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ABSTRACT

Data are presented on the effects of Animated Agents on multimedia learning environments with specific concerns of split attention and modality effects. The study was a 3 (agent properties: agent only, agent with gestures, no agent) x 3 (picture features: static picture, sudden onset, animation) factorial design with outcome measures of mental load rating scale, a persona rating scale, multiple-choice questions, a matching test, a retention test, and transfer tests involving creative solutions. Overall, there were no split attention or modality effects found with integrating the agent into the display. (Contains 17 references and 1 table.) (Author)

Does an agent matter?: The Effects of Animated Pedagogical Agents on Multimedia Environments

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Abstract: Data are presented on the effects of Animated Agents on multimedia learning environments with specific concerns of split attention and modality effects. The study was a 3 (agent properties: agent only, agent with gestures, no agent) x 3 (picture features: static picture, sudden onset, animation) factorial design with outcome measures of mental load rating scale, a persona rating scale, multiple-choice questions, a matching test, a retention test, and transfer tests involving creative solutions. Overall, there were no split attention or modality effects found with integrating the agent into the display.

KEYWORDS: **animated pedagogical agents, multimedia learning, split attention effects, attentional control**

Interest in the use of animated pedagogical agents in instructional design involving multimedia in virtual learning environments has increased recently, as new technologies have made them more accessible (Craig, Hu, Marks, & Graesser, 1999; Johnson, Rickel, & Lester, 2000). An animated pedagogical agent is a computerized character (either humanlike or otherwise) that can interact with a user in order to impart some type of information. Because these agents are relatively new, there has been little research into their proper construction, capabilities, use, or limitations.

Animated agents can be seen as logical extensions of the development and customization of new learning interfaces. A line of research conducted by Byron Reeves and Clifford Nass (1996) provides a context for exploring these interfaces. They put forth the basic principles of what they call the "Media equation theory." This model holds that people naturally interact with various forms of media in the same ways they interact with other people. In this context, media can include anything from written text to television to computer programs.

If people tend to anthropomorphize media such as computers and the programs that run on them, there may be real advantages to implementing pedagogical agents in computer interfaces. First, agents increase the bandwidth of communication by the addition of a direct conversational partner, a partner who is potentially capable of showing varied emotional states and patterns of deixis. Second, agents may increase the computer's ability to engage learners and motivate them. Furthermore, appropriate lifelike behaviors make agents appear knowledgeable, attentive to the learner, and helpful (Johnson et al., 2000).

Animated pedagogical agents would seem to provide a challenge to multimedia environments, given the precepts of the cognitive theory of multimedia learning (Moreno & Mayer, 1999). If the agents are integrated as a part of an illustration or animation, their presence could cause split-attention effects (Sweller & Chandler, 1994), or modality effects (Moreno & Mayer, 1999). Modality effects could result from both the agent and learning materials being presented in the visual modality. Such effects might not be overcome entirely by the integration of spoken text with a picture or animation, because learners might concentrate on the agent and ignore the learning materials. What might be required is to direct attention away from the agent who provides the spoken text and toward the appropriate visual materials, for example gesturing by the agent (Johnson et al., 2000) or attention capture within the animation itself (Yantis & Hillstrom, 1994). There is currently evidence that animated pedagogical agents used in virtual learning environments can promote baseline problem solving skills (Johnson et al., 2000; Moreno, 2001; Moreno, Mayer, Spires, & Lester, 2001). However, it is not clear what role agents play in learning environments (Andre et al., 1999).

One of the first studies (Lester, Voerman et al., 1997; Lester, Towns, Fitzgerald, 1999) of animated agents led to what is called the "Persona effect." The claim is that the presence of a lifelike character in the environment has a positive impact on the learner's interactive experience. The study also revealed that more expressive agents are given higher ratings on clarity and utility than the less expressive. Herman the bug was the agent in the study. Participants gave ratings on how helpful Herman was as an aid to their learning experience. However, it is important to note that the Persona effect is silent on whether participants learn more when interacting with agents (Lester, Voerman et al., 1997). It only states that learners enjoy the experience more.

The present study was designed to investigate issues related to attention by manipulating agent properties and features of the pictorial information. Two possibilities present themselves in this context. First, consider the agent, deictic gesture can be used to direct the learner's attention while integrating the animated agent with a picture or animation. Pointing and gesturing are a natural way in which both adults and children attempt to direct attention (Alibali & DiRusso, 1999; Krauss, 1998). Gestures should occur simultaneously or prior to the onset of the speech act that they signify (Morrel, & Krauss, 1992). A second option is to capture attention by using parts of a picture or animation itself. According to attention research, an excellent way capture attention is by an abrupt onset and motion (Jonides & Yantis, 1988; Yantis & Hillstrom, 1994).

The design was a 3 (agent properties: agent only, agent with gestures, no agent) x 3 (picture features: static picture, sudden onset, animation) factorial. If the use of an agent leads to split attention effects and if these effects are reduced by agent gesture, then we would expect to see the no agent condition > the agent condition < agent with gesture condition. If there were no split attention effect, then no differences would be seen between agent properties. The cognitive theory of multimedia learning would predict that within the picture features animation > static picture. Also, within the picture features sudden onset > static picture if attention capture is sufficient for learning.

Methods

Participants

Participants in this experiment were 135 students drawn from an undergraduate psychology students at the University of Memphis who volunteered from a pool of participants. This pool consisted of all students taking either of two levels of introductory psychology courses.

Materials

The materials for the experiment were of two kinds: computerized materials and pencil and paper. The computerized materials consisted of the visual and narrative information presentation (training section). The pencil and paper materials consisted of a questionnaire for domain knowledge, a test of spatial ability, a mental load rating scale, a persona rating scale, multiple-choice questions, a matching test, a retention test, and transfer tests involving creative solutions.

The computerized materials were created using three different computer application packages. The agent and voice were created using the Microsoft Agent software package (Microsoft, 1998). The multimedia animations were created using Macromedia Flash 3.0 (Macromedia, 1998). These packages were integrated using a Program called Xtrain (Hu, 1998; Hu & Craig, 2000).

Likert-type scales were used for the Persona test and mental load rating. The persona test ranged from 1 to 6 with 1 being extremely enjoyable and 6 being extremely not enjoyable. The scale was similar to those that were described in previous research literature (Johnson et al., 2000; Lester et al., 1997). The mental load rating ranged from 1 to 6 with 1 being extremely easy and 6 being extremely difficult. This subjective rating has been used in previous research as a measure of the cognitive load of a task (Kalyuga, Chandler, & Sweller, 1999; Paas & Van Merrienboer, 1993, 1994).

Participants also received two pencil and paper tests at the outset of the experiment session. Both of these tests were brief and were given prior to the multimedia information presentation. The tests were for domain knowledge and spatial ability.

The test of domain knowledge was a standard screening test used in related research (Mayer & Moreno, 1998; Moreno & Mayer, 1999). This questionnaire consisted of a seven item activity checklist containing statements concerning weather knowledge, with one point added for each checked item and a five level-self assessment from less than average domain knowledge (1) to very much (5). The cut-off criterion adopted was six (out of a maximum 11) in order to be consistent with related research (Mayer, 1997; Mayer & Moreno, 1998; Moreno & Mayer, 1999). The test of spatial ability was a standard paperfolding task with scores used as a covariate. In the task, participants were simply given twelve minutes to correctly answer as many questions as they could (Bennet, Seashore, & Wesman, 1972).

The information presentation was concerned with the process of lightning formation. These materials have been shown to be effective for achieving learning gains in previous research (Mayer & Moreno, 1998; Moreno & Mayer, 1999). The scenario presented followed a causal path from how a storm front forms to the creation and display of lightning.

The three remaining tests have been used in previous research (Mayer & Moreno, 1998; Moreno & Mayer, 1999). These involved retention, matching, and transfer. The retention test consisted of one question, "Please write down an explanation of how lightning works" (See Appendix D for example). These tests were collected after five minutes. The matching test consisted of four frames with instructions that ask the participants to circle and label the cool moist air, warmer surface, updraft, freezing level, downdraft, gusts of cool wind, stepped leader, and the return stroke. These were collected after three minutes. The test for creative solutions consists of four questions presented one at a time for three minutes each.

In addition to the tests used by Mayer, participants were also presented with a series of six multiple-choice questions requiring a forced choice among four possibilities, one correct with three other foils. These six questions assessed three categories of knowledge (explicit shallow, explicit deep, and implicit deep). The explicit shallow questions focused on the shallow surface level information from the presentation (e.g., The upper portion of the cloud is made up of what?). The explicit deep questions focus on understanding of the concepts what were presented in the information delivery (e.g., When do downdrafts occur?). The Implicit deep questions focus on the application of the underlying concepts to problems that were not focused on in the information delivery (e.g., Why does it get colder right before it rains?).

Procedure

The basic procedure was as follows. When the participants first entered the laboratory, they were issued a packet of materials. This packet contained their informed consent, test of domain knowledge, and the test of spatial ability. After these were completed, those eligible for the study (those scoring under half on the domain knowledge test) received instructions for part two of the experiment. They were presented with the information delivery, which took about three minutes. Afterward, they were given the retention question (5 minutes), the Multiple-choice questions (2 minutes), the matching test (3 minutes), and 4 transfer questions (3 minutes each).

Results and Discussion

Persona effect

A 3 (agent properties: no agent, agent, agent with gesture) x 3 (picture features: picture, onset, motion) ANOVA was performed on the persona data. There was no evidence for a persona effect in this study. There could be several explanations for this. Participants were only exposed to one condition and thus, they had nothing to make a comparison with. If this is the case, a within subject design would be an accurate measure. Also, the agent was displayed for only 180 seconds and that might not have been long enough to produce an effect. Since the persona effect is based on the agent making the learning experience more enjoyable (Johnson et al., 2000), an agent interaction within the learning environment for 180 seconds was probably not enough to produce an effect.

Even though the persona effect (Andre et al., 1999; Lester, Convers et al., 1997) was not significant, a trend can be seen in the data. In the scale, a lower score indicated a more positive rating. The means ratings for the three groups were $\underline{M} = 3.44$ for no agent present, $\underline{M} = 3.42$ for agent present, and $\underline{M} = 3.07$ for agent with gestures with lower numbers indicating a more positive rating. A Cohen's f effect size was calculated for the persona data. These analyses yielded effect size score of .42 in the agent-with-gestures vs. no-agent comparison, and a score of .02 in the agent-only vs. no-agent comparison. This shows a supportive trend for the persona effect.

Cognitive Load

A 3 (agent properties: no agent, agent, agent with gesture) x 3 (picture features: picture, onset, motion) ANOVA was performed on the cognitive load data (Paas & Merrienboer, 1993). It yielded a significant effect between the picture features, ($\underline{F}$ (2,126) = 3.737, $\underline{p} < .05$). A post hoc test performed on the three picture features groups yielded significant differences in perceived comprehension ratings between the picture condition ($\underline{M}$ = 3.62) and the motion condition ($\underline{M}$ = 3.09), ($\underline{p}$ < .05). This finding is in line the cognitive theory of multimedia learning. It predicts a decrease in the difficulty of comprehension for the motion condition over the picture condition when synchronization of the display is attained that ensures temporal and spatial contiguity (Moreno & Mayer 1999).

Matching

A 3 (agent properties: no agent, agent, agent with gesture) x 3 (picture features: picture, onset, motion) ANOVA was performed on the matching task data. It yielded a significant effect only for picture features, $\underline{F}(2,133) = 12.434$, $\underline{p} < .001$. Tukey contrasts revealed that both onset ($\underline{M}$ = 4.42) and motion ($\underline{M}$ = 4.56) conditions performed significantly better than the picture condition ($\underline{M}$ = 3.13, $\underline{p} < .001$), but that the onset and motion conditions do not differ from each other.

Although these results differ from previous results that did not find differences in the matching data (Mayer, 1997; Moreno & Mayer, 1999), they support the cognitive theory of multimedia learning. According to this theory, in order for successful learning to occur, there must be an integration of the verbally based and the visually based models of the material (Mayer, 1984). This integration may be enhanced by the use of animations over pictures (Moreno & Mayer, 1999). Both the motion and the onset conditions provided the verbal and visual integration needed for matching in the present study. The difference was possibly due to the decreased presentation time that prevented the ceiling effects found in previous research by Moreno and Mayer (1999).

Retention

A 3 (agent properties: no agent, agent, agent with gesture) x 3 (picture features: picture, onset, motion) ANOVA was performed on the retention data. It yielded a significant effect only for Picture features, $\underline{F}(2, 133) = 25.73$, $\underline{p} < .001$. Tukey contrasts yielded a difference between the picture condition ($\underline{M}$ = 1.93) and both the onset ($\underline{M}$ = 4.20) and motion ($\underline{M}$ = 5.07) conditions. There was no difference between the latter two groups.

Transfer

The transfer task probed the extent to which participants applied the concepts they learned to other problems and exhibited creative solutions. A 3 (agent properties: no agent, agent, agent with gesture) x 3 (picture features: picture, onset, motion) ANOVA was performed on the transfer task data. This analysis yielded a significant effect of picture features only, $\underline{F}(2,133) = 4.03$, $\underline{p} < .05$. Tukey contrasts yielded a difference between the onset ($\underline{M}$ = 2.13) and picture ($\underline{M}$ = 1.44) conditions ($\underline{p} < .05$). The motion condition ($\underline{M}$ = 1.89) was intermediate and did not differ from either of the other two groups.

The differences between the onset and picture conditions provides support for claim the that a sudden onset of a color singleton directs attention as needed to assist the construction of mental models that facilitate the implicit inferences necessary to construct creative solutions.

Multiple-Choice Questions

A 3 (agent properties: no agent, agent, agent with gesture) x 3 (picture features: picture, onset, motion) ANOVA was performed on the total score obtained from the multiple-choice questions. This yielded a significant difference only between picture features, $\underline{F}(2,133) = 7.58$, $\underline{p} < .001$. Both the onset ($\underline{M}$ = 2.13) and motion ($\underline{M}$ = 1.89) groups significantly outperformed the picture ($\underline{M}$ = 1.44) group ($\underline{p} < .001$). There was no difference between onset and motion conditions.

Explicit Shallow. The multiple-choice questions attempted to evaluate three types of knowledge (explicit shallow, explicit deep, and implicit deep). A 3 (agent properties: no agent, agent, agent with gesture) x 3 (picture features: picture, onset, motion) ANOVA performed on the data from the questions that tapped explicit shallow knowledge yielded only a significant effect of picture features, $\underline{F}(2, 133) = 3.08$, $\underline{p} < .05$. Tukey contrasts showed that participants in the motion condition ($\underline{M}$ = 1.64) outperformed the picture condition ($\underline{M}$ = 1.36), ($\underline{p} < .05$). This result is consistent with findings from the matching task, which tested for shallow knowledge.

Explicit Deep. A 3 (agent properties: no agent, agent, agent with gesture) x 3 (picture features: picture, onset, motion) ANOVA was performed on the data for the explicit deep questions. It yielded only a significant effect for the picture features, $\underline{F}(2,133) = 7.93$, $p<.001$. Tukey contrasts revealed differences between both the onset condition ($\underline{M}$ = .71) and the motion condition ($\underline{M}$ = .79) when compared to the picture condition ($\underline{M}$ = .29). The participants in the motion condition outperformed those in the picture condition ($p < .001$). Similarly, those in the onset condition outperformed participants in the picture condition ($p < .01$). These findings suggest that by directing attention appropriately the onset of the color singleton (Yantis & Hillstrom, 1994) facilitated deeper learning of core concepts as effectively as an animation with motion in the present relatively brief presentation. This would seem to indicate that the onset provided the temporal contiguity that, according to Moreno and Mayer (1999), was required to get full integration of the verbal and visual representations.

Implicit Deep. The final multiple-choice questions were designed to tap implicit deep knowledge. A 3 (agent properties: no agent, agent, agent with gesture) x 3 (picture features: picture, onset, motion) ANOVA that was performed on the data yielded no significant effects, but picture features was marginally significant, $F(2,133) = 2.738$, $p = .068$. Furthermore, the means (picture $M = .96$, onset $M = 1.20$, motion $M = .91$) were in a somewhat similar direction as the transfer data, which attempted to tap the same pool of knowledge.

The means and standard deviations for all conditions and measures are presented in Table 1 below.

	Persona Test	Matching Test	Retention Question	Transfer Questions	Multiple Choice (Total)	Explicit Shallow	Explicit Deep	Implicit Deep
Agent Properties								
No agent	3.44	4.04	3.91	1.69	3.40	1.56	0.67	1.18
Agent Only	3.42	4.04	3.80	1.76	2.96	1.53	0.49	1.00
Agent w/ Gesture	3.07	4.02	3.49	2.02	3.02	1.52	0.59	0.89
Picture features								
Picture	3.62	3.13	1.93	1.44	2.60	1.36	0.29	0.96
Onset	3.24	4.42	4.20	2.13	3.47	1.56	0.71	1.20
Motion	3.09	4.56	5.07	1.89	3.31	1.64	0.79	0.91

Table 1. Table of Means and standard deviations

Summary and conclusions

The study revealed several findings. First, there were no differences due to agent properties and, thus, there was no evidence of split-attention effects. The presence of the agent in the learning environment was not detrimental to learning. It appears that agents can be safely integrated into brief multimedia presentations without fear of interference, as proposed by Johnson et al (2000). Second, most of the analyses revealed differences among the image-type conditions that supported the cognitive theory of multimedia learning (Moreno & Mayer, 1999). Close temporal synchronization of the narration with the animated display enhanced learning, presumably by establishing relationships between the visual and verbal representations. Third, the findings suggest stimulus onset is just as effective and in some cases more effective in directing attention to appropriate parts of the display as motion in a fully animated display.

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