Software Agents in Multimedia: An Experimental Study of their Contributions to Students' Learning

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ABSTRACT

How does the presence of software pedagogical agents affect students' learning in a multimedia environment? In order to answer this question, the following set of studies was conducted. First, to determine the role of the auditory and visual presence of the agent we varied whether the agent's words were presented as speech or on-screen text and whether or not the agent's image appeared on the screen, both with an animated fictional agent (Experiment 1), and a video of a human face (Experiment 2). Next, to determine the role of language style as indicator of presence, we varied whether or not the agent's explanations were provided in a personalized style (i.e. as dialogue or monologue) both using speech (Experiment 3), and on-screen text (Experiment 4). Finally, to determine the role of the interaction between agent and student, we varied whether or not the student was able to participate in the lesson before receiving the agent's explanations (Experiment 5). The theoretical and practical implications of the findings are discussed.

1 INTRODUCTION

The dissemination of software agents in instructional design brings up the need to investigate the effects of agents' presence in human-computer interaction. Believable agents with lifelike qualities figure prominently in multimedia learning environments (Bradshaw, 1997). The argument for using highly visible agents in human-computer interaction generally relies on the assumption of anthropomorphism--the fact that people unconsciously ascribe mental states to computers and are quite adept at relating to and communicating with other people (Laurel, 1997). Based on this assumption, it is possible to propose a social-cue hypothesis according to which, the more social cues provided in the communication process, the better the outcome of the communication (Rutter, 1984). More specifically for multimedia learning, the social-cue hypothesis favors the inclusion of highly visible agents who participate with the learner in the process of knowledge construction by means of one-on-one personalized conversations.

The goal of the present set of studies was to test the social-cue hypothesis for a multimedia-learning environment. To do so, college students learned about environmental science with the help of a software pedagogical agent. The learning environment used in this study is based on a multimedia program called Design-A-Plant in which an agent offers advice concerning the relation between plant

features and environmental features by providing students with feedback on the choices that they make in the process of designing plants (Lester, Stone, & Stelling, 1998).

2 METHODOLOGY

The social-cue hypothesis was tested in three different settings. First, to determine the role of the auditory and visual presence of the agent, we varied whether the agent's words were presented as speech or on-screen text and whether or not the agent's image appeared on the screen, both with an animated fictional agent and a video of a human face. In the first study, 64 college students learned in one of four conditions: with or without the image of a fictional agent who gave narrated explanations to them and with or without the image of a fictional agent who gave explanations as on-screen text. In the second study, 79 college students participated in the same four treatment conditions with the exception that the image and voice of the fictional agent were replaced by the video and voice of a human agent.

Second, to determine the role of the language style of the agent, we varied whether or not the agent's explanations were provided in a personalized style (i.e. as dialogue or monologue) both using speech and on-screen text. In the third study, 39 college students learned either with a personalized conversation spoken by the agent or a non-personalized monologue spoken by the agent. For the fourth study, 42 college students learned either with a personalized conversation displayed as on-screen text, or a non-personalized monologue displayed as on-screen text.

Third, to determine the role of the interaction between agent and student, we varied whether or not the student was able to participate in the lesson before receiving the agent's explanations. The fifth study included 38 college students who learned either with or without participating in the process of plant design before receiving the agent's advice.

For each study, students visited eight different environments and their goal was to design the root, stem and leaves of a plant that would survive under the respective conditions. For each environment, students were presented with the corresponding library of plant parts' graphics and names, and asked to click on one of the possible options to design their plant. After interacting with the respective computer program, all participants were given a retention test, a 7-page problem-solving test, and a program-rating sheet.

3 RESULTS

The findings from Experiments 1 and 2 gave evidence in favor of students' communicating with a fictional agent by means of speech by demonstrating a *modality effect* on retention, transfer, and program ratings. Students who learned with the voice of the agent (auditory modality) recalled more ($p < .005$), were better able to use what they had learned to solve new problems ($p < .0005$ and $p = .0001$ for Experiments 1 and 2, respectively), and rated the lesson more favorably ($p = 0.05$) than students who learned the same verbal materials as on-screen text (visual modality). However, these studies failed to confirm an *image effect* on retention, transfer, and program ratings. Students who were presented with the agent's image did not recall more, use what they had learned to solve new problems better, or rate the lesson more favorably than students not presented with the visual presence of the agent.

The findings from Experiments 3 and 4 gave evidence in favor of students' communicating with a pedagogical agent by means of a personalized conversation by demonstrating a *self-reference effect* in retention and transfer: Students who communicated via a self-referenced dialogue recalled more ($p <$

.005 and $p < .05$ for Experiments 3 and 4, respectively), and were better able to use what they had learned to solve new problems ($p < .0001$) than students who communicated via a monologue. In addition, for Experiment 4, students who learned via a dialogue rated more favorably the lesson than students who learned via a monologue ($p = 0.05$).

Finally, Experiment 5 yielded evidence in favor of participatory environments for learning by demonstrating an *interactivity effect* in multimedia learning environments: Students who learned in a participatory agent-based environment remembered more ($p = 0.01$) and were better able to solve far transfer problems ($p = 0.04$) than students who learned in a non-participatory agent-based environment. However, students did not differ in their program-ratings.

4 CONCLUSIONS

The reported results support the social-cue hypothesis when three cues are present in the program: the agent's voice, a personalized language style, and students' interaction. These findings have important theoretical implications. First, the advantages of speech over text in multimedia learning (such as the modality effect found in Experiments 1 and 2) have been interpreted as due to more effective working memory and relatively effortless maintenance of the auditory input in comparison to the visual input provided by text (Moreno & Mayer, 1999). Second, the self-reference effects found in Experiments 3 and 4 can be attributed to a combination of less cognitive effort (from a more direct and natural way of communicating) and more active processing of the materials. Encouraging students to encode the lesson as a personal experience facilitates the processing of the content by making available experiences in memory to which the lesson can be related (Moreno & Mayer, 2000). Finally, the interactivity effects found in Experiment 5 suggest that participatory environments encourage the deep processing of the materials of a lesson by engaging students in an active search for meaning (Moreno et al., in press). The most direct practical implication of these studies is that in a multimedia science lesson where students learn with the help of a pedagogical agent, personalized spoken messages and interaction with students play a fundamental role in the promotion of meaningful learning.

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