Investigating Multimedia Learning with Web Lectures

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Abstract

Naturalistic research has shown that a web lecture intervention that includes multimedia lectures studied before class, short homework assignments, and in-class application activities can increase students' grades and satisfaction. The multimedia lectures, called web lectures, are a combination of video, audio, and PowerPoint streamed over the web. This experimental study was motivated by a desire to understand the contribution of web lectures themselves to the web lecture intervention's success. Educational multimedia design guidelines from Cognitive Load Theory (CLT) and the Cognitive Theory of Multimedia Learning (CTML) were used to evaluate and hypothesize about the learning efficacy of three information-equivalent—Video+Audio+PPT (web lecture), Audio+PPT, PPT+Transcript—and one information-nonequivalent—PPT-Only—educational presentation conditions. 60 randomly assigned participants studied the educational materials and completed a posttest and exit survey. Participants in the web lecture condition performed statistically significantly better on the posttest than all other conditions, and survey responses indicated that participants perceived the combination of modalities used by web lectures as more educationally effective than those used in the other conditions. This study verifies the educational contribution of web lectures to the web lecture intervention, web lectures' educational effectiveness as standalone learning objects, and the value-added of video for educational multimedia. These results were not completely in line with our hypothesis based on CLT and CTML, suggesting these theories' limited applicability for multimedia presentations with characteristics of those used in this study. Several possible factors that might account for the results inconsistent with CLT and CTML are identified, including the visibility of gesture in the video and the length and subject matter of the presentations.

Introduction

We have been exploring the use of multimedia lecture presentations on the web (web lectures), consisting of video, audio, and PowerPoint (PPT) (Figure 1). Our goal is to make the classroom a more active learning environment. In our web lecture intervention, web lectures and short lecture homeworks (LHWs) are pre-class supplements. Web lectures provide the information, concepts, and context of the traditional classroom lecture; they are studied by students *before* and *outside* of class. With the traditional lecture offloaded onto the web, in-class time is used for in-depth discussion and hands-on application of the web lecture content. LHWs provide motivation for students to study the web lectures before class, and, more importantly, act as a pedagogical linking mechanism between web lectures and subsequent classroom activities.

In our classroom studies, we have found that students using our web lecture intervention achieve grades approximately 10% higher than students using a traditional in-class lecture format [1, 2], and students report strong positive attitudes about all aspects of the intervention [1-3]. These positive results led us to question what contribution, if any, the web lectures themselves lend to the observed learning gains of the intervention as a whole, and how we might improve them. More specifically:

- Are web lectures any more or less effective than other similar multimedia instructional materials? Does the video add educational value? The audio? Or would simple PPT slides be as effective as web lectures?
- What attributes of multimedia presentations like web lectures contribute to their educational effectiveness?

Cognitive Load Theory (CLT) [4] and the Cognitive Theory of Multimedia Learning (CTML) [5] are two prominent theoretical frameworks that study the characteristics of and provide design guidelines for educationally effective multimedia materials. Both theories, albeit with somewhat different foci, explicate ways to manage humans' limited working memory resources by leveraging our perceptual and cognitive capabilities. Improved learning occurs when multimedia instructional materials are designed to reduce cognitive load on working memory and thus to increase available resources for other cognitive processes (e.g., active integration of verbal and pictorial mental models with long term memory). For instance, CLT and CTML suggest that simultaneous presentation across multiple modalities (e.g., auditory and visual) can improve learning, as compared to presentation with one modality [6, 7]. However, the applicability of these theories to lengthy, lecture-style multimedia presentations is unknown. Zolna and Catrambone, for example, have found results in contradiction to CLT and CTML design principles when using long presentations with audio narration [8].

This study experimentally investigates differences in learning efficacy of three information-equivalent multimedia presentations. The independent variable was the combination of modalities used by each presentation. The three information-equivalent conditions were: Video+Audio+PPT (VAP), Audio+PPT (AP), and PPT+Transcript (PT); a fourth information-nonequivalent condition, PPT-Only (PO), was included as well. The VAP presentation was *exactly* the same as the web lectures used in previous naturalistic studies. The dependant variable was performance on a posttest that assessed

participants' retention and transfer of the subject matter presented. Subjective attitudinal data were also collected using an exit survey.

As we will discuss in more detail below, of the information-equivalent conditions the VAP and AP conditions follow many, but not all, guidelines suggested by CLT and CTML; the PT condition does not adhere to as many of the guidelines (e.g., overloading the visual channel with PPT and transcription text), and is therefore likely to cause high, learning-detrimental cognitive load. Thus, we went into this study with the following hypothesis: posttest performance for the VAP and AP conditions will be approximately equal, the PT condition performance will be worse than VAP and AP, and the information-nonequivalent PO condition will produce the worst performance of all four conditions (VAP = AP > PT > PO).

However, other factors outside the scope of CLT and CTML might also facilitate or hinder learning efficacy. For instance, research by Goldin-Meadow and others suggests gestures and other nonverbal communication—visible in web lectures' video of the presenter—enhance learning [9-12]. Also, Schnotz has suggested learners' experience with electronic media, as well as affective and motivational factors must be considered with cognitive factors when considering contributions to effective learning with multimedia [13]. Finally, differences in the characteristics between the multimedia presentations used in this study and those primarily used in CLT and CTML studies (e.g., length [8]) might lead us to identify new conditions for effective application of those theories.

Thus, two primary research questions guided this study:

1. How does the combination of modalites used in web lectures affect educationally effectiveness, as compared to information-equivalent presentations using different combinations of modalities?
2. How appropriate are CLT and CTML as theoretical frameworks for predicting the learning efficacy of multimedia presentations with characteristics different from those which the theories are primarily based? What other factors may be influencing educational effectiveness?

This paper begins by providing some background on web lecture multimedia presentations and a recently-conducted quasi-experiment that investigated their use in classrooms. We then outline CLT and CTML, and provide a brief analysis of their guidelines to web lectures (VAP) and the other conditions (AP, PT, and PO) used in the present experiment. A description of the experimental design is followed by presentation and discussion of the results. Finally, we close with a discussion of future work and conclusions.

Web Lectures Background

Web lectures are studio-recorded, condensed lectures. A typical web lecture is 15-25 minutes in length, and covers about the same amount of material as 30-45 minutes of classroom lecture. Web lectures are purposefully kept at around 20 minutes in length to help maintain the attention of the viewer, but the condensed time in comparison to the

same classroom lecture comes about naturally because administrative announcements, instructor tangents, and student questions are not included.

Web lectures are authored using Microsoft Producer [14], a free plug-in for Microsoft PowerPoint 2003. Microsoft Producer facilitates seamless integration of one video feed, two audio feeds, Microsoft PowerPoint slides, and static or live web pages. Any or all of these components are organized together with customizable presentation layouts, which can include a table of contents navigable in real time. For recording, we set up a small studio with a laptop, digital video camera, microphone, and appropriate lighting and background, at a total cost of less than US$3000. Recorded web lectures are published to the web in both streaming and downloadable formats for easy viewing anytime, anywhere.

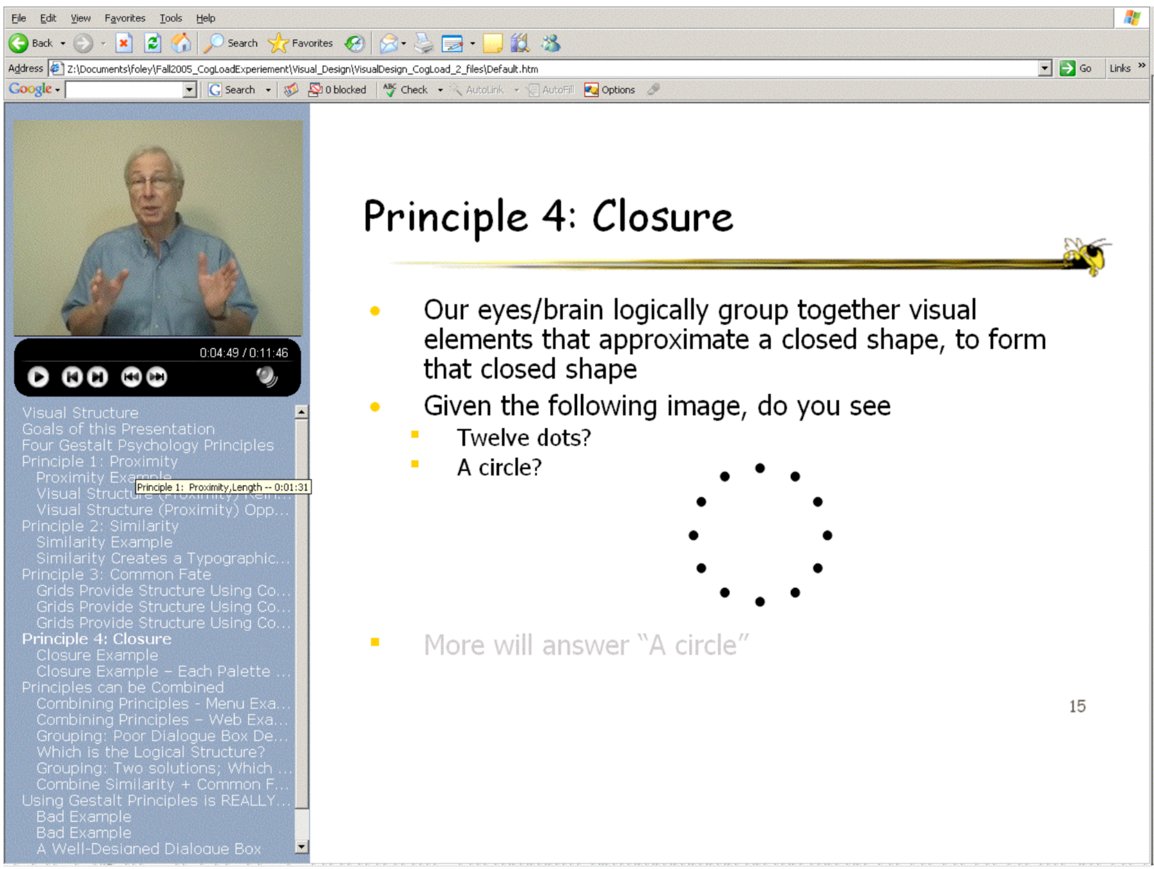

Figure 1. Web lecture playback in a web browser. This screen shot is from the web lecture used in the VAP condition.

Figure 1 shows an example web lecture viewed in a Microsoft Internet Explorer browser window, which is in this case divided into three panes. The upper left pane is the streamed video image, displayed by the Windows Media Player. The lower left pane is the Table of Contents (ToC), a list of links that correspond to each slide in the lecture; each link also contains a synchronized anchor point in the video stream. Thus, viewers can easily skip around in the web lecture simply by clicking on the ToC entries. The right pane is the current PowerPoint slide. To help focus viewers' attention, bullet points on each slide change from light gray to black as they are discussed by the lecturer.

Quasi-experimental Investigation of the Web Lecture Intervention

Encouraging findings from multiple naturalistic pilot studies [3, 15] motivated a more controlled investigation that allowed us to evaluate the web lecture intervention not only in terms of students' opinion, but also in terms of educational outcomes. A longitudinal quasi-experiment was conducted over the 15-week Spring 2005 semester with 46 students in two sections of the same course: one section using web lectures and one using traditional lectures [1, 2]. Many control measures were in place to ensure internal validity, including: blind grading; same instructor, topics covered, lecture slides (used in class or in the web lecture), assignments/exam, and required time on task (equating to seven fewer class meetings for the experimental group). Students in the web lecture section scored higher grades on *all* assignments and exams, and their overall course grades were significantly higher (10%) than the traditional lecture section. Also, on four surveys administered throughout the semester web lecture students reported increasingly strong positive attitudes about all aspects of the intervention (e.g., web lectures, LHWs, in-class activities, the intervention as a whole, etc.). Moreover, web lecture students' superior objective course performance in terms of grades was reflected in subjective self-reports: when asked to rate how much they had learned from the course, web lecture students reported learning more than traditional lecture students. Thus, we continue classroom evaluation of the web lecture intervention as improvements are made.

However, naturalistic classroom studies, while providing great insight into contextualized and longitudinal application, preclude a certain amount of experimental control [16]. As a result, many educational researchers employ both naturalistic and experimental methods (e.g., [17]).To complement our classroom studies, we have also begun a thread of experimental investigations (the first of which is presented here) intended to better understand learning with web lectures independent of associated LHWs and classroom activities. Based on their prominence in the fields of multimedia instructional design, Cognitive Load Theory and the Cognitive Theory of Multimedia Learning were chosen as theoretical frameworks for conducting our experimental investigations. Because some characteristics of web lectures are different from the multimedia materials used in building these theories, this research also allows us to better understand conditions for their effective application.

Cognitive Load Theory and the Cognitive Theory of Multimedia Learning

Cognitive Load Theory (CLT) considers how the interaction between cognitive architecture and information structures can inform instructional design. Four basic assumptions are made about cognitive architecture in CLT [4, 18]:

1. We have a very limited working memory.
2. We have an effectively unlimited long-term memory.
3. Our primary learning mechanism is schema acquisition; schemas are cognitive constructs that allow us to categorize multiple elements of information into a single element with a specific function.

4. We can effectively bypass working memory limitations through automation of schema use and other cognitive processes.

The information structures we interact with have different levels of elemental interactivity that affect how difficult it will be for us to learn any given material; learning low-elemental interactivity material will not depend on other elements, while learning high-elemental interactivity material requires understanding of multiple inter-dependant elements. Paas et al. use learning to use a photo-editing program as an example [19]. Learning the effects of various function keys is an example of low elemental interactivity, because each element can be understood without reference to any other elements. Learning to edit a photo, on the other hand, is an example of high elemental interactivity; although the relevant elements can be learned independently (e.g., color tone, darkness, contrast), these elements interact and must be processed simultaneously to be understood.

CLT posits three different types of cognitive load on working memory: intrinsic, extraneous, and germane. Intrinsic cognitive load is directly proportional to elemental interactivity, and therefore cannot be altered by instructional design for a given learning task. Omitting interacting elements to form a simpler, *different* learning task (e.g. simple-to-complex approach) is perhaps one way to reduce this load. Extraneous cognitive load refers to unnecessary working memory demands imposed by the way material is presented or the learning activities required (e.g., spatially or temporally separating text from illustrations forces learners to hold information in working memory to make sense of each). Finally, germane cognitive load is load incurred when learners are devoting working memory to the beneficial process of schema acquisition and automation (e.g., instructional techniques such as example variation and prompting imagination can facilitate learners' schema acquisition and automation). Both extraneous and germane cognitive load can be influenced by instructional design, but extraneous load interferes with learning whereas germane load aids learning. These three cognitive loads are additive; total cognitive load must be below working memory capacity to facilitate learning. Thus, for a task with a given intrinsic load, the goal of the instructional designer is to reduce extraneous load to free up working memory available for germane load. For instance, studies by Mousavi et al. indicate that extraneous cognitive load can be reduced by designing instructional materials that make use of both auditory and visual presentation modes [6].

The Cognitive Theory of Multimedia Learning [5] developed by Richard Mayer recognizes the centrality of cognitive load on working memory for CLT, and goes on to propose how learners actively construct knowledge while studying multimedia materials. For CTML, multimedia materials consist of both words and pictures, and presentations can be either book-based (e.g., text and diagrams) or computer-based (e.g., audio narration and animation). CTML research is concerned with determining the conditions under which multimedia materials are most likely to promote meaningful learning. The theory relies on the following assumptions:

1. The dual channel assumption: the human information-processing system consists of an auditory/verbal channel and a visual/pictorial channel. This assumption is based on a combination of Baddeley's [20] working memory model for auditory and visual processing (sensory modalities), and Pavio's [21] dual code theory for verbal and pictorial knowledge processing (presentation mode).

2. The limited capacity assumption: each channel (auditory/verbal and visual/pictorial) has a limited capacity for cognitive processing.
3. The active processing assumption: a substantial amount of cognitive processing in each channel is required for learning to occur, which includes attending to the material presented (select), organizing the material presented into a coherent structure (organize), and integrating the presented material with existing knowledge (integrate).

Mayer distinguishes among three types of cognitive load that are loosely equivalent to those put forth by CLT: representational holding (intrinsic load), incidental processing (extraneous load), and essential processing (germane load). Mayer and Moreno have outlined nine ways to reduce cognitive load in multimedia learning [7]. For example, Mayer and Moreno suggest 'off-loading' when one channel is overloaded with essential processing demands. If one channel is overloaded, some of the load in that channel can be off-loaded onto the other channel for more efficient processing. An example of this in practice—referred to as the 'modality effect'—suggests students learn better when words are presented as audio narration with an animation as opposed to on-screen text with an animation.

Web lectures (VAP condition) adhere to many of the design guidelines ('effects') suggested by Mayer and Moreno:

- Modality effect [7]: the presenter's words are presented as audio narration, as opposed to on-screen text transcription—moving some essential processing from the visual to the auditory channel;
- Multimedia effect [5]: learners receive words and pictures (supporting diagrams in the PPT), as opposed to words alone—facilitating construction and connections between verbal and pictorial mental models;
- Segmentation effect [7]: content is presented in learner-controlled segments, paced by the learner instead of presented as a continuous unit—helping avoid working memory overload by breaking material up logically (PPT divisions) and allowing individual control (playback controls and navigable ToC);
- Signaling effect [7]: PPT bullet animations and presenter gestures provide cues for how to process the material—reducing extraneous load;
- Temporal contiguity effect [7]: audio and visual elements are presented simultaneously rather than successively—minimizing need to hold representations in memory;
- Personalization effect [22]: the presenter speaks in 1st and 2nd person conversation style, rather than 3rd person—helping learners relate material to personal experiences, reduce processing effort needed to make sense of the material, and promote mental interactions in active understanding.

Some aspects of web lecture design do not adhere to multimedia instructional guidelines. For instance, although PPT text is not a direct transcription of the presenter's narration, it could be argued that it is redundant information (redundancy effect [5]), which could overload the visual channel and reduce resources available to select/organize/integrate other relevant information. However, Mayer notes that the redundancy effect may not

apply to lecture-style presentations where notes or outlines (like those provided with PPT text) could aid learner processing [5]. Also, it could be argued that the video of the presenter—in addition to also possibly overloading the visual channel—does not add instructional value, and in fact adds an extraneous material that competes with the PPT text and diagrams for cognitive resources (split-attention [23] or coherence [5] effects). In studies of animated pedagogical agents (which are similar to our video) in multimedia materials, however, no evidence has been found for the split-attention effect caused by the agent [24].

Based on similar comparisons of multimedia design to CLT and CTML suggestions, the AP condition is arguably as or more effective than the VAP condition; it adheres to all the positive effects of VAP, without the possibility of negative split-attention / coherence effects. The PT condition, on the other hand, does not positively adhere to many of the guidelines, and suffers from obvious negative modality effects; the transcribed text and PPT text likely overload the visual channel.

This study is a step in determining whether CLT and CTML guidelines are applicable to multimedia instructional material somewhat different from those used in the development of the theories. The multimedia materials used in CLT and CTML studies were primarily textbook-like diagrams with audio or textual descriptions and short (less than 1 minute) presentations using animations with audio or textual descriptions; mathematics and cause-effect explanations (e.g., how lightning forms, how breaks work) were common subject matter. The multimedia presentations used in this study are much longer (almost 12 minutes)—the application of these theories has been called into question for lengthy multimedia presentations by Zolna and Catrambone [8]. The VAP condition adds video of the presenter, and although diagrams are used on the PPTs, no animations (other than the text highlighting) are used. Moreover, the subject matter used in this study was not mathematical or based on causal explanations, and a navigable ToC was present.

Method

In this section, we outline the research design for our experiment. Full text of the materials used in the experimental procedure are included in the appendices where noted.

Experimental Conditions

The modality distribution of the four experimental conditions is shown in Table 1 below.

	Video	**Audio**	**Text Transcript**	**PPT**
Video+Audio+PPT	X	X		X
Audio+PPT		X		X
PPT+Transcription			X	X
PPT-Only				X

Table 1. Summary of experimental conditions.

The VAP condition was a combination of video, audio, and PPT, exactly like a web lecture; the AP condition was the exact same web lecture, except that audio narrative was present without video of the presenter; the PT condition was a normal PPT presentation with a transcription of the audio narration used in the VAP and AP conditions; and the PO condition was a normal PPT presentation (the same set of slides used in the VAP presentation). Conditions VAP, AP, and PT were all information-equivalent—only the modality of presentation was manipulated—and condition PO was an approximate 'control' condition used as a baseline for the kind of material typically available to students before class. Note that the PO condition was not information-equivalent, as it was missing narration information that the other conditions present in one modality or another. Other combinations of modalities (e.g., Video+PPT without audio) and/or other conditions (e.g., a text excerpt) could have been used; we selected the four used in this experiment because we felt they were the most likely modifications to a web lecture, and we wanted to limit this experiment to four conditions to ensure an adequate number of subjects for statistical analysis. Some other conditions were motivated by the results of this study, which are discussed in the future work section below.

Multimedia Instructional Materials

For the topic of the educational materials, we selected visual design—a presentation on the use of visual structure principles to inform user interface (UI) design. This topic was selected because we felt it would be learnable by participants with no prior knowledge of UI design. Thirty PPT slides were used to describe four basic ideas of Gestalt perception (similarity, proximity, good continuation, and closure) and how the principles apply to UI design. Many of the PPTs included images illustrating a particular visual design principle or UI exemplar. The video used in the VAP condition was recorded in our web lectures mini-studio by the second author (J. Foley); PPT slide timing from the video session was applied to all conditions. The audio for the AP condition was stripped from the video, and that audio was transcribed for use with the PT condition. All conditions were presented within the Microsoft Producer interface, which included the navigable ToC. The uninterrupted, full running time of all presentations was 11 minutes and 45 seconds. See Appendix A for screenshots from each condition.

Participants

Students were recruited from the psychology subject pool at Georgia Institute of Technology. Participation eligibility required no prior coursework with the presenter and no previous HCI coursework. There were 60 subjects: 15 in each condition. Table 2 below summarizes participant demographics. There was a wide distribution of majors among participants: 22 unique majors ranging from Architecture to Undecided, the largest frequency of which were 9 Management majors.

	Sex	**Age**		**Multimedia Use**	
		M	***SD***	***M***	***SD***
Video+Audio+PPT	8 M, 7 F	19.87	2.26	2.67	0.90

Audio+PPT	7 M, 8 F	19.87	2.36	2.67	1.49
PPT+Transcription	8 M, 7 F	19.80	1.47	2.86	1.06
PPT-Only	5 M, 10 F	20.33	2.09	2.73	0.96
All Conditions	28 M, 32 F	19.97	2.09	2.73	1.10

Table 2. Sex distribution, average age, and average self-reported educational multimedia use of participants. The "Multimedia Use" column represents average responses to a Likert scale question (1—None to 5—A Lot) regarding prior use of multimedia instructional materials.

Experimental Protocol

The experiment was conducted in the Georgia Institute of Technology GVU Center usability lab. The participant area is equipped with two new PCs with 17 in. flat-panel monitors. Upon arriving at the usability lab, each participant was randomly assigned to an experimental condition and went through the following protocol:

1. Scripted introduction and tutorial on how to view the educational material
2. Entrance survey
3. Up to 20 minutes to study material for the randomly assigned condition
4. Up to 20 minutes to complete a posttest on the materials
5. Exit survey

Scripts and Tutorials

To assure that each participant received that exact same information, a script was created for each condition. The scripts for each condition differed only when addressing the particulars of the educational materials determined by the condition. The scripts summarized the purpose and procedure of the study, and provided a condition-specific tutorial for the controls and use of the multimedia presentation. To ensure participants were not exposed to presentation content before the session actually began, paper screenshots that displayed only the title slide were used for the tutorials.

Entrance Survey

The purpose of the entrance survey was to collect demographic data, redundant screening for incoming HCI experience or coursework with the presenter, and to query participants' incoming experience with and attitudes about multimedia instruction [Appendix B].

Exposure to Educational Materials

Participants' maximum time with the educational materials was limited to 20 minutes—about 12 minutes for a full viewing and about 8 minutes to review. At anytime during the session, a participant could notify the experimenter that they were finished reviewing the materials and ready to take the posttest. If a participant had not done so within 20 minutes, the experimenter would close the participant's presentation and administer the posttest. The amount of time each participant spent studying the materials was recorded, which allowed us to evaluate each condition in terms of learning *efficiency*

in addition to learning *efficacy*. Thus, even if no difference in posttest scores was evident across the conditions, we had data useful for determining if one or more conditions required significantly less time to match the posttest performance of the others.

Testing Instrument

The objective measure of educational effectiveness across conditions was based on posttest performance; all participants in all conditions completed the exact same posttest. Similar to those used by Mayer [5], our posttest consisted of two separate learning assessment tests: a retention test with 18 questions and a transfer test with 5 questions [Appendix C]. The retention test was administered using a web-based application, and it was comprised of questions in multiple choice, fill in the blank, and true/false formats. One question was presented at a time; participants could not go back to previous questions, but could skip a question without choosing an answer. Participants were informed before taking the posttest that scoring would consider only the number of correct answers. The transfer test was administered on paper after participants finished the retention test. Because three of the questions on the transfer portion asked participants to critique UI screenshots, it was administered on paper so that participants could easily circle a section of interest quickly, draw suggestions directly on the screenshots, etc. The transfer portion consisted of application questions, whereas the retention portion consisted of questions about information specifically covered in the PPT slides. Participants were allowed up to 20 minutes to complete both the retention and transfer tests.

All questions were created from information on the PPT slides *before* the audio/video was recorded; this was done to ensure that all questions could be answered from slide content alone. For instance, the slide shown in Figure 2 provides the answer to the following fill in the blank retention question:

> Which two principles can be combined to create a *stronger* typographical hierarchy? ___________and _____________

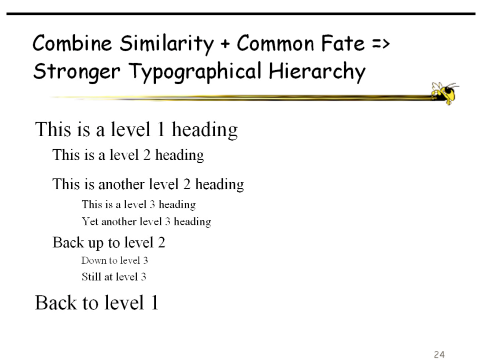

Figure 2. Example slide that provided information necessary to answer a question on the retention portion of the posttest.

Because the questions on the transfer portion of the posttest were intended to assess participants' understanding and application of the principles covered in the presentation,

the information needed to answer the transfer questions was not *explicitly* included in the slides as it was for the retention questions. However, relevant examples of applying the principles were included in the PPT slides that should have adequately prepared participants to answer the transfer questions. Consider, for example, the slide shown in Figure 3, and the following transfer question:

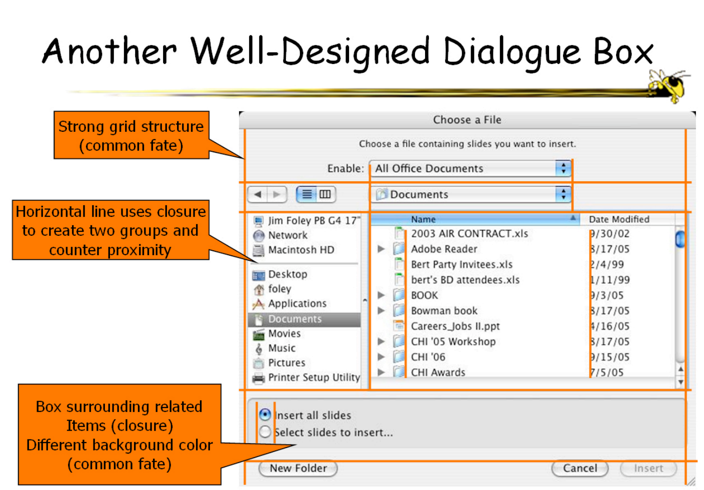

Figure 3. Example slide that provided a UI critique that could be similarly applied to answer a question on the transfer portion of the posttest.

In terms of visual structure, would you consider the UI screenshot below (Figure 4) good, bad, or a little of both? Use the four principles of visual structure discussed in the presentation to **justify your answer**.

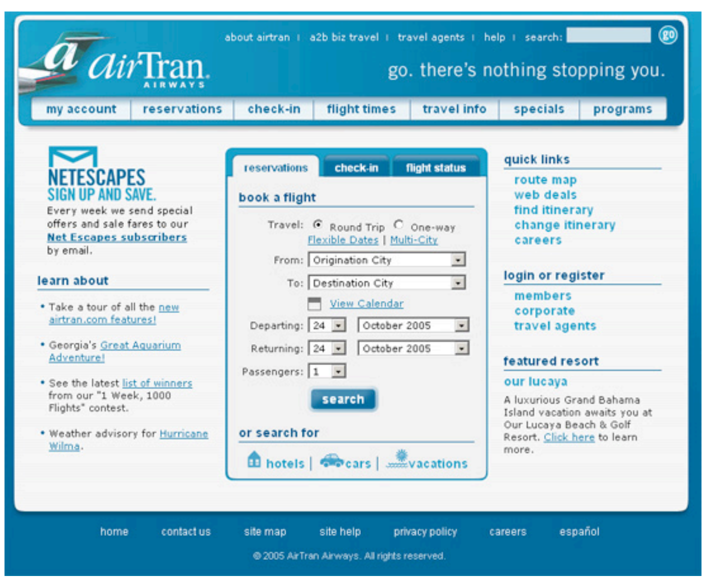

Figure 4. UI screenshot provided for critique on the transfer portion of the posttest.

For purposes of scoring, each question on the transfer test was broken down into the smallest objective parts possible, to come up with a standard, objective scoring scheme. For example, consider the following transfer question:

> Sketch a simple representative example (not used in the PowerPoint presentation) of one of the four principles discussed in the presentation. Identify the principle and explain your example.

This question above was worth 3 points, scored as follows: 1 point for a representative sketch not used in the PPT, 1 point for correctly labeling the principle, and 1 point for a correct and adequate explanation of example given.

The first two authors independently developed a set of acceptable answers before the experiment was conducted, and revised them based on the range of responses after the experiment. The two sets were reconciled to come up with the final set of acceptable answers. Two coders then scored the same six tests independently using the objective scoring scheme and set of acceptable answers. To assuring inter-rater reliability, consistency across scorers was compared, and the process was repeated twice, at which time scoring differences were less 5%. Also, to control for bias during scoring, all tests were scored condition-blind.

Exit Survey

The exit survey [Appendix D] collected subjective participant attitudes about the multimedia instructional materials and self-reports of compatibility of the presentation method used with their study practices.

Results

This section discusses our analysis of posttest performance and survey responses, as well as implications of these results. Unless noted otherwise, statistical significance was determined using two-tailed independent groups t-tests assuming equal variances, with a familywise alpha of .05.

Review and Test Taking Time

Participants were allowed *up to* 20 minutes to review the educational material (recall that the running time for all conditions was 11 minutes 45 seconds), and *up to* 20 minutes to complete entire posttest (retention and transfer portions). The average amount of time taken for review and posttest completion is displayed in Table 3 below.

	Review Time		Retention Time		Transfer Time		Overall Posttest Time	
	M	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***
Video+Audio+PPT	16.40	4.05	4.07	1.58	13.73	2.52	17.73	1.98
Audio+PPT	16.33	3.15	4.07	2.02	13.67	3.20	17.73	2.84
PPT+Transcription	15.40	3.52	3.73	1.53	12.07	3.20	15.80	3.34
PPT-Only	14.27	3.65	3.87	1.30	12.67	4.27	16.33	4.10

Table 3. Average times (in minutes) and standard deviations for review and posttest completion.

On average, participants in the VAP and AP conditions used slightly more time for both review and test taking than those in the PT and PO conditions, but the differences were not statistically significant.

Posttest Performance

Scores by condition for the retention and transfer tests (and the combined overall posttest score) are in Table 4 below. The retention and transfer tests were both scored out of 20 points; the overall test score is simply the sum of the retention and transfer tests (40 points).

	Retention Test		Transfer Test		Overall Posttest	
	M	***SD***	***M***	***SD***	***M***	***SD***
Video+Audio+PPT	18.2	1.26	17.17	2.34	35.37	2.89
Audio+PPT	17.07	1.83	14.67	2.84	31.73	3.08
PPT+Transcription	16.33	2.26	14.63	3.30	30.97	4.73
PPT-Only	14.53	3.46	13.30	3.94	27.83	6.33

Table 4. Performance averages and standard deviations on test instruments.

Both retention and transfer test scores were the highest for participants in the Video+Audio+PPT condition, followed by those in the Audio+PPT condition, the PPT+Transcript condition, and participants in the PPT-Only condition scored the lowest. Overall posttest performance is visually represented in Figure 5 below.

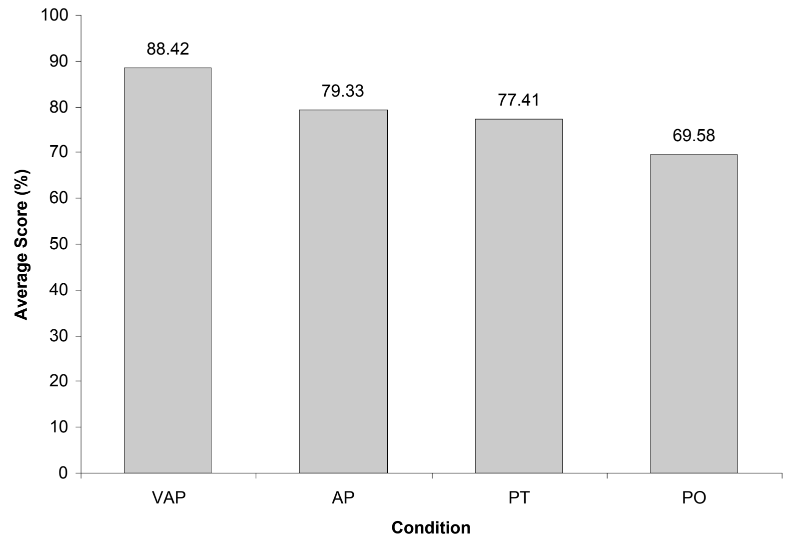

Figure 5. Average overall test score (%) by condition.

A one-way fixed effects ANOVA revealed a significant difference among the groups' mean overall posttest scores, $F(3, 36)=3.91$, $p<.05$, $MSE=9.99$. Post-hoc comparisons indicated VAP participants' overall posttest scores were statistically significantly higher than participants in the other three conditions. Also, AP participants' overall posttest performance was higher than the PO condition, but was marginally insignificant. Table 5 below shows the resulting *p*-values for all pair-wise comparisons.

	Video+Audio +PPT	Audio+PPT	PPT+Transcript	PPT-Only
Video+Audio+PPT		0.0024*	0.0053*	0.0004*
Audio+PPT			0.6035	0.0442
PPT+Transcription				0.1366
PPT-Only				

Table 5. *P*-values for pair-wise condition comparisons on overall test performance. An asterisk (*) indicates statistical significance after Bonferroni correction.

Exit Survey – Likert Scale Questions

All 60 participants responded to all Likert scale questions on the exit survey. Table 6 provides an overview of responses to selected questions.

	Q1: General Learning Effectiveness		Q2: Posttest Preparation Effectiveness		Q3: Comprehension		Q4: Likelihood of Use	
	M	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***
Video+Audio+PPT	4.27	0.46	4.47	0.64	4.47	0.83	4.67	0.49
Audio+PPT	3.87	0.83	4.2	0.56	3.87	0.74	4.00	0.76
PPT+Transcription	3.27	0.59	3.67	0.90	3.60	0.74	3.40	0.91
PPT-Only	3.33	0.72	3.40	0.99	3.47	0.99	3.60	0.63

Table 6. Average responses to exit survey questions by condition. Q1) In terms of your general learning, how would you rate the effectiveness of the educational materials you were provided? Scale 1—Very Ineffective to 5—Very Effective. Q2) In terms of preparing you for the posttest, how would you rate the effectiveness of the educational materials you were provided? Scale 1—Very Ineffective to 5—Very Effective. Q3) Consider the presentation mode of the educational materials separately from the content. How does the mode of delivery affect your comprehension of the content? Scale 1—Greatly Decreases Comprehension to 5—Greatly Increases Comprehension. Q4) How likely is it that you would choose to use the kind of educational materials you were provided? Scale 1—Very Unlikely to 5—Very Likely.

We were interested in participants' perception of the effectiveness the educational material provided, both in terms of learning in general and in terms of preparing them for the posttest taken as part of the experiment. Figures 6 and 7 below show average responses to two questions addressing learning from each of these perspectives.

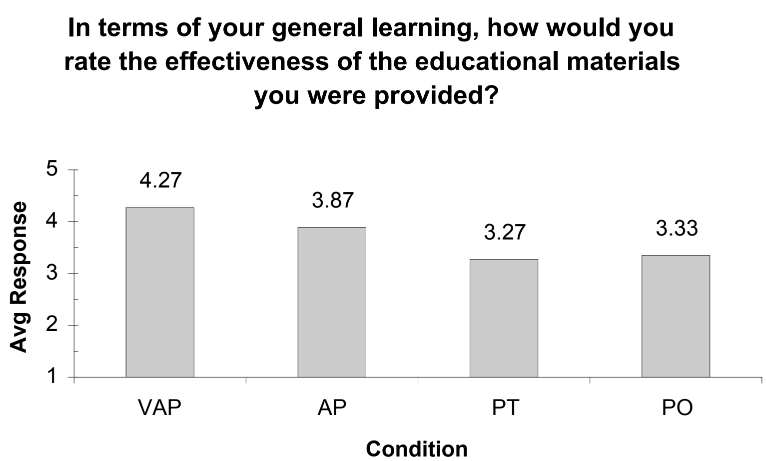

Figure 6. Average responses in terms of education in general, scale 1—Very Ineffective to 5—Very Effective.

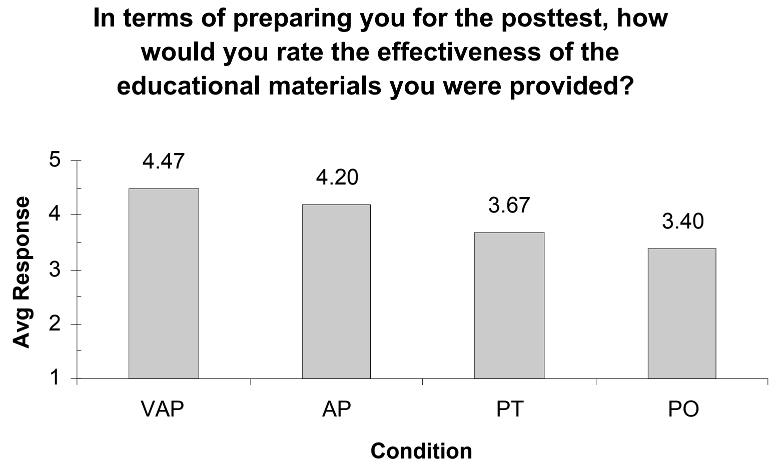

Figure 7. Average responses in terms of test preparation, scale 1—Very Ineffective to 5—Very Effective.

For learning in general, VAP participants' perception of effectiveness was statistically significantly higher than PT ($p<0.01$) and PO ($p<0.01$) participants, as were AP participants over those in the PT ($p<0.05$) condition. Similarly for posttest preparation, VAP participants' more positive response over the PT ($p<0.01$) and PO ($p<0.01$) participants was statistically significant, as were AP participants over those in the PO ($p<0.05$) condition.

We were also interested in participants' perception of how the mode of delivery affected comprehension of the presentation content. Figure 8 below displays average responses. VAP participants' responses were statistically significantly higher than the other three conditions ($p<0.01$).

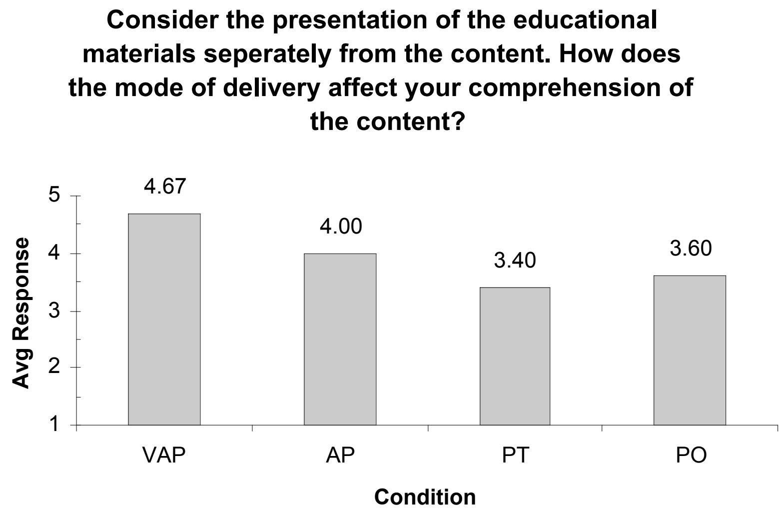

Figure 8. Average responses to comprehension question, scale 1—Greatly Decreases Comprehension to 5—Greatly Increases Comprehension.

Figure 9 shows how likely participants would be to choose to use the kind of multimedia instructional material they used during the experiment. Again, VAP participants' responses were statistically significantly higher than the other three conditions ($p<0.05$), indicating a strong subjective preference for multimedia materials that include video as opposed to only audio, only transcription text, or the PPT slide alone.

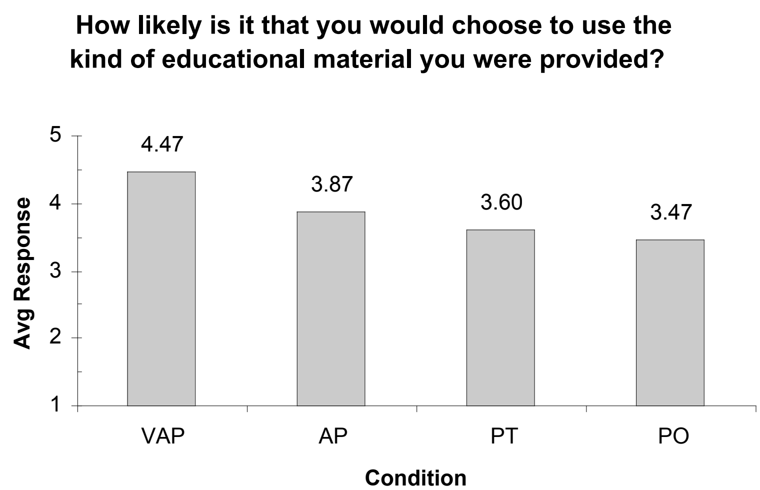

Figure 9. Average responses to likelihood of use question, scale 1—Very Unlikely to 5—Very Likely.

Exit Survey – Open-Ended Questions

The exit survey had eight open-ended questions: participants answered 98%. All responses were aggregated by question and condition, and then coded. For selected questions, we summarize relevant trends the coding revealed, and provide representative responses. Numbers in parentheses after a statement indicate the frequency of responses that fell into that coding category.

- *What did you like best about the mode of delivery (the presentation alone, considered independently of the content) of the educational material?*

  Across all conditions, a common response was the presence of the ToC for context and review (8) and the helpfulness of the animated slides (4). Participants in the VAP and AP conditions highly praised the ability to use the audio/video controls for review (7) and keeping the presentation at a pace suitable for their learning styles (5). Some participants in the AP condition particularly like the addition of audio to the PPT (4), and the presence of an actual *human* voice was noted as well (2). Finally, participants in the VAP condition expressed appreciation specifically for the video of the presenter (5), for the addition of audio/video in general (8), and for the similarities to being in a live lecture (3). Representative quotes from participants in the VAP condition are:

  - "I like how the presenter could be viewed. It was very nice to not just listen to a presentation that you watched, but that you actually had a person to look at—like in an actual lecture."
  - "The idea of a video and PPT [is] really good. It is like going to class, but at your own pace and better because you can go back to things you missed."
  - "I liked being able to watch the speaker talk because if I was having trouble focusing on what he was saying, I could look at him to refocus."

- *What did you like least about the mode of delivery (the presentation alone, considered independently of the content) of the educational material?*

  The most common response across all conditions related to the speed of the presentation (15). Participants noted that the standalone pace of the presentation advanced a little too quickly. We attribute this to our effort to make the presentation as short as possible. Other responses across all conditions included stating that nothing was wrong with the presentation (13) and the volume was too loud (4). For the PT condition, participants found reading all of the transcribed text and the PPT text to be difficult (5): "The transcribed text at the bottom, it was too hard to pay attention to that and the slide." This comment could be explained by the split-attention effect [23] or a combination of modality and spatial contiguity effects [7]. One participant in the VAP condition stated that the video was not necessary, that the audio alone would have been enough.

- *Please describe any ideas you have about what would make the educational material more effective.*

  Many responses to this question were suggestions for kinds/number of examples and the order of material in the presentation. These responses point out a small flaw in the way we asked the question; we were more interested in ideas to improve the mode of delivery rather than the content, which was not clear in the question. Some of the suggestions were relevant, however. For instance, VAP and AP participants suggested adding some interactive functionality (6) such as integrated quizzes or student note taking areas. Also, across all conditions except the VAP condition, participants suggested specifically adding video (7) or adding audio/video (7). Representative quotes are:

- “I would have learned even more if there had been a window on [the] panel where I could have taken my own notes.”
- “More visual stimuli (videos, animations) would bore the viewer less, but otherwise it was good.”
- “Video or sound. More color. A person giving the real world examples would be helpful.”

- *What is your goal(s) when you engage in normal pre-class preparation? Do you think the mode of information presentation you just experienced would support you in achieving that goal(s)?*

  Across all conditions almost all participants indicated their pre-class preparation goals involve familiarizing themselves with the material so they can understand the lecture better or comprehending a topic in order to complete a home work assignment or quiz. VAP participants reported strong support from the mode of presentation:

  - “To become somewhat familiar with the topic. Of course this would support that, it is like having someone explain it to me in person.”
  - “Pre-class preparation is to give a basic understanding of the material prior to class. I think this mode of information would greatly support achieving that goal. I would understand the material better.”
  - “The goal of pre-class preparation is to comprehend the topic about to be lectured on better than hearing it for the first time in class. The video is very helpful toward that goal.”

- *Please provide any other feedback you might have here.*

  This question was not considered one of the eight open-ended questions, but there were a few interesting comments from the VAP participants:

  - “I think it would make my study time less, because I would have auditory and visual reinforcement at the same time rather than at separate times.”
  - “I enjoyed learning this material. And I hope that you can convince some professors to use this presentation mode to teach us.”
  - “I would be pleased to see this used in the classroom.”

Discussion

The VAP condition outperformed the other three conditions. Participants who studied materials using a combination of video, audio, and PPT scored statistically significantly higher than all other conditions on both the retention and transfer portions of the posttest. Analysis confirms that posttest performance was not affected by self-reported multimedia exposure, sex, age, major, time spent reviewing material, or time spent completing the posttest. At least for HCI-related subject matter, this objective measure of learning ranks Video+Audio+PPT educational materials such as web lectures the most learning effective, followed by materials with Audio+PPT, PPT+Transcript materials, and finally materials using PPT-Only. These data do not suggest an effect on learning efficiency for any of the conditions.

These results are partially in line with our hypothesis based on Cognitive Load Theory and the Cognitive Theory of Multimedia Learning. The VAP and AP conditions did produce better learning results than the PT and PO conditions, and PT participants scored higher than those in the PO condition. However, based on our application of CLT and CTML guidelines to each of the information-equivalent conditions, we expected the performance of participants in the VAP and AP conditions to be approximately equal, with the presentation in the AP condition arguably being the best in terms of minimizing cognitive load. This was not the case. These data clearly indicate that VAP materials produce significantly improved learning over the modality combinations used in other conditions, including AP.

Based on this unexpected result, we believe effective distribution of cognitive load is only one important factor that facilitates improved learning in the VAP condition, and thus CLT and CTML have limited application to multimedia materials used for lengthy, lecture-style presentations such as those used in this study. The *only* difference between the VAP condition and the AP condition was the video image of the presenter (from the chest up), yet the overall posttest scores for participants in the VAP condition were more than 11% higher than the AP condition. As suggested by Goldin-Meadow [9] and others [10-12], we suspect that the gestures and other nonverbal cues that are visible in the video of the VAP presentation are another factor that contribute to improved learning. The gestures and other nonverbal cues produce germane (essential) cognitive load that facilitates schema acquisition and active processing, rather than extraneous (incidental) cognitive load that detracts from the message. Goldin-Meadow points out the need for more research to better understand the conditions under which gestures promote learning [9], and this is an area we intend to investigate with future research. The positive effect of video on learning in this study is evident from posttest performance across the information-equivalent conditions, whether it is attributable to gestures and/or other factors.

The contribution of factors manifest in video of a human presenter might be an extension of Moreno and Mayer's personalization effect [22]. Open survey responses in this study and anecdotal evidence from previous web lecture studies indicate learners' appreciation of the video for many reasons, the most common of which is the familiarity of an embodied (as opposed to disembodied when there is audio but no video) human instructor speaking much like they would in a classroom. The video adds an element of personalization that could be helping learners identify with the presenter and actively relate personal experiences and knowledge to the presented material. With students in web lecture classes—who have had prolonged exposure to web lectures along with consistent in-person contact with the presenter—this effect is even stronger; students report feeling "more committed" to watching the presentation because they personally know and consistently interact with the presenter. Related research with animated pedagogical agents has found evidence for positive personalization effects (similarly called dialog [25] or persona [26] effects). For example, Atkinson [27] argues that lifelike animated agents in computer-based tutoring systems increase learning because they share characteristics (e.g., gesture, motivational and affective features) of successful human tutors. Arguably, humans are better at personalization and active dialog than animated agents; thus, learning improvements observed with agents are likely even stronger when the agent is replaced by video of a human.

Of the information-equivalent conditions (VAP, AP, and PT), PT is the poorest at distributing information across multiple processing channels using different modalities; all of the verbal information presented in the VAP and AP conditions was transcribed and forced into the visual channel in the form of additional on-screen text. Thus, it is not surprising that the PT condition is the least learning effective of the information-equivalent conditions, as CLT and CTML would predict.

The difference in test scores between the AP and PT conditions was surprising, however. Although participants in the AP condition did score higher than those in the PT condition on both retention and transfer tests, the improvement was only marginal. Based on the modality distributions, we hypothesized the same rank order of learning effectiveness our results produced; however, we expected to see a larger performance difference between the AP and PT conditions. This unexpected deviation from what CLT and CTML would suggest might be due to the presentation length (cf. [8]), the lecture-based nature of the presentations, the broader subject matter, and/or the presence of a navigable ToC that effectively outlined the presentation content. Again, this result suggests the limited applicability of CLT and CTML guidelines for the types of multimedia presentations used in this study.

It is interesting that the PPT-Only condition performed so poorly in comparison to the other conditions. Although the condition lacked the additional narrative information available in the other three conditions, the test instruments were designed from information *only* on the PPT slides—exposure to the narration was not necessary to answer any of the questions. This condition is not discussed in terms of cognitive load because it was not information-equivalent, but the result is important for instructional design, as PPT is a very common form of educational material.

In addition to performing significantly better on the objective learning measure, VAP participants also self-reported subjective perceptions of learning and comprehension that were higher than the other three conditions. Moreover, when asked how likely they would be to use the educational material provided, VAP participants reported higher likelihood of use than the other three conditions. Interestingly, for most of the Likert survey questions there was a clear distinction between the VAP / AP conditions and the PT / PO conditions. Though posttest results did not show a significant improvement of AP over the two latter conditions as expected, survey results indicated a larger increase in perceived learning and comprehension.

As briefly mentioned above, open-ended survey responses suggest the value-added of video. Many participants in the VAP condition expressed strong positive opinions in favor of the video feed, citing its ability to aid focus, make the presentation feel more like a classroom lecture, and add to the feeling of engagement with the material. Schnotz suggested that affective and motivational factors such as these must also be considered when assessing learning gains from multimedia instructional materials [13]. Also, many participants who were not in the VAP condition suggested adding video as a way to improve the presentation.

Future Work

There are many ways for us to expand and improve upon the experiment presented here. For instance, some limitations of this study that could be addressed in future studies

include more rigorous pretests of incoming knowledge, spatial ability, and working memory capacity. Mayer's individual differences principle suggests that design effects are stronger for low-knowledge, low-spatial learners, and CLT in particular recognizes the importance of working memory capacity; these factors can be measured upfront and treated as covariates to control for individual differences.

In terms of extending the experiment, there are other relevant conditions to test. For example, a condition for an information-equivalent passage of reading could be added. The reading condition would not be a transcription of the audio narration, but instead be a true simulation of what a common reading assignment over the presentation topic would entail. Like the PPT-Only condition, this is another type of material that is commonly provided for students, and thus would be another information nonequivalent, yet educationally relevant condition to examine.

The results of this study have motivated a number of other conditions and parameters to manipulate in subsequent experiments. In particular, including animated agent and live lecture conditions could help us determine the conditions under which personalization effects are most beneficial to learning. Also, subjective data suggests that participants' familiarity with the presenter could be an important factor in determining learning effectiveness; this is a parameter we intend to experimentally manipulate to get a better understanding of its possible effects on the learning efficacy of multimedia educational materials. Another parameter we intend to investigate is the amount of gesture and other nonverbal communication visible in the video image. This would include varying the amount of gesture use, the visibility of the presenter (e.g., full body, torso up, head-only), the speech style (e.g., monotone, highly accentuated), etc. A better understanding of the role of gesture and nonverbal communication in multimedia learning could have a significant impact on the use of video in multimedia instructional materials. To increase the external validity of our results, we also intend to create and test materials with multiple presenters.

Finally, a number of factors were identified that differentiate the presentations used in this study from those used in most CLT and CTML studies. To determine their possible effects on the applicability of CLT and CTML guidelines for multimedia educational materials, subsequent experiments will manipulate presentation length, subject matter, and presence of a navigable ToC. To better understand the impact of cognitive load on learning with the types of presentations we are using, we are also considering the use of direct objective measures such as dual-task performance [28] in addition to our indirect objective learning outcome measures.

Conclusion

This study supports much previous research in showing learning gains can be realized by presenting multimedia instructional materials using multiple modalities. We manipulated the modalities of three information-equivalent multimedia presentations, and found that combining video, audio, and PPT resulted in improved learning (in terms of both objective measures *and* subjective self-reports) over the same presentations using combinations of audio and PPT, and PPT with transcription text. A information-nonequivalent condition with PPT slides alone was also included, which produced the poorest learning.

Our motivation for conducting this study grew out of an empirically-validated educational intervention using web lectures. Because Video+Audio+PPT presentations are exactly the same as web lectures used in the intervention, the results of this study provide support for the contribution of web lectures to the learning gains observed at the intervention level. When evaluating the web lectures intervention in the classroom, the effect of web lectures could not be teased out from other aspects of the intervention, such as increased participation in in-class application activities. Although we acknowledge the inherently decontextualized use of web lectures in the lab setting, we believe this study justifies the use of web lectures as opposed to other similar pre-class educational materials. Moreover, it provides evidence for the educational effectiveness of web lectures as standalone learning objects.

The significantly better learning of participants studying Video+Audio+PPT presentations cannot be wholly attributed to multimedia design consistent with CLT and CTML guidelines. Otherwise, Audio+PPT participants should have performed the same (or better) than Video+Audio+PPT participants. We identified some other factors present in the video that may have contributed to the observed learning gains, such as the visibility of gestures of and other nonverbal communication, and affective and motivational factors (e.g., personal identification with a human presenter), but more work is needed to determine the extent of these factors' effect on learning with video multimedia materials. As a start, this study provides experimental evidence and subjective support for the value-added of video in educational presentations, which suggest multimedia instructional designers should integrate video of a human presenter when possible. Note that the presenter video used in this study was studio-recorded from the torso up; we believe this type of shot produces a more one-on-one, engaging experience than less personalized video, such as recorded classroom lectures.

Our investigation was framed by CLT and CTML, but our results were not completely in line with our interpretation of what those theories would predict. Learning measures for the Audio+PPT and PPT+Transcript conditions were much closer than an analysis of cognitive load for each would suggest. Longer, lecture-style characteristics of the presentations, the presence of a navigable ToC, and different subject matter have been identified as possible causes of these unexpected results. Some of the effects of high or low cognitive load may not be as powerful when exposure to the material is longer than the conditions under which those effects were recognized in developing CLT and CTML. Our results suggest that CLT and CTML have limited application to multimedia materials such the ones used in this experiment. More studies are needed to determine the conditions under which CLT and CTML guidelines can be effectively applied.

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Appendix A: Screenshots used in tutorial for each condition.

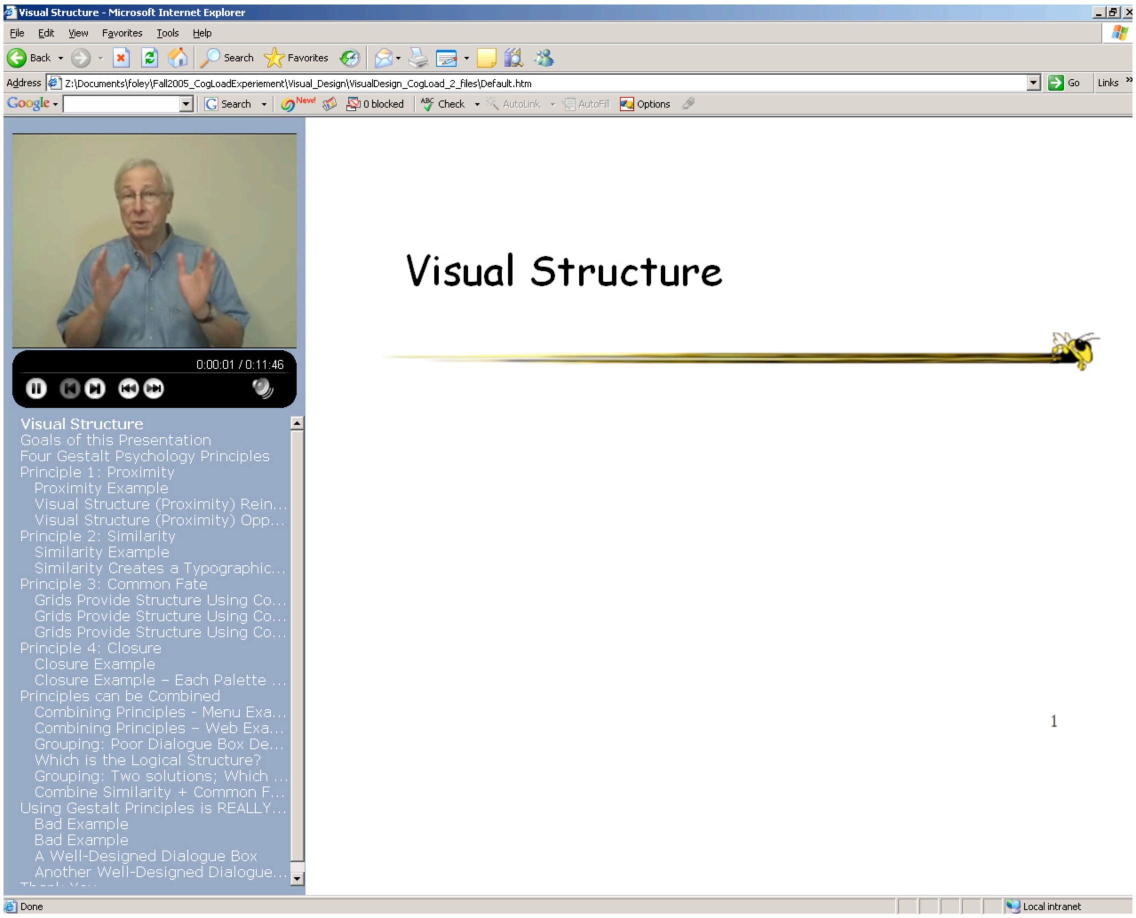


Figure 10. The Video+Audio+PPT (web lecture) presentation.

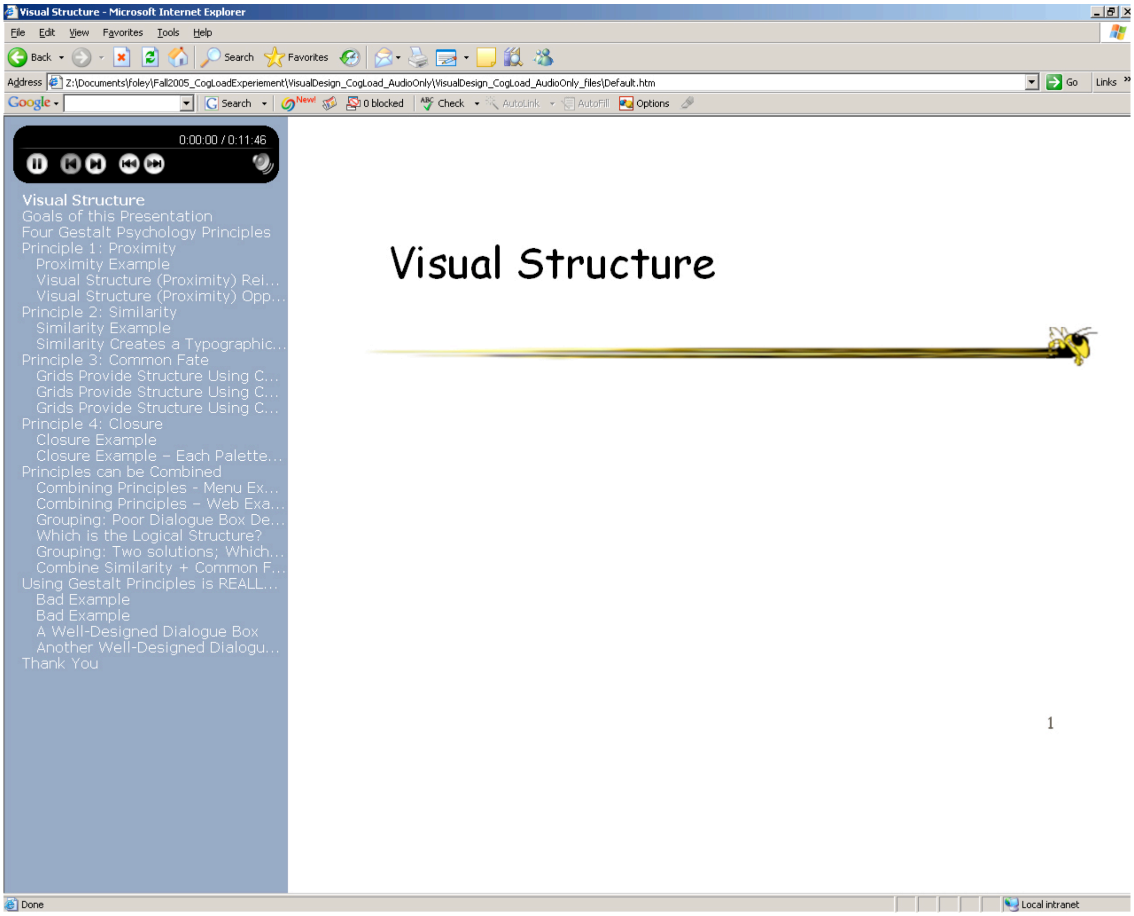


Figure 11. The Audio+PPT presentation.

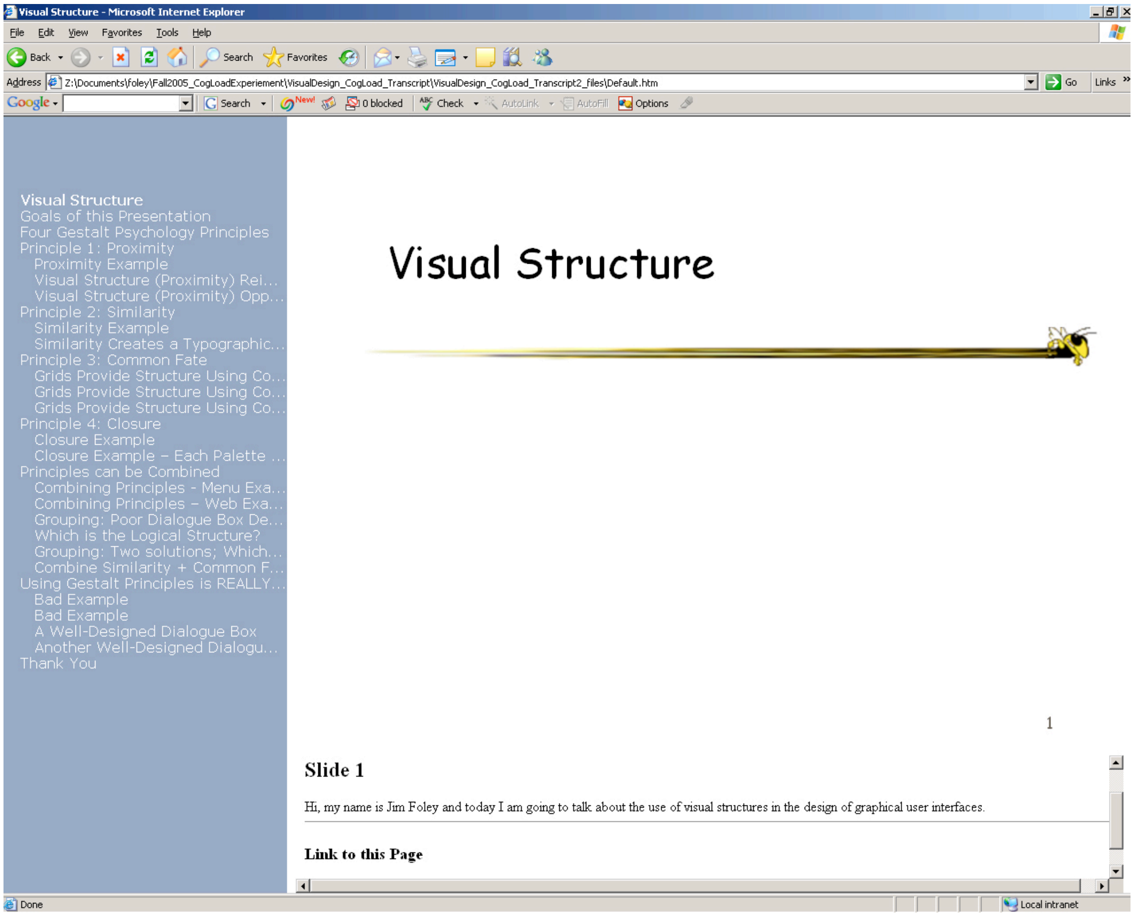


Figure 12. The PPT+Transcript presentation.

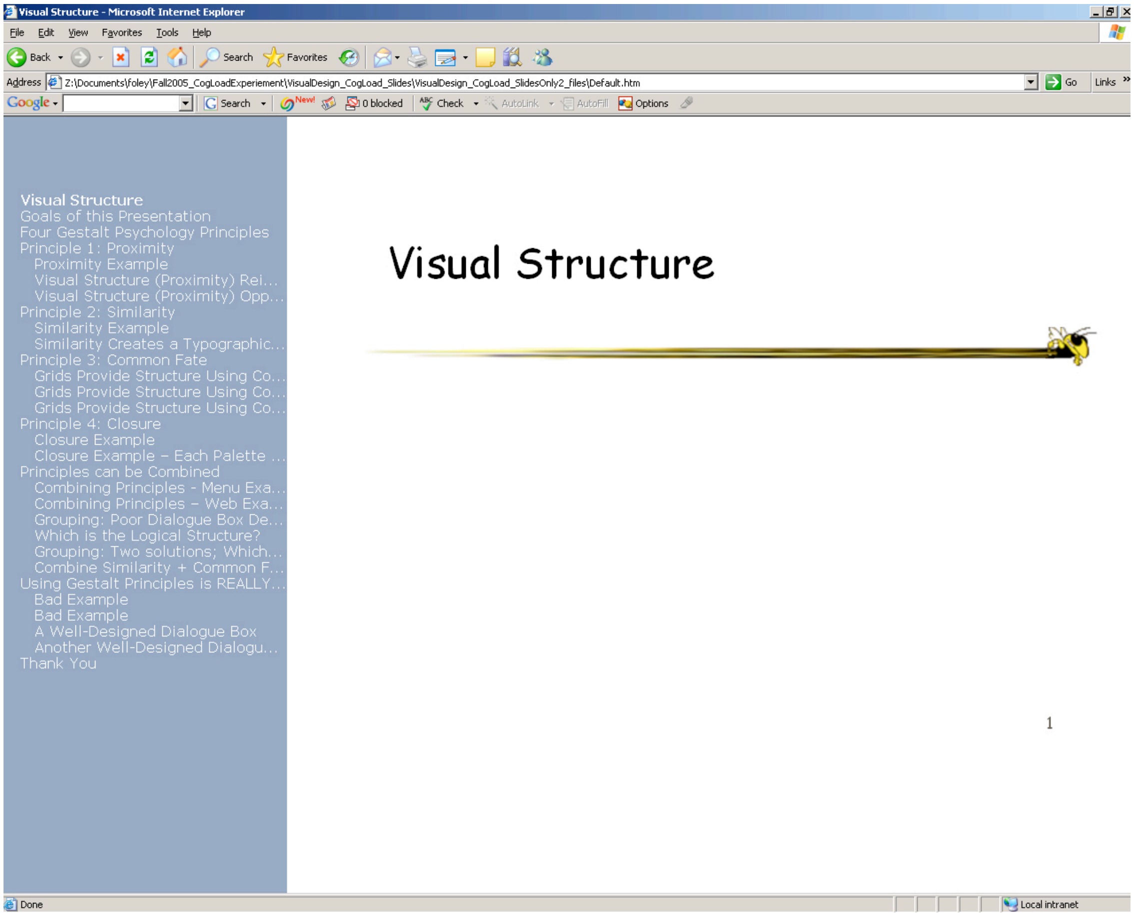


Figure 13. The PPT-Only presentation.

Appendix B: Entrance Survey

Entrance Survey

Study Title: Investigating the Effects of Variously Moded Educational Materials on Learning

Please answer the following questions about your background experience. If at any point you have a question, please ask the study administrator.

Demographic Data

1. What is your age? _______

2. What is your gender? Male / Female

3. What year are you?

Freshman Sophomore Junior Senior Other:_____________

4. What is your major? _____________________

5. Have you taken or are you taking any Human-Computer Interaction (HCI) or related courses (e.g. CS/PSYC4750, CS/PSYC6750, etc.) ?

   Yes No

6. Have you taken or are you taking a course with Prof. Jim Foley?

   Yes No

7. How much exposure / interaction / use of multimedia educational materials have you experienced?

1	2	3	4	5
None	Not Very Much	Some	Quite a Bit	A Lot

8. Please list and briefly describe all multimedia educational materials you have had experience with:

Appendix C: Testing Instrument, both Retention and Transfer portions.

Retention Questions:

1. The principles presented were from what branch of psychology?

   Cognitive Gestalt Educational Developmental Organizational

2. "Our eyes/brain logically group together visual elements that are close to one another." This is the definition for which of the following:

   Common Fate Proximity Situatedness Similarity Closure

3. "Our eyes/brain logically group together visual elements that are alike to one another." This is the definition for which of the following:

   Situatedness Similarity Common Fate Proximity Congruency

4. "Our eyes/brain associate elements that are aligned alike to one another." This is the definition for which of the following:

   Common Fate Congruency Proximity Closure Similarity

5. "Our eyes/brain logically group together visual elements that approximate a whole shape, to for that whole shape." This is the definition for which of the following:

   Extension Similarity Common Fate Proximity Closure

6. Which Gestalt principle causes you to group the "h" at the end of the first word in this sentence with the first word as opposed to seeing it as part of the second word?

   Closure Continuation Proximity Extension Similarity

7. Indentation can provide structure representative of which principle? ___________

8. How many principles of visual structure were presented? _________

9. Grids can provide structure representative of which principle? ____________

10. Use visual structure to ____.

11. Which two principles can be combined to create a *stronger* typographical hierarchy? _____________ and ________________

12. T / F . If combined, Gestalt principles always compliment one another.

13. T / F . Visual design principles are good to use for dialog boxes, but not for web page design.

14. T / F . Items close together appear to have a relationship.

15. T / F . Gestalt principles cannot be combined.

16. T / F . Grids avoid disconcerting irregularities.

17. The mantra for visual design for user interface design is, "Use visual structure to reinforce logical structure."

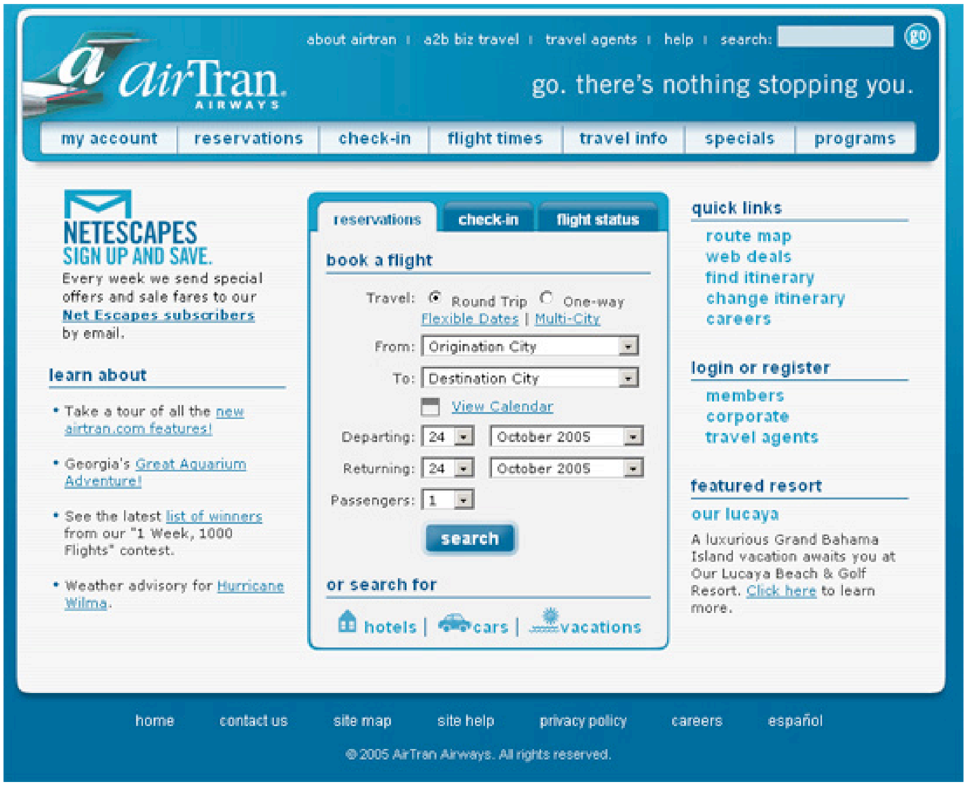
18. T / F. The Closure principle provides guidelines for logical placement of "Close" and "Exit" buttons in dialog boxes.

Transfer Questions:

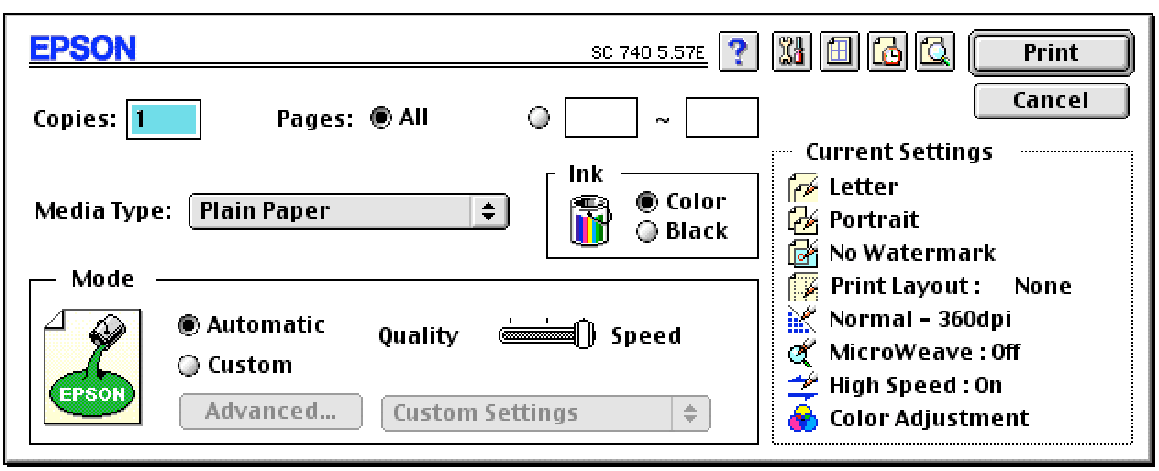
1. Sketch a simple representative example (not used in the PowerPoint presentation) of one of the four principles discussed in the presentation. Identify the principle and explain your example.

2. Sketch a simple representative example (not used in the PowerPoint presentation) of one of the three remaining principles discussed in the presentation. Identify the principle and explain your example.

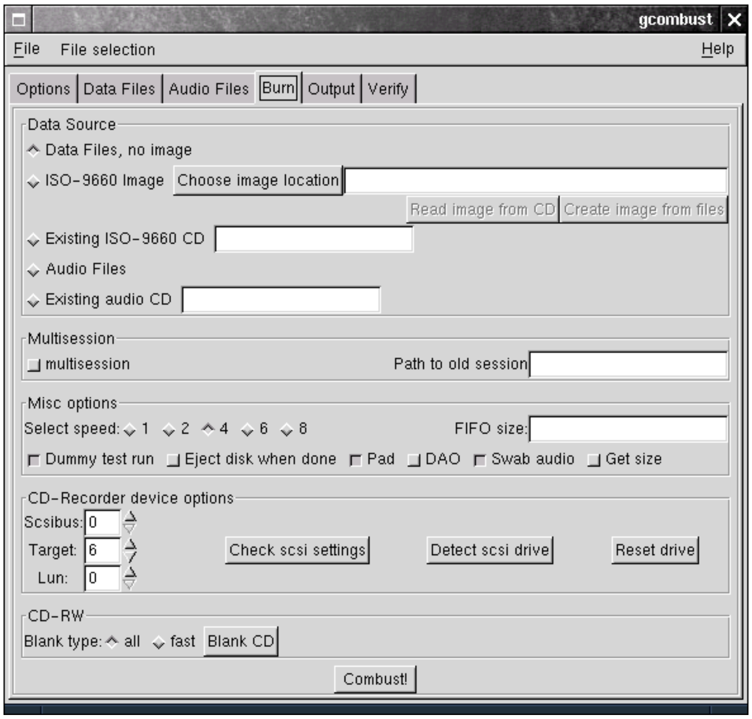
3. In terms of visual structure, would you consider the UI screenshot below good, bad, or a little of both? Use the four principles of visual structure discussed in the presentation to **justify your answer**.



4. In terms of visual structure, would you consider the UI screenshot below good, bad, or a little of both? Use the four principles of visual structure to **justify your answer**.



5. In terms of visual structure, would you consider the UI screenshot below good, bad, or a little of both? Use the four principles of visual structure to **justify your answer**.



Appendix D: Exit Survey

Exit Survey

Study Title: Investigating the Effects of Variously Moded Educational Materials on Learning

Please answer the following questions about your experiences while participating in this study. If at any point you have a question, please ask the study administrator.

1. In terms of your general learning, how would you rate the effectiveness of the educational materials you were provided?

1	2	3	4	5
Very Ineffective	Ineffective	Neutral	Effective	Very Effective

2. In terms of preparing you for the test, how would you rate the effectiveness of the educational materials you were provided?

1	2	3	4	5
Very Ineffective	Ineffective	Neutral	Effective	Very Effective

3. How likely is it that you would choose to use the kind of educational material you were provided?

1	2	3	4	5
Very Unlikely	Unlikely	Neutral	Likely	Very Likely

4. What did you like best about the mode of delivery (the presentation alone, considered independently of the content) of the educational material?

5. What did you like least about the mode of delivery (the presentation alone, considered independently of the content) of the educational material?

6. Please describe any ideas you have about what would make the educational material more effective:

7. How much does your opinion of the effectiveness of the educational material you were provided depend on the mode of delivery?

1	2	3	4	5
Not at All	Not Very Much	Some	Quite a Bit	A Lot

8. Think about the mode of delivery of the educational material independently of the content again. How does the mode of delivery affect your comprehension of the content?

1	2	3	4	5
Greatly Decreases Comprehension	Decreases Comprehension	No Affect on Comprehension	Increases Comprehension	Greatly Increases Comprehension

9. Consider the following course format: students are assigned educational material such as you were provided to study *before* coming to class, so less class time is needed for lecture and students come into class with some basic knowledge. Freed up class time is used to engage students with real-world application activities, discussion, and other active learning.

a. In terms of educational effectiveness, how would you rate this course format in comparison to the traditional in-class lecture format?

1	2	3	4	5
Much Worse	Worse	About the Same	Better	Much Better

b. In terms of overall course enjoyment, how would you rate this course format in comparison to the traditional in-class lecture format?

1	2	3	4	5
Much Worse	Worse	About the Same	Better	Much Better

10. How would you rate your general attitude towards the effectiveness of educational technology?

1	2	3	4	5
Very Negative	Negative	Neutral	Positive	Very Positive

11. How would you characterize your learning style?

Audio Learner   Visual Learner   Audio and Visual Learner   Other:__________

12. Please list your normal study activities and/or pre-class preparation.

13. Think about any study habits you have that involve direct interaction with the study materials (highlighting text, skipping around in a PPT, taking notes on the material, etc.) Would the direct interaction mechanisms (technological affordances such as clickable table of contents, pause capability, etc.) offered by the mode of information presentation you just experienced support your normal study activities and/or pre-class preparation? Why or why not?

14. Think about any study habits you have that do not involve direct interaction with the study materials (note taking on separate paper, thinking aloud, etc.). Would the mode of information presentation you just experienced support these kinds of study habits? Please explain.

15. Would the mode of information presentation you just experienced allow you to learn and think about material in the same way your normal study activities do? Please explain.

16. What is your goal(s) when you engage in normal pre-class preparation? Do you think the mode of information presentation you just experienced would support you in achieving that goal(s)

17. Please provide any other feedback you might have here.