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The effects of video on cognitive load and social presence in multimedia-learning

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Abstract

Two studies examined the use of video in multimedia learning environments. In Study 1, participants (N = 26) viewed one of two versions of a computer-based multimedia presentation: video, which included a video of a lecture with synchronized slides, or no video, which included the slides but only an audio narration of the lecture. Learning, cognitive load and social presence were assessed, but a significant difference was found only for cognitive load, with video experiencing greater cognitive load, t (24) = 2.45, p < .05. In Study 2, students (N = 25) were randomly assigned to either video or no video condition. Background knowledge and visual/verbal learning preference were assessed before viewing the presentation, and learning, cognitive load, and social presence were assessed after viewing. No significant differences were found for learning or social presence. However, a significant visual/verbal learning preference by condition interaction was found for cognitive load, F(1,21) = 4.51, p < .05: low visual-preference students experienced greater cognitive load in the video condition, while high visual-preference students experienced greater cognitive load in the no video condition.

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One of the great promises of computer technology for education is the ability to combine text, sound and images to create multimedia learning environments. For educational researches, the question to be investigated is not whether these new forms of media are
effective tools for learning – there is ample evidence that new media can be effective tools for education, depending upon the context and method by which they are used, as well as on the learner. Instead, the challenge for researchers is to identify the conditions under which different media are the most effective for learning (Mayer & Moreno, 2002). A second advantage of computer-based learning environments is that they are easily customizable and, therefore, can be tailored to meet the specific needs of individual learners. The question to be addressed then becomes, under what conditions are various media effective educational tools for different learners? In the current paper, two studies are presented that investigate how video affects learners’ experiences in a computer-based multimedia learning environment.

1. Theoretical background

To be effective, computer-based learning environments should be designed to accommodate the nature of the human mind and to account for inherent limitations of perceptual and cognitive systems. Sweller’s (1999, 2003) Cognitive load theory (CLT) provides a model for how the mind processes multimedia information. A central feature of CLT is that visual and verbal information are processed under the constraint of limited working memory capacity. The theory distinguishes between three types of cognitive load that compete for the limited resources of working memory when complex visual and verbal information is processed (Sweller, 1999). Intrinsic load is inherent to the materials being learned. The more complex the material, the greater the intrinsic load. Extraneous load is associated with the mental effort imposed by the instructional activities, their design and presentation. Extraneous load does not directly contribute to understanding of the material being taught. Finally, germane load is the mental effort that is exerted by learners to process the new information and to integrate it into existing knowledge structures. Because it is a property of the material being taught, intrinsic load is often thought to be invariant (Sweller, 1994), however, recent research suggests that in certain conditions, intrinsic load can be manipulated (e.g., Lee, Plass, & Homer, 2006). As a general principle, learning materials should be designed to reduce extraneous load in order to allow for the greatest amount of mental resources to be dedicated to germane load.

One method of partially overcoming the limits of working memory is to present part of the information being taught in a visual mode and part of it in a verbal mode. There is considerable evidence that humans have two separate working-memory systems, or channels: one for processing visual or pictorial information, and one for processing auditory or verbal information (Baddeley, 1986; Baddeley & Logie, 1999; Paivio, 1986). Because each system has a relatively limited capacity, it is easy for a system to become overloaded if more than a few chunks of novel information are processed simultaneously (e.g., Baddeley, 1986; Miller, 1956; Sweller, 2003). These findings form the basis of Mayer’s (2001) cognitive theory of multimedia learning. Mayer (2001) posits that there are three levels of cognitive processes involved in multimedia-learning: (1) selection of relevant visual and verbal information, (2) organization of the information into coherent visual and verbal models, and (3) integration of the mental models with each other and with previously existing knowledge. Presenting unique information in both visual and verbal formats allows and the learner to construct integrated mental models that make the retrieval of the information more likely (Paivio, 1986; Plass, Chun, Mayer, & Leutner, 1998).
Based on CLT and the cognitive theory of multimedia learning, it follows that providing redundant or irrelevant information in either visual or verbal formats will not help learning, and may in fact hinder it by adding to extraneous load. This means that multimedia learning environments should be designed such that any sound or video that does not convey information directly related to what is being taught should be eliminated as a possible hindrance to learning. However, it is possible that some of the sound and video that could be considered to add extraneous load may actually play an important role in the learning process.

One of the most common types of computer-based multimedia material for learning involves the online presentation of videotaped lectures. Presentations typically involve audio and video of a lecture, along with a visual presentation of the presenter’s slides. CLT and the cognitive theory of multimedia learning suggest that this type of presentation is not ideal for learning because it divides visual attention between the video of the speaker and the visual of the slides, creating a split-attention effect (Mayer & Moreno, 1998; Mousavi, Low, & Sweller, 1995). The video does not provide relevant information beyond what is conveyed in the audio track of the lecture, but instead creates a visual distraction, taking attention away from the visual information in the slides. However, the video may be having other effects that enhance learning. For example, the video may give learners a sense of interacting with a “real” person while watching the lecture. In other words, the video may help create a sense of social presence (Gunawardena, 1995).

Social presence was originally investigated as an issue in telecommunications (Short, Christie, & Williams, 1976). More recent work has identified social presence as an important factor in computer mediated communication, such as e-mail, discussion boards and video conferencing (Gunawardena, 1995; Kim & Biocca, 1997; Tu, 2002). A general finding from this body of research is that when information is presented in a way that increases social presence, it is more engaging and better remembered by learners. Similarly, for computer-based environments with little or no social component, feeling engaged with the environment, or telepresence (Steuer, 1992), predicts learning outcomes (Skadberg & Kimmel, 2004). For multimedia presentation of learning materials, this suggests that if video increases learners’ sense of engagement, it could compensate for the increase in cognitive load created by the video. Therefore, video may improve learning outcomes for students, even though it adds to cognitive load.

Although few studies have specifically examined social presence in computer-based multimedia learning environments, there is some evidence that social presence does have a positive effect on learning. Moreno and Mayer (2000), for example, found that in a multimedia-learning environment consisting of an animation and a narration, learners were more likely to be able to apply what that they had just learned to novel situations – indicating a deeper level of learning – if the narration used less formal language and directly addressed the learner (e.g., used “I” and “you”). The authors suggest that the informal communication made the students more socially engaged, and therefore more cognitively engaged with the learning materials. These findings stress the importance of investigating social and emotional issues in addition to cognitive factors in order to fully understand learning.

The current paper presents two studies that investigated how video affects learners’ experiences viewing a computer-based multimedia presentation. Of specific interest was how video would affect learners’ experience of cognitive load, social presence, and learning outcomes. The first study was a lab-based experiment that compared a video and no video condition of the same multimedia presentation. Based on the results of Study 1, a second study
replicated and extended the findings of the first study by examining how characteristics of individual learners affected their learning experience with the multimedia presentation.

2. Study 1

The first study examined the effects of video in a computer-based multimedia presentation of a videotaped lecture. Two versions of the presentation were created: a standard, video version of the presentation, which consisted of a video of the speaker delivering his lecture, an audio track of the lecture, and a visual presentation of the lecturer’s slides, as well as a no video presentation, which included the audio but no video of the lecture, along with the slides. Dependent measures were cognitive load and social presence. In addition, pre- and post-tests were given in order to look for group differences in learning outcomes. It was hypothesized that participants in the video condition would report great cognitive load, but also report a greater sense of social presence. No directional hypotheses were made for learning outcomes because there is not enough prior research to predict how cognitive load and social presence would interact to affect learning.

3. Method

3.1. Participants

The participants for Study 1 were undergraduate students (N = 26) from a large university. The participants were all enrolled in an introductory psychology course and received course credit for participating in the research. The participants came from diverse ethnic and cultural backgrounds, but all were fluent in English. The sample was 73% female.

3.2. Materials

A computer-based multimedia presentation was developed using an archived presentation from Webforum 2001: The Millennium Dialogue on Child Development. This conference brought together top researchers in the field of child development who were asked to provide a “state-of-the-art” summary of their particular sub-discipline. The talk used for the current studies was a 20-min presentation on the developing brain given by a leading developmental neuroscientist. In pilot testing, all students responded positively to this presentation and reported it to be informative and engaging. Two versions of the presentation were prepared. The video version involved a QuickTime movie of the speaker (with audio and video) and a synchronized PowerPoint presentation of the speaker’s slides. In the no video version, the video portion of the QuickTime movie was omitted, leaving just the audio component of the talk and the synchronized PowerPoint slides. Both versions of the presentation included VCR-style buttons that allowed the user to pause, play, rewind or fast-forward the presentation.

3.3. Measures

3.3.1. Test of background knowledge

Participants were given a brief, 15-question multiple-choice test of their background knowledge in the area of developmental psychology. The questions were drawn from a test
3.3.2. Social presence questionnaire

After viewing the presentation, participants were asked to complete a brief social presence questionnaire that asked about the degree to which they felt socially connected to the speaker during the presentation. The social presence questionnaire was adopted from a self-report scale used by Kim and Biocca (1997), which was originally used for web-based collaborative learning. For the current studies, the questions were modified to fit with an individual multimedia-learning experience. The questionnaire consisted of 10 statements about the participants’ perception of social presence (e.g., “When the computer presentation ended, I felt like I came back to the “real world” after a journey.”) Participants indicated the degree to which they agreed with each statement by selecting either: strongly agree, agree, disagree, or strongly disagree.

3.3.3. Cognitive load questionnaire

After the presentation, participants filled out a brief questionnaire that assessed the cognitive load they experienced while learning from the presentation. The cognitive load questionnaire was based on the one developed by Paas and van Merrienboer (1994) and has been used in a number of other related studies (e.g., Mayer & Moreno, 1998; Moreno & Mayer, 2000). It consisted of three Likert-scale questions that asked the participant to indicate the degree of difficulty and effort involved in their experience with the presentation.

3.3.4. Assessment of learning

Immediately following their viewing of the multimedia presentation, participants were given a test to assess what they learned from the presentation. Learning outcomes were measured at two levels: (i) a more basic “recall” level, with questions that tested for comprehension of key concepts, and (ii) a more advanced “transfer” level, which assessed participants ability to apply information presented to novel situations. Recall was tested using multiple-choice questions and transfer was tested using short-answer questions.

3.4. Procedure

Testing was carried out in small groups of 2–4 participants in a computer lab. All participants were first given the test of background knowledge and a demographic questionnaire. They were then randomly assigned to either the video or no video condition. In the video condition, participants observed the QuickTime video of a lecture along with synchronized PowerPoint slides, and in the no video condition, participants were given the presentation that included the slides and only the audio of the lecture. Each participant watched the presentation on a PC running Windows XP with QuickTime and they listened to the presentation via headphones connected to the PC. Immediately after viewing the presentation, participants were given the cognitive load, social presence, and learning outcomes (recall and transfer) measures.
4. Results

Total scores were calculated for cognitive load, social presence, and learning outcomes (recall and transfer). Means and standard deviations for both video and no video groups are reported in Table 1. *T*-tests were conducted to determine if condition affected social presence or cognitive load. No effect was found for social presence, \( t(24) = .72, p > .47 \). However, a significant effect was found for cognitive load, \( t(24) = 2.56, p < .05 \): the video group experienced significantly greater cognitive load than the no video group, with an effect size of \( d = 1.02 \). This corresponds to what Cohen (1988) describes as a “large” effect size. To determine if there were significant group differences in learning, two ANCOVAs were conducted with group as the independent variable, background knowledge as a covariable, and (i) Recall and (ii) Transfer scores as the dependent variables. No significant group differences were found for either recall, \( F(2, 23) = .32, p > .73 \), or for transfer, \( F(2, 23) = .84, p > .87 \).

5. Discussion

The results of Study 1 suggest that having video as well as PowerPoint slides created a split attention effect, which caused increased cognitive load. Typically, increased cognitive load results in reduced learning (Sweller, 1994), but this was not found in Study 1: overall, the participants were able to learn as well in the video condition as in the no video condition, even though the video condition required increased mental effort. One possible explanation for this finding is that other factors are affecting learning outcomes. Social presence was investigated as a possible factor, and although no difference was found between the two groups on their reported feelings of social presence, there may have been an interaction between condition (i.e., the presence or absence of video) and individual learners’ characteristics. A learner characteristic that is likely to have had an effect is preference for learning novel information from visual materials, a factor that has previously been found to affect learning in multimedia environments (Plass et al., 1998). This possibility was investigated in Study 2.

6. Study 2

A second study was carried out in which the multimedia presentations on brain development from Study 1 were incorporated into the curriculum of two graduate-level university courses. In both courses, one class was dedicated to viewing the multimedia presentation on brain development. The second study served to replicate Study 1 in the “real-world” setting of a university class, and also to examine how characteristics of individual learners affect their experiences interacting with multimedia presentations. Speci-
cally, individuals’ preference for learning from visual or verbal information was examined. The independent variables were condition and visual/verbal learning preference. Dependent variables were again cognitive load, social presence, and learning outcomes (recall and transfer). Background knowledge was considered as a covariate. It was hypothesized that there would be an interaction between condition and visual/verbal learning preference for all of the dependent variables (i.e., cognitive load, social presence, and learning outcomes).

As part of their coursework, the students also viewed a second presentation from the same conference as the developmental neuroscience lecture. Video and no-video versions of the second presentation were also created. Students viewed the version of the second presentation that differed from the version of first presentation that they had viewed. In other words, all students viewed the video version of one presentation and the no video version of the other presentation. Because of concerns about order effects and differences between the content and styles of the two lectures, a within-subjects design was not feasible. However, focus groups were conducted with each class after all students had viewed both presentations in order to get feedback about the students’ experiences with the two formats of presentation. This allowed for some informal qualitative data to be collected about students’ experiences with the multimedia presentations.

7. Method

7.1. Participants

The participants for Study 2 were graduate students (N = 25) from a large urban university. The students came from diverse ethnic and cultural backgrounds, but all students were fluent in English. The sample consisted of 80% females. Participants were enrolled in a graduate-level course in either cognitive development or cognitive science. All students in the courses were required to view the multimedia presentation, but students had the option of not allowing their data to be included in the study. To ensure that students did not feel coerced into participating in the research, consent forms and all paper and pencil data were placed in a sealed envelope and not opened until after final grades for the courses were submitted. However, all students did consent to allowing their data to be used in the study.

7.2. Materials

The two versions of the multimedia presentation on brain development from Study 1 were used for the quantitative portion of this study. For the informal discussion groups, two versions of a second computer-based multimedia presentation were developed. The basis of the second presentation was a lecture from the same conference as the lecture in the first presentation. The second lecture was given by a prominent developmental psychologist who spoke on the ways in which social factors influence children’s development.

7.3. Measures

All of the same measures from Study 1 were used again. These included: demographic questionnaire, test of background knowledge, cognitive load questionnaire, social presence
questionnaire, and learning outcomes test. In addition, the *Visualizer/Verbalizer Questionnaire* (VVQ) (Plass et al., 1998; Richardson, 1977) was used in Study 2. The visualizer/verbalizer learning preferences questionnaire is a brief, 10-item questionnaire that assesses whether individuals prefer acquiring new information in visual or verbal format.

### 7.4. Procedures

Testing took place during a regularly scheduled class meeting. Viewing the presentations was a requirement of the course, but students had the option of not filling out the questionnaires and not having their data included in the study. Before viewing the presentations, participants completed the demographic questionnaire, the test of background knowledge, and the VVQ. Participants were then randomly assigned to either video or no video conditions and watched the corresponding presentation on brain development: participants in the video condition viewed the presentation with a movie of the lecturer and synchronized PowerPoint slides, and those in the no video condition viewed the presentation that had the video was omitted. After the presentation, participants were given the tests of learning outcomes (recall and transfer of knowledge). Participants also filled out the cognitive load and social presence questionnaires.

After completing all the questionnaires and tests for the first presentation, students viewed one of the two versions of the second presentation on social influences of children development. Each student viewed the opposite format from the first video (i.e., every student viewed one video and one no video presentation). After all the students had completed viewing the second presentation, the experimenter conducted an open-ended group discussion with the entire class, asking about their preferences and experiences in viewing the two types of presentations. The discussion lasted for approximately 20 min. and was videotaped for later review.

### 8. Results and discussion

Total scores were calculated for all of the questionnaires. A median split was done on the VVQ in order to categorize participants as having either a “high” or “low” visual learning preference (*visual preference*). Two ANCOVAs were conducted with condition (video, no video) and visual preference (high, low) as independent variables, background knowledge as a covariable, and recall and transfer scores as dependent variables. No significant effects were found for recall, $F(4, 20) = 2.86, p > .05$. One participant did not complete the transfer questions and so the analyses for transfer were conducted with the remaining 24 students. No significant effects for transfer were found, $F(4, 19) = .62, p = .65$.

To examine the effects of condition and visual preference on social presence and cognitive load, ANOVAs were then conducted with condition (video, no video) and visual preference (high, low) as independent variables, and social presence and cognitive load as dependent variables. No significant effects were found for social presence, $F(3, 21) = 1.13, p = .36$. There were no main effects for cognitive load, however, there was a significant interaction between visual preference and condition, $F(1, 21) = 4.15, p < .05$. The partial eta squared for the visual preference by condition interaction was .18, meaning that the interaction by itself accounted for 18% of the overall (effect + error) variance. As seen in Fig. 1, students with low visual preference reported greater levels of cognitive load in the
video condition, whereas students with high visual preference reported greater cognitive load in the no video condition.

The quantitative data from Study 2 indicate that individual learner’s differences – in this case, learners’ preference for acquiring new information via a visual format – and variations in the multimedia-learning environment (i.e., presence or absence of video) interact to affect cognitive load. Although learning outcomes did not differ significantly, the differences in cognitive load indicate that participants with higher visual preference scores needed to exert greater mental effort to learn in the no video condition, while participants with lower visual preference score needed to exert greater mental effort to learn in the video condition. This suggests that determining efficient instructional techniques requires taking into account learners’ individual differences.

Comments made by students during the informal group discussions that occurred after students viewed the second presentation provided further evidence of the importance of individual differences. Some learners felt that the video enhanced their learning experiences, while others reported that they felt the no-video condition was better for them to learn. For example, one student said that she felt that, “the presence of the video of the lecturer made it easier to pay attention and feel engaged.” Similarly, another student suggested that, “I felt that the video gave me a feeling of ‘being there’.” Other students, however, preferred not having the video. One student said, “I learned more from the lecture without the lecturer because it was less distracting for me.” Another student had a similar comment, “to my great surprise, I was way more engaged with the audio only presentation than the video presentation. I found myself more drawn in, looking at the slides closer.” These comments suggest that video did affect the level of engagement felt by students, but the video could either increase or decrease engagement, depending on the individual student. This is consistent with the quantitative data and stresses how individual learners’ differences affect their learning experience.
9. General discussion

The primary objective of the current research was to identify the effects of video, specifically the video of a speaker, in computer-based multimedia learning environments. The framework for addressing this question was CLT and the theory of multimedia learning, which suggest that the inclusion of video with additional graphics, such as slides, is not optimal for learning because it divides learners’ visual attention, creating a split-attention effect. An alternative explanation was also explored, which suggested that the addition of video may increase learners’ feeling of social presence and thereby increase engagement with the learning materials. In Study 1, video was found to increase the cognitive load experienced by learners, but this did not affect social presence or learning outcomes. The second study added the question of how individual learner differences may interact with the effects of video in multimedia learning environments. In Study 2, video was again found to affect cognitive load, however, the effect was not uniform for all learners: individuals with a lesser preference for visual information experienced more cognitive load in the video condition, while individuals with a greater preference for visual information actually experienced less cognitive load in the video condition. There was no effect of video or visual preference on either learning outcomes or social presence, however, the qualitative data from Study 2 suggests that learners did differ in whether they felt more engaged in the video or the no video condition.

The two studies presented above are part of a growing body of work that emphasizes how characteristics of individual learners interact with characteristics of learning materials to affect learning. The strongest example of this phenomenon comes from research on the effects of learners’ prior knowledge. There is considerable evidence of an expertise reversal effect, in which instructional design features that are very effective with less knowledgeable learners lose their effectiveness or even hinder learning with more knowledgeable learners (Kalyuga, 2005; Kalyuga, Ayres, Chandler, & Sweller, 2003; Lee et al., 2006). Similarly, in the current studies, video increased the cognitive load for learners with a lesser preference for visual materials, but decreased the cognitive load for learners with a greater preference for visual materials.

An interesting finding in both studies was that the increased cognitive load associated with the video did not result in a reduction in learning. One possible explanation for this is that the learning assessed in the current studies was not taxing enough on the learners’ cognitive resources to be affected by the increase in cognitive load. Perhaps learning effects would be found in situations with more in-depth learning and more prolonged use of the learning environment, such as distance education classes where the entire course is presented on the Web. A second possibility is that video is having an effect on a second factor that counteracts the increased cognitive load. Social presence, as measured in the current studies, was not this factor. However, video may affect student’s engagement, which could be better measured by a different instrument.

The current studies provide a first step in understanding how video affects learning experience in multimedia learning environments. Further research is needed to identify ways in which video can enhance learning for particular individuals. For example, does including the video of a lecturer increase certain learners’ motivation or interest? Visual preference was found to influence the effects of video, but other individual characteristics, such as self-regulation, may also play an important role. Together, the two studies presented here argue for the need to consider multiple factors, including characteristics of
individual learners as well as social and emotional factors when designing multimedia learning environments.

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