Chapter 21

Can Seventh Graders Learn Fractions from a Web-Based Pedagogical Agent? Using Comparison Groups Three Times Over Several Weeks

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Learning Objectives

After reading this chapter and considering the issues, you will be able to:

1. Describe the research question / problem in the introduction.
2. Summarize in your own words orally or in writing the gist of the literature review, including the theoretical framework to support the questions, problem, or need.
3. Describe the gist of the methodology, including:
   a. The participants [e.g., level, prerequisites, prior knowledge of the dependent variable under consideration, motivation to learn (intrinsic better job, etc.)]
Abstract

In this study, a Web-based pedagogical agent presented 7th grade students (n = 91) with examples and practice questions involving the multiplication and division of fractions. Pedagogical agents are animated, talking characters that can be made to introduce, guide or otherwise enhance educational Web sites. It was expected that school-age students using moving and talking pedagogical agents would retain more and find more creative solutions to problems than students in the other treatment conditions. A repeated measures-by-occasion research design was used to determine if the movement and or talking by the agent helped them learn to multiply and divide fractions. Results of the analyses showed that students learned from the pre-test to immediate post-test. But there were no effects for either modality (speech vs. text) or agent animation (movement vs. no movement). Consistent with a previous study with 7th grade students
using educational multimedia (Mann, Newhouse, Pagram, Campbell, & Schulz, 2002) positive findings from using speech in educational multimedia may only be generalizable to adults and older adolescents. Implications are discussed regarding the instructional design of educational Web sites.

**Introduction**

The purpose of this research was to extend investigations on pedagogical agents to school-aged students. At present, research on learning from pedagogical agents has explored several factors, including: the presence and movement of an agent, the agent persona, the modality accompanying the agent (speech and static, flashing or bubble text), and the number of agents on-screen. Animated pedagogical agents are cartoon-like characters that can be programmed to move around the computer screen gesturing, doing tricks, and talking to the student in sound prompts or bubble text. At present, most of the research on using animated pedagogical agents has been conducted with adult learners, mostly undergraduate psychology majors or pre-service teachers. Pedagogical agents are typically expected to maintain student attention to critical information on the computer interface (Dehn & van Mulken, 2000) and provide dynamically individualized scaffolding through educational Web sites (Callaway, Lester, Towns, & Voerman, 1999; Moreno, Mayer, & Lester, 2000). In this way, pedagogical agents are intended to enhance the learning experience.

**Review of the Literature**

We anticipated that school-age students, like their adult counterparts, would extract details from reading, and acoustically encode the gist from listening, as suggested in the literature on cognition (Estes, 1980; Hildyard & Olson, 1982; Reyna, 1992; Brainerd & Reyna, 1990). Recent research in educational multimedia (Mann, Newhouse, Pagram, Campbell, & Schulz, 2002), however, suggests that these positive findings from using speech in educational multimedia may only be generalizable to adults and older adolescents. A new study was needed with school-age students to focus on the prediction that school-aged students would learn better from animated pedagogical agents when critical information was presented as speech rather than on-screen text. In this research, temporal speech cueing, from the Structured Sound Function (SSF) Model (Mann, 1992) was designated for empirical study with school-age students. The SSF Model accounted for the interrelatedness of spatial and language representations, and for the different predispositions of readers and listeners.

Does the simple presence of an agent affect learning? The role of the agent’s image and animation in recent agent research has become less clear (Baylor & Ryu, 2002). Moreno, Mayer, Spires, and Lester (2001) found no benefit from the presence of an agent on either
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delayed post-test of facts or problem solving transfer in undergraduate psychology students ($n = 64$). Moreno, Mayer, and Lester (2000) reported that students who were presented with the image of a pedagogical agent did not rate the lesson more favorable, recall more, or were better able to use what they had learned to solve problems than students who were not presented with the visual presence of the agent. And Craig, Gholson, and Driscoll (2002) also found that agent properties per se produced no significant gains in undergraduate student learning ($n = 135$).

Does the movement of an agent affect learning? Johnson, Rickel, and Lester (2000) speculated that agent motion and gesturing could capture student attention and offer feedback without breaking the student’s train of thought. However, Craig, Gholson, and Driscoll (2002) found that learning was no better or worse with a moving agent than with a stationary agent in undergraduate students ($n = 135$).

Do multiple agents affect learning? Whereas multiple agents can serve to effectively operationalize instructional theory, Baylor (2002) found that learning with multiple agents was actually worse for graduate education students ($n = 135$). This finding is consistent with split attention effect and cognitive load theory (Chandler & Sweller, 1991; Yeung, Jin, & Sweller, 1997), and may be explained by stochastic roles assigned to the agents’ speech (Mann, 1997a).

Does the modality accompanying an agent affect learning? The inclusion of voice has been found to be a key element for agent-based learning environments (Baylor & Ryu, 2002). Previous research on student learning from modality in educational multimedia improved in adults and older adolescents (i.e., apprentices, college and university students) when critical information was presented in speech rather than on-screen text (Chandler & Sweller, 1992; Mann, 1995a; Mann, 1997a; Mayer, 1997; Moreno & Mayer, 2000). Moreno, Mayer, and Lester (2000) reported that undergraduate psychology students who learned with the voice of a pedagogical agent rated the lesson more favorably, recalled more, and were better able to use what they had learned to solve problems than students who learned the same verbal materials as on-screen text. Moreno, Mayer, Spires, and Lester (2001) reported better problem solving transfer with a speaking agent, with both undergraduate psychology students ($n = 44$) and with 7th graders ($n = 48$), but did not find better results for their delayed post-test of facts in either group. Craig, Gholson, and Driscoll (2002) also found better delayed post-test of facts and problem solving transfer in undergraduate students ($n = 135$) using a speaking agent. However, a recent study with 7th graders in Australia (Mann, Newhouse, Pagram, Campbell, & Schulz, 2002) reported no differences between speech cueing and on-screen text cueing. And while Atkinson (2002) found no differences in a pilot study with undergraduate psychology students ($n = 30$) between synthesized voice plus agent, synthesized voice-only, and text-only conditions, separate studies using a human digitized human voice with undergraduate students ($n = 50, n = 75$), indicated better learning with the speaking agent than the agent with text.

The goal of this research was to determine whether or not school-aged students would learn from “agent animation” (movement or no movement) and “modality” (auditory or on-screen text). It was expected that students learning from a moving and talking Web-based animated pedagogical agent would retain more knowledge, and find more creative solutions to problems than students using agents that did not move or talk. Neither “the
presence nor absence of an agent,” nor “multiple agents” were studied in this research. Agent presence was held constant across all learning conditions.

Method

Participants

Participants ranged between 12 and 15 years of age ($n = 91$) enrolled in 7th grade at a public High School in a small city in Eastern Canada. Small sample sizes are common in psychological research on learning from educational multimedia (Atkinson, 2002; Craig, Gholson, & Driscoll, 2002; Moreno, Mayer, Hillier, & Lester, 2001). The students had not yet been introduced to multiplication or division of fractions. The participants in this study with proper consent were randomly assigned to one of the four treatment groups: Movement with Speech (M, S), No Movement with Speech (NM, S), Movement with Text (M, T), and No Movement with Text (NM, T).

The Setting

The Mathematics Department Head at a high school in Eastern Canada expressed concerns that a large number of 7th grade students were unable to remember the correct procedure to complete fraction problems after they had been taught. It seemed that the students received enough instruction, but were unable to retain how to do the problems. Teacher contracts were under negotiation at the time, so special tutoring for students was not an option. Several different mathematics software titles were reviewed at the university library. All of the programs reviewed were well done, but did not deal exclusively with fractions, since a fraction problem may come up every tenth problem. This is where the students needed the most practice.

A prototype was developed as a lesson enhancement to help students learn and apply the basic rules of multiplication and division of fractions using a tutorial Web site that incorporated elaborate interrogation and an animated, pedagogical agent embedded in the school’s Web site. For these reasons, a study was initiated with 7th grade students (originally 1,010 students) at a high school in Eastern Canada to determine the success of modality (sound or text) and agent animation and meet the need for tutorial with fractions.

Dependent Variable

The dependent variable consisted of a test of near transfer items that were structurally similar to items encountered during instruction, in keeping with Atkinson (2002), namely (1) concept learning: students were asked to recall the rule for the multiplication and division of fractions to the question, “What is the rule for the division of fractions?” and,
(2) rule-using- students’ application of the rule for the multiplication and division of fractions including conversion to simplest form, as in “What is the best answer for 1/3×2/4?”

1. 2/12
2. 1/6
3. 6/1
4. 6

One 15 question test of student knowledge and skill with multiplication and division of fractions was administered in WebCT, and used as the pre-test, immediate post-test, and delayed post-test.

**Materials**

The programmable Microsoft Agent “Peedy” was used to activate associations between relevant prior knowledge and the new information, and temporal speech cueing procedures were applied from the SSF Model (Mann, 1996, 2000) for empirical study with the students. The Peedy character has been used recently in Atkinson’s (2002) research with animated pedagogical agents. The program presented progressively more difficult fractions problems to solve.

Since the students in this study already had prior knowledge regarding the calculation of fractions, this design was expected to be beneficial. Several educators and students examined the prototype: (1) A subject matter expert (SME) had been the Math Department Head for the past three years and had been a mathematics teacher for the past 12 years.

*Figure 1. Peedy, a Web-based animated, talking pedagogical agent presents instruction on how to use the Web site*
at a high school in Eastern Canada. The SME’s role in this quality review was to look at the content and grammar used in the fractions prototype; (2) This instructional design (ID) expert was currently employed as an environmental engineer, working at instructional design and web development on a regular basis. The ID expert’s role was to review the prototype with the following aspects in mind: ease of use of program, appearance and flow of program, coherency of prototype, and visible features including audio and animation; (3) Two students from the target audience from 8th grade with average math background reviewed the prototype. The students’ role was to see if they liked the prototype, and if they could easily progress through the program on their own with little direction. The student reviews determined that the content would be of benefit to students aged 12-13 who had just introduced to the rules of multiplying and dividing fractions.

In 1997, Lester and his colleagues developed a similar math prototype for 100 7th graders. The animated pedagogical agent was “Herman the Bug.” The students were randomly assigned to one of five groups. Each group consisted of 20 students with a cloned “Herman.” The five Hermans differed from one other with respect to their modes of expression and in the level of advice they offered in response to students’ problem-solving activities.

**Design**

The design of this study on fractions was the same as that of an experiment, namely: a repeated measures ANOVA experiment with two independent factors, “agent animation” (movement or no movement) and “modality” (auditory or on-screen text information) (see Figure 2). The fractions test was administered prior to the treatment, pre-test, upon completion of the treatment, immediate post-test, and six weeks later, delayed post-test. The pre-test was similar to Atkinson’s (2002) 11 item pre-test.

**Procedure**

The procedures in this study followed those suggested in previous studies of this kind (Brown & Mann, 2001; Mann et al., 2002). A number of activities were done simultaneously and the final schedule established at the mutual convenience of the participants and the investigators. The entire process lasted just under an hour and comprised the following steps: Written consent was obtained from the parents, from the School Board,

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**Figure 2. Research design to investigate modality (sound or text) and agent animation (movement or no movement) factors in educational multimedia**

<table>
<thead>
<tr>
<th>Cues Type</th>
<th>Movement</th>
<th>No Movement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speech cues (S)</td>
<td>(M, S)</td>
<td>(NM, S)</td>
</tr>
<tr>
<td>Text cues (T)</td>
<td>(M, T)</td>
<td>(NM, T)</td>
</tr>
</tbody>
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the School Principal, from the Regional Superintendent, and from the Interdisciplinary Committee on Ethics in Human Research at the university. Next, all grade 4 and 5 students with proper consent were treated as one sample with each student being individually randomly assigned to one of the four treatment groups. The groups were as identified in Figure 2: Movement with Speech, No Movement with Speech, Movement with Text, and No Movement with Text. One week later, the test of usage and interpretation of rules was administered in WebCT as a pre-test. Four weeks later, students were administered the treatment and immediate post-test. This was followed six weeks later by administration of the delayed post-test.

Results

The collection and analysis of the fractions data showed that some students were missing for the testing sessions: 96 students were present for the pre-test, 92 for the treatment and immediate post-test, and 96 for the delayed post-test, with complete data for 79 students. Scores were imputed for students who obtained the treatment and immediate post-test and missed either the pre-test or the delayed post-test—seven were imputed on the pre-test and five on the delayed post-test. This resulted in complete scores for 91 students (see Table 1). Imputation was calculated by multiple regression with a stochastic component. For example, a missing delayed post-test was be replaced with the value produced from a multiple regression of the delayed post-test on the pre-test and

<table>
<thead>
<tr>
<th>Agent animation</th>
<th>Modality</th>
<th>Fractions test</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Pre</td>
</tr>
<tr>
<td>Movement</td>
<td>Speech</td>
<td>M</td>
</tr>
<tr>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Text</td>
<td>M</td>
</tr>
<tr>
<td></td>
<td></td>
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</tr>
<tr>
<td>No movement</td>
<td>Speech</td>
<td>M</td>
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<tr>
<td></td>
<td></td>
<td>n = 23</td>
</tr>
<tr>
<td></td>
<td>Text</td>
<td>M</td>
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<td></td>
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<td></td>
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<tr>
<td></td>
<td>n = 91</td>
<td>s</td>
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Table 1. Means on fractions test for the four groups over the three testing times

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Figure 3. Three administrations of a test with 7th graders on “multiplying fractions”

Post-test, based on complex data plus a random component. The procedure followed one described in Allison et al. (2002) and in Peugh and Enders (2002). Preliminary ANOVA on the fractions pre-test means of the four treatment groups indicated that they did not differ significantly, $F(3, 87) = .37$ ($p = .772$). The groups were nearly equivalent in their prior knowledge of fraction multiplication and division. Figure 3 depicts the means for the four groups over the three testing administrations of the fractions test, and Table 1 presents the descriptive statistics.

The lines in Figure 3 shows that the changes between pre-test, immediate post-test and delayed post-test indicate substantial gains in learning from pre-test to immediate post-test, but that this learning does not maintain over the delayed post-testing.

While it appears in Figure 3 that the speech movement group performed higher on the immediate post-test than did any of the other groups, this was not born out in the analysis. There was no significant interaction effects of modality or of modality and agent animation with pre-test, immediate post-test, and delayed post-test (see Table 2).

The results were similar for the four groups of grade 7’s performance in fractions so that all four conditions could be readily collapsed to show the magnitude of change in student performance over time. The wide range of scores, particularly on the immediate post-test, served to obscure this apparent difference making it less than statistically significant. Since no interactions were significant, further analysis was conducted on all four groups combined to determine which pre-test, post-test delayed post-test differences were significant.
Figure 3 illustrates the deterioration in the abilities in all four treatment groups to multiply fractions on the delayed post-test. One plausible explanation for the deterioration in performance across the board may be attributed to events occurring in the school during the day of the delayed post-test. That day, the whole school turned out to see their school friends leave to return home to France. A sad occasion to be sure. This event however, affected all four treatments equally and does therefore not account for the 15 point drop in the “speech movement” scores.

### General Discussion

Learning fractions by the 7th graders was similar for all four conditions, namely: dramatic improvement in performance for all four groups, but dropping-off just as dramatically (see Figure 3). What is of concern is that apparently the learning did not maintain over time, as indicated in the delayed post-testing. Despite their apparent fascination with the pedagogical agent, or “little Dude” as he was called by some of the children, expectations about student learning from the movement of the agent were not supported. The results with these 7th graders coincided with the results of a previous study with 7th graders using speech prompts in educational multimedia (Mann et al., 2002). Whereas the children in the sound group appeared to be more absorbed in the experience, they were unable to formulate coherent understandings from the media mix. More research is needed to determine how 7th graders’ control the frequency and strength of referential mental connections between brief sentences on the screen and the spoken prompts, and between the animations and the spoken prompts to formulate coherent understanding from the presentations.
Implications

One of the implications of this research is that a moving agent didn’t get different results from that of an agent that did not move, despite speculation that agent motion and gesturing could capture student attention and offer feedback without breaking the student’s train of thought (Johnson, Rickel, & Lester, 2000). Similar results were found in previous research (Craig, Gholson, & Driscoll, 2002).

A second implication is that listeners to agent speech and readers of agent screen attend differently to information. In general, readers seek the surface features of the text aloud at word-level, as suggested by Halliday (1987). The readers adopted a message focus, in Tannen’s terms (1985), expressing themselves in complex, syntactic constructions and lexicalization for identification. Conclusions arising from the analyses of these data augment previous bimodal research (Brainerd, 1993; Halliday, 1987; Hildyard & Olson, 1982; Mann, 1993; Penney, 1989; Reyna, 1993).

A third implication of this research is that the modality principle is well-suited to university and elementary students alike, yet less adequately describes the situation for 7th grade students. According to the modality principle, college students that learn with concurrent narration and animations will outperform those that learn with concurrent on-screen text and animations (Chandler & Sweller, 1992; Mann, 1995a; Mann, 1997a; Mayer & Moreno, 1998; Moreno & Mayer, 1999, Experiment 2). On difficult divided-attention tasks or with unfamiliar items, attention focusing becomes serial. Only one task is processed at a time, as mentioned earlier. Meaningful learning occurs when the learner selects relevant information in each store, organizes the information in each store into a coherent representation, and makes connections between corresponding representations in each store (Mayer, 1997). To engage in the appropriate attentive state, they must self-initiate a system of information processing (Borich & Tombari, 1995). With increasing age and experience, children’s processing becomes more efficient. Maturation may be certainly be considered a partial explanation, the design of the interface possibly another, and the nature of the testing conditions yet another. Longer studies might investigate the developmental stages in life as they relate to our capacity to extract gist from sound in multimedia presentations.

Limitations

Limitations of the research must also be noted. One limitation was that the experimental method itself restricted our investigations to a tightly controlled, narrowly defined curricular focus, namely: the multiplication and division of fractions by 7th graders. All the teachers of these students were completely excluded from the experiment, quite unlike their daily multimedia learning experiences. The results indicate, therefore, that whereas the nature of the presentations used and results from the experiment were valid, they may not be completely generalizable to other groups of school-age students.

A second limitation of the research was that motivational strategies were left unplanned because the focus of this study was solely informational. Only simple learner controls...
on the interface were used instead of more sophisticated methods evident in children’s educational software, such as learner-control with advisement, or printed guides.

A third limitation was that although the students were randomly assigned to treatment groups, the children in both experiments were nevertheless a population of convenience wherein whole (intact) classes of students were used.

A fourth limitation of the research was the method of testing. In this research, the children’s abilities were assessed with a performance test of multiple choice and short-answer items, in accordance with adult methods of assessing learning from multimedia. A method of testing more consistent with Mayer’s (1997) cognitive theory of multimedia learning would include an expanded inventory of tests of constructed response items or a protocol analysis of the children’s verbalizations to investigate the referential connections that young students make between verbal and spatial instructional materials.

Future Directions

In this research, only speech prompts were applied. Differences between music, sound effects and speech as informational cues were not addressed. Agent speech is an important part of the pedagogical agent persona and should continue to be considered in the design of instructional materials. Temporal speech cueing by the agent was designated for empirical study with these students. No other function of sound was investigated. With temporal speech cueing, the instructional intent is that the pedagogical agent uses explanations of the reasoning process in step-wise fashion and context-sensitive program directions to enhance the activity-eliciting potential of the multimedia learning environment. Temporal speech cueing is but one of six possible functions of sound that can assist students in learning difficult or unfamiliar tasks from a multimedia environment, as suggested in the structured sound function (ssf) model. Instead, a speaking pedagogical agent could for example, be programmed to present one or more points-of-view, or establish a particular locale, atmosphere, feeling or mood. The origin (Mann, 2000, 1995a, 1992) and research application (Mann, 1995b, 1996, 1997a, 1997b, Mann et al., 2002) of the ssf model is beyond the scope of this paper.

Finally, a single pedagogical agent was used in both experiments. Multiple agents could quite readily be explored for split attention effects, especially with school-aged and perhaps even pre-school children. Possible dependent or moderating variables could include: reduced clicking backward and forward between Web pages; conserved screen space; complementarity with Web site mathemagenics such as formatted text, graphics and static or moving visuals; aging, and; forgetting and reminiscence.

References


Moreno, R., Mayer, R. E., Hillier, S., & Lester, J. (2001). The case for social agency in computer-based teaching: Do students learn more deeply when they interact with animated pedagogical agents? *Cognition and Instruction, 19*(2), 177-213.


