crucial to understand the complex interactions among emotions, SRL process deployment, and PAs for effective learning and training.

Past research with MetaTutor has indicated that one of the four PAs, Sam the Strategizer, provokes the strongest negative affect in students, compared to the other PAs (Mudrick et al., 2014). As such, we hypothesize that Sam's presence while interacting with the student is what promotes these negative emotional reactions. Because he prompts students to use cognitive learning strategies, he interacts with the student more than any of the other three PAs. Therefore, we compared the frequency of Sam's interventions with the second most prevalent agent of MetaTutor, Mary the Monitor, and the subsequent affective impact his presence provokes in students.

In this study, we address the following questions: (1) What is the overall impact of Sam the Strategizer, in relation to the other PAs, on students' affective responses during learning with MetaTutor? (2) How do these emotions relate to student- and PA-initiated cognitive strategy use while using MetaTutor?

Method

Participants

One hundred undergraduate students (M_{age} = 21 years, SD = 3.2) recruited from three major North American universities participated in this 2-day study. Participants were compensated up to $40, at a rate of $10/hour.

Materials

The participants interacted with MetaTutor (Azevedo et al., 2013) for both sessions. During each session, we collected multichannel data related to CAMM processes. These included log-files, a physiological measure of arousal (i.e., GSR bracelet), self-report questionnaires of emotions and motivation, videos of participants' facial expressions of emotions, screen recordings of student-system interactions, eye-tracking data, and audio recordings of each participant's interactions with MetaTutor.

MetaTutor and Procedure

Within the version of MetaTutor used for this study, there are 47 pages of text and diagrams that cover various aspects of the human circulatory system (e.g., blood components, malfunctions, etc.). The role of the four PAs in MetaTutor will be discussed in more depth below.

Participants were asked to participate for a total of two sessions. The first session lasted 30–45 minutes, the second was completed over a 3-hour period, and the participants were required to complete both sessions within 3 days of each other. During the initial session, participants filled out a consent form and were given a description of the study. They were then instructed to begin their interaction with the environment and complete a series of self-report questionnaires that assessed demographic information, achievement emotions, and emotional regulation strategies. Lastly, the participants completed a 30-item pretest questionnaire covering their prior knowledge of the human circulatory system and were compensated $5 for the completion of this session.

During the second session, participants started their interactions with the learning environment and chose two out of seven predetermined subgoals that covered various components of the human circulatory system, for which Pam the Planner was programmed to recognize and lead the student to choose. Once the participants set their subgoals with the help of Pam, Gavin the Guide introduced the system by presenting videos that portrayed the various elements of the system interface, as well as how to interact and navigate through the environment while using SRL processes. Then, Pam the Planner prompted again and facilitated the students in the activation of their prior knowledge regarding the current subgoal they set to complete. Finally, the participants were allowed to interact with the system and engage in various SRL processes (e.g., summarizing and taking notes) and metacognitively monitor and judge their learning (e.g., monitor their current progress toward their specific subgoals) through clicking the SRL palette presented to the right of the interface. Throughout learning with MetaTutor, the participants were presented with a variety of self-report questionnaires, such as the Emotions and Values Questionnaire (EV), which asks the students to self-report the emotions they are currently experiencing, The EV was presented every 14 minutes (Harley et al., 2015). Upon completion of the overall learning session, the participants were presented with a 30-item posttest and a series of questionnaires, such as the EV, as well as the Agent Reaction Inventory (ARI; a modified version of Baylor's [2011] Agent Persona Inventory) that assessed their overall emotional reactions to the four PAs. The participants were then debriefed, thanked, and compensated.

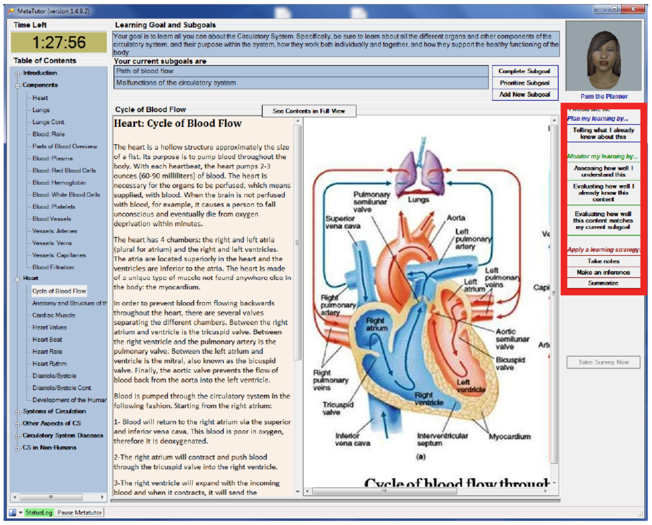

Figure 1: The MetaTutor interface. The SRL palette is highlighted.

Two conditions were tested in this study, the *prompt and feedback condition* and the *control condition*. Within the control condition, participants were allowed to navigate through the learning environment with minimal agent intervention, scaffolding, or feedback. They could deploy various SRL processes by clicking on the SRL palette, yet they were not prompted by the agents to do so if in this condition. Participants assigned to the *prompt and feedback* condition were provided with prompts for the use of various SRL processes and scaffolding, in addition to receiving adaptive feedback from the four PAs. The agents intervene based on a series of system-initiated production rules related to the student's performance on the various cognitive and metacognitive tasks of MetaTutor. Participants in this condition were also free to use the SRL palette to self-initiate SRL processes. Ultimately, this serves to create a dialogue with the students as they engage in SRL processes while learning about the human circulatory system. As the purpose of this study was to examine how the PAs impacted students' affective reactions on a whole, the conditions were not considered.

As previously discussed, three of the four agents (excluding Gavin the Guide) are responsible for distinct aspects of cognitive and metacognitive SRL processes. Their varied presence within the system is based on the success of one-to-one human tutoring and its ability to provide adaptive, supportive scaffolding and guidance of cognitive and metacognitive skills (Azevedo & Aleven, 2013; VanLehn, 2011). Pam the Planner assists the students in the activation of prior knowledge, in addition to helping establish the subgoals the participants are to complete for the duration of the session. For these reasons, Pam is not as present, as she helps with the initial interactions throughout the participants' session with the MetaTutor learning environment. Mary the Monitor embodies the metacognitive components associated with SRL process usage, prompting the students to monitor their progress toward their established subgoals, evaluate the content on the page and its relevancy for those subgoals, judge their learning (both for the page presented and overall), and assess how well they feel they know the information. As such, the number of metacognitive process prompts contributes more interaction between the students and Mary. Lastly, Sam the Strategizer supports the students in summarizing the content they read, to take notes on the content, coordinate the informational sources (text and diagram), and reread, if needed. The cognitive strategies prompted by Sam contribute to a notable amount of time interacting with the students.

Figure 2: The four pedagogical agents in MetaTutor.

Data Sources, Coding, and Scoring

For the purposes of this paper, the questionnaire assessing the participants' emotional reactions to specific agents and their likeability (the ARI) was used. Specifically, the items covering the learner-centered emotions (D'Mello & Graesser, 2012a) of enjoyment, frustration, boredom, confusion, curiosity, and neutral for each of the specific PAs (for example, *SAM made me feel bored* and *MARY made me feel that I am enjoying myself*) were extracted from the ARI. In addition, log-files provided both PA- and student-initiated SRL strategy frequencies. The items from the ARI were correlated to determine the overall affective impact that these agents elicited from participants. Then, regression analyses using both PA- and student-initiated SRL process frequencies, obtained from the log-files and the emotions mentioned above, were conducted to determine the extent to which these emotions were predicted by the amount of student- and PA-initiated strategy use while engaging with MetaTutor.

Results

Research Question 1: What is the overall impact of Sam the Strategizer, in relation to the other PAs, on

students' affective responses during learning with MetaTutor?

To determine the agent that induced the strongest affective responses during learning with MetaTutor, correlations were conducted with items from the ARI. Results indicated that the affective states directed toward the agents, such as enjoyment for Gavin, Mary, Pam, and Sam, were all highly correlated. The item *Gavin made me feel that I am enjoying myself* was positively correlated with the items addressing enjoyment for each of the other three agents, Pam ($r = .66$, $p < .001$), Mary ($r = .55$, $p < .001$), and Sam ($r = .43$, $p < .001$). These correlations were not limited to positive learning-centered emotions, as evidenced by high correlations across the ARI item addressing frustration. *Sam made me feel frustrated* correlated strongly with frustration directed at the other three agents, Gavin ($r = .25$, $p < .001$), Pam ($r = .56$, $p < .001$), and Mary ($r = .58$, $p < .001$). However, within-agent correlations demonstrated a different trend. More specifically, correlations within agent-directed affect for Sam the Strategizer indicated the strongest and most consistently negative correlations amongst the agent-specific directed emotions. See Table 1 for a summary of the correlations among emotions directed toward Sam the Strategizer.

Table 1: Correlations among emotions directed toward Sam the Strategizer.

	Enjoyment	Curiosity	Neutral	Boredom	Frustration	Confusion
Enjoyment	---					
Curiosity	0.38**	---				
Neutral	0.27*	0.82	---			
Boredom	0.22*	0.01	0.13	---		
Frustration	–0.41**	–0.003	–0.30*	0.33**	---	
Confusion	–0.26*	0.20*	–0.23*	0.29*	0.39**	---

***p* < .001 level.
**p* < .05 level.

Research Question 2: How do these emotions relate to student- and PA-initiated cognitive strategy use while using MetaTutor?

To determine the extent of SRL strategy prompts, both PA- and student-initiated, during the overall learning session, a chi-square analysis was conducted with the two most prevalent agents within MetaTutor: Mary the Monitor and Sam the Strategizer. The outcome of this analysis indicated a significant difference between the amounts of PA-initiated SRL prompting, feedback, and guidance ($\chi^2(1) = 55.82$, $p < .001$). Sam's prompts occurred significantly more frequently than Mary's, occurring on average 17.9 times and 13.7 times per student, respectively, over the 3-hour period that comprised the second experimental session.

Subsequently, a regression analysis was conducted to determine the extent to which the prompts of SRL processes Sam was responsible for (summarizing, taking notes, coordinating informational sources, and rereading) predicted these negative emotion ratings, specifically boredom. The affective state of boredom was chosen due to its deleterious impact on overall learning. Results from this analysis indicated that the overall model was significant and predicted 5.7% of the variance ($R^2 = .057$, $F(1, 97) = 5.85$, $p = .017$). Boredom directed toward Sam was significantly predicted by the frequency of student- and Sam-initiated SRL processes ($\beta = .24$, $p = .017$).

Discussion

The results from this study demonstrate the affective influence that PAs can have on students during learning with ITSs. Sam the Strategizer ultimately impacted students in a negative way. The frequency of Sam-initiated and student-initiated SRL prompts by Sam was found to be significantly predictive of boredom when using MetaTutor. It is important to note that the frequency of SRL prompts by Sam was significantly higher than those covering the metacognitive components, for which Mary was responsible. A possible explanation for the relationship found between the frequency of Sam's prompts to the students' self-reports of boredom could be that the students are simply being overprompted (Bouchet et al., 2013).

It seems as though this overprompting may interfere with the students' agency, and therefore limit their ability to self-regulate. This is an important consideration, as a fundamental premise behind the inclusion of PAs in ITSs is their perceived capacity in facilitating the students' CAMM processes during learning and training.

However, it is also important to consider not only the SRL strategies that Sam is responsible for prompting the students with, but also the system-based rules that evaluate the quality of the students' overall summary. It is possible that the students simply do not want to engage in the strategies of summarizing, taking notes, coordinating informational sources, or rereading, as prompted by Sam. As such, future studies should tease apart the affective responses to the PA from the prompted strategy or process. By analyzing the role of boredom in this manner, we can expand on the information-processing model of SRL that focuses exclusively on cognitive and metacognitive SRL processes (Winne & Hadwin, 2008).

Furthermore, the natural language processing measure, which the system uses to assess and evaluate the content of the summaries that Sam prompts the student to make, could be responsible for this outcome. MetaTutor gauges the quality of the student's summary by recognizing specific key words related to the content of the page the student is currently reading, in addition to limiting a "good" summary to approximately three sentences. The student is informed at the beginning of the session, as well as when Sam reintroduces the summarization component, that a "good" summary is limited to these requirements. As such, it is possible that the student's summary was "good" and took note of the various components related to the specific context of the page, yet either did not include the key words of the page or contained too many sentences to be deemed concise. As shown by Table 1, Sam, overall, significantly impacted the students' enjoyment in a negative way through his induction of both frustration and boredom. Future analyses regarding this topic should include measures of engagement and frustration as possible predictors of overall learning strategy use and, ultimately, learning gains.

We have seen that boredom is detrimental to learning and engagement, but this study reveals that it is also related to the frequency of various SRL strategies the PAs within an ITS prompted and modeled for the students. . These findings can be partially explained when situated within the *dynamics of affective states model* of D'Mello and Graesser (2012a). Their model proposes that students' affective states will fluctuate when they experience contradictions, incongruities, obstacles to growth, and/or other impasses while learning with advanced learning technologies (ALTs). Specifically, students begin in a state of engagement/flow as they pursue the superordinate goal of mastering the information, and when they are interrupted (e.g., when Sam the Strategizer prompts the students to summarize the presented material), they become frustrated. Prolonged frustration may then transition into boredom, with students ultimately disengaging from the learning process (D'Mello & Graesser, 2012a). Other research with ALTs suggests that these interruptions from a tutor or PA that block goals can be potential antecedents that lead to a student's experience of frustration (D'Mello et al., 2006; Kapoor et al., 2007). Ultimately, it seems that when Sam the Strategizer prompts students to engage in cognitive SRL strategies, students' superordinate goal of mastering the material is blocked. Consistently prompting the students to engage in these strategies at such a high frequency then prolongs the initial state of frustration that culminates in high self-reports of boredom. Transitioning from students' self-reports of boredom back to a state of engagement/flow could be promoted by a more sophisticated student model (Woolf, 2009) that would provide Sam the information needed to adapt the frequency of prompting cognitive strategies. In sum, our results have significant implications for the conceptualization and measurement of the impact of external regulating agents (e.g., PAs) on students' learning, as well as the design of PAs in ITSs.

The design of PAs that assist students in the effective deployment of CAMM processes and positive learning outcomes must pay close attention to the level of interaction between the PA and the student. As shown here, affect is a significant component to the human-PA dialogue, indicating the necessity for the future design of affect-sensitive multiagent ITSs. Furthermore, overprompting the processes that are understood to assist students in learning and training could have a damaging outcome on students' engagement and positive affect and, consequently, the effectiveness of the ITS paradigm. Future research should examine the temporality of agent-based prompting to examine if there are key affective thresholds (i.e., overly prompting within a short amount of time) that can lead to frustration or boredom, as caused by prompts in close temporal proximity and over the learning session. Additionally, subsequent research should consider the inclusion of synchronous multichannel facial expressions as well as physiological and self-report data capture as students engage with PAs and ITSs in order to determine specific and representative data patterns of human-PA emotional interactivity. This will ultimately allow for the design of online, real-time feedback mechanisms from the student into the system to provide a more adaptive and versatile learning environment to future students.

One limitation in this study is the lack of differentiating the analyses by condition. The purpose for not doing so in this study was to analyze the overall affective impact the PAs had on all learners who interacted with MetaTutor. As such, it is necessary for future research to examine the differences in affective responses between the two experimental conditions. The use of self-reports also limits the findings of this study, as this only provided l learners' post hoc perceptions of their affective responses toward Sam. Future studies should examine the impact of PAs in real time, using facial expressions from emotion recognition software, to examine the actual affective impact PAs have as learners interact with ITSs. This will allow us to pinpoint the key components of the PA-learner interaction that can result in a negative affective response and detract from their learning outcomes.

As one of the fundamental goals of ITSs is to facilitate students' overall learning (e.g., by promoting the effective use of SRL strategies), it is imperative to understand the interplay among boredom (and affect as a whole), the role of PAs, and the promotion and deployment of SRL strategies and processes as students engage with ITSs. The results presented in this study have provided a first step toward a better understanding of such interactions, and provided immediate results to improve MetaTutor. However, deeper analyses (by both the authors and the ITS community) will be needed to reach a clearer understanding of this difficult topic.

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