

Pedagogical agents as scaffolds: The role of feedback timing, number of agents, and adaptive feedback

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Abstract: This exploratory experimental study explored the role of feedback with animated pedagogical agents according to three factors: 1) timing (summative vs. just-in-time); 2) number of agents (1 or 2); and, adaptivity (adaptive, non-adaptive). Results are discussed by type of interaction using the theoretical framework of cognitive load theory.

Introduction

Cognitive Load Theory (CLT) has recently become an important theory in instructional design for decreasing learning difficulty and, subsequently, for enhancing learning achievement as well as transfer performance (Sweller, 1994). Managing cognitive load is critical to effectively design computer-based learning environments (Kalyuga, Chandler, & Sweller, 1999). At this point in time, limited research has been conducted as to the role of cognitive load issues with animated pedagogical computer-based agents. Researchers such as Atkinson (in press), Moreno and colleagues (Moreno, Mayer, Spires, & Lester, 2001), and Baylor (2002a, 2002b; Baylor & Ryu, in press) have considered some agent features such as image, animation, and voice and their role with cognitive load; however, the delivery of pedagogical agent *feedback* has not yet been systematically examined. The purpose of this exploratory experimental study is to explore the relationships between cognitive load and feedback provided by pedagogical animated computer agents on learner attitudes, transfer performance, and perceived agent value. The following questions are addressed, within the context of the MIMIC (Multiple Intelligent Mentors Instructing Collaboratively) agent-based research environment (see Baylor, 2002a, 2002b):

1. Should feedback come from one or two agents? (SOURCE of feedback)
2. When is the best time to initiate feedback (during or after a set of performances)? (TIMING of feedback)
3. Does basic adaptive feedback support desirable? (ADAPTIVITY of feedback)

Methods

The study is a 2x2x2 factor design with a total of eight conditions, operationalized as follows:

1) TIMING of feedback: *Summative* [Feedback is presented by the agent(s) in a pop-up window on the screen when the student has finished each major stage of the process] or *JIT (Just-In-Time)* [The agent(s) is available at all times to provide immediate feedback.]

2) ADAPTIVITY of feedback: *Adaptive* [the participant self-evaluates his/her performance in several areas for each stage and the agent(s) provides adaptive feedback based on the participant's self-rating] or *Non-adaptive* [no self-evaluation is embedded in the program with no adaptive feedback]

3) SOURCE of feedback: *Singular* (1 agent) or *Comparative* (2 agents).

The participants included 145 undergraduates in an introduction to educational technology course. They were randomly assigned to conditions by MIMIC. After developing a complete instructional plan within the environment, they answered several transfer questions, attitude measures, rated their enjoyability of the program, and the perceived value of the agents. The entire procedure took approximately 90 minutes. There were six dependent measures assessed following the intervention: agent persona, agent value, enjoyability of program, self-efficacy, reflection, and transfer. All measures were implemented in previous research and consisted of Likert scale items, with the exception of transfer which was open-ended and was scored according to a rubric.

Data analysis consisted of three 3-factor MANOVAs for the following sets of dependent measures (given that they were comprised of multiple items): 1) agent persona; 2) agent value; and, 3) enjoyability. Three-factor ANOVAs were conducted for the following dependent measures: 1) self-efficacy; 2) reflection; and 3) transfer. Given space limitations, Table 1 summarizes the statistically significant results ($p < .05$), grouped by interaction.

Table 1. Summary of results, grouped by type of interaction.

Dependent variable	Results	Trend
Enjoyability of program	TIMING*SOURCE	JIT- comparative>JIT-singular Sum-singular >Sum-comparative
Reflection	TIMING*SOURCE (approaching significance)	JIT- comparative>JIT-singular Sum-singular >Sum-comparative
Agent persona	TIMING*SOURCE TIMING*SOURCE*ADA PTIVITY	JIT- comparative>JIT-singular Sum-singular >Sum-comparative
Self-efficacy	TIMING*ADAPTIVITY	Sum-non>Sum-Adapt JIT-Adapt>JIT-non
Agent value	TIMING*ADAPTIVITY TIMING main effect	Sum-non>Sum-Adapt JIT-Adapt>JIT-non
Transfer	ADAPTIVITY*SOURCE	Adapt-singular > Adapt-comparative Non-comparative> Non-singular

Discussion

Consistent TIMING*SOURCE interactions were revealed for enjoyability of program, reflection, and agent persona. This indicates that it is important for the amount of information presented at a time to be limited for the program to be enjoyable, for the agent to be believable and for the participant to be able to reflect. Specifically, if one agent was present, the summative form of feedback was desirable whereas with two agents the JIT feedback was preferred. This suggests that cognitive overload may be an issue, since too much information was presented at a time (e.g., two agents with summative feedback). Perhaps students preferred multiple agents with JIT feedback because program was less interesting and dynamic with just one agent with JIT feedback.

There were consistent TIMING*ADAPTIVITY interactions for self-efficacy and agent value, also indicating that the nature of the feedback (e.g., whether it was adaptive or not) was inter-related with its timing of presentation. Interestingly, when participants were given adaptive feedback, their confidence for future instructional planning was greater when it was given immediately (JIT) rather than following completion of that sub-task (summative). This seems to indicate that such personalized feedback has more direct effect when given immediately. Similarly, the agents were perceived as more valuable when they provided immediate adaptive feedback.

Transfer was the only measure to have an ADAPTIVITY*SOURCE interaction. This interaction indicated that with one agent, adaptivity positively affects transfer perhaps by encouraging the learner to self-evaluate. Thus, by providing seemingly expert feedback, the information may be processed more deeply by the learner. However, with two agents, this rationale did not hold because perhaps the learner was distracted by having multiple agents respond and thus could not focus on the key issues at hand.

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