Characteristics of Effective Multimedia for Teaching: Applying Cognitive Theories of Multimedia Learning to Complex Content

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Abstract:

The present study tests the impact of six multimedia presentation designs on participants’ comprehension and situational interest (SI) of complex ethical and regulatory concepts. Designed based on principles of the cognitive theory of multimedia learning (CTML) and the cognitive-affective theory of learning with media (CATLM), the six conditions differ in their use of visual attention cuing, verbal or printed information delivery, and the simultaneous or serial presentation of information. Participants are shown one of six randomized multimedia presentations and then asked ten questions in which they apply the information from the presentation which measure comprehension. Six additional questions measure SI. The current study is in progress, but this paper introduces CTML and CATLM with discussion on their application to the presentation of complex ideas in higher education as well as the communication of regulatory information in multiple contexts.

Keywords:

cognitive theory of multimedia learning, cognitive-affective theory of learning with media, dual coding theory, visual attention cuing, animation, motivation, infographics, podcasts

1. Introduction

Communicating complex ideas can be aided by multimedia or undermined by multimedia. Ill-considered information presentation can result in cognitive overload by placing competing processing demands on working memory systems. Cognitive overload typically results in reduced comprehension and increased frustration and learner fatigue (Sweller, 1988, 1994; Sweller, Ayres, & Kalyuga, 2011).

Well designed multimedia can be a highly effective means of communicating complex educational content, however. Two theories of multimedia design, the cognitive theory of multimedia learning and the cognitive affective theory of learning with media, inform the development of instructional tools that can result in greater comprehension of information and increased positive feelings toward the content.
1.1 Cognitive Theory of Multimedia Learning

CTML is based on theories of cognitive load (Sweller, 1999; Sweller et al., 2011), dual coding theory (Paivio, 1986) and constructivism (Piaget, 1952). CTML marries these three complementary theories and contextualizes them into multimedia learning.

A fundamental tenet of cognitive load theory is that human working memory has limited capacity (Sweller, 1988; 1994). Instruction must be carefully designed in order to obtain an optimal threshold of load that will result in both learning and engagement. Too little load results in boredom, too much load results in frustration (Sweller et al., 2011). In CTML, Mayer and Moreno (2003) refer to the element of cognitive load theory as the limited capacity assumption.

Dual coding theory illustrates the relationship between language and imagery. Paivio’s (1986) theory is that verbal and nonverbal stimuli we encounter in the environment through our sensory systems organize themselves into groups of language and sounds (logogens) and images, smells, and tastes (imagens). Logogens and imagens relate to themselves by making continual associative connections. At the same time each is engaged in associative connections, logogens and imagens are also continuously reaching out to each other. In this way, we assign language to sensory perceptions and vice versa. Mayer and Moreno (2003) refer to the interplay of dual coding theory in CTML as the dual channel assumption.

Constructivism (Piaget, 1952) is an educational theory which says that people continuously and actively construct their own knowledge through assimilation of new information with prior knowledge and by accommodation, which is the act of reframing one’s mental representation of the world. The inclusion of constructivist ideas in CTML is the active processing assumption.

CTML is grounded in cognitive load theory, dual coding theory, and constructivism but takes them one step further by contextualizing them in multimedia. As seen in Figure 1, CTML maps the introduction of words and pictures through the eyes and ears into working memory. Mayer (1997) has embedded the fundamental mechanisms of dual coding theory into the working memory processes and the element of prior knowledge into long-term memory, thus including constructivist learning theory.
1.2 Cognitive-Affective Theory of Learning with Media

The cognitive-affective theory of learning with media (Moreno, 2007) expands on CTML (Mayer, 1997) by positing that motivational factors mediate the cognitive processes involved in learning from multimedia materials. The inclusion of visual attention cuing, color, shapes, representational images, and arrows can all be used to increase motivation, positive feelings, and situational interest. Further, viewers who are more engaged in the content spend more time with it which can also have a positive effect on comprehension.

The use of round or oval shapes and colored backgrounds has been found to elicit positive feelings (Um, Plass, Hayward, & Homer, 2012) toward the content of a presentation. Embedding arrows to indicate directionality through printed text can improve the efficiency with which the reader navigates the content, which in turn can have a positive impact on the readers’ coherence of understanding (Holsanova, Holmberg, & Holmqvist, 2009). Representational images (Carney & Levin, 2002) have been found to aid the viewer’s dual coding process in some cases based on learner characteristics (Magner, Schwonke, Aleven, Popescu, & Renkl, 2014).

Researchers have measured the impact of simultaneous presentation of information against a serial presentation. Serial presentation is thought to perhaps mitigate cognitive overload that can occur when information is presented all at once. Serial presentation can also produce a transience effect, however, because it is only available to the viewer/listener for a short time. The transience effect has been particularly apparent with complex content (Tversky, Morrison, & Betrancourt, 2002).

Illustrated in Figure 2, CATLM adds tactile, olfactory, and gustatory sensory input to CTLM. Moreno’s (2007) model also introduces elements of motivation and affect and self-regulation mediated by the selection of information for processing in working memory, organization in working memory, the integration and retrieval of semantic and episodic knowledge, with a terminus in long-term memory.

1.3 Questions for the Present Study
Before conducting research with human participants, studies must be approved by an Institutional Review Board (IRB) whose purpose is to ensure that participants are unlikely to be harmed as a result of taking part in the study. The IRB makes its determinations based on ethical principles and federal regulations, most of which are complex in nature. The IRB is tasked with explaining these concepts to researchers but the regulatory language can impede understanding rather than facilitate it. The purpose of this study is to explore ways that basic regulatory requirements of human subjects protections can be effectively conveyed to researchers by an Institutional Review Board (IRB).

There are two research questions in this study:

1. Which combination of presentation of visuals (with or without visual attention cuing), text (printed or spoken), and timing (simultaneous or serial) will result in the greatest understanding of the content?
2. Which combination of presentation of visuals (with or without visual attention cuing), text (printed or spoken), and timing (simultaneous or serial) will result in the greatest situational interest (SI) for the content?

2. Methods

This study utilizes an experimental design comparing the comprehension and situational interest for information on the coercion and undue influence of human research participants presented in six randomly-assigned multimedia conditions through an online, anonymous survey.

2.1 Participants and Setting

Study participants are any student, faculty or staff in any institute of higher education, research facility, or research institution. The content for the current study relates to the ethical principles of recruitment for research with humans. As such, the population being studied are those who could be involved in human research in their student or professional careers at some point. Potential participants with vision or hearing impairments are excluded from participation because the evaluation of all of the six conditions require the ability to see the presentations, hear the presentations, or both.

2.2 Materials

The study tool is an electronic survey built in Qualtrics software. The survey takes participants through the experiment, including a screening question, demographic questions, one of six randomized conditions, six questions about participants’ affective responses and ten questions measuring participants’ understanding of the content.

The six conditions differ in their use of visual attention cuing, simultaneous or serial presentation of the text, and whether the text is printed or spoken. Three of the six conditions (conditions two, four, and six) include the use of round or oval shapes and colored backgrounds to elicit positive feelings (Um et al., 2012), arrows to indicate directionality through the text (Holsanova et al., 2009), and representational images to aid the viewer’s dual coding process (Paivio, 1986). The other three conditions (conditions one, three, and five) have either plain white backgrounds or no background at all in the case of condition five which is a podcast.
In addition, two of the conditions present the text simultaneously, or all at one time, while the four others show the text serially. Conditions one and two are documents that are read on the computer screen. Conditions three, four, and six are animated cartoons and condition five is a podcast. The text for each of these is presented serially in the video or spoken on a podcast.

<table>
<thead>
<tr>
<th>Without visual attention cuing</th>
<th>Simultaneous, printed presentation of content</th>
<th>Serial, printed presentation of content</th>
<th>Serial, spoken presentation of content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Condition 1 (control)</td>
<td>- Resembles a web page</td>
<td>Condition 3</td>
<td>Condition 5</td>
</tr>
<tr>
<td></td>
<td>- Narrative text</td>
<td>- One to three sentences</td>
<td>- Podcast</td>
</tr>
<tr>
<td></td>
<td>- White background</td>
<td>presented serially</td>
<td></td>
</tr>
<tr>
<td>With visual attention cuing</td>
<td>Condition 2</td>
<td>Condition 4</td>
<td>Condition 6</td>
</tr>
<tr>
<td></td>
<td>- Infographic</td>
<td>- One to three sentences</td>
<td>- Powtoon</td>
</tr>
<tr>
<td></td>
<td>- Text chunked by idea</td>
<td>presented serially</td>
<td>- Spoken content</td>
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<tr>
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<td>- Colored background</td>
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<td>- Representational images</td>
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Table 1. Six experimental conditions

2.2.1. Condition 1

Participants read the content script on a web page in 12 point Times New Roman font on a plain background without visual attention cues. The content is presented all at one time. This condition mimics the format that human research protections information is typically presented on Human Subjects Protection Program websites.

2.2.2. Condition 2

The content script is presented in a pictograph format. The text is chunked by idea and include three types of visual attention cues: colors and shapes, representational images, and arrows. Content is presented all at one time.
2.2.3. Condition 3

This condition uses an animated video format to present the content script in a serial format in varying durations with text presented at the rate of approximately three words per second of (Trauzettel-Klosinski & Dietz, 2012). The text is on a plain background.
An example of undue influence is if a professor were to promise her students extra credit if they participate in her research.

2.2.4. Condition 4

Condition four also uses an animated video format, again in a serial format with text presented at the rate of approximately three words per second. The text is accompanied by visual attention cues in the form of colors and shapes, representational images, and arrows.
2.2.5. Condition 5

The content text is read on podcast technology in condition five at the rate of approximately 2.5 words every second.

2.2.6. Condition 6

Like condition four, condition six also uses an animated video format, again in a serial format, the difference being that the content is presented in spoken format at approximately 2.5 words each second. The text is accompanied by visual attention cues in the form of colors and shapes, representational images, arrows, and a few printed words.

![Figure 5. Excerpt of Animated Video Used in Condition 6](image)

2.3 Instruments

We are using two assessment tools to evaluate each of the two research questions, one concerning participants’ comprehension of the content and a second to measure participants’ situational interest in the content.

Ten questions measure comprehension through participants’ ability to apply the principles of coercion and undue influence in research to 10 individual situations. Through selecting a radio button, participants indicate whether each situation is an example of coercion, undue influence, neither, or both. An example question is as follows:

An elementary teacher is conducting a research study with students in her school. She tells parents that students who participate will receive additional one-on-one tutoring for upcoming standardized testing and students who do not participate will be required to sit quietly in the hallway while the research activities are taking place. Is this an example of coercion, undue influence, neither, or both?
Six additional questions evaluate participants’ SI. Based on Linnenbrink-Garcia, et al. (2010) and Magner et al. (2014), our six questions ask participants to rate their affective response to the presentation. Respondents indicate their agreement to positive statements such as “I found this presentation interesting” on a six point likert scale ranging from strongly agree to strongly disagree.

In addition to assessing comprehension and situational interest, the survey tool is collecting information on participants’ gender, age range, role at their institution, previous exposure to the information contained in the presentation, and level of education.

2.4 Procedure

Participants are being recruited to participate through convenience sampling using a snowball approach. Colleagues and friends of the researchers who meet the inclusionary criteria are sent an email inviting them to complete the survey. Once in the survey, a screening question to determine whether the respondent meets the inclusionary criteria allows the participant to continue or results in a message thanking the person for being willing to participate.

Eligible participants watch, read, or listen to one of six randomly assigned multimedia conditions. The content script of all of the conditions are identical. The text provides information on two complex ethical principles of human subjects research: the uses of coercion and undue influence in participant recruitment (see appendix A for the complete script). After a short introduction the script provides a definition and examples of each.

The survey asks participants to respond to the six questions intended to gauge their situational interest in the content immediately after the presentation to reduce an interference effect that might occur with the introduction of the comprehension questions.

In an effort to capture participants’ direct feedback, an additional question asks the question, “To what extent is this mode of multimedia a good format for conveying information through a website?” Participants are provided with a comment box for their response.

3. Results and Discussion

Based on previous research (Plass, Heidig, Hayward, Homer, & Um, 2014; Um et al., 2012) we would anticipate that any of the three conditions that include visual attention cues will result in higher situational interest, particularly for participants who have engaged in human research previously. It is not uncommon for researchers to feel that reading regulatory information is dry and that the regulations themselves are unnecessarily complicated and burdensome. Participants who enter the task with this perspective may be pleased to encounter a mode of communication that is more visually engaging and that includes supports for attention and meaning.

Indeed, preliminary statistical trends and participants’ anecdotal responses support previous findings. With limited (290) responses we are already starting to see some indications, based on survey completion rates, that presentations with images are grabbing and holding attention better than text-only presentations. Completion rates for conditions 2, 4, and 6, the three with visual attention cues, were 94%, 86%, and 87% respectively. In contrast, just 60% of participants who received condition 1, featuring a page of plain text, completed the survey and only 75% of those who listened to an audio recording of the text in condition 5 finished. Whether or not these trends will hold true with more robust data is yet to be determined.
Whether a simultaneous or serial presentation is preferred will likely depend upon variables influencing cognitive load for those who encounter those conditions. Participants’ with greater background knowledge of research or the concepts of coercion and undue influence are likely to respond better to a simultaneous presentation than those with less background knowledge for whom the simultaneous presentation may induce cognitive overload (Pollock, Chandler, & Sweller, 2002). Equally, those with greater background knowledge may get bored with the serial presentation, missing the optimal cognitive load that should result in efficient learning and active engagement.

Previous research on this topic has typically addressed the use of multimedia presentation for procedural knowledge in higher education. This study is unique in its exploration of effective applications of CTLM and CATML for teaching and learning more abstract, complex content.

Although the content displayed to participants of this study is limited to one specific topic, the conditions evaluated are generalizable such that the results may also inform other types of trainings or courses such as disability awareness training or single-topic reading assignments in a college course.

Additionally, these results may also be applicable to other entities that are tasked with conveying complex, regulatory language through websites or other multimedia resources. Communication of information on financial investment options, laws, or policies are all examples of possible applications for the results of this study.

References:


Appendix A

Complete Script for All Conditions

Regulatory Guidance Regarding Coercion and Undue Influence in Research with Human Subjects

The federal government provides regulations for the ethical conduct of research with human subjects. These regulations tell us that “an investigator shall seek such consent only under circumstances that provide the prospective subject or the representative sufficient opportunity to consider whether or not to participate and that minimize the possibility of coercion or undue influence” (45 CFR 46.116). Understanding the difference between coercion and undue influence is the first step to minimizing these issues in research.

Coercion: Coercion occurs when there is an overt or implicit threat of harm or loss of benefits to the potential subject. Coercion is bullying behavior in research. Subjects must never be coerced to participate in a study. If a prospective subject is told or perceives that refusing to participate in the research can result in an unfavorable outcome, then the researcher is coercing the subject. Subjects may inappropriately be told that their jobs, promotions, grades, or something else they value are contingent upon research participation.

Coercion can occur in many ways, both subtle and not-so-subtle. For example, a researcher might tell a prospective subject that he will lose access to needed health services if he does not participate in the research. Equally, the researcher could simply imply that the prospective subject could lose his health services. Regardless whether the researcher explicitly states or implies that any harm or loss might occur, if the circumstances of recruitment and consent lead a subject to think a harm or loss of benefit might occur —this is still coercion.

Undue Influence: Undue influence, by contrast, occurs through an offer of an excessive or inappropriate reward or other overture in order to obtain compliance. Undue influence is bribing behavior in research and is not allowed. An example of undue influence is if a professor were to promise her students extra credit if they participate in her research. If that was the only way a student could earn extra credit, the researcher is unduly influencing her students.

What constitutes “excessive” or “inappropriate” rewards will depend upon the situation of the subjects and the nature of the research study. For example, offering a college student $50 for answering a 10-minute survey may unduly influence the student to participate. Offering a physician the same compensation might not constitute undue influence.

The potential for both coercion and undue influence may be greater if the researcher has an existing or previous relationship to the potential subject. For example, students may feel coerced to participate in a researcher study being conducted by their instructor if they believe they will be graded poorly for non-participation. Or, an employee may more easily unduly influenced to participate in research by offers of rewards from their supervisor. The possibility for coercion and undue influence is highly individualized and must be carefully considered by the researcher and by the IRB for each proposed study.