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The effects of animated pedagogical agents in an English-as-a-foreign-language learning environment

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ABSTRACT

Animated pedagogical agents (APAs) have frequently been used as a powerful addition to learning environments, since APAs have been known to facilitate learning. APAs can present various features, such as voice, movements, gestures and pointing, and researchers have sought to verify specifically which features of agents effectively contribute to learning. Previous studies have studied these features by comparing different degrees of agent embodiment in the evaluation of the image effect (i.e., students learn more when learning systems have visual APAs), the embodied agent effect (i.e., fully embodied agents that deliver instruction aurally and use gestures to improve learning outcomes in text-only learning systems), the modality effect (i.e., oral instruction contributes to the learning process), and the expressiveness effect (i.e., fully embodied agents promote more effective learning than static ones). Some of these studies have investigated the image, embodied agent and modality effects in the same learning environment, but they were not the same studies that investigated the expressiveness effect. The expressiveness effect allows us to separate the movements of the agent from its other features, such as the agent's image, so investigating this effect is as important as investigating the other effects. We are not aware of any studies that investigated all of these four effects within the same learning system, nor that evaluated any of these effects in language learning environments. Accordingly, this paper describes the design, implementation, and analysis of an APA designed to evaluate the abovementioned effects. The APA was integrated into a computer-assisted language learning (CALL) system to teach English as a foreign language to Brazilian students. A total of 72 Brazilian undergraduate students were divided into four groups, each of which used a different version of the APA in the same CALL system: no agent, a voice-only agent, a static agent, or a fully embodied agent. We compared students' gain scores (i.e., difference between pre- and posttest scores) across groups to evaluate each of the four effects. Though the outcomes of our study supported the presence of the embodied agent and modality effects, we were not able to demonstrate the image or expressiveness effects in the experiment. Our results indicate that the voice of the agent might contribute more positively to learning than movements, gestures and pointing.

1. Introduction

Animated pedagogical agents (APAs) are animated on-screen characters that assist learners in multimedia learning environments (Johnson et al., 1998; Lester and Stone, 1997). APAs can exhibit various types of lifelike behaviors, including speech, emotions, gestures, and movements of the eyes, head, and even body (Dehn and van Mulken, 2000). Such characters can flexibly represent numerous pedagogical roles, including those of instructors, coaches, tutors, and learning companions (Chou et al., 2003; Baylor and Kim, 2005; Haake and Gulz, 2009).

Since APAs' behaviors in some way mimic social exchange present in human interactions, they are considered to be a powerful addition to multimedia learning environments, because they allow these environments to exploit both verbal and nonverbal forms of communication (Johnson and Lester, 2015). Furthermore, as some research (Jeung et al., 1997; Mousavi et al., 1995) has indicated, APAs can be used during the learning process to partially reduce cognitive load.

However, using APAs is not invariably beneficial. One negative effect of their use can be the so-called split-attention effect, which occurs when the agent and its presence are not cognitively integrated enough for the content to be taught. In such cases, the

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image of the agent represents an additional, non-desirable cognitive load, likely because students are distracted by the agent and pay more attention to it than to the visual content that should be integrated with the spoken text (Dunsworth and Atkinson, 2007; Craig et al., 2002). A possible alternative to avoid the split-attention effect is to explicitly direct learners' visual attention to the content (Alibali and DiRusso, 1999).

In research on APAs in multimedia learning environments conducted over the years (Johnson et al., 1998; Lester and Stone, 1997; Finkelstein et al., 2013; Jaques et al., 2009), a recurring issue has been how to evaluate agents toward determining which degree of agent embodiment is most effective. For these evaluations, Atkinson (2002) has proposed three agent effects to take into consideration: the *image effect*, which represents whether the agent's on-screen presence helps in learning; the *embodied agent effect*, which concerns simulating the student–instructor relationship; and the *modality effect*, which holds that orally delivered instruction aids learning more effectively than textually delivered instruction. Moreover, some studies, including that of Lusk and Atkinson (2007), have investigated the so-called *expressiveness effect*, which maintains the effectiveness of fully embodied agents using gestures, locomotion, and gazes over static APAs.

Although several studies in different learning domains have sought to verify how these different effects impact students' learning, we are not aware of any studies that have investigated these four effects together in the same learning system. Some studies have tried to verify the image effect, the embodied agent and the modality effect in the same learning system (Atkinson, 2002; Dunsworth and Atkinson, 2007). However, these effects do not consider static versions of the agent, which limits conclusions about the impact of the agent's level of animation on learning. Adding the evaluation of the expressiveness effect in the same experiment allows us to verify and compare the effects of the agent's level of animation independently from other features of the agent.

This paper reports a study of the four aforementioned effects in an experiment involving a multimedia computer-assisted language learning (CALL) system. We hypothesize that our system will be able to demonstrate all the four abovementioned effects, i.e., that the agent's visual presence (image effect), ability to simulate the student–instructor relationship (embodied agent effect), voice (modality effect), and gestures locomotion and gazes (expressiveness effect) facilitate learning.

This paper is organized as follows. Section 2 discusses APAs and the effects proposed by Atkinson (2002) and by Lusk and Atkinson (2007). The system created for the project is described in Section 3, while the experiment is detailed in Section 4.1. Results from the data appear in Section 5, a discussion of the results in Section 6 and some final remarks in Section 7.

2. The agent effects

Although findings of previous studies suggest that the use of APAs facilitates learning (Johnson et al., 1998; Lester and Stone, 1997; Finkelstein et al., 2013; Jaques et al., 2009; Schroeder et al., 2013), Lusk and Atkinson (2007) posit that the effectiveness of APAs may in part be due to their degree of embodiment. Thus, we need to study features of agents in different APAs' degrees of embodiment to build most effective agents.

Moreno and Mayer (2000) have proposed a way to analyze the several questions related to the cognitive and affective impact of APAs. They measured the agents' impact on learning according to the image effect, embodied agent effect, and modality effect (Moreno and Mayer, 2000; Atkinson, 2002). The definitions of the image, embodied agent, and modality effects used in our work are presented in the following paragraphs, along with the primary findings for each effect. The definitions we use are aligned with the works of Atkinson (2002) and Dunsworth and Atkinson (2007). Though other authors cited in this section did not use the same terms for the effects, their definitions for what they evaluated correspond with our definitions of the effects.

The *image effect* refers to how the presence of an agent during learning affects a student's performance. For example, the on-screen agent may use gestures and gazes to direct the learner's attention (Dunsworth and Atkinson, 2007). To evaluate the image effect, two aurally delivered instructions are compared: one with the agent on-screen and the other without the image of the agent.

The image effect has been observed in an array of studies. Atkinson (2002) used an APA to optimize a multimedia learning environment designed to teach learners how to solve word problems. In that environment, the agent could deliver instruction either textually or orally, as well as use gazes and gestures to direct the students' focus to the relevant parts of the example. Some years later, Lusk and Atkinson (2007) presented the results of a similar system that also helped students to solve word problems, whereas the work of Dunsworth and Atkinson (2007) aimed to evaluate the effects in a system that lectured on the human circulatory system. Though the results of these three works detected the effective presence of the image effect, neither Moreno et al. (2001), with their system to teach students to design plants, nor van der Meij et al. (2015), with their system to teach kinematics, identified the presence of the effect. In both of these latter projects, the on-screen image of the agent did not provide any cognitive or motivational advantage for students' learning.

The *embodied agent effect* refers to the use of a fully embodied agent that delivers aural instructions and uses gestures, gazes, and movements to direct the learner's attention. An agent with those characteristics of instruction delivery is capable of simulating the social relationship between students and instructors and thus can facilitate learning (Atkinson, 2002). To gauge the embodied agent effect, researchers compare the learning outcomes of instruction delivered by a fully embodied agent and that delivered by text-only environments (Dunsworth and Atkinson, 2007).

The embodied agent effect was found in the systems of Atkinson (2002), Dunsworth and Atkinson (2007), Johnson et al. (2014) and Moreno et al. (2001). In their work, Johnson et al. (2014) argues that both the agent's image and visual signaling improve the performance of students with low prior knowledge. However, in van der Meij et al. (2015)'s experiment, the embodied agent effect could not be found, an outcome that the authors explained did not correspond to their initial hypothesis. They argued that their agent's voice was computer-generated and sounded monotonous, which might have negated effects on the agent and thereby negatively impacted the results.

The *modality effect* refers to the modality principle, which maintains that textual information should be presented to students orally, not in the form of written words (Mayer, 2001). The principle also states that learning increases if textual information is presented by means of audio with related visual information (Ginns, 2005). Though Ginns (2005) has successfully proven this principle, other authors (Schueler et al., 2008; Schroeder et al., 2013) have held that under certain circumstances, the modality principle does not apply. To show the modality effect, usually a learning system with a voice-only agent is compared with the same system with no agent whatsoever.

The modality effect was also detected in several systems, including those of Mousavi et al. (1995), Moreno and Mayer (1999), Moreno et al. (2001) and Atkinson (2002). Although the narration condition of Dunsworth and Atkinson (2007) achieved a higher mean score on tests addressing retention and near transfer, they found no presence of the modality effect — the results of the