A Paradigm for Classroom Presentations on Large, High-Resolution Displays

by

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A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF

Doctor of Philosophy

in

The Faculty of Graduate Studies

(Computer Science)

The University of British Columbia

September, 2009

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Abstract

Large classrooms traditionally provided multiple blackboards on which entire lectures were visible. In recent decades, classrooms were augmented with data projectors, allowing computer-generated slides to replace hand-written blackboard notes. Many lecture halls and conference rooms are now equipped with multiple projectors that provide large, high-resolution displays of sizes comparable to old-fashioned blackboard arrays. The predominant presentation software, however, is still designed for a single projector. Our research was to understand how software tools for classroom presentations can bridge the gap between traditional and newer technology to take full advantage of increased screen resolution and real estate to benefit both instructors and students.

As a first step, we conducted observational studies to see how blackboards and computer slides were used in classroom and conference settings. We developed a classification of usage for traditional and electronic visual aids. We then introduced six guidelines for designers of presentation tools to support learning. Based on the guidelines, we developed MultiPresenter – a novel presentation system designed to work on large display surfaces with multiple or high-resolution displays. MultiPresenter allows instructors to organize and present pre-made and dynamic presentations using a personal laptop. Instructors can employ the extra screen real estate to provide short- or long-term persistency of information. MultiPresenter was used by eight instructors in fifteen classes over five consecutive semesters. We collected usage data and iteratively refined the software. Based on our data, we identified a set of pedagogical practices for using extra space in electronic presentations and we revised our design guidelines. This led to a conceptual framework for effectively using large display surfaces in classrooms.

To empirically examine the effect on students' learning of increasing screen real estate, we conducted a controlled laboratory study. Results indicated that, when used properly, a lecture shown on multiple screens can improve learning over a regular single-screen lecture.

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Acknowledgements

First and foremost, I would like to thank my supervisor Kelly Booth, who has guided and supported me throughout my time at UBC. I am deeply grateful for his creativity, originality, and ability to generate great ideas with spark and enthusiasm. Through Kelly I have learned, in the broader sense, how to conduct meaningful research, and have been given an example that I would strive to follow through my academic career.

I am thankful for my supervisory committee members Steve Wolfman and Gary Poole for their comments, encouragements and help during this thesis. Will Evans, Yair Wand and my external examiner, Yvonne Rogers, have all provided valuable comments for this dissertation.

I am also thankful for many helpful discussions with Tony Tang, Kirstie Hawkey, Leah Findlater, Karyn Moffatt and Garth Shoemaker. Richard Guindon has graciously reproduced his 1966 cartoon for this dissertation.

The research reported in this dissertation was funded by the Natural Sciences and Engineering Council of Canada under the discovery grants program and under the strategic networks program through NECTAR, the Network for Effective Collaboration Technology through Advanced Research. Microsoft Corporation and SMART Technologies were major sponsors of NECTAR. Their support is gratefully acknowledged. Additional equipment and other infrastructure necessary for the research was provided by funding from the Canadian Foundation for Innovation and the British Columbia Knowledge Development Fund. The Department of Computer Science at UBC provided technical support that made the research possible.

Finally, this thesis is dedicated to my love, Shuli, who set me on the path and supported me throughout this journey. Her continuous support, encouragement and confidence in me have been invaluable. Needless to say, I could not have done this work without her.

Joel Lanir, 2009

Statement of Co-Authorship

All the research in this dissertation was conducted under the supervision of Dr. Kellogg S. Booth. Dr. Kirstie Hawkey played a supervisory role for the controlled laboratory study reported in Chapter 6.

I am the primary contributor to all aspects of the research. Leah Findlater participated in the data analysis and acted as a second coder in the structured observational study reported in Chapter 3. Tony Tang contributed feedback on the design of MultiPresenter that appears in Chapter 4. The code for the client application in the extension to MultiPresenter reported in Section 4.6 was based on code from the Lacome client originally written by Zephyr Liu.

Large parts of Chapters 3 and 4 are updated versions of published papers for which I am the primary author, with contributions from my co-authors:

- The first observational study in Chapter 3 was published as: Lanir, J., Booth, K. S. (2007). Understanding instructors' use of visual aids in classroom setting. *Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications 2007*, 788-794.
- The structured observational study in Chapter 3 was published as: Lanir, J., Booth, K. S., & Findlater, L. (2008). Observing presenters' use of visual aids to inform the design of classroom presentation software. *Proceedings of SIGCHI Conference on Human Factors in Computing Systems*, 695-704.
- The MultiPresenter system without its extension was published as: Lanir, J., Tang, A., & Booth, K. S. (2008). MultiPresenter: A presentation system for (very) large display surfaces. *Proceedings of the 16th ACM international conference on Multimedia*. 519-528.

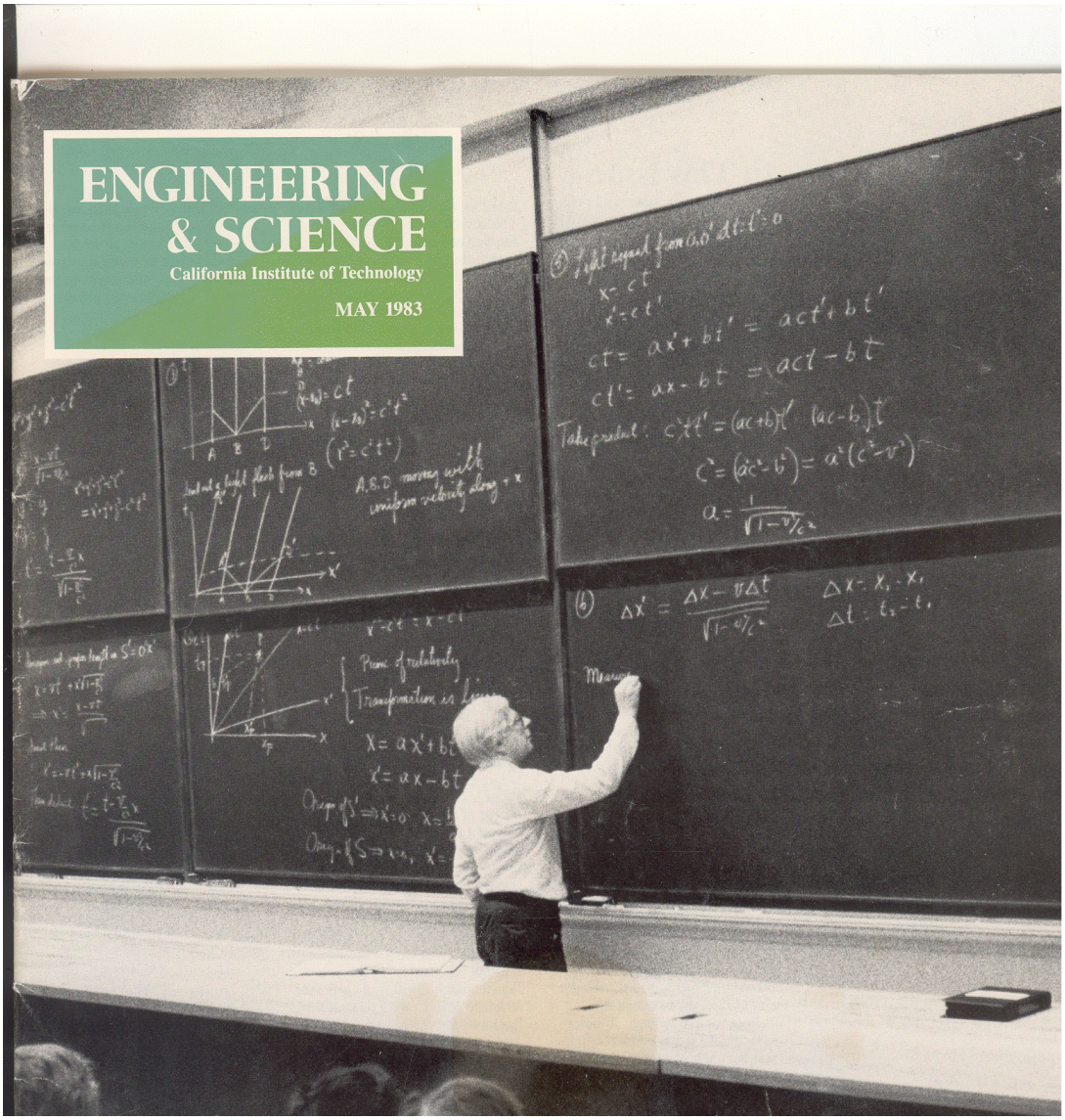


Figure 1.1 – President Marvin Goldberger of Caltech teaching a physics class using an array of sliding boards. This illustrates the traditional use of large screen real estate prior to the advent of PowerPoint and digital projectors. Used by permission.

Chapter 1

Introduction

The dominant method of teaching in higher education has historically been, and still is, conventional lectures in which the instructor presents information to a group of students. Although the effectiveness of this didactic form is debatable, the fact remains that the majority of higher education is taught in this way (Abowd, 1999; Bligh, 2000). As universities accommodate more students and face increasing financial and resource constraints, many classes, especially at the introductory level, are taught in large lecture halls. While most educators agree that smaller classes provide better learning environments with stronger student-instructor interaction, large lectures are likely to persist in the near future. Fortunately, the same economies of scale that have led to large class sizes and large lecture halls also allow universities to invest in technological infrastructure for lecture facilities (Wolfman, 2002). Therefore, many large lecture halls are equipped with multiple projector screens and it is likely that future lecture halls will have even more screen real estate using higher resolution projectors or more projectors.

Electronic presentations are widely used in higher education, especially in large lecture halls (Levasseur & Sawyer, 2006), often replacing traditional blackboards or whiteboards. While electronic presentations have a number of advantages such as multimedia capability, the ability to share and reuse material, and higher legibility and organization, it is unclear if computer slides are the best visual aid to support learning. Many critics claim that computer slides support a rapid, thin, sequential type of information that is more suited for business presentations and less for classrooms in which complex reasoning and non-linear explanations are needed (Abela, 2008; Tufte, 2003). Existing slideware, it has been suggested, supports a cognitive and pedagogical style that is not suited to higher education classrooms in which higher analytical thinking and the acquisition of interpretive understanding is needed (Kjeldsen, 2007; Parker, 2001). While researchers report that students generally prefer slides over other

Figure 1.2 – Lecture halls with multiple displays

traditional visual aids (Bartsch & Cobern, 2003; Daniels, 1999; Levasseur & Sawyer, 2006; Savoy, Proctor, & Salvendy, 2009; Susskind, 2005; Susskind, 2008; Szabo & Hastings, 2000), most studies have not found classes taught with slides to improve students' learning outcomes compared with other visual aids such as blackboards or overhead transparencies (Bartsch & Cobern, 2003; Daniels, 1999; Levasseur & Sawyer, 2006; Savoy et al., 2009; Susskind, 2005; Susskind, 2008; Szabo & Hastings, 2000).

Current presentation software, in classrooms and beyond, is tied to a paradigm of a single, static slide projected onto one display screen, changing sequentially over time similar to the style used for 35mm slides. Yet, with increasing large display resolution, increasing computer power to support multiple displays and animation, and decreasing projector prices, there is no need to stick with this paradigm. Many lecture halls are already equipped with two or more projectors (Figure 1.2). Unfortunately, instructors often lack the tools to fully exploit this infrastructure. As a result, they generally use commercial electronic presentation tools to simply project the same image onto both screens when two projectors are available.

In this dissertation, we investigate the design of next-generation presentation tools that will capitalize on larger and higher-resolution displays to support existing practices while capturing more of the advantages of traditional visual aids such as blackboards and whiteboards. When designing new technologies to support future practices, we believe that it is important to understand current practices first. Boards as teaching aids have

been used by teachers for almost two centuries, and their use is ingrained in the way classes are taught. With the move from blackboards and whiteboards to computer-generated visual aids, classrooms lectures have lost many important learning practices such as information persistency and flexibility in the lecture delivery. Blackboards afford a large dynamic surface for conveying ideas and have been used in classrooms for over two centuries. Buxton (1999) notes the introduction of the blackboard into classrooms in the Province of Ontario in the mid-1800s as a revolutionary educational shift. Buxton further comments on the impact this had on education, quoting from May (1855), and observing that although personal slates using the same "technology" that blackboards use were already in widespread use within classrooms, teachers had no means of visually presenting information to a room full of students. The blackboard allowed the teacher to communicate visual ideas to larger classes. The obvious benefits of the blackboard were soon recognized by all, and by 1850 the blackboard was to be found in almost every schoolroom in America. A similar revolution is happening in classrooms and large lecture halls in this decade. Technology is being introduced into schools and higher education, and in many classrooms computer-generated presentations shown by projectors have replaced traditional whiteboards or blackboards.

Teaching using a wall-size surface as a visual aid is not a new idea. We are motivated in part by the use of multiple sliding blackboards in large lecture halls in higher education, a practice that has been used for decades in many university lecture halls (Figure 1.1). Multiple sliding boards afford a very large surface on which the instructor can dynamically decide during a lecture how to present information. Instructors can decide what to erase and what to leave for future reference. They can allow a large amount of information to be simultaneously visible to students. In our approach, we want to understand how instructors use traditional wall-size displays, and combine the advantages of new technologies with knowledge from years of successful proven practices using older technologies.

Current presentation software is commonplace and seemingly accepted in today's popular culture. Electronic slide presentations are ubiquitous in many areas other than classrooms. They are so pervasive that it is almost inconceivable today for a salesperson or a presenter at a conference to appear without a pre-prepared computer-generated slide

deck. In business settings, company meetings, and conferences, presenters use computer-generated slides as the main visual aid to support their presentations. While the research presented in this dissertation is targeted at classroom presentations, we believe the results of this research may generalize to many other presentation scenarios that aim to promote learning.

In this chapter, as well as the entire dissertation, when we consider large display surfaces, we mean either multiple projectors or higher-resolution projectors. We refer to this as a large display surface, and sometimes use the term "screen real estate" somewhat ambiguously to either mean a large physical space or a large number of pixels. Usually a large display surface is both a large number of pixels and a large physical space, but the salient feature is that it adequately displays significantly more information in a manner that is easily viewed by those in the audience.

1.1 Problem statement

Computer generated slides have become the main visual aid in many classrooms at schools and higher education institutes. While commercial presentation tools enable the instructor to easily build sophisticated presentations that use transition animations and other multimedia capabilities, many critics claim they are not suited for classrooms in which non-linear explanations and complex reasoning is needed (Tufte, 2003). Furthermore, research on the use of slide presentation in classrooms has found no substantial evidence that teaching with computer generated slides improves students' learning abilities or outcomes (Levasseur & Sawyer, 2006). Current presentation tools are mostly built to run in a "one slide on one screen" mode and do not support more elaborate scenarios such as multiple screens, or very large, high-resolution displays capable of showing much more information.

The main research problem addressed in this dissertation is how to design effective classroom presentation tools for large, high-resolution displays. Lecture halls today have advanced technological infrastructure to support presentations, yet lack software tools that accommodate this infrastructure while taking into account the instructor's teaching task. By getting a better understanding of how to build these tools we can benefit both instructors who teach and students who learn in large classroom environments.

1.2 Research questions

The high-level goal of this dissertation is to gain a better understanding of how to design rich classroom presentation tools that make use of the larger screen real-estate available with modern high-resolution displays. More specifically, our goal was to answer the following three research questions:

1. How can we best combine the advantages of traditional visual aids such as blackboards and whiteboards with the advantages of electronic presentation systems?
    a. How do instructors currently utilize a large display surface when using traditional blackboards?
    b. Can we use the same techniques with an electronic presentation system?
2. How can a presentation system that uses large, high-resolution displays best support instructors and learners?
    a. What affordances should a classroom presentation system provide to instructors?
    b. From an instructor's point of view, what pedagogical practices using larger screen surfaces support learning?
    c. From a learner's point of view, what are the positive and negative aspects of learning with information presented on a larger screen surface?
3. Objectively, is there benefit for learning using a larger screen surface?
    a. If there is such benefit, how should we use the extra screen real estate to best improve learning?
    b. Is there a trade-off beyond which more information can actually hinder learning?

1.3 Research methodology and overview

Our general approach has been to pose our research questions from technical, educational, and psychological perspectives. From a technology perspective, we look at what is feasible to implement with advances in the technology. While technology is not a driving force, any computerized system should acknowledge existing technologies, and be designed as best as possible to fit future technological capabilities. In particular, the growing ubiquity of multiple and high-resolution displays afford new features that we can add to presentation tools. We outline a technological framework for building these features and tools in Chapter 4. From an educational perspective, we look at presentation software as a pedagogical tool and examine how presentation tools should be designed to promote student's learning. From a psychological perspective, we look at the cognitive challenges that both presenter and audience face. The presenters need to focus on the material presented. It is therefore essential not to add to their cognitive load when using the presentation system. The audience's cognitive abilities should also be taken into account when building presentation tools. Human cognitive abilities are limited and working memory can overload when too much stimulation is induced (Sweller, 1988). When designing presentation systems, we should be aware of how people see, remember, and understand content.

To satisfy the goals of the research reported in this dissertation, we took a multifaceted approach:

1. We conducted an exploratory observational study to understand current practices with traditional visual aids such as blackboards or whiteboards as well as with existing presentation software. This resulted in design guidelines for building presentation software that promotes learning.
2. We designed and implemented a presentation tool for large, high-resolution displays, based on the understandings from the first step.
3. We evaluated our presentation tool in laboratory and natural settings to examine its viability, and to see how it affects learning.

1.3.1 Understanding current practices

To address the first research question of how to best combine old and new practices, we conducted a two-phase exploratory observational study that examined instructors' current practices of using visual aids (Chapter 3) for presentations. In the first phase, we conducted general observations of visual aids usage in classrooms, developed a catalogue of usage patterns, and formed hypotheses that were used for the second phase. In the second phase, we conducted a larger, more structured study that compared the usage of electronic slides with the usage of a large array of blackboards in both classroom and conference settings. The goal of the study was to explore the advantages of each medium and to understand how we can harness the advantages of traditional visual aids when developing computer-based presentation tools. Drawing on the findings from this study, we developed six design guidelines for electronic classroom presentation tools.

1.3.2 Designing and implementing MultiPresenter

Based on the findings from the observational study, and in order to address the second research question of how a presentation system that uses high-resolution displays would best support learning, we developed the MultiPresenter system. The design and implementation details of MultiPresenter are presented in Chapter 4. MultiPresenter is a novel presentation system designed to work on large, high-resolution displays. In the observational study, we demonstrated that instructors frequently use the extra screen real estate provided by multiple blackboards to allow persistency of information to students, often referring back to previously shown information. This was articulated in the short- and long-term persistency guidelines (Section 3.5). Based on these guidelines, MultiPresenter was designed to provide various methods of supporting information persistency. Another important guideline, derived from the dynamic nature of blackboards, was to allow presenters to dynamically add, control, change, and remove content. We therefore designed MultiPresenter to support a wide range of presentation practices including pre-made as well as dynamic presentations.

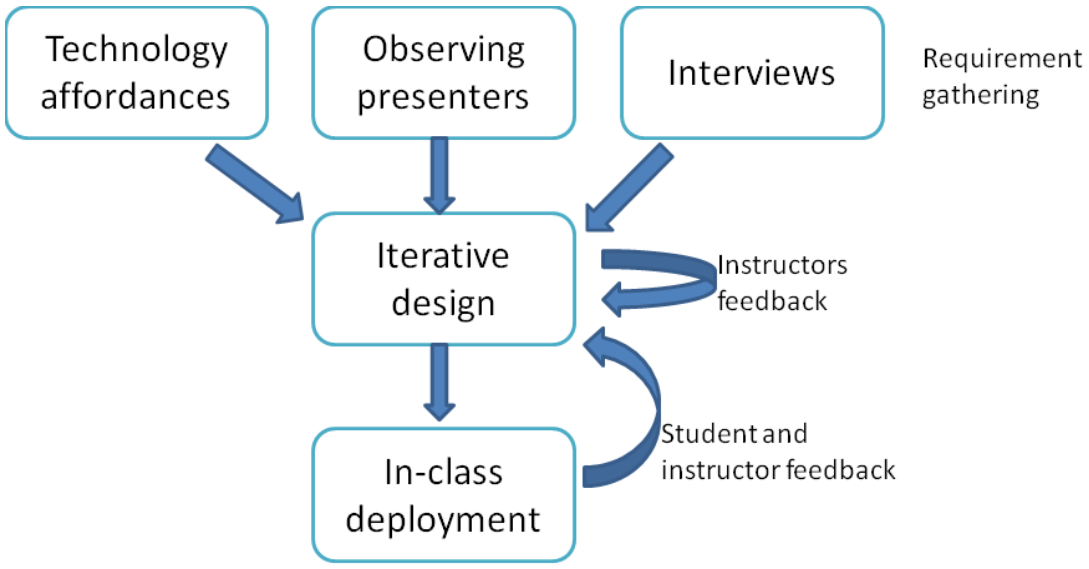


Figure 1.3 – The User-centered approach of MultiPresenter

Throughout the development of MultiPresenter, we took a user-centered design (UCD) approach (Figure 1.3). Most systems have one type of user that the designer has to focus on when designing the system. In our case, both the presenters and the audience are users. First focusing on the presenter, we emphasized usability of the system. It was imperative that the system be easy and intuitive to use – especially during a presentation when the presenter needs to pay attention to the material and often cannot afford to devote much cognitive effort to running the presentation. To better understand this and other requirements, we involved instructors and presenters early in our design process. Colleagues with teaching experience were shown the interfaces of early prototypes and were encouraged to comment and to suggest needed features. We then iterated on the prototypes, changing the design and resolving problems during each iteration.

We next focused on the audience, trying to understand how to build presentation software that would promote the audience's learning or understanding of the material. Using extra screen real estate in a presentation does not necessarily help the observer. Showing too much information that is redundant to the spoken words may in fact hinder the learning process (Mayer, Heiser, & Lonn, 2001). Although this is very dependent on the way a presenter uses the system, the way the software is designed (e.g., its defaults

and affordances) also affects the way information is presentation to the audience (Tufte, 2003).

In order be able to address our second research question, it was not sufficient to design and implement a presentation system. We also had to see how it was used in practice. We evaluated MultiPresenter by deploying it in actual classrooms (Chapter 5). Eight instructors used MultiPresenter to teach fifteen courses. Each instructor used MultiPresenter during most lectures of a class in a given semester. We gathered various data from these courses including log files, screen shots, classroom observations, instructor interviews, and student questionnaires. To address research question 2a about what affordances should exist in a presentation system, we looked at the usability of the software and the use of different features. To address research questions 2b and 2c about the pedagogical practices from the instructor's and the learner's points of view, we examined which features were favoured and which were found to be most effective by students, and we looked at the various pedagogical usage patterns instructors utilized when teaching with multiple screens. Evaluating MultiPresenter in real classrooms enabled us to reflect on our guidelines from Chapter 3, and to examine their feasibility and effectiveness.

Any research project has to consider the balance between the theoretical questions asked and the practical ways to address those questions. Often real-world practicalities determine much of the methodology and the way the research is conducted. This affects the scope of the questions that can be answered. Our main research question asked how can we design classroom presentation tools for large, high-resolution displays. Our intent was to examine how instructors would use a very large, perhaps unbounded surface, but most current large lecture halls have only two projection screens. We thus designed MultiPresenter to support just two displays, and to support current practices (instructors using existing PowerPoint decks). The deployment provided us with invaluable information on how instructors would actually use a high-resolution display, information that could not have been gathered had we designed a less practical tool. This dissertation is a first, important step toward understanding how to use large display surfaces. We believe that most of the findings reported in this dissertation generalize to even larger

surfaces. We discuss the implications of using larger surfaces in the future work section of Chapter 7.

1.3.3 Empirically assessing the advantages of more screen real estate

To address the third research question about objective learning benefits, we conducted a controlled laboratory study (Chapter 6). The study was conducted in order to assess the effect that increasing screen size and utilizing it to present more information has on students' learning. The study was designed to drill down and examine which specific usage patterns were most effective, and whether adding more visual information might actually hinder learning in some cases. The study included 103 participants. Each participant viewed two lectures given in two different delivery styles. One delivery style used a regular one-stream PowerPoint presentation, while the other used a two-stream presentation run by MultiPresenter. Participants' immediate and longer-term recall was assessed using several retention quizzes. Results indicate that, when used properly, a two-stream lecture can improve learning over a one-stream lecture. More specifically, the two-stream lecture was most effective when pertinent prior information was shown alongside current information that built or relied upon it.

1.4 Summary of research contributions

The primary contributions of the research reported in this dissertation are summarized here. We provide a high-level description of the contributions and elaborate on them in our final discussion (Chapter 7).

1. We conducted an in-depth analysis of the current use of visual aids in classrooms, including a taxonomy of events and content types for blackboard and slide usage. We demonstrated several important concepts and practices that are used with blackboards but were lost with the transition to electronic slides, such as persistency of information and the dynamic use of visual aids.
2. We investigated the design space for classroom presentation software, providing a framework for effective use of larger screen surfaces in classroom presentations, and provided guidelines on how to design classroom presentation software for larger screens.

3. We designed and implemented MultiPresenter, a robust classroom presentation system that can utilize the multiple screens available in many of today's classrooms. Previous classroom presentation systems with multiple displays only support one method of presentation delivery, namely, showing a number of previous slides alongside the current slide (Abowd, 1999; Röüling et al., 2004). These systems require fairly complex infrastructure support. In contrast, MultiPresenter supports a wide range of presentation styles, from an automated, scripted sequence of pre-made slides to highly dynamic ad-hoc styles, and it works from an instructors' laptop directly connecting to two screens in any classroom that has connections for two projectors.

4. We catalogued a variety of pedagogical usage patterns that instructors utilize when using MultiPresenter in classrooms. We also analyzed the features used and the way instructors used the user interface of MultiPresenter. This provides further details on how to design classroom presentation software that controls larger surfaces.

5. We found empirical evidence that increased screen size when teaching with the aid of electronic slides size can improve classroom learning. More specifically, we present empirical evidence from a laboratory studying suggesting that pertinent prior information when shown alongside the current information is beneficial for learning.

1.5 Dissertation outline

In Chapter 2 we begin by presenting related work. Chapter 3 describes the two-level exploratory study of unstructured and structured observations of instructors' use of blackboards and electronic slides in different settings. It summarizes our findings with design guidelines for building classroom presentation software. Chapter 4 builds on these design guidelines and describes the design and implementation of MultiPresenter, while Chapter 5 describes the deployment of MultiPresenter in classrooms. Chapter 6 presents the results of a controlled laboratory study that empirically examined the relationship between extra screen space and learning. Finally, in Chapter 7 we reflect on

how well the guidelines developed for building classroom presentation software (Chapter 3) were implemented in MultiPresenter (Chapter 4), and whether or not they were validated through classroom deployment (Chapter 5). Chapter 7 also summarizes the dissertation and the research contributions, and outlines a few avenues for future work. Following these chapters, several appendices present the study materials.

Previous versions of some of the work presented in this dissertation have already been published in conference proceedings. The unstructured observations from Chapter 3 were published at AACE ED-MEDIA 2007 (Lanir & Booth, 2007). The structured study from Chapter 3 was published at ACM CHI 2008 (Lanir, Booth, & Findlater, 2008). Major parts of Chapter 4 were published at ACM Multimedia 2008 (Lanir, Tang, & Booth, 2008).

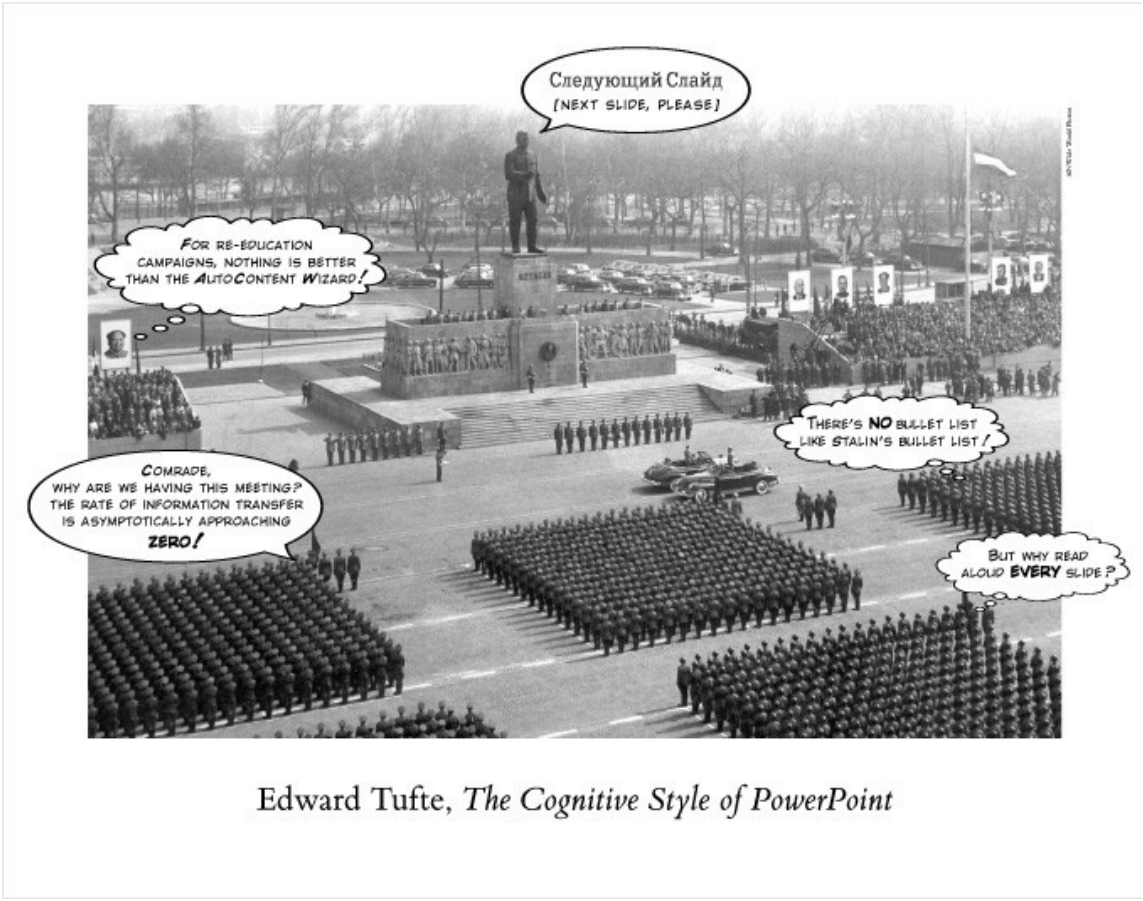


Figure 2.1 - The cover of Edward Tufte's famous essay "The Cognitive Style of PowerPoint" (Tufte, 2003). The essay makes the claim that PowerPoint has a number of limitations and recommends against using it in classroom situations. Used by permission.

Chapter 2

Related Work

This dissertation draws inspiration from a number of disparate fields. The primary concern is the design of software for effective classroom presentations that takes advantage of the extra "real estate" afforded by multiple high-resolution projectors. The goal is to increase learning within the classroom by deploying such software. Before undertaking such a crusade, it is important to understand the current use of technology within classrooms, both traditional blackboard-based technology and new computer-based technology, and also what is known about how students learn within a classroom environment, especially how audio-visual aids are believed to support learning. For the latter there is a wealth of research reported in the peer-reviewed literature because pedagogical studies have been underway for many decades analyzing both the fundamental nature of learning and how specific techniques and technologies that could be deployed within classrooms might improve learning environments. Less certain are the assessments of computer-based technologies, especially of the computer-based presentations systems that we refer to as "slideware". In many cases the most often-cited literature on this newer technology is not peer-reviewed articles in journals or international conferences, but rather it is in the popular press or on the many unregulated websites offering opinions about all manner of things that one accesses on the Internet.

This chapter provides an overview of research on presentation systems focusing on their use in classrooms. We first present highlights of the somewhat non-scientific debate on the merits of existing presentation software, and some commentaries on slide design. We then describe existing presentation systems, mostly from the perspective of the human-computer interaction (HCI) and educational technology fields, and we address some of the limitations of the systems that are described in the research literature. We briefly discuss electronic whiteboard systems and then summarize the education literature on the use of presentation software in classrooms. We conclude with an

overview of related cognitive and educational psychology theories with references to more authoritative sources where detailed descriptions can be found.

2.1 Slideware

The most prominent presentation tool currently in widespread use is PowerPoint, which in 2001 was estimated to account for about 95% of presentations world-wide (Parker, 2001). In 2004 it was estimated by Microsoft that over 1.25 million presentations were created by PowerPoint every hour (Levasseur & Sawyer, 2006). As the most widely adopted tool, PowerPoint has drawn the vast majority of critical attention, but similar critiques can no doubt be applied to almost all other presentation tools, such as Apple's Keynote or OpenOffice's Impress. Because of its prevalence, and for specificity, we will in this chapter and beyond without further apology use the terms slideware and PowerPoint interchangeably to refer collectively to this class of tools.

2.1.1 The PowerPoint debate

Perhaps because of its prevalence, PowerPoint has generated much criticism. The most well known critic is former Yale professor and information visualization expert Edward Tufte. In his famous essay "The cognitive style of PowerPoint" (Figure 2.1) he claims that PowerPoint is presenter-oriented and not content-oriented or audience-oriented. According to Tufte PowerPoint degrades communication by forcing presenters to separate content and analysis, reduces concepts to meaningless bullets, and enforces strict hierarchies that are not needed. He further claims that PowerPoint slides have low resolution of information and thus limit the amount of information the presenter displays to the audience, and that it generates much "Phluff" that confuses the viewers (Tufte, 2003). More relevant to our purposes, one of Tufte's major claims (echoed by others (Kjeldsen, 2007; Parker, 2001)) is that PowerPoint breaks up the narrative and information into small fragments by supporting a rapid temporal sequence of thin information that is not suited for learning, instead of a thorough analysis to support complex reasoning. Another important criticism is that the restricted display area of slides may cause authors to edit their content to fit the slides (Farkas, 2009).

Tufte's criticism was the high point of a popular backlash against PowerPoint. An early example of the backlash is the "Gettysburg PowerPoint presentation" (Norvig, 2000). It is a parody of what the Gettysburg address would have looked like if Lincoln had used PowerPoint to create it. Among other reflections criticising PowerPoint are that 'friends don't let friends use PowerPoint' (Stewart, 2001) and that PowerPoint turns 'middle managers into bullet-point dandies' (Parker, 2001). Others criticize PowerPoint for creating fragmentation of thoughts, and editing ideas by dictating how information should look and be organized (Kjeldsen, 2007; Parker, 2001).

Others, answering these critics, say that PowerPoint is only a tool that is sometimes poorly used by its clientele. Rather than being the *source* of poorly planned, disorganized presentations, PowerPoint simply reflects flaws in authors' design skills, communication ability, or rhetorical expertise (Norman, 2004; Shwom & Keller, 2003). A second argument in response to Tufte's and others' criticism is that oral presentation is different from written documents, so one should not analyze slides outside the context of the talk. Slides are not supposed to display all the information, but rather support the spoken words of the presenter, or display the outlines of the ideas being presented (Doumont, 2005). A core drawback of the debate is that it has been conducted primarily through essays that reflect authors' opinions rather than relying on empirical evidence (Farkas, 2006).

2.1.2 The slide metaphor

One defining characteristic of presentation software is the slide metaphor. Information is segmented into a series of discrete display units called slides (Farkas, 2006). Although there are several alternatives to the slide metaphor (see Section 2.2.1), all major commercial presentation software uses this metaphor to such an extent that presentation software is often called (as in this dissertation) **slide**ware. Farkas (2009) notes that slides have strong display unit boundaries that contrast with the weak display unit boundaries of books, newspapers or electronic documents. When authoring a book or an electronic document, authors do not usually consider the boundary of the medium as a constraint. This is not so with slides.

Slideware's strong boundaries are a major constraint when the author designs the visuals of a talk (Farkas, 2009). This constraint causes a problem defined by Farkas as *content cutting,* which refers to the removal of content by the author to respect the slide's boundary constraint. Because of the strong boundaries, users of slideware often eliminate informative text or graphical content to fit the available space. This can either be in the form of removing content, or shrinking content so its informative value is diminished. Another way authors cope with the slide boundary constraint is by putting the information on two separate slides. *Overflow distortion i*s when creators reorganize content onto two slides, but do this in a way that breaks the logical organization. Reorganization may cause inconsistencies if the hierarchy of the slides is changed or unclear. In practice, slide deck creators usually tend to cut content instead of using two slides because of a desire for closure. Using a larger surface naturally solves these problems by giving authors a larger, almost "boundless" surface they can use to present their information.

2.1.3 Slide design

A good presentation design is as much an art as it is a science. Therefore, much of the advice on slide design comes from visual designers or presentation experts. The most common slide design in presentations is the canonical layout of a slide title plus one or more levels of bullet points (Farkas, 2006). However, using bullet points, which are often non-grammatical shorthand for fully formed sentences, is one of the most controversial aspects of designing slide decks. Many commentators advocate minimizing the use of bullet points because they tend to simplify ideas (Tufte, 2003), they are boring and not graphically pleasing (Atkinson, 2005; Reynolds, 2007), and they tend to form unneeded deep hierarchies (Tufte, 2003). Others suggest a design approach in which a slide should have a title phrased as a succinct sentence as opposed to a single word or a short phrase, accompanied by images or diagrams in the body of the slide instead of multiple bullet points (Alley et al., 2006; Atkinson, 2005).

In general, many commentators and visual designers speak against using too much text on a single slide. Slides, according to these experts, should be designed with a primarily visual approach in which there are fewer words and more images. In this style

of presentation design, the presenter's commentary is synchronized with and augmented by simple, elegantly designed slides comprising mostly high resolution images with text used sparingly (Atkinson, 2005; Reynolds, 2007). Minimalism is also encouraged by marketing guru Seth Godin (2004), who advocates using no more than six words on a single slide

A problem with all of these guidelines is that most of their sweeping recommendations usually address a specific presentation genre. Godin clearly focuses on business presentations and sales pitches, and does not necessarily intend his remarks to apply to other presentations genres such as scientific conferences or classroom presentations. Tufte, when arguing for high-resolution images to be given away as hand-outs and not projected during the presentation, does not address keynote speeches or marketing presentations in which visuals are meant to provoke emotions in the audience and not necessarily to simply convey information. Abela (2008) aims at resolving this conflict by identifying two kinds of presentation idioms: ballroom style and conference style. Ballroom style presentations are colourful, attention grabbing, and typically take place in a large room such as a hotel ballroom. Their purpose is to inform, impress or entertain a large audience. In these circumstances, having a mostly visual presentation with many images and little or no text on the slides is appropriate. Conference style presentations, on the other hand, are small meetings in which the presentation objective is to engage, persuade, or to come to a conclusion. They typically take place in a small conference room. For these presentations, visuals should have more pages with more details and are more likely to be printed on handouts rather than shown on projected slides. We suggest a third kind of presentation idiom that is of increasing importance and is in fact the focus of concern in this dissertation: classroom presentations. These are computer-based presentations that are given in small or large classrooms and are aimed to support learning. In Chapter 3, we suggest some design guidelines specific to classroom presentation systems.

2.2 The research literature on presentation systems

We first report on various presentation tools developed in the HCI domain, often as prototypes. We then report on presentation systems that were developed to enhance learning experiences in classrooms.

2.2.1 Presentation systems in HCI

A number of HCI researchers have developed presentation tools to address some of the limitations of PowerPoint and other commercial presentation tools. Some systems focused on adding support for *delivering* the presentation by using physical index cards that are digitally linked to slides (Les Nelson, Pedersen, & Adams, 1999), interactive paper to enable PowerPoint presentations to be controlled and annotated from printed slide handouts (Signer & Norrie, 2007), or handheld devices to control the presentation flow (Myers, 2001). Others added support for a presenter's view that is different than what is seen by the audience (Anderson et al., 2003; Röüling et al., 2004).

Drucker et al. (2006) explored ways to compare and manage multiple slide presentations from a single document within an application. The focus of this research was on managing multiple versions of a presentation, not on the presentation act itself. Several systems were developed to break the inherent linearity of existing slideware presentations. Using Zoomable User Interfaces (ZUIs) (Good & Bederson, 2002), static slides are arranged on a large canvas at various scales of magnification. Transitions are made between slides using pan and zoom across the canvas, allowing viewers to understand the structure of the talk according to the visual locations and groupings of the slides. Mindmaps (Holman et al., 2006) are special diagrams linked to and arranged radially to provide more cues about the structure of a talk, and to enable the speaker to flexibly move through a presentation. Combining concepts from mindmaps and ZUIs, Fly (Lichtschlag, Karrer, & Borchers, 2009) was developed as a more mature system that further breaks out of the slide metaphor. Fly provides a unified environment that focuses on authoring and delivering presentations based on a planar space. Similar to ZUIs, information parts and graphical elements are positioned on an infinite plane according to natural grouping. The presenter can then provide a path that during the presentation will continuously go through the information, or decide on a path in a more dynamic way.

Unlike ZUIs, Fly does not constrain authors to use slides as the basic building blocks, nor does it permit arbitrary-scale display. It also focuses more on the authoring aspects of the presentation rather than on the delivery aspects.

All of these non-linear approaches separate content from the actual presentation by making *navigation* through the information space a core part of the presentation delivery. Similarly, SLITHY (Zongker & Salesin, 2003) is a system created by Zongker and Salesin that provides a conceptual separation between content and presentation and focused on design principles of animation for use during presentations. Zongker and Salesin identified a number of authoring paradigms for animated presentation systems as well as a set of design principles for appropriate use of animation within presentation systems. The disadvantage of SLITHY is that authoring a presentation requires use of a scripting programming language, and is therefore not suited for presenters unfamiliar with procedural programming languages or scripting systems.

There has been some effort to support delivering presentations on multiple projectors. Röüling et al. (2004) implemented a system that showed previous slides on different projectors. They also supported electronic ink and a separate view for the instructor. Chiu et al. (2003) proposed a slide-based multi-display presentation system. In their system, the user was able to show previous slides on multiple displays, and was able to use a touch interface to control the slide presentation flow. The EPIC system of Liu et al. (2004) is designed to allow presentations on multiple devices in a complex meeting room infrastructure. It supports the managing of several streams of information on different predefined devices. We use these systems as starting points, supporting multiple projectors for slides and providing support for existing slideware tools. In the MultiPresenter software described in Chapter 4, we extended this idea by adding support for dynamic presentation practices and also some new static practices, and we simplified the infrastructure requirements to allow more rapid adoption in classrooms to enable it to be run on an instructors' laptop rather than on specialized platforms that are part of the physical infrastructure required in a classroom.

2.2.2 Presentation systems in classrooms

There have been many attempts to deploy technology in classrooms to enhance learning. Much of the effort has concentrated on capturing the lecture for later viewing. Classroom 2000 (Abowd, 1999) was the first major project to incorporate technology into the classroom to facilitate capturing, archiving, retrieving and presenting classroom activities. Mukhopadhyay and Smith (1999) aimed at capturing lectures using a more passive and less invasive capturing process. Others emphasize integrating the various captured streams (audio, video, slides, and whiteboard) for later retrieving in various levels of automated methods (Müller & Ottmann, 2000). Presentations can also be captured and transmitted to a large group of audiences via webcasting systems (Baecker, Moore, & Zijdemans, 2003; Baecker, Wolf, & Rankin, 2004).

Some approaches enhancing face-to-face communication in the classroom aim to make presentations more dynamic by adding electronic ink to the presentation. PowerPoint 2007 has a minimal set of annotation tools to support electronic ink. Classroom Presenter (Anderson et al., 2004) added more complex writing tools to augment prepared slides by integrating PowerPoint slides with pen-based writing on a tablet PC. E-Chalk (Friedland et al., 2004) allowed instructors using electronic whiteboards to combine the ability to record whiteboard activities in classrooms, including multimedia items and pen-based writing. Focusing on the audience, Livenotes (Kam et al., 2005) affords cooperative note taking by students overlaid on top of the instructors' slides using TabletPCs. All of these systems emphasize the importance of electronic ink as a mechanism to add some degree of dynamic interaction for the presenter, the audience, or both.

Commercial slideware tools mostly support a one-way presentation in which the instructor transmits information for students to absorb. However, most educators believe that lectures, even ones with limited audience involvement, should be dialogues in which the instructor implicitly or explicitly ascertains whether the presentation delivery is clear, and modifies the delivery as necessary to reinforce a point by revisiting a concept, or by providing more detail when necessary (Bligh, 2000). Focusing on the need to promote student-instructor interaction in lectures, several projects in the field of educational technology have used laptops, PDAs or other electronic devices held by students to add

another channel of communication between students and instructors. ClassTalk (Dufresne et al., 1996) is an early system built to facilitate active learning in classrooms. It allows an instructor to manage different types of tasks, and to facilitate activities by individuals or groups of students working on workstations in a large classroom. ActiveClass (Ratto et al, 2003) is a system built to encourage classroom participation by allowing students to anonymously ask questions, answer polls, and give the professor feedback using wireless mobile devices. Other systems (Anderson et al., 2003; Peiper et al., 2005; Wilkerson, Griswold, & Simon, 2005) transmit the instructor's slides over the network to students' computing devices. Using TabletPCs or PDAs students can annotate slides to give back-channel context-related feedback to the instructor.

These approaches all require students to have an electronic device, dedicated software, and access to communication infrastructure in the classroom. In many classes, for financial or practical reasons, this is not possible. Because presentation infrastructure scales far more efficiently in large classrooms than does provision of individual student devices or the establishment of better communication infrastructure, we have pursued a lightweight solution that focuses on enabling more dynamic slide-based lectures to enhance interactivity of large lectures using existing classroom infrastructure. This does not preclude adding audience interactivity, an option that we consider more fully in a later chapter.

2.3 Electronic whiteboards

Electronic whiteboards are large touch sensitive screens that are connected to a computer connected to a projector. They were initially developed for small office meetings used for presentation and collaborative brainstorming. The first electronic board was developed in Xerox Parc (Stefik et al., 1987) in order to support collaboration of small groups using a pen-sensitive large-size display. Very soon after, manufacturers started selling affordable digital whiteboard systems. At first the systems were developed mainly for office settings. Initial whiteboard projects were primarily studied as shared collocated collaborative tools for meetings by researchers interested in computer-supportive cooperative work (CSCW). Projects such as Tivoli (Pedersen et al., 1993) allowed groups of users to collaborate in real time to flexibly organize and arrange

materials on the board through direct manipulation. Other projects (Mynatt et al., 1999; Rekimoto, 1998) investigated the types of collaborative activities that could be supported by electronic boards, and how electronic whiteboards might support those activities. Stanford's iRoom (Johanson, Fox, & Winograd, 2002) explored how users can move information and share control of applications in a collocated interactive workspace environment that integrated several large screen displays, workstations, and PDAs. Focusing specifically on interaction with large screen displays, Guimbretière et al. (2001) provided "fluid interaction" techniques for direct pen-based interaction on large wall-size displays to utilize a wide variety of actions while minimizing the amount of attention required to operate the interface.

These projects investigated how an electronic whiteboard might be used in an informal office work setting. They did not look at electronic whiteboards as a tool for the classroom. In recent years, electronic whiteboards have become more prevalent in small classrooms, mainly in K-12 classrooms, and less so in higher education where projected computer slides are more common. Commercial companies like Smart Technologies[1] provide custom solutions for electronic whiteboards for classrooms. Some researchers have proposed interaction techniques and guidelines on interface design for giving presentations in a classroom using pen-based input devices (Anderson et al., 2004; Hürst & Meyer, 2004; Moran, Chiu, & Van Melle, 1997). Smith et al. (2005) and Glover et al. (2005) survey the literature on the effect of interactive whiteboards on learning. Most of the research they survey was small-scale studies of the impact of interactive whiteboards on pedagogy and on the classroom environment. They note positive feedback from both students and teachers. Teachers generally reported having more flexibility and versatility in their classes. Students were often reported to be more motivated because of the high level of interaction the electronic whiteboard enables.

[1] http://smarttech.com/

2.4 The benefits of slide presentations in university classes

In this section we outline the major studies that have been conducted on the effects that computer slides have on students' experiences and students' learning in higher education classrooms. For a comprehensive survey, see (Levasseur & Sawyer, 2006).

Computer slides are widely used in higher education, mainly as visual aids to help instructors during face-to-face presentations. Although increasingly prevalent in the classroom, the pedagogical implications of using computer generated slides remain unclear. One of the challenges when introducing technology into the classroom is ensuring that the technology enhances students' learning rather than just modernizing the classroom or easing the instructors' teaching. Looking at the widespread penetration of computer slides into classroom teaching, an obvious question that needs to be addressed is: Do computer slides actually enhance students' learning? If they do, we might further ask: How does this happen?

Most studies focusing on whether or not computer-generated slides are beneficial have found that students responded positively to the use of computer-generated slides in the classroom in comparison to blackboards and overhead transparencies (Bartsch & Cobern, 2003; Daniels, 1999; Levasseur & Sawyer, 2006; Savoy, Proctor, & Salvendy, 2009; Susskind, 2005; Susskind, 2008; Szabo & Hastings, 2000). Students have indicated that slides help them improve organization of the course and their notes, help them learn course material more effectively, and make classes more interesting and entertaining (Levasseur & Sawyer, 2006). Students often displayed more positive attitudes toward an instructor who used computer slides indicating that the professor "did a better job" when class lectures included PowerPoint (Susskind, 2005). In many classes, instructors are expected by students and sometimes by administrators to use presentation software, and those who do not use slides are viewed as unprofessional (Parker, 2001). The reasons for preferring computer slides might be attributed to a novelty factor (most of these studies were conducted when computer slides had just entered into the classroom), or to a possible preference by students to have copies of the lecture notes provided to them by the instructor, which is a side benefit of most computer-based slide systems.

How students react to computer slides is important, but a more important question is what effect do computer slides actually have on student learning. Most studies

examining the effect computer slides have on learning outcomes have found no significant improvement in student performance when slides were used, compared to using other visual aids such as overhead transparencies or blackboards (Bartsch & Cobern, 2003; Daniels, 1999; Levasseur & Sawyer, 2006; Savoy et al., 2009; Susskind, 2005; Susskind, 2008; Szabo & Hastings, 2000). An exception to this is that in some cases computer slides appear to enhance learning when students have access to copies of slides (Mantei, 2000). This might be attributed to students getting an organized set of notes for the class from the instructor and not needing to spend cognitive effort in note taking during class if they have the slides in advance. We are not aware of any studies reported in the literature that adequately compare the full two-by-two array of lectures with and without slides and with and without instructor-prepared copies of the lecture material.

While the education community is still unsure of the pedagogical implications of introducing computer slides into classrooms, and debate about if and how slides should best be employed, everyone seems to agree that computer slides are already in widespread use in today's higher education classrooms (Parker, 2001). Seldom, however, does the literature address questions of how presentation system software should be designed to aid students' learning. This seems to be a significant lack in the literature giving the apparent inevitability of even more reliance on presentation systems in the foreseeable future.

2.5 Educational and cognitive psychology theories

Theories of cognitive and educational psychology acknowledge the advantage of using visual aids to assist learning (Faraday & Sutcliffe, 1997; Mayer, 2001; Sweller, 1988). By processing information through two separate channels and integrating these channels in working memory to form schemas in long-term memory, learning is promoted (Mayer, 2001; Paivio, 1990).

Cognitive load is a major factor when acquiring knowledge. Cognitive load is a general term referring to the load on the working memory a person has when completing a task or when processing information. We are interested in the cognitive load that the listener in a presentation experiences when trying to actively learn from the presentation.

Cognitive psychology research has emphasized *limited attention* and *working memory capacity* as bottlenecks related to cognitive load during human information processing (Baddeley, 1989; Sweller, 1988; Wickens, Sandry, & Vidulich, 1983). Cognitive Load Theory (Sweller, 1988) states that working memory is limited when learning new information. Learned information is stored in long-term memory as schemas – sophisticated structures that permit us to perceive, think and solve problems. From an instructional perspective, cognitive load theory speculates that the best learning is achieved when cognitive load on working memory is minimized.

Richard Meyer (2001) constructed a cognitive theory of multimedia learning. His theory draws upon Sweller's cognitive load theory (Sweller, 1988), Baddeley's model of working memory (Baddeley, 1989) and Paivio's dual coding theory (Paivio, 1990). Meyer states three assumptions:

1. ***Dual channels*** - humans possess separate channels for processing visual and auditory information;
2. ***Limited capacity*** - humans are limited in the amount of information that they can process in each channel at one time (cognitive load);
3. ***Active processing*** – humans engage in active learning by attending to relevant incoming information, organizing selected information into coherent mental representations, and integrating mental representations with other knowledge.

According to Meyer's theory, as illustrated in Figure 2.2, the learner engages in three cognitive processes: *selecting* to transfer incoming verbal and visual information into working memory, *organizing* or creating a verbal or pictorial model of the words or images retained in working memory, and *integrating* these as the learner builds connections between the verbal and visual models and with previous knowledge from long-term memory.

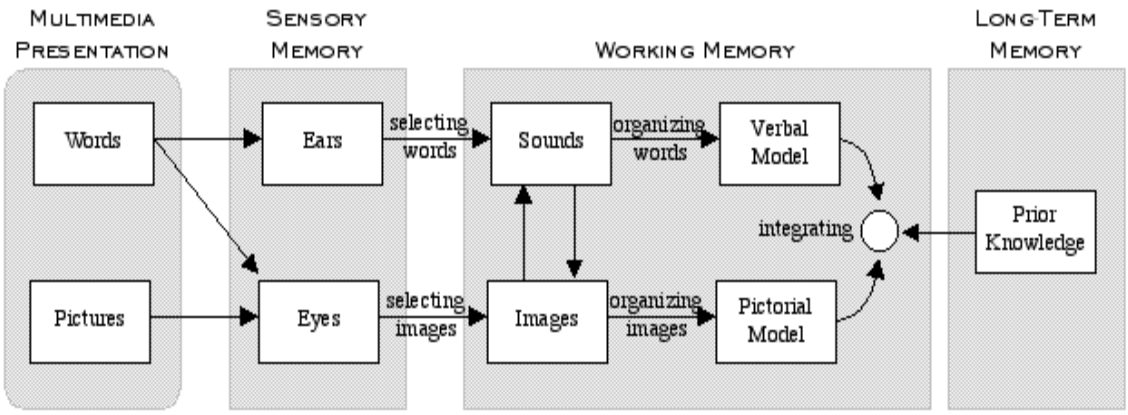


Figure 2.2 – Meyer's theory of multimedia learning (taken from Meyer, 2001)

Cognitive theories can be used both to support and to disclaim the advantages on learning of computer slides (Levasseur & Sawyer, 2006). On one hand, computer slides contain color, vivid images, and motion that may generate a stronger level of sensory stimuli, which is generally associated with a high level of audience arousal. Arousal Theory (Weiner, 1992) states that there is a link between arousal and learning and that emotionally aroused messages enhance learning motivation and therefore will enhance learning. The advantages of computer slides for learning purposes are also supported by what may be called the *multimedia principle.* This principle, as stated by Mayer (2001) claims that words and images better enhance learning over words alone. On the other hand, we can use cognitive theories to argue that computer slides are not beneficial for learning. Cognitive scientists agree that working memory is limited (Baddeley, 1989; Sweller, 1988). In her Limited Capacity Model, Lang (2000) claims that arousing messages can impede information processing. Arousing messages tend to place higher information processing demands on working memory. Because information processing is limited, arousing content can overload processing resources. This overload hinders the ability to encode, store and retrieve informational messages (Lang, 2000). With Computer slides, this phenomenon can happen when instructors use PowerPoint to show what Tufte has termed "Phluff" (Tufte, 2003). These extraneous visual elements might overload processing capacity at the expense of more significant instructional content. This is supported by Meyer's coherence principle (Mayer, Heiser, & Lonn, 2001), which

states that student learning is hindered when interesting but irrelevant words, pictures or sounds are added to a multimedia presentation.

Meyer's multimedia learning theory can be used to support the use of a larger display surface in classroom teaching. Meyer's spatial and temporal contiguity principles state that people learn better when words and graphics are presented together side by side (spatial contiguity) at the same time (temporal contiguity) rather than spread out spatially or temporally (Mayer, 2001). This relates to Ayres and Sweller's split-attention principle of multimedia learning (Ayres & Sweller, 2005), which states that

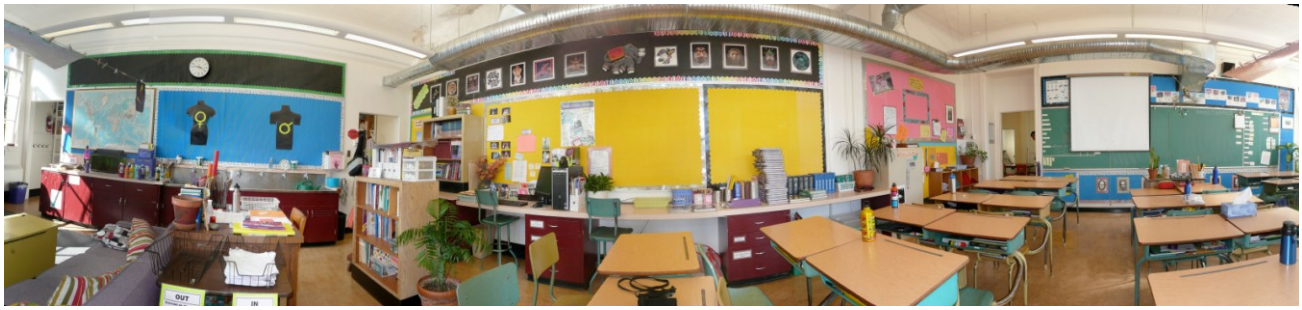
> "[W]hen designing instruction, it is important to avoid formats that require learners to split their attention between, and mentally integrate, multiple sources of information. Instead, materials should be formatted so that disparate sources of information are physically and temporally integrated thus obviating the need for learners to engage in mental integration."

Based on these principles we hypothesized that using the extra screen real estate available with high resolution and multiple displays to put relevant information side by side instead of temporally sequential on different slides is a good idea and that it might promote students' learning. It has been observed that many instructors do indeed temporally sequence information in order to work with the strong boundaries of slides (Farkas, 2009). We present a preliminary examination of our hypothesis in Chapter 6.

2.6 Summary

Our survey of related work shows that there are many unresolved issues with respect to if and how to best use presentation software for business and educational purposes. There are three issues that are of specific interest for our work. First, many commentators critique existing presentation software and the way it is used, yet few have concrete guidelines for how or even if it should be used to promote learning. We offer a suggestion in Chapter 3. Second, while there has been work on the use of electronic ink in classrooms and research that looks at how to promote instructor-student interaction, little research has examined how to best use the large display surfaces available in today's modern classrooms for educational purposes. We address this gap in the

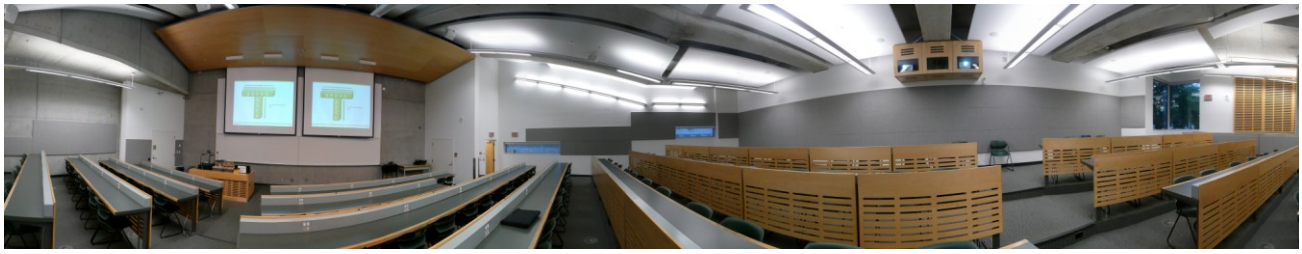
literature by presenting the design and implementation of the MultiPresenter system in Chapter 4, and an evaluation of MultiPresenter in Chapter 5. Third, although our survey found various empirical studies that have been conducted to examine the utility of computer slide use in classrooms, researchers have not yet empirically determined whether learning can be improved by using extra screen real estate. We examine this in Chapter 6.



(a)

(b)

(c)



(d)

Figure 3.1 – Panoramic photos of four classrooms that illustrate the relative sparsity of persistent information available to university students (d) compared to elementary school (a) and high school social studies (b) and science (c) students.

Chapter 3

Understanding Instructors' Use of Visual Aids

Our first step to gain an understanding of how to design classroom presentation software was to observe how instructors and presenters currently use different visual aids. We started by observing the use of general visual aids in classroom lectures at our university. From these initial observations we developed a catalogue of usage patterns, which formed the basis for a coding scheme for presentations that we then applied in a larger, structured observational field study. The structured study examined current practice with both electronic slides and more traditional visual aids, comparing presentations in both conference and classroom settings to identify problems with existing presentation software and to understand how best to utilize multiple high-resolution screens to support both presenter and viewers. A blackboard (this term refers equally to whiteboards unless otherwise noted) allows instructors to visually present ideas using a large surface that they dynamically control. Lecturers decide what information to write, what to erase and what to leave for future reference. Multiple blackboards, possibly sliding up and down or left and right with or without overlap, allow a large amount of information to be simultaneously visible to viewers, whereas newer computer slide systems seldom do. The study presented in this chapter formalizes these ideas by providing a taxonomy of event types, distinctions between content types and their respective roles, and analysis of temporal and spatial positioning of content. We demonstrate how presenters use previously shown content and compare this between slide and blackboard usage. Based on our findings, we developed six design guidelines for electronic classroom presentation tools.

We are motivated in part by the variety of visual aids used to support collaborative learning in what is probably an idealized and stereotypical view of a K-12 or K-6 classroom, but still a view that is useful when considering how university lecture halls might better support collaborative learning (Figure 3.1). A K-12 classroom often has one

wall of windows, one wall with blackboards, and two other walls that are either blackboards, bulletin boards, or shelving for books and other learning artifacts. At the lower end of the K-12 range there might also be flip charts, felt boards, or manipulables to support learning; at the higher end of the range there may be maps of various sizes, periodic charts of the elements, or other specialized representations of information specific to the topics relevant to the class. All of these visual aids have degrees of persistence, they can be updated in parallel, and they are accessible to anyone in the room to use, subject only to the social conventions of the class. Thus students in K-6 are welcome to bring newspaper clippings to school to post on the bulletin boards, or to use the side blackboards to discuss a math problem with the teacher or another student, and in Kindergarten students come to the felt board to move felt cutouts around as part of their active learning experience.

What is interesting is that as we move upward in the K-12 hierarchy, classroom activity becomes less and less collaborative. As one educator has noted, "The only thing kids learn in Kindergarten is to share and to work together. But as soon as they learn that, we tell them to never to do it again because it's cheating. Employers then wonder why new college graduates can't work in teams." Our goal is to reverse that trend by developing technology to encourage shared representations of information that are persistent, manipulable, and that support collaborative learning. We will focus on large lecture courses at the university level, but our techniques apply to many other settings as well.

3.1 Initial observations

As a first step, we observed lectures in a number of classes at our university and noted general use of the different visual aids. We gathered and then analyzed observational data on the type of content displayed on each visual aid and the way the instructor interacted with the visuals.

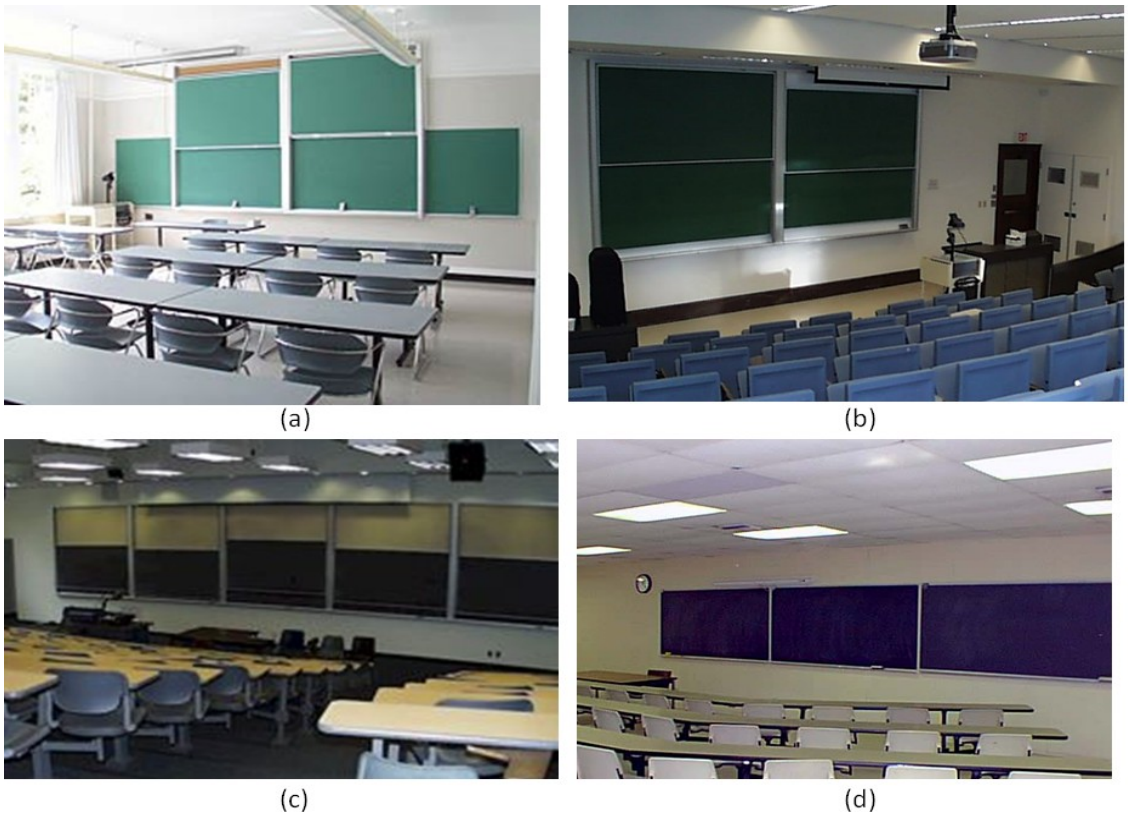


Figure 3.2 – Examples of blackboard configurations in university classrooms. (a) two horizontal sliding blackboards in the center, with an additional static board on each side. (b) two horizontal sliding boards. (c) five horizontal sliding boards. (d) three boards filling a wall.

3.1.1 Initial observation methodology

We attended 60 hours of undergraduate classroom lectures to develop a general understanding of how instructors use visual aids in the classroom, and to identify categories of usage that could be used to build a coding scheme for subsequent structured observations. We observed many different lecturers on a variety of subjects including biology, chemistry, computer science, economics, geography, political science, psychology and more. We purposely attended lectures in classrooms of various sizes and with different visual aids: whiteboards, blackboards, overhead transparencies, computer-generated projected slides and combinations of these. Board numbers and sizes varied from two or three blackboards covering most of the wall, to 3x3 upwards-sliding boards, to two horizontal blackboards with one sliding horizontal blackboard over top (Figure 3.2). Generally speaking, the larger the lecture hall was the more boards it had. Sliding boards were more common in large lecture halls, although as can be seed in Figure 3.2a

which shows a small classroom with sliding board, this is not always the case. We did not record detailed interactions or content during this early stage of our research, but instead gathered general observations concerning visual aid usage.

3.1.2 Categories of blackboard use

In all the classrooms we visited, the boards were separated into small units by seams or bezels. We call a *board unit* a part of the board that an instructor uses as one logical area. If the physical seams create units too large, the instructor often draws a line to divide it into two or more units. In some classes, the boards slide up and down to form two or three board units tiled vertically. In other cases the boards slide right and left to allow boards to tile horizontally. The reason for this is to allow more board real-estate than there is physical space on the wall. That way the students can see what has been done during the previous 3-6 board units and the instructor can refer back to previous information at any time. All classes we observed had between three and nine board units. An interesting observation is that one board unit has about the same capacity of information as a single slide. Thus, when presenting slides the instructor at any given time shows only a fraction of what can be seen on a regular blackboard.

We identified five usage categories for whiteboards and blackboards in classrooms: logical progression, immediate visual aid, text, diagram, and table or graph. The first four categories are shown in Figure 3.3

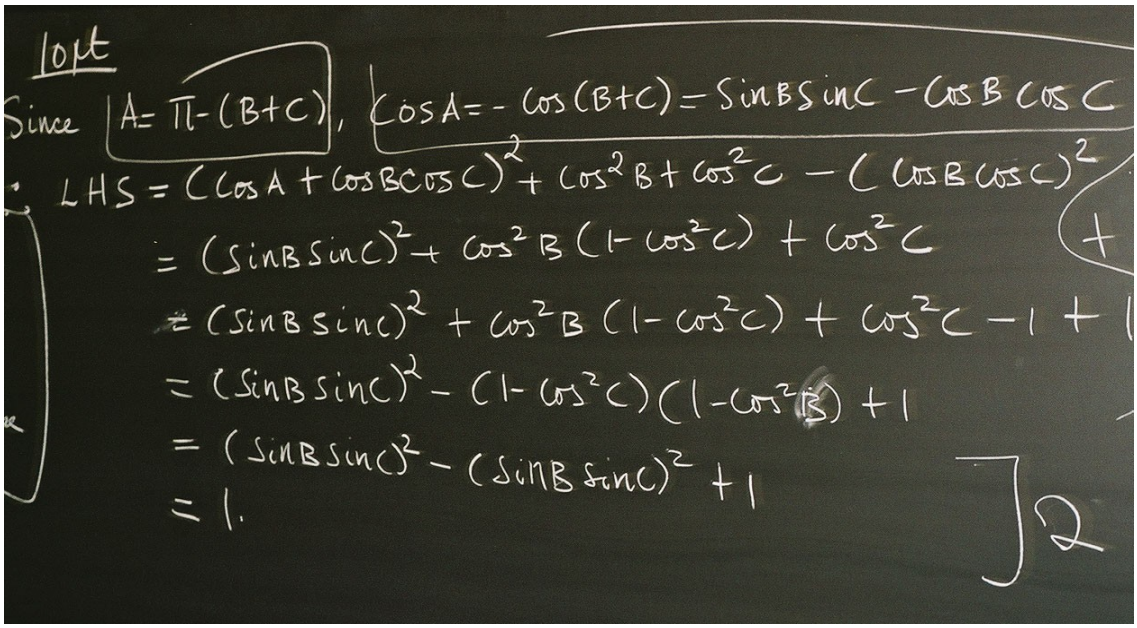


Figure 3.3 (a) – Logical progression

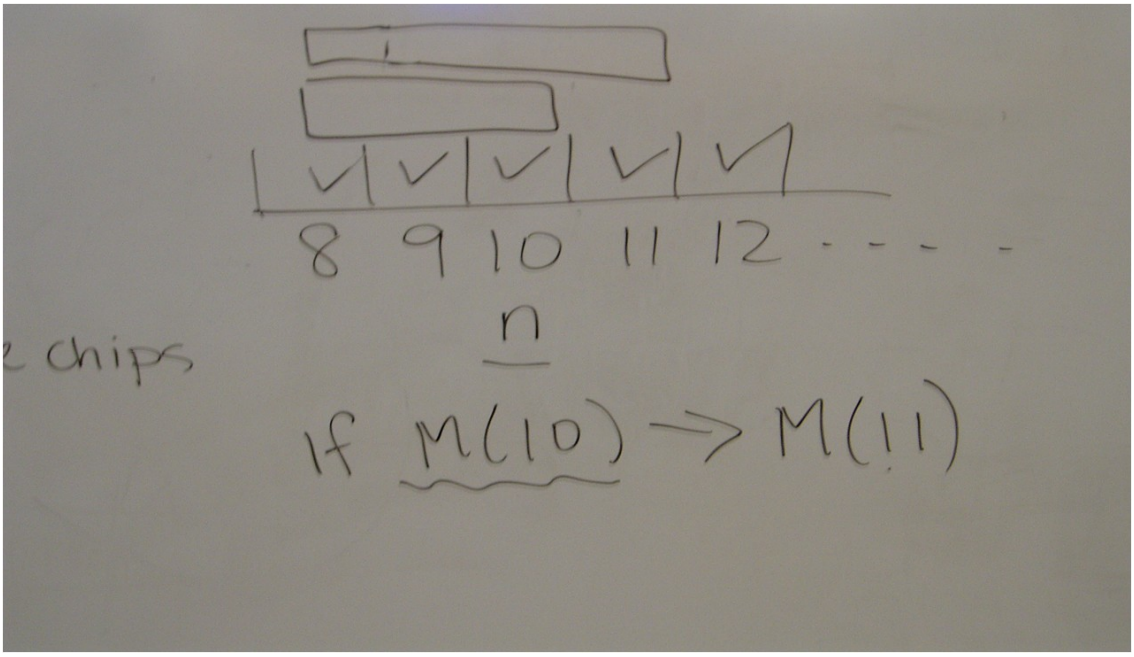


Figure 3.3 (b) – Immediate visual aid

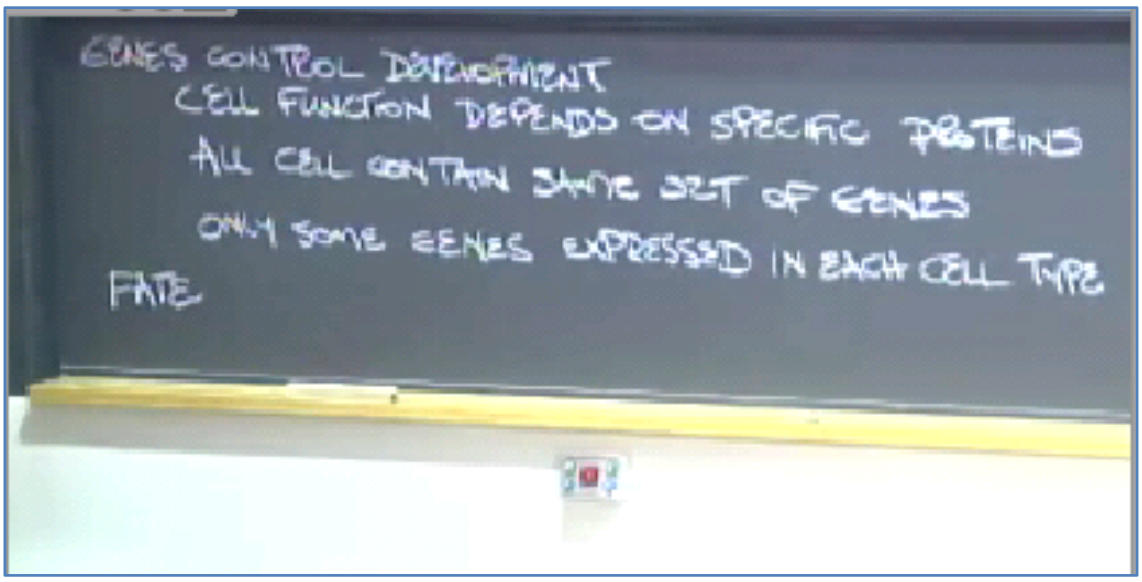


Figure 3.3 (c) – Text

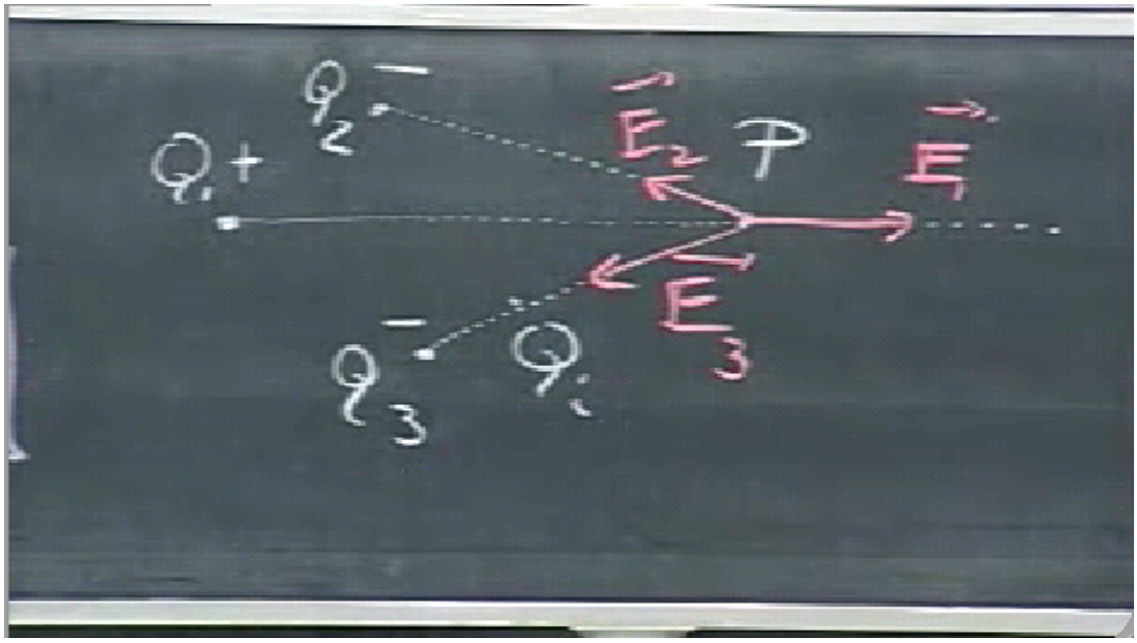


Figure 3.3 (d) - Diagram

Figure 3.3 - Examples of different categories of board usage: (a) logical progression, (b) immediate visual aid, (c) text, (d) diagram

Logical Progression (LP)

Logical Progression (Figure 3.3a) is common in science, engineering and mathematics classes. Usually the instructor is trying to solve some equation or problem, and writes one line of the solution beneath another. Each line is derived somehow from a previous line (sometimes from more than one line) until some sort of conclusion is made. An example of this is an instructor writing a proof for a mathematical statement in a mathematics course. Another example is a list of chemical equations describing how to balance a chemical reaction. Often this is accompanied by a diagram or other annotation to illustrate the problem, or some aspect of the problem. This usually occupies at least one board unit and may span onto several board units. The instructor usually uses many hand gestures for explanations. Gestures help illustrate how previously written lines contribute to the current line. After the problem is solved, the area is rarely gestured at again, indicating no need for long time persistency of information beyond the point at which it was used.

In general, this type of usage is difficult to emulate in slides. Some instructors using slides were observed trying to write down a logical progression in a single slide, revealing one line at a time and explaining each line as it was revealed. This was characterized by most instructors and students as bad practice. This may be because the flow of solving the problem which is natural when the instructor is writing it on the board is not as natural when each line is introduced one at a time. Also, the instructor on the board simulates problem solving in real time and explains his or her way of thought better when writing down each line.

Immediate Visual Aid (IVA)

This category of board usage is a "just-in-time" visual aid for the instructor. It only persists in the context of explaining something specific. It is characterized by the fact that looking at the board without hearing the talk usually will not have much meaning for an observer. The board will look like a collection of disconnected sketches, equations, numbers or words (Figure 3.3b). Their only purpose is as an anchor, a tangible object for the instructor to have concurrent with his or her words. For example, a math instructor might say: "take for example a circle" and then draw a circle on the board, or compare the two expressions "n^2" and "n!" in some context and then write both on the board as

part of the explanation. This usage category often occurs when an instructor is giving an example. It will be accompanied by many gestures during the explanation and by gestures further on in the lecture when the instructor refers back to the concept illustrated by an immediate visual aid. The instructor will usually write the immediate visual aid on any vacant place of the board, not necessarily in any order or on any specific board unit. This usage category is better suited for boards than for slides, because it is spontaneous and essentially an extension of the lecturer's associative stream of thought.

Text

The Text usage category (Figure 3.3c), the instructor uses the board to emphasize an important point that he or she wants to make, to give a heading for a topic that is being discussed, to write down a bulleted list, or to define or spell out a new term. The instructor writes the information on the board, often saying it aloud while writing it. This multimodal redundancy may serve as a communicative strategy to draw attention to the meaning of dialogue-critical terms (Kaiser et al., 2007). For example, a chemistry instructor may write down "Atomic and Molecular Structure" as a title for what she is going to talk about next. When the instructor is explaining molecular structure she might write down on the board "In a neutral atom, number of electrons = number of protons". The purpose of this is usually to emphasize a fact the instructor deems to be important and to help students to focus, as well as to structure the talk and highlight the context of the current discussion. In general, this type of board usage is well suited for slides: it is exactly what slides are good at, structured, ready-made headings to support a talk. A specific case of this type is writing one word. This will usually be to introduce a new term, perhaps by writing the new term as a topic heading. Another purpose for writing a word is to show the audience how to spell the new term. A stand-alone mathematical equation could be categorized as either a text or a logical progression. A mathematical equation written alone is usually written as a statement, not a derivation from other equations. It is then treated as a heading (i.e. in chemistry – here is the entropy equation), and therefore, in our opinion, fits the text category better.

Diagram

In this category of blackboard usage the instructor draws a sketch to convey an abstract concept. All of the instructors' remarks are usually referring to the diagram. For example, in a lecture on physics particles acting in an electric field can be visually illustrated (Figure 3.3d). During the explanation, the instructor will gesture at the diagram many times, often adding temporal layers to the diagram, sometimes using colors. The temporal aspect of drawing a diagram is important to the understanding of the concepts behind it. While drawing the instructor is explaining the different parts of the diagram and the processes that cause one part of the diagram to relate to other parts. The temporal build up of the diagram allows the instructor to explain better how each part relates to the others. After a diagram is completed, the instructor often gestures at the diagram when he or she is referring to the concept that the diagram conveys (e.g., an electric field).

Table or Graph

This category of blackboard usage occurs when the instructor draws a tabular arrangement and or when the instructor draws a chart or graph. These are special cases of Diagram, or hybrids of Diagram and Text, and act similarly to the Diagram type. For example, an instructor might use a table to explain a sorting algorithm. The instructor will draw an array, fill it with numbers, draw a second array underneath it, and show how the first array transforms into the second array. This can be enhanced with arrows, colors and more. Often the instructor will erase entries in cells of a table – rewriting them as an algorithm or calculation progresses to show how the algorithm works over time.

3.1.3 Instructors' gestures and gaze

During our initial observations, we noticed that instructors' gestures and gaze are an important part of the way they use the visuals. Most instructors gesture frequently at the board to help explain how the verbalized ideas are related to the visual aids. When the instructor uses only slides, he or she often uses either a laser pointer or the computer's mouse or stylus cursor to point at a portion of the slide and moves the pointer back and forth or in a circular motion to allow students to see where the laser or cursor is. The purpose of the pointer is to make a link between what the instructor is saying and the

slide's content. In biology or chemistry, for example, there are often many slides showing diagrams of important processes. These may be biological processes happening in a cell, or various chemical reactions. A ready-made PowerPoint diagram is often used to show these processes, perhaps because they have high degree content that is difficult or time-consuming to draw on the board. When the instructor explains the different parts of the process he or she frequently refers to the diagram. In most large lecture halls the projection screen is much higher than the instructor's reach, so the instructor must use some sort of aid to point to the slide.

The instructor's gaze into the classroom is important to keep the audience engaged in the lecture and to keep the instructor aware of the audience's attention (Birnholtz et al., 2008). An instructor who looks at the audience will keep the audience's attention better than one who does not. Other non-verbal behaviours such as stance, smiles, nods, and body postures are also important means for reducing the physical or psychological distance between teacher and students (Bligh, 2000). There is sometimes a feeling of a disembodied voice when the audience is viewing slides and only hearing the instructor's commentary. An instructor writing on the board and gesturing at what is written will retain audience attention on her and will therefore usually maintain the non-linguistic behaviour that is important for the student-teacher interaction. We have observed that when an instructor looks at the slides projected on the wall, or stands behind the podium looking at his or her laptop, the audience will focus on the slides and not on the instructor. This may create a learning environment in which there is no interpersonal engagement between instructor and students, and thus reduce learning outcomes (Levasseur & Sawyer, 2006). Standing near the board creates an embodiment of the instructor, integrated with the visual aid through gestures that serve as deictics to help students connect the visual and audio components.

Often, when instructors verbally refer back to a concept that they have illustrated on the blackboard, they will simultaneously gesture to the diagram or visual aid that was used when explaining this concept if it is still visible on the board. This helps students to easily recall the previous item and reduce their cognitive load when they learn new items, presumably because they connect the concept with the place and visual image on the visual aid. We noticed that this *visual referral back* happened quite often during most

classes, regardless of the category of board usage the instructor was employing. This suggests the importance of keeping information persistent as long as possible. Because of this, we examined how gestures were used during our structured observations (as described in the next section) as a means to understand when and how instructors used previously shown information.

3.1.4 Using different kinds of visual aids together

It was not uncommon for instructors to use different visual aids in one lecture. For example, often instructors would use boards and computers slides in the same lecture. There were two main styles in which computer slides and boards were combined. In the first, the main aid was the board and slides were used to show either pre-made high-resolution material, or images showing important information. The second style was to use slides as the main visual aid, and the board primarily for digressions from the main theme to answer questions or for more dynamic type of usage such as immediate visual aids or as sentence headings. Other types of visual aids were used in conjunction with slides. For example, overhead projectors with blank overhead transparencies were used as a writing surface in a large classroom (where it might be difficult to see the board), and overhead transparencies and the blackboard were used together with the overheads acting like computer slides. Interestingly, in one class we saw the instructor use two overhead projectors to show two streams of transparencies. In this case, he used one projector to show an overview of the content, and the other to show more details. One thing we never saw was two different sets of computer slides used at the same time.

3.2 Methodology for structured observations

Based on our initial observations and the five categories of usage we had seen, we developed a two-level coding scheme for the main field study. We coded use of visual aids during presentations from three different corpora: (1) conference presentations that used computer slides, (2) university lectures in which the majority of the lecture was given using computer slides, and (3) online lectures in which the majority of the lecture was given using a blackboard or a whiteboard. We chose these corpora to compare usage of computer slides in two different settings (conference and classroom), and to compare

slides with multiple blackboards (whether sliding or non-overlapping) because blackboards are more dynamic and provide more real estate.

3.2.1 Conference slide presentations

We attended 21 presentations at the ED-Media conference held in Vancouver, British Columbia, in June 2007. These were research presentations in the field of educational multimedia held in small rooms (up to 50 seats) using a standard data projector and a free-standing screen with an approximate size of 1.5m x 1.5m. The screen was situated at the front of the room with the top of the screen at a height of approximately 2.5 meters so the presenter could gesture at a slide. Average presentation time was 17.8 min (*SD* = 4.4).

3.2.2 Classroom slide lectures

To see if presentation style and use of slides differ between formal conference presentations and classroom lectures, we attended 18 undergraduate lectures by 12 different instructors presented at our university in which the main visual aid was computer slides. Classes included anatomy, biology, chemistry, economics, nutrition and political science. All were held in large lecture halls (more than 150 seats) equipped with projectors. The size and location of the screens varied, but most were positioned high above the presenter. To gesture some instructors used a laser pointer or a laptop's mouse, while others did not use a gesturing device but instead used their hands. Average lecture duration was 48.0 min (*SD* = 8.7).

3.2.3 Classroom blackboard lectures

We coded 15 lectures by 15 different instructors offered on the MIT Open Courseware website[2]. All used blackboard or whiteboard as the main visual aid. The videos were professionally recorded during MIT undergraduate classroom lectures. Most (13) were in large lecture halls using a 3x3, 3x2 or 5x2 grid of sliding boards (Figure 3.4). The remaining two were in smaller classrooms using only two blackboards. Classes included biology, chemistry, computer science, electrical engineering, material science, mathematics and physics. Average lecture duration was 44.8 min (*SD* = 6.0).

[2] MIT Open Courseware. http://ocw.mit.edu/OcwWeb/index.htm

Figure 3.4: Classrooms with 3x3 and 5x2 arrays of sliding blackboards.

We used online lectures rather than classroom observations, because we found from our initial observations that there was much more interaction during board-aided lectures. As opposed to the slide lectures in which coding was fairly simple, the annotation in the board lectures was much more difficult. Coding videos of lectures instead of live lectures allowed us to pause and recheck our annotations. Even using the videos, we continued to refine the coding scheme for the first few lectures, so we recoded each video twice to ensure consistency in our coding.

3.2.4 Coding schemes

We developed two different coding schemes, one for the blackboard lectures and one for the slide corpora. The overall goal was to explore how content is spatially and temporally organized and presented. In both coding schemes we defined a set number of events that were distinguishable and would examine the way the instructors used the visual aid. Gestures events were recorded because they show interaction with the material being presented, thus providing an indication of how and when content was used.

Slide coding scheme.

For both the conference and the slide lecture corpora we used the same coding scheme, recording the time for each event type. Table 3.1 lists the different event types for the slide coding schemes, their descriptions and what was recorded. Event types that were recorded in the slide coding scheme included: new slide, layer, slide back and gesture types.

EVENT	DESCRIPTION	RECORDED
New slide	A new slide appears. Slides were further categorized based on their most prominent type of content: text, logical progression, diagram, graph, image, or table.	time, content type
Layer	New information is added to a slide	time, content type
Slide back	The instructor returns to a previous slide	time
Gesture	Hand gestures or gestures using an aid, such as a laser pointer or the computer's cursor, were counted as gesture events	time

Table 3.1 – Events recorded for the slide coding scheme

Blackboard coding scheme.

An event occurs on a single board unit. We recorded the board unit, and time for each major event type. Table 3.2 lists the event types for the board coding scheme. For the gesture event, we recorded a single gesture as a *gesture incident*. If the gesture incident was targeted at a writing event, we recorded the writing event that was associated with the gesture incident. However, there were times when an instructor would start a writing event, gesture at it, continue writing, gesture again and so forth. This would happen, for example, when an instructor would write a complex diagram and would pause to explain it during the writing. This is defined by us as a single *writing episode* (coded as a single writing event) with multiple *gesture iterations*.

EVENT	DESCRIPTION	RECORDED
Writing	A single writing event was coded according to the content: text, logical progression, immediate visual aid, graph, diagram, and table. The act of drawing a diagram or writing a sentence was coded as a single event.	time, content type, board unit
Layer	New information is added to content written earlier.	time, content type, board unit
Erase	The entire board or item of content is erased.	Time, board unit
Gesture	Gestures at the board were recorded.	Time, board unit, writing event gestured at

Table 3.2 – Events recorded for the board coding scheme

3.2.5 Coding reliability

All lectures were coded by a first coder (the dissertation author). To assess the reliability of the coding scheme, a second coder coded two of the classroom slide lectures and two randomly chosen blackboard lectures. Cohen's Kappa coefficient was used as an index of interrater reliability. A value between 0.80 and 1.00 is usually thought of as very good agreement (Altman, 1991). For slide lectures, there was a 94% agreement on events between the two coders (Kappa coefficient = 0.89), with only a few gesture events missed, and 93.2% agreement on content (Kappa = 0.85). In the blackboard corpus there was 86.7% agreement on events (Kappa = 0.79), but we encountered difficulties assessing content. For the first blackboard lecture, the second coder forgot about the immediate visual aid category and coded those events as text. This was identified and corrected for the second lecture, but only four out of the seven IVA events were coded by both coders. This suggests there may be a lack of precision in the IVA category. Coding the three missed IVA events as text yielded a 91.5% agreement on content (Kappa = 0.87); coding them as errors yielded an 84.1% agreement (Kappa = 0.80).

3.2.6 Interviews

To supplement the observational results, we conducted semi-structured interviews with six experienced university instructors from commerce, computer science and mathematics. During a one hour session, instructors were asked about their usage of visual aids, including but not limited to blackboards and slides. They were asked when and why they used each medium, what medium they preferred in which circumstances, what kind of information did they use for each medium and general strategies for slide and board usage. The goal was to understand what types of aids were used, and for what purpose different types were used. Interview questions are presented in Appendix A. While all participants were asked the same questions, we encouraged instructors to elaborate on what they felt was important. Interviews were conducted by the same researcher, recorded and then analyzed.

3.3 Findings from structured observations

We report both quantitative and qualitative findings. Comparing classroom to conference slide presentations allowed us to understand if and how people adapt their use of presentation software between the two settings. When comparing slide-use and board-use our goal was not to quantitatively compare slides and boards because interactions with each were quite different. Our purpose was instead to isolate and identify the differences and understand how blackboards are used in ways that slides are not.

3.3.1 Similarities of slide-use in the two settings

Computer slides were used as the main visual aid in both conference and slide classroom corpora. The average time spent on a slide was significantly less in the conference setting (54.5s) than in the classroom setting (112s), $t(806) = 35.2$, $p < 0.001$. This matched our expectations because conference presentations are shorter and usually have higher density of information. Differences in the average time spent on different content types within each corpus were not significant.

The distributions of content types in the three corpora are shown in Figure 3.5. In both slide corpora, text was the main visual component (67.9% of conference slides and 75.1% of lecture slides). In the blackboard corpus, different types were more evenly distributed, with less text content and more diagram and LP content. While this can be partly attributed to the types of classes using the blackboard (more mathematical and engineering classes), it may also be caused by the fact that writing of text on the blackboard takes too much time.

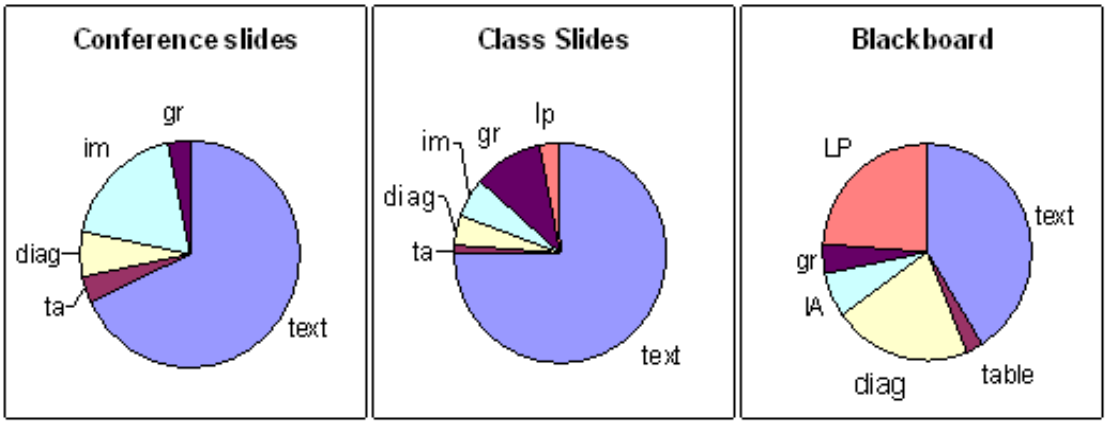


Figure 3.5: Proportion of each content type for conference (390 slides), classroom slide (413 slides), and blackboard (474 writings) corpora. gr=graph, im=image, diag = diagram, LP = logical progression, IA = immediate visual aid, ta = table

Figure 3.6 shows the percentage of slides gestured at for both slide corpora. The corpora were surprisingly similar. Although very different in the setting, type and content, and significant differences were found in time per slide, the distribution of types of slides and the amount of gesturing for each type of slide (Figures 3.5 and 3.6) were relatively similar in comparison to the blackboard corpus.

3.3.2 Grouping of content types

As can be seen in Figure 3.6, in both slide corpora there was a dramatic difference between the percentage of gestures on text slides and on other types of slides. Text slides were least gestured at (17% in the conference corpus and 11% in the classroom corpus). Diagrams, graphs and tables, on the other hand, were highly gestured at (combined, 73% of the conference corpus and 88% in the classroom corpus). Image slides were gestured at (36% and 25% of the conference and classroom corpora, respectively) more than text and less than tables, diagrams and graphs.

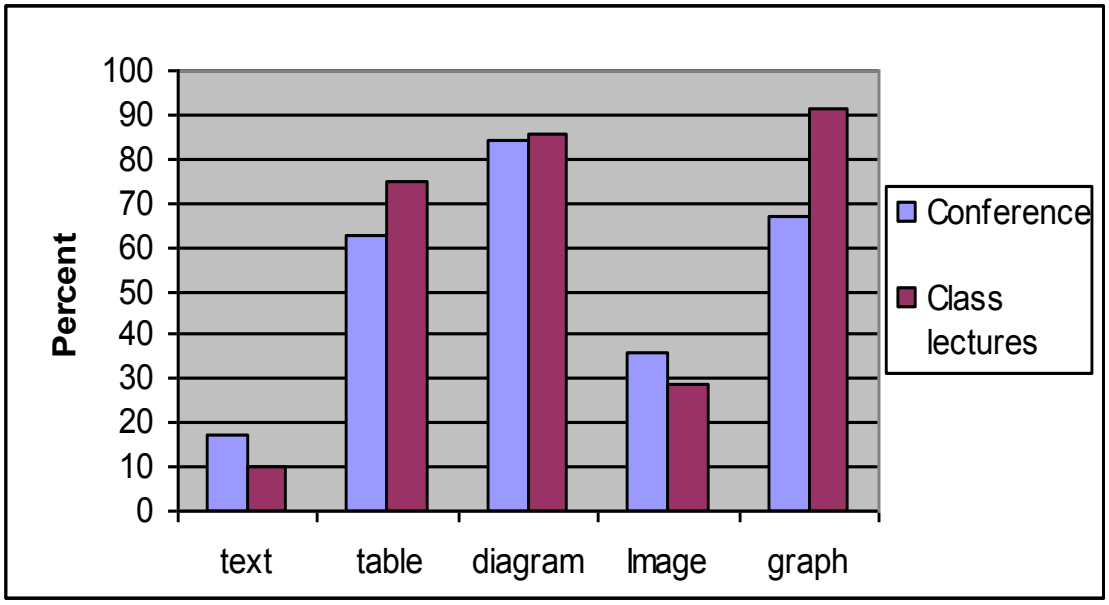


Figure 3.6 - Percentage of slides gestured at for each content type for conference and class slide corpora.

Figure 3.7 presents the percentage of events gestured at for each type of content in the blackboard corpus. The pattern is similar to that of slides, with a high percentage of gestures for tables, diagrams, graphs and LPs (combined 75.2%), and a lower percentage on text (27.6%) and IVA (40.6%).

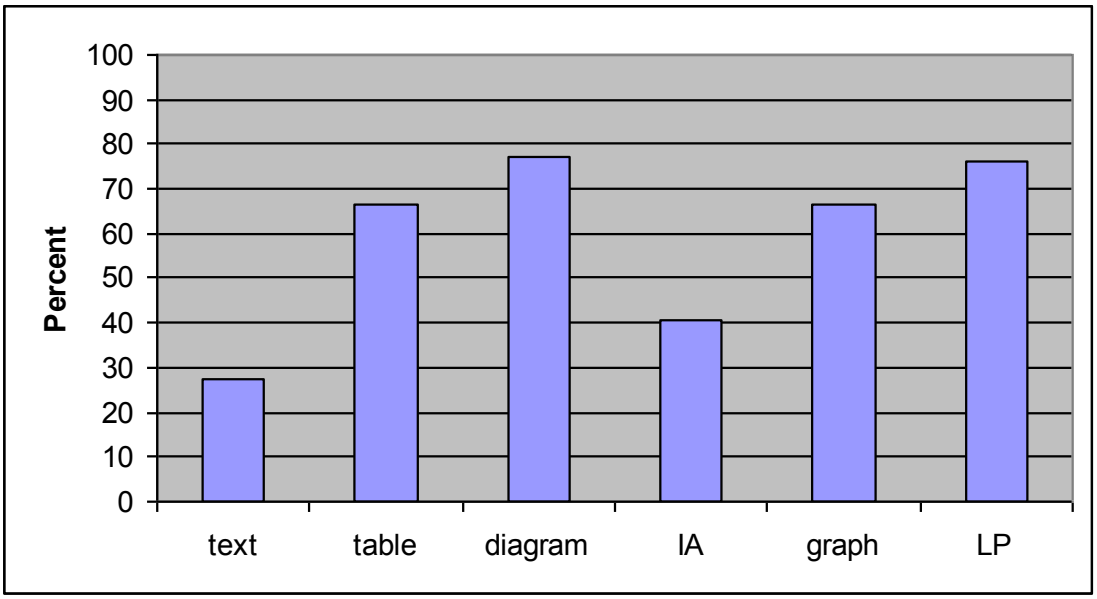


Figure 3.7: Percentage of writing events (*N*=474*)* gestured at for each content category in the blackboard corpus.

Figure 3.8 shows the average amount of time instructors spent writing each type of information in the blackboard corpus. This was measured from the beginning to the end of writing, and may include pauses for explanation. We conducted a one-way ANOVA to evaluate the effect of content type on writing time. A main effect of content type was significant ($F(1,5) = 16.4$, $p < .001$). Pairwise comparisons, using a Bonferroni adjustment, showed that text ($M = 18.9$s) was significantly faster to write than diagrams ($M = 53$s), graphs ($M = 54$s) and LP ($M = 36.1$s), ($p < .001$ for all comparisons). IVA ($M = 9.8$s) content was also significantly faster to write than diagrams, graphs, and LP ($p < .001$).

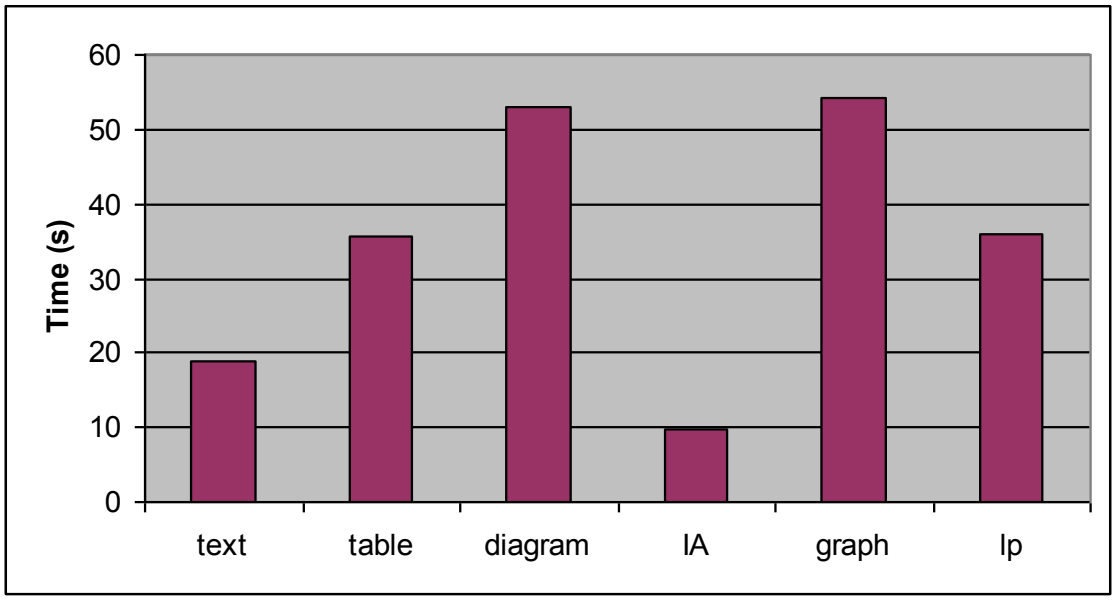


Figure 3.8 - Average duration of writing events for each content type for the blackboard corpus.

These findings clearly distinguish two different groups of content types. *Rich content* includes diagram, table, graph and LP types, while *support content* includes text, IVA and image types of content. Rich content is focused on much more by the instructor: it is gestured at more often (Figures 3.6 and 3.7), takes more time to be written (Figure 3.8), and has more gesture iterations (Table 3.1) than support content. In contrast, support content takes less time to write, and is gestured at and iterated upon less.

In the rich content group the presenter uses the visual as the focus of the idea, spending more time and gesturing often. Support content, on the other hand, is used as a

secondary visual aid to the spoken explanations. Text, for example, is used mainly for headings or redundancy. It is self explanatory and in the same modality (linguistic) so it does not need to be gestured at.

3.3.3 The importance of gestures

During a writing event, many times the instructor would lift the pen or chalk, explain the content while gesturing, then continue writing the same content. We recorded this as one writing event, but we also recorded the number of *gesture iterations* in a single writing episode, counting the number of gestures between the beginning and the end of the writing event. The average number of iterations and frequency of iterations can be seen in Table 3.3. We can see that for the rich content types, especially graphs (41.1%) and diagrams (42.8%), a high percentage of events were iterated compared to a very low percentage of iterations for text writings (0.5%) and IVA (3.1%). This further emphasizes the difference between rich content type, when the instructor often stops to explain and then continues to write, and the support content type, when the instructor usually writes at one burst and then explains.

	D	G	LP	Table	IVA	Text
Average iterations	3.4	4.6	3.3	3.6	2	3
% of events iterated upon	41.1	42.8	32.4	25	3.1	0.5

Table 3.3: Average number of iterations and percentage of events iterated on for each type of content for the blackboard corpus (D = Diagram, G = Graph, LP = Logical Progression, IVA = Immediate visual aid)

In a blackboard setting, the instructor is usually close to the board, making it easier and more natural to gesture at desired content because there is an embodiment of the instructor near the visual aid. We therefore had expected there would be more gestures for the blackboard corpus than in the slide corpora. To compare the number of gestures using the blackboard and computer slides, we compared between the two classroom corpora. There was a significant difference with more gestures in blackboard classes *(M*

= 38.2) than in slide classes *(M* = 6.5), $t(28) = 16.4$, $p < 0.001$, even though the lecture lengths were similar between the two corpora.

As noted in our initial observations, gestures are an important part of a lecture especially when using the visual aids. Greiffenhagen and Sharrock (2005) examined instructor's gestures in a mathematical blackboard lecture. They concluded that in a blackboard lecture gestures are used to connect what is written on the board with the accompanied commentary, to integrate different sections of the board (their definition of section matches our board unit notion), and to integrate the *organization* of a mathematical proof on the board. We also noted that gestures are employed so the presenter can connect the audio and visual parts of the presentation, focus the attention of the audience on the visual aid, or show specific detail on the visual. In the following section, we will discuss the importance of gestures for integrating different sources of information on the board.

3.3.4 Information persistency

We looked at how long information persisted in the blackboard lectures, and more importantly whether instructors used that information later in the lecture, and we compared that with the more linear style of electronic presentations.

Long-Term Persistency

Using the blackboard, information persists for longer than when using slides, allowing the audience to see more of the previous content. To examine if information not only persists longer, but is also used more at later points by the presenter or audience, we examined gesture and layer events on older board units.

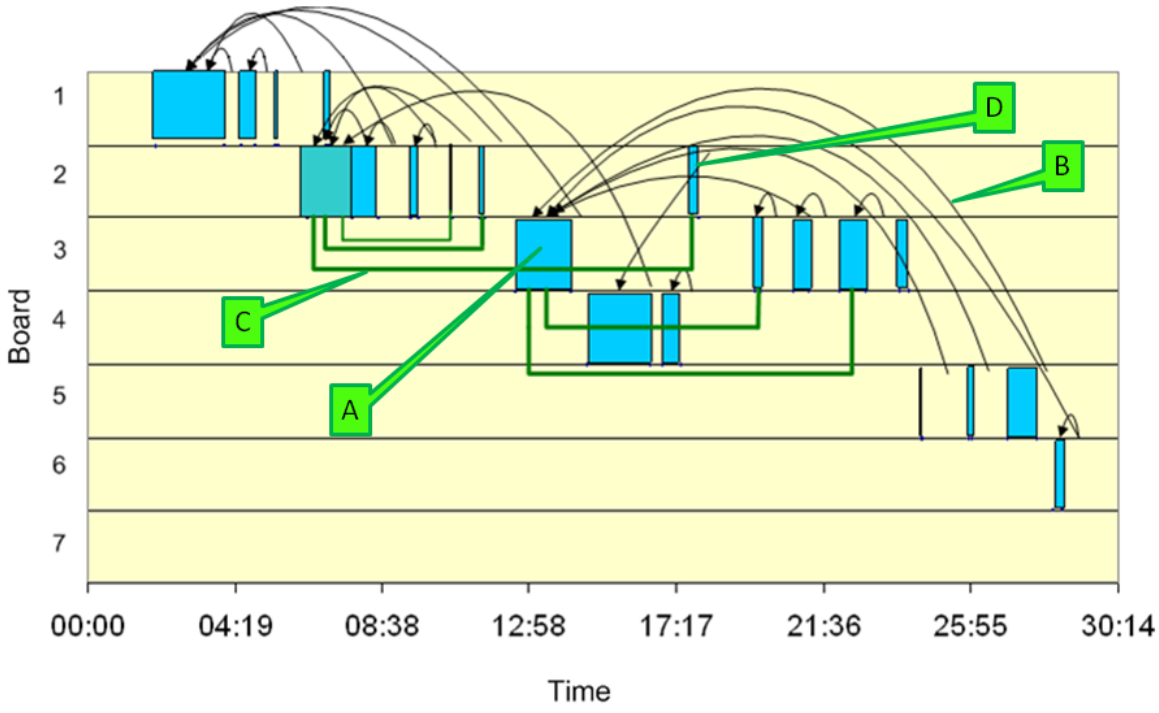


Figure 3.9: Diagrammatic example of a blackboard lecture. Blocks represent writing events (A,D), backward curved arrows represent gestures (B), rectangular straight lines represent layer events (C).

To illustrate the degree to which instructors refer back to previous content in blackboard lectures, Figure 3.9 shows the progression throughout time of one blackboard lecture using seven sliding boards. The X axis represents time, while the Y axis represents board units. Each box represents a writing event in time (X) and in space (Y). Arrows represent gestures at the corresponding content, and bottom rectangular straight lines represent the addition of layers on top of existing content (e.g., adding new content to a previously sketched graph). This diagram helps to understand the flow of blackboard use and illustrates how content is being used throughout a blackboard lecture.

An active board is the board where the most recent writing event occurred. A *referral back* is a gesture to a previously written content item on a board unit other than the active board. Often, when instructors verbally refer back to a concept, they gesture at the visual aid used when that concept was originally explained. This helps students recall the previous item and reduces their cognitive load when they learn new items. An example of a referral back can be seen in Figure 3.9 (in the figure, B is the gesture event that refers back to writing event A). In the blackboard corpus, there were 117 referral

backs for an average of 7.8 per lecture (*SD* = 4.4). The average elapsed time between a writing event and a referral back to that content was 8:55 min (*SD* = 6:43m). If we try to find an equivalent to blackboard referral backs on computer slides, the only similar behaviour is the presenter navigating backward through the slide presentation to a previous slide. This behaviour occurred only six times in the entire classroom slide corpus and only three times in the conference corpus. Although we did not explicitly record duplicate slides, which could be used as a pre-planned form of referral back, our informal observation is this rarely occurred.

A *write back* is a writing or layer event on a previously used board that is not the active board. This usually occurs when the instructor adds a layer to existing content (such as a diagram) or when the instructor writes new content in proximity to previously written content, often because it is semantically related. An example of this can be seen in Figure 3.9D. Instructors averaged 2.0 write backs a lecture (*SD* = 2.9).

We observed that in many lectures, there were content items that were the center of attention for a long time. The writing event highlighted in Figure 3.9A, for example, was written around 13 minutes from start of the lecture and took a minute and a half to write, but then from around minutes 20 to 30 it was referred back to and written on several times and was clearly active again in the class discussion. To examine how many content events that were highly referred to occurred per lecture, we defined a *highly referenced content* item as one that was gestured at or layered back on at least five times from different points in the lecture. Given this definition, there was an average of 1.9 highly referred to content events per lecture (*SD* = 1.2). All but one of these events was of rich content. This suggests that only a few items need to be kept persistent for a long length of time.

Short-term Persistency

Most of the gestures instructors made were to recent information. Referral backs, which are mostly at items written less recently, comprised 23.5% of gestures, while the other 76.5% were on the active board. 62.3% of the gestures were at content items that were no more than four writing events in the past. This emphasizes that instructors most often use information that was recently presented. From informal discussion with students, we believe that students can benefit largely from having the most recent information

persistent. First, having previous content visible may help students understand the context of the current explanation. Second, students copying notes often need recent information to be kept for longer. Third, by having more information persistent, the control of what to look at and how to assimilate information is transferred from the instructor to the student. Using slides, the instructor tells students what they are expected to look at. Using sliding boards with the entire lecture data available, students are empowered to use what is best for them, thus encouraging active learning.

Erasing information

An erase event was defined as erasing an entire board or an entire writing event after it had been written. Ten out of 13 lectures using sliding boards did not erase a single board, keeping all information written on the board available to the audience throughout the lecture. Three out of the five instructors who did erase a whole board during lecture did it because of lack of space; they erased the oldest content on the board. Two instructors skipped over certain boards from this "Least Recently Used" treatment, because they wanted the information on the skipped boards to be persistent. This is supported by the fact that they later gestured at the skipped boards. Single writing events were rarely erased. This happened only four times by three instructors, but it is interesting to note that out of these four times, three events were of immediate visual aid and one event was of text, all of the events belonging to the support content group (see Section 3.3.2).

3.3.5 Pacing and in-depth exploration of rich content

From our initial observations, we hypothesized that a slide lecture shows more information than does a blackboard lecture, and that the pace of a blackboard lecture is slower. Five of the six instructors interviewed agreed to this, and one instructor commented:

> "You can move more quickly with slides. […] I use the whiteboard whenever I want to slow down the pace."

To get a very rough estimate of the amount of information in slides and boards, we conservatively estimate the number of slides that would be required to display the visual information in the blackboard lectures according to the following transformation: any

one diagram graph or table event, two LP events, or three text or IVA events equals one slide. Using this estimation, we calculate that blackboard lectures present less visual information on average; when the duration of lecture is divided by the number of estimated slides, the average is 162s per slide. In contrast, the average slide duration in the slide classroom corpus was 112s. This supports the conjecture that slide lectures show more information in a shorter period of time than do blackboard lectures. This difference in pacing could be because the computer slides are premade and do not require content creation during the lecture. Another possibility is that the slower pacing of the blackboard is a result of its support for more in-depth, dynamic development of rich-content ideas. Using slides, presenters usually follow a steady pace, going from one idea to the next in a linear manner. Blackboards, on the other hand, seem to support a slower, less deliberate pace, showing less information for longer periods of time. For example, in our interviews, one math instructor who mainly uses the blackboard commented:

> "The first thing I can say about blackboard teaching is that the pace is slower, and that already has much value […]. The pace of writing stuff on the board is much more adequate in terms of the ability of people to digest [mathematical] derivation."

Boards support more in-depth exploration of a single idea. The temporal build up of a problem plays an important role, allowing the audience to gradually understand each building block of the problem. This is shown mainly in rich content types such as diagrams or LP that usually represent more abstract, complex information. Indeed, the diagram (21%) and logical progression (24%) event types were much more common in the blackboard corpus than in the class slide corpus (4% and 2% respectively). Looking back at Table 3.3, we see that rich content has a higher number of gesture iterations for a writing episode suggesting temporal build up of the information. This can also be seen when looking at the layer events. In the blackboard corpus there were a total of 47 layer events in which additional information was added onto existing information. Although possible to do in existing slideware, this type of behaviour was not observed at all in the slide corpora.

3.3.6 Using slide handouts

There is an increased demand from students that instructors provide their lecture slides. Students like to have the lecture slides because they provide them with a set of organized notes prepared by the instructor and because it helps them with the note taking during class (Levasseur & Sawyer, 2006). Some instructors post their slides on the Web prior to class to allow students to bring printed handouts of slides to class, relieving them from the need to copy notes, or making it easier for students to write notes on top of existing slides. Other instructors prefer not to provide their slides. In interviews, some instructors said they were reluctant to post slides because students might not attend or would not pay attention in class, having the content available ahead of time. While handouts do allow content persistence for students, we did not observe that this affected instructors' teaching styles. An instructor teaches the same way if students have slide handouts and if not. Instructors cannot refer back to handouts in the same way they interact with information displayed for the entire class. Students having handouts of slides can refer to previous information. However, it is difficult for students to find the relevant slide in the relevant time, and if the instructor is teaching using a regular slide presentation, the lecture is usually build in a linear way.

3.3.7 Comparing between two content items

We noticed that in some cases instructors explicitly compared two items on a single board or on two different boards. This could be identified by the instructor gesturing back and forth between two content items. We asked instructors if they compared items when they use the board. All instructors said that they do compare items, and some said they wished they could compare two slides. One instructor commented:

> "I often feel a slide is too small, and a lot of times it's because there is something I'd put on one slide that I wish I could put on the other slide and see them at the same time"

3.3.8 Dynamic vs. static nature of content

Slides are commonly presented in a static manner. Rarely does one see a presenter navigating through his or her slides in an order other that which was predefined; in our observations, presenters returned to previously shown slides only 3 and 6 times in the

conference and classroom corpora, respectively. Although it is possible to annotate slides using electronic ink in PowerPoint, which would allow for more flexibility, we did not observe this in either slide corpus. Blackboards, on the other hand, afford much more spontaneity. As one instructor has said:

> "I tend to switch back to the whiteboard when I'm doing something particularly ad-hoc or spontaneous".

Using the blackboard, the presenter can drift from one idea to another without having to plan the entire lecture in advance. Using immediate visual aid content, for example, the instructor uses the visual aid as support for spontaneously given explanations.

3.4 Discussion

According to Tufte (2003), using PowerPoint as the main visual aid dictates a certain cognitive style of presenting information that most presenters use regardless of the situation and content of presentation; this should also apply to competing commercial presentation tools that encourage monolithic presentation styles. Our findings support Tufte's claim by showing similar trends for the usage of slides in two very different corpora when using slides, and by showing different trends of usage than when using a different medium such as a blackboard. Our data also suggest that instructors are not adapting their slide use for teaching, but rather they use the same style that is used for slide-based conference presentations.

Slide presentations are inherently sequential over time, showing one slide after another: we observed that presenters using slides rarely go back to previously shown slides. Our finding may have implications for cognitive load theory (Sweller, 1988), which states that learning is best achieved when the cognitive load on working memory is minimized. This suggests that instead of loading the working memory by mentally integrating pieces of information one should try to physically integrate these sources of information. When instructors refer back to information using the blackboard, they physically integrate the different pieces of information. Using slides, on the other hand, increases cognitive load of the audience because of the need to remember previous ideas.

We suggest a two-fold approach for encouraging information persistency in presentations. First, we suggest broadening the window of persistence of current content. As we have shown, most gestures are aimed at recent writing events. Showing the most recent content as long as possible will accommodate the audiences' need for immediate context. Second, we suggest allowing the presenter to keep certain information available for longer times. We have shown that usually only some information needs to be referred to from later parts of the lecture. This need not take up much space. We have shown that only two items on average were referred to multiple times throughout a lecture. By allowing the instructor to keep these items persistent, students would be able to visually assimilate the disparate pieces of information instead of relying on their working memory to process and recall previous information (Ayers & Sweller, 2005). This may help reduce student's cognitive load, and thus assist them in learning.

Other learning theories, suggest that having multiple representations is valuable when learning complex concepts. Switching between abstractions and different views may facilitate the process of sensemaking (Rogers et al., 2009). Therefore, it seems that using more screen space, such as multiple blackboards or multiple screens, to show different representations of the same information, can stimulate cognitive processing and enhance learning. According to Ainsworth (2008), multiple representations can support learning by (1) allowing for complementary information or complementary processes, (2) allowing one representation to constrain interpretations of another one, and (3) by supporting the construction of deeper understanding by having learners identify the shared features of a domain and the individual features of a representation. Indeed, we have seen that when using multiple boards instructors have used several boards to show different representations of a problem. Explaining a physics concept, one instructor has laid the verbalized problem on one board, a diagram of the problem on another board, and the mathematical solution on another.

We distinguished between two types of visual information: rich content and support content. We found that rich content, which includes diagrams, graphs, tables, and logical progression, took longer to write, had more gestures, and in the blackboard corpus also had more iterations of gestures per writing event. When supporting rich content in presentation software, we should allow more space, focus attention on it, provide long-

term persistency possibilities, and, if possible, support gesturing and even encourage it if possible. Support content, in particular text, does not necessarily need to be the focus of the attention. Immediate visual aid content is a special case. While all other types refer to the information's content, IVA is distinguished by how the information is being used. Without electronic ink or some other interaction technique, it would be difficult to emulate this type of behaviour with slides alone because of its dynamic nature.

In our observations we found that the pace of the presentation is different when the presenter uses slides or boards. Slides show more information in given time period, and generally have a faster pace, and therefore may be more suitable for business or conference settings in which the presenter wishes to convey more preset information in a short amount of time. Boards, on the other hand, may be more suitable for learning complex ideas. Boards are more dynamic, and support more in-depth exploration of rich-content ideas by allowing temporal build-up of the information. They also better support non-linearity because a presenter can more easily show how several ideas, written previously on the board, support the current idea under discussion

3.4.1 Boards vs. slides

Slides are similar to overhead projectors much more than they are to a traditional blackboard. This is not surprising, given the history of PowerPoint, which was originally used to make slides for overhead projectors and only later predominantly used with projectors. Yet unlike overhead projectors, slides are designed to produce more sensory stimulation, allowing instructors to produce dynamic as well as static images. Slides also allow the instructor to present graphics in higher resolution than any other teaching aid, enabling images, video and audio elements.

Most of the instructors using slides use them as a tool for one-way transfer of knowledge. Instead of engaging students in interactive learning, students are left passively receiving information. This has been observed in other studies (Koppi & Pearson, 2003). One explanation for this pattern is that it fits the constraints of large classrooms where it is difficult to engage students in active learning. Although a number of systems to encourage participation in large lecture halls exist (Anderson et al., 2003; Dufresne et al., 1996; Ratto et al., 2003), they are still not in widespread use. The

common way of teaching in large lecture halls is still a one-way presentation. We can therefore conclude that slides are better suited for large lecture halls in which student involvement is usually minimal, but may be less suitable in small classrooms in which student-instructor interaction is more common, and in which learning as a process or as an active experience is recommended (Laurillard, 1993).

Next we describe the relative advantages of boards and slides in more detail, based on our findings (summarized in Table 3.4). When designing effective classroom presentation systems, ideally we would like to incorporate the advantages of each medium.

Advantages of board:

- *Dynamic, Spontaneous and flexible*. If an instructor diverges from the original outline of the lecture, he or she can still use the board as a visual aid. Boards can also be used as an immediate visual aid to answer questions from students.
- *More space*. An important diagram or visual reference can stay on a board for a longer time, or if needed the whole duration of a lecture. This enables instructors to refer back to the visual aid later in time, relating a current learning theme to a previous one, or allowing students to easily recall previously learned items. This especially enables instructors to easily compare between two items.
- *Gestures*. Gestures are natural when instructors use a board. The instructor usually stands in front of the board that is most accessible for writing at the appropriate height. Gesturing at a diagram that was just written is simple and natural, as is gesturing at other parts of the board. In a large lecture hall this may not be the case. The projection screen is often very large or very high, which prevents the instructor from accurately pointing at some areas of a slide. Even worse, information is less persistent, preventing the instructor from visually referring back using gestures.
- *Temporal continuity*. It is easier to build a temporally changing diagram with layers being added step-by-step to explain a concept one layer at a time.
- *Non-linearity*. Slides are linear by nature, showing one slide after another. The board, on the other hand, can be used in a non-linear fashion. An instructor can write

any number of different items on the board and then show how they help in constructing a new item.

- *Simulates problem solving in real-time*. When the instructor illustrates how to solve a problem using the board, this illustrates the methods and also the time it takes to solve real problems, thereby directly modeling activity that students will subsequently do. A further benefit is that it reveals the way the instructor is thinking because each step is explicitly shown to the students.

Advantages of slides:

- *Multimedia*. Slides can show a wide variety of multimedia types such as video, images and audio.
- *Pre-made content*. The instructor is able to prepare the slides in advance, and can therefore better use them to plan the structure of a talk, and has time to develop high quality examples and illustrations that may not be easily created or obtained during a presentation.
- *Long-term persistency*. Students can easily obtain copies of slides for future use. If provided in advance, students do not need to expend cognitive efforts copying from the board and can spend their attention listening instead of copying notes. Instructors can re-use material from previous semesters.
- *Higher resolution*. Slides can include higher resolution diagrams or tables or other information rich information. The ability to incorporate professionally produced visuals and employ high quality text fonts makes material potentially more readable.
- *Legibility and organization.* Slides have a high degree of legibility and usually are highly organized. They also can give a formal structure to the presentation that may help increase students' learning and understanding.

Computer Slides	Boards
Multimedia capability Easily shows pre-made content Information persists before and after presentation High resolution images displayed Legible and organized	Dynamic and spontaneous More space (multiple boards) Natural gesturing – embodiment of presenter with visual aid Enables temporal build up of rich information Non-linear Simulates problem solving

Table 3.4 - Comparison of the advantages of slides and boards

3.4.2 Limitations

Most of the courses in the blackboard corpus were science and engineering lectures. Mathematics-related courses especially often use blackboards for visual support because of the inherent support that boards provide for problem solving and slower pacing. This poses a possible limitation on how our results generalize to other domains. We believe that although our insights stem from observations of mostly science and engineering lectures, they are valid for any area that conveys complex reasoning and learning and perhaps they apply even more broadly.

3.5 Design guidelines

The following six guidelines are suggested for designers of presentation systems that support learning. The guidelines summarize the important points from our analysis.

1. *Provide short-term persistency of information*. Information usually builds on top of other data. Showing the latest information for longer is beneficial to the audience.
2. *Provide long-term persistency of information*. Some information is important for longer periods during the presentation. It is important to provide the instructor with a means of showing specific selected information for longer.
3. *Support gradual build-up of information*. Gradual, temporal build-up of the problem description or topic is important for learning complex ideas.

4. *Rich content is different than support content.* Designers of systems that handle content should emphasize features for presenting rich content information, allowing for long-term persistency and easy gesturing. Support content can be more peripheral or ephemeral than primary content.
5. *Gestures are important.* Gesturing connects a visual aid with the presenters' auditory explanation. Ideally, a presentation tool should support gesturing at specific areas of the visual presentation. This is especially important for high-resolution, wall-size displays where the audience may need to have attention directed to the appropriate region.
6. *Support dynamic content.* Presenters should be allowed to dynamically add, control, change, and remove content during a presentation without having to revert to "authoring mode" to ensure that the flow of a presentation is not interrupted by the technical details of the presentation tool.

3.6 Summary

We conducted a two-phase observational study that examined the usage of different types of visual aids in classroom and conference settings, focusing on the use of blackboards and slides and the differences between them. We identified important themes and trends such as similar usage patterns for slides in two different settings, the need for and importance of both long- and short- term persistency of information, and differences between types of information that we identified as rich content and support content. We developed design guidelines for presentation systems intended to support large high-resolution displays or multiple displays.

To validate these design guidelines and to fully elaborate the principles derived from the observational field study, we implemented MultiPresenter, a prototype system that enables lecturers to present computer-based visual aids using multiple or high-resolution display screens. The implementation details and design rationale for MultiPresenter are presented in the next chapter.

Figure 4.1 – Examples of university classrooms with multiple screens, both for writing and for projection.

Chapter 4

MultiPresenter: a Presentation System for (Very) Large Display Surfaces

This chapter describes MultiPresenter, a novel presentation system designed to work on very large display surfaces such as multiple displays (Figure 4.1) or physically large high-resolution displays. The current version of MultiPresenter is based on the design guidelines outlined in Section 3.5 and was used to validate those guidelines and to further understand how to design presentation software for large surfaces. It allows presenters to organize and present both pre-made and dynamic presentations that take advantage of a very large display surface accessed from a personal laptop. Presenters can use the extra screen real estate to provide short- and long-term persistency of information for an audience. Our focus in the first implementation of MultiPresenter was on supporting presentation flow and a variety of presentation styles, ranging from automated, scripted sequences of pre-made slides to highly dynamic ad-hoc, and non-linear content. By providing smooth transitions between these styles, presenters can easily alter the flow of content during a presentation to adapt to an audience or to change emphasis in response to emerging interests. Throughout this chapter we use the term 'presenter' to refer to an instructor in a classroom or more generally to someone presenting information to a group, and we use the term 'audience' to refer to the group of students or other people who are the intended recipients of that information. In the following sections we describe our goals, rationale and design process, providing a detailed description of the latest production version of the system. We also describe an extension for MultiPresenter that supports audience control of the screen using personal devices.

4.1 Motivation for design

In Chapter 3 we described observed blackboard and slide usage and reached several conclusions and guidelines on how to design presentation software for learning purposes.

These guidelines, however, are based on observations of current blackboard and slideware usage and are not necessarily practical to implement or guaranteed to be useful. In order to validate these guidelines, better understand if and how these guidelines can be implemented, and inspire new ideas based on actual experiences, we developed and later evaluated MultiPresenter. To set the scene for MultiPresenter's feature set, we briefly review the major findings from Chapter 3 that identified presentation practices common with traditional technologies that are inadequately supported by current slideware tools, and we describe how these practices are supported by MultiPresenter.

Spontaneous and non-linear presentation styles. In contrast to slideware presentations, presentations using traditional technologies were frequently spontaneous, dynamic and often non-linear (Section 3.3.8). Presenters frequently diverged from what appeared to be a planned path through the content, drilling down into content when necessary, or spontaneously using visual aids either to answer questions or to follow important tangents, facilitating discussions when appropriate. One of our emphases when designing MuliPresenter was to better support such spontaneous and non-linear presentation styles.

Revisiting earlier information. With traditional media, presenters many times referred back to previously written content—sometimes to information recently presented, and other times to content originating from much earlier in a presentation (Section 3.3.4). This practice was employed differently for more recent content compared to older content, but in both cases there was convergent evidence of these non-linear presentation styles in lectures that we observed. The practice of revisiting information that was previously presented illustrates the importance of persistent content on the display—it is only because information is persistent in traditional media (especially blackboards and whiteboards) that referring back to content is possible. For this reason MultiPresenter was designed to supports both short- and long-term persistency of information enabling instructors to revisit earlier information as needed.

Creative use of multiple sliding whiteboards. In the classroom blackboard lectures that we observed, many lecture halls had as many as nine sliding whiteboards in a 3×3 grid of boards, and instructors frequently made use of all of them (Section 3.2.3). Sliding boards afford an extremely large surface, allowing an entire lecture to be visible

to the audience. Even though it is a large surface, the seams between the whiteboards facilitate a form of partitioning. We saw highly creative use of these partitioned surfaces: instructors might place important content in a top corner to be easily referred to later as a reinforcing mechanism; in other instances instructors wrote a problem on one board, a diagram explaining the solution on a different board, and the formal solution on yet another board. During their explanations, instructors sometimes switched back and forth adding additional information when referring to these three board areas. We envision similar usages with MultiPresenter.

Cognitive benefits of a larger display surface. In interviews we conducted, instructors suggested that they needed more space to present complex ideas. They felt that with sufficient space spatial relationships between concepts could be used to encode meaning (Section 3.2.6). Indeed, studies by cognitive scientists have borne out this belief: spatial and temporal grouping of related items is important for learning (Ayres & Sweller, 2005). When entities needed to be compared, instructors could draw the entities on adjacent whiteboards, allowing students to see both the construction of each entity, and to see them simultaneously for comparison purposes. Slides do not facilitate this practice as easily. Using MultiPresenter, it is straightforward to compare two ideas and to show their relationships spatially.

Motivated by these and other findings from our observational study, we designed MultiPresenter, a presentation system that provides a presenter control over multiple high resolution displays, and gives the presenter a suite of *in-presentation* tools to dynamically modify the flow of a presentation. These tools allow the presenter to make content persistent, to modify content on the fly, and to re-arrange the order of slides *during* a presentation, independent of any originally authored flow and independent of the type of the authored content.

4.2 Separation of content and presentation style

Most existing slideware systems, such as PowerPoint, act more as *content authoring tools* than as *presentation tools*. They facilitate content creation from a variety of media sources and provide highly sophisticated layout schemes. Indeed, the content created

often has a life of its own outside of the context of the presentation, being used for other purposes such as exchanging information, or students' notes, or even to produce content for entirely non-presentation purposes, such as greeting cards, official documents and certificates, or posters. As *presentation tools*, most slideware systems impose a fairly sequential presentation style. They are well suited to highly structured presentations that have a well-planned and singular flow. Yet we have seen in our observations that presenters often employ a variety of presentation practices beyond this structured sequential flow when given the presentation medium (boards) that affords this style of presentation. Our core design approach was therefore to *separate content from presentation,* and in so doing, build a presentation system whose sole focus is *providing presenters with in-presentation tools* to support dynamic restructuring of content as well as to support various static practices. In this section, we articulate the philosophy behind this design approach.

We distinguish between the *content*, the *layout*, and the *presentation style* of a presentation (Figure 4.2). The *content layer* of a presentation may include text, images, videos, clip art or other types of media. The organization of this content onto slides is the *layout layer*. The *presentation layer* consists of the animations within slides, animations between slides, and the transitions from one slide to another as well as the order in which slides are presented. These three layers are logically distinct. In fact, they could be constructed by three different people. For example, a CEO of a company might have her assistant develop the content, a graphical designer formulate the layout of that content for PowerPoint slides, and then deliver the presentation herself using her unique personal presentation style.

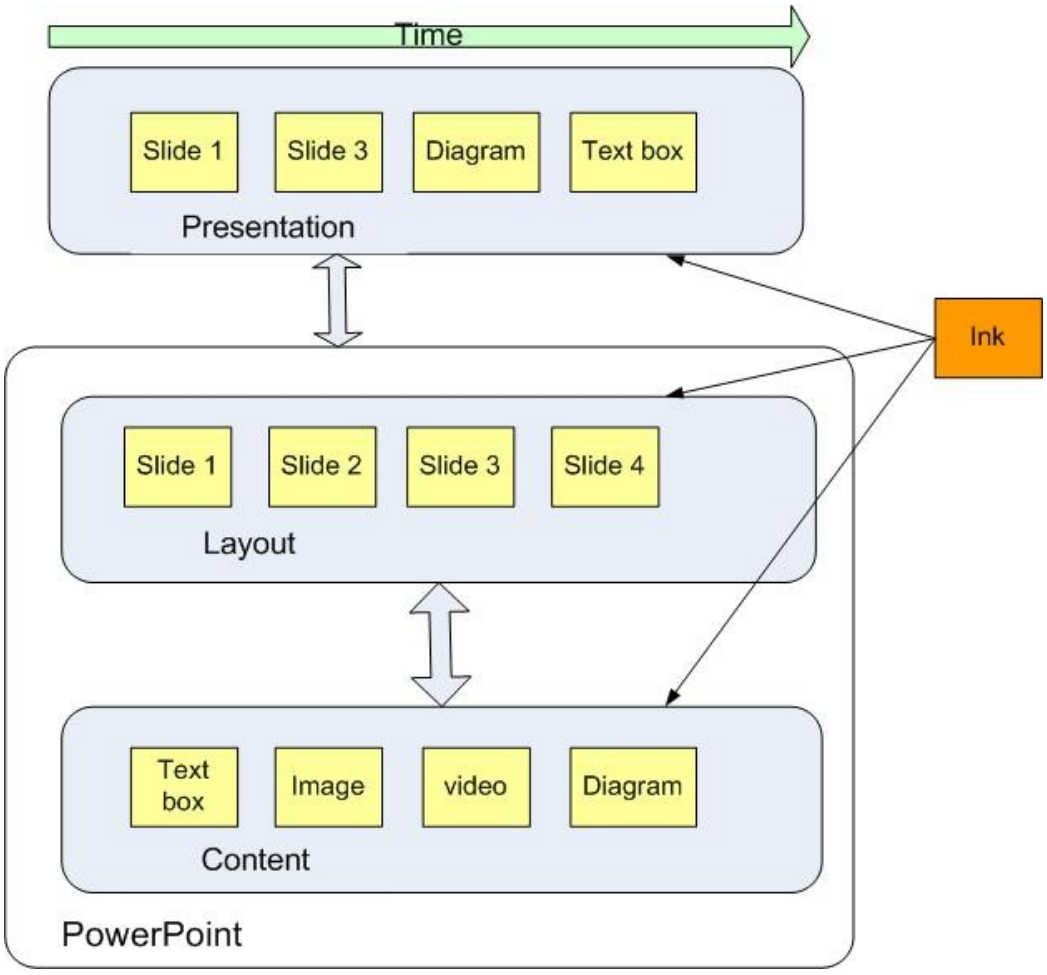


Figure 4.2: Separating Content, Layout and Presentation into three separate layers with Electronic Ink as a distinct component that applies to all three layers.

With most conventional slideware tools, such as PowerPoint, all three aspects of a presentation are constructed simultaneously, thereby marrying content and layout alongside presentation semantics. The key drawback of this approach is that layout and presentation are unified instead of allowing flexibility during presentation delivery. Some presentations need to be more dynamic: instructors with traditional presentation technologies such as blackboards often reframe or spontaneously provide more detail about concepts if they see that students do not understand the content (Birnholtz et al., 2008). Thus, presentations are often dynamic events in which a fixed flow of slides determined during authorship does not meet the needs of either the instructor or of the audience.

MultiPresenter focuses on the *presentation layer* of this process, independent of the content authoring and layout processes. It provides the presenter with different ways and styles to give a presentation, facilitating fully automated scripted transitions between slides, completely ad-hoc use of content, and hybrid approaches that semi-automate presentation while still allowing spontaneity. MultiPresenter provides smooth transitions between these presentation styles even during a presentation. Thus, presenters can construct the flow, or "presentation layer" of a presentation independently after authoring the content and layout of the slides themselves, right up to and during the actual presentation of the material.

By separating the presentation layer from the layout and content layers, we facilitate more dynamic presentations because the flow of a presentation can be specified *during* the presentation, rather than during the authoring process. A presenter is thus able to choose before or during the presentation the specific content or layouts (slides) that he or she wants to be seen at a given time. This separation facilitates many different types of presentation styles other than the one-slide-on-one-screen commonly used by PowerPoint and other slideware tools. This can be seen in the upper part of Figure 4.2, which illustrates the presentation layer. Beyond simply supporting modification of the *flow* of the presentation, MultiPresenter also provides several tools that allow the presenter to change the *way* content is presented. For example, a presenter may choose to only show slides on one projector, while using the second projector as "scratch space." Alternatively, slides or specific content can be selected for persistence and be displayed on the second projector for an extended period of time, allowing the presenter to repeatedly refer back to that information. *Separating presentation from content* is a powerful enabling design concept that MultiPresenter uses in many ways.

In contrast to the three layers just described, electronic ink is in some ways a unifier of the presentation, layout and content layers because it can be used in each stage. Electronic ink is written during the presentation, and can be used for attentional gestures – to emphasize or show certain areas in a diagram on the slide (Anderson et al., 2004). It is therefore part of the presentation layer. Yet it can also be considered part of slide layout if the presenter uses ink to connect two objects on a slide, or as basic content if a presenter uses it to write persistent information. Ink should thus be considered as a

separate component or layer because, in certain instances, such as when reusing the slides for a new presentation or when we are only looking at the presentation slides without the talk, we may want to separate out or even completely disregard the ink layer.

Separating content and presentation has significant implications for archiving. Current slideware only provides limited support for creating several different presentations from the same content. By explicitly separating content creation from presentation, multiple presentations can be created and stored referring to the same source content. Most slideware typically assumes that a stored presentation is a file containing the content and layout; however, if we wish to save the presentation level, we need to also consider the dynamic *presentation delivery* as a core part of the presentation, so we must archive it as well for future viewing. Unlike content and layout, the presentation level is dependent on time. We must archive the events as a sequence of events over time– which content appeared where and at what time.

Separating content and presentation is a common design philosophy. We have recently seen the philosophy employed on the Web, where HTML and XHTML mark up defines the semantic content and structure of webpages, while CSS or XSL style sheets define the visual layout or presentation of content. Similarly, LaTeX (Lamport, 1994), Scribe (Reid, 1981), and UNIX's troff (Ossanna, 1980) all employed this philosophy years earlier in the typesetting domain. These systems embody the understood advantages of separating the authoring of content from the layout and the presentation of the content, which allows each process to be more flexible and independent. The same content can be easily presented in different styles (technical report, journal article, academic thesis) if either content or presentation can be changed without affecting the other. For example, a citation in the text can be shown in one style as a footnote, in another style as a reference to an entry at the end of the document, and in another style as a hyperlink to a web page. In MultiPresenter, we do much the same thing by separating the authoring and layout of content, which is done elsewhere, but we take this much farther and consider the presentation of the content in real-time as a third independent component or layer with electronic ink a fourth component.

4.3 Design goals

During the design of MultiPresenter, we had several goals stemming both from our previous research and from the design process. We summarize these here.

- *Separate content and layout from presentation* – As stated earlier, we wanted users to understand that the system was a presentation system, different from their existing slideware authoring tools. Presenters should understand implicitly that the system focuses primarily on enhancing the presentation process. Thus, MultiPresenter does not support authoring of slide content. PowerPoint and other slideware tools already do a very good job building slides using different fonts, backgrounds, diagrams, clip art and other media. So content can be created with existing authoring tools and can then be imported into MultiPresenter as a set of images. A PowerPoint plug-in to directly import content and run a presentation on multiple or high-resolution screens is possible, but not yet implemented.
- *Support both dynamic and non-dynamic modes* – We wanted to support different types of presentation styles, most notably both dynamic and static styles of presentations. Static, scripted presentations are better for reducing cognitive load on the presenter because the presenter only needs to advance the pre-made materials. Dynamic presentations are important when some ad-hoc or spontaneous interaction with the audience is needed.
- *Be usable in practice* – We wanted the system to be as usable as possible in the real world. We therefore designed the system to run from a single computer. For the system to be adopted, we believe it must support compatibility with existing practices of current presentation software. Presenters already are used to running slide decks in a sequential matter. If we want people to use the system, we need to use this as a starting point, building upon users existing ways of presenting slides while adding other features that afford other possibilities.
- *Reuse of content* – Presenters already have existing single-display slide decks. Some have invested significant effort in preparing this material. Similar to Abowd (1999), we wanted to minimize the amount of work that instructors had to do to prepare for the lectures. Presenters should be able to use previously authored content and existing presentations in the context of multiple screens with minimal effort.

- *Minimize cognitive load* – When giving a presentation, the presenter needs to focus on delivering the presentation itself, rather than on the interface to the presentation software. The use of the presentation system must be intuitive and must demand minimal cognitive resources from the presenter.

4.4 System description

MultiPresenter comprises two main pieces: presentation authoring and presentation

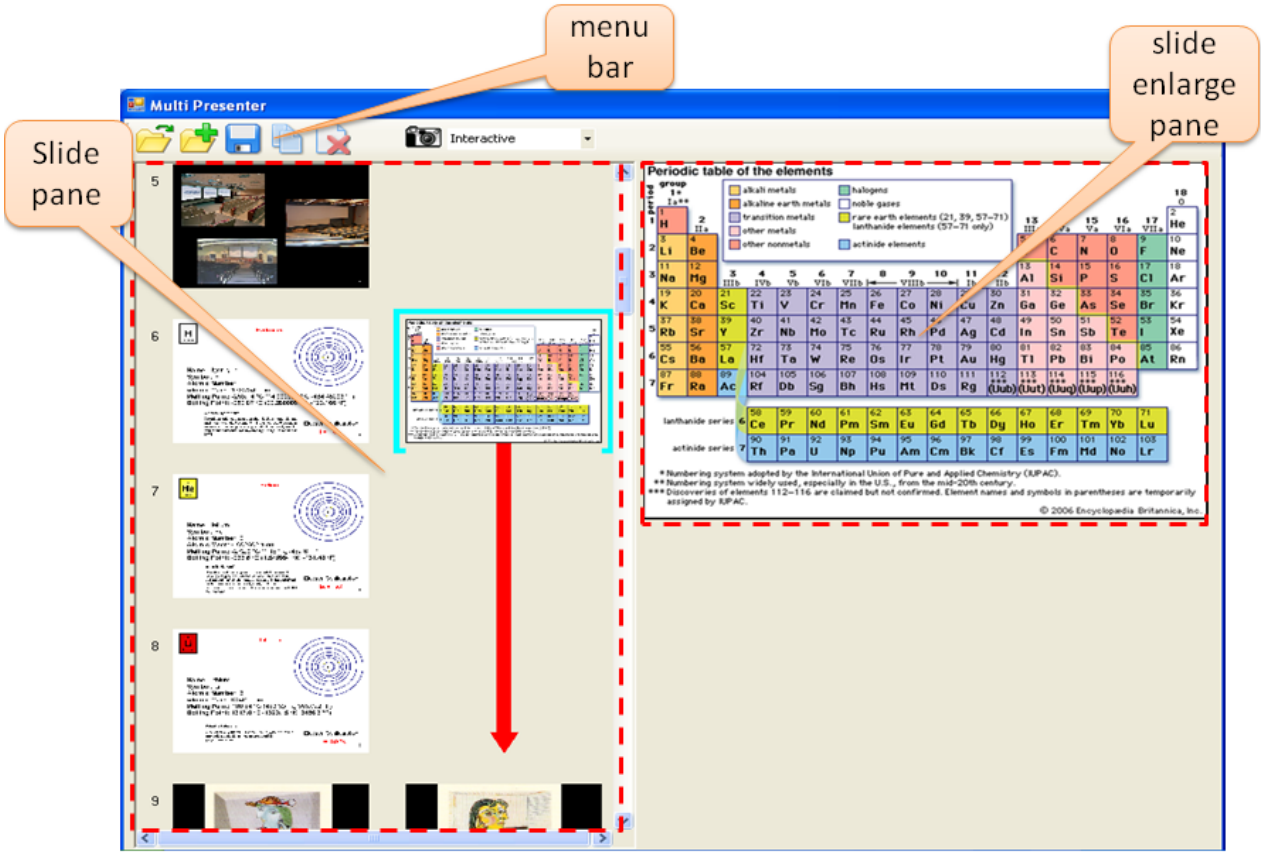


Figure 4.3 – Authoring view showing the *visual presentation* of the presentation across multiple projectors

delivery modes. The presentation authoring mode facilitates the creation of the *flow* of the slides, and is used before delivery of the presentation. The presentation delivery mode is invoked during presentation and provides the view displayed by each projector, and allows the presenter to easily switch between scripted flow, ad-hoc flow, or completely manual control of each projector view. We describe these modes, and the

different features that MultiPresenter facilitates. We then describe the system architecture and the infrastructure support needed to run MultiPresenter.

4.4.1 Presentation authoring

The *presentation* authoring mode allows a presenter to author the flow of a two-projector or high resolution presentation from existing slides, and should not be confused with *content* authoring (which is done using an external slideware tool such as PowerPoint). In the *authoring view* (Figure 4.3), the presenter can design a pre-made presentation for two screens. The slide pane on the left side of the authoring view has two columns of slots into which slides can fit, representing the two screens. This is where the author can build a pre-planned dual-screen presentation. When the author clicks on a slide it is marked, and a larger view of it can be seen on the right pane.

Loading, saving and creating a presentation

The menu bar of the authoring view (Figure 4.4) can be used to load, save, or start a presentation, as well as to enable some specific slide-level operations. Using the open file icon, the user can load an existing MultiPresenter two-stream presentation (previously saved as a .mpr file type), a regular PowerPoint presentation or a list of slide image files. A PowerPoint slide deck presentation or a list of image files loads by default into a single column on the left side of the authoring view. Because we assume that most instructors would use existing PowerPoint presentations, we adopted a paradigm in which the instructor uses a *primary screen* to show the main stream of slides and the *secondary screen* to augment this stream by showing previous information. While this is not the only way to use MultiPresenter, it is a useful way to understand much of MultiPresenter' affordances.

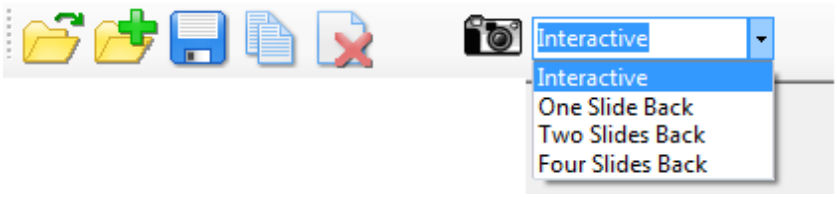


Figure 4.4 – Menu bar of authoring view, enlarged from top of Figure 4.3

The user can then author a dual-screen presentation using right-click context menu commands on slides (such as copy, paste or delete), menu bar buttons (copy or delete buttons), or intuitive direct manipulations actions such as moving or stretching any slide to one or more locations in the second column. For example, the presenter can drag an overview slide to the second column and stretch it so it will be seen during a predefined part of the presentation on the secondary screen. When running the presentation, the slides will be presented as the presenter sees it in the two columns. After the dual-screen presentation is prepared the user can use the save button (Figure 4.4) to save it as a .mpr file, and reload it at a future time in order to continue authoring or to run the presentation. To start a presentation, the presenter presses the camera icon. The presentation starts by default in interactive mode, which shows the presentation as seen in the slide pane view. The presenter can change this to one- two- or four- slides back, which shows one, two or four previous slides on the secondary screen.

Scripted, dual-screen presentations

Using the authoring view, a presenter can build a pre-made presentation that will show slides on either of the two screens or on both simultaneously. This is useful when comparing two slides (e.g. an art history presentation comparing two paintings), when showing an overview slide and a detail slide (i.e. having an overview of the presentation with the current location in the presentation always visible), or when keeping an important slide visible for part of the presentation alongside the regular stream of slides (e.g. a chemistry lecture showing the periodic table throughout the lecture).

The basic authoring view supports building a scripted presentation that assumes the presenter does not wish to interact with the system during the presentation. Many presentations, such as sales pitches or conference talks, are prepared talks in which the presenter has prepared a script and the entire sequence of slides in advance. In these types of talks, there is usually no need for the presenter to interact with the system other than progressing to the next slide. Similar to PowerPoint, the presenter decides beforehand exactly what will be seen on the screen (in this case on both screens), and progresses forward in time in a linear fashion.

Our presentation authoring mode easily affords creating multiple "presentations" from a single set of slides, each of which can be saved, loaded and employed separately. While some existing slideware tools (e.g. PowerPoint) can be used in this way, the functionality is not readily exposed by the interface, and is frequently somewhat difficult to use. Typically, users create multiple versions of the same slide deck, and cut-and-paste slides—a non-optimal solution since content changes are not propagated across slide decks. Drucker et al. (2006) explored ways to compare and manage multiple slide presentations, but their focus was on managing multiple presentation versions and not on the presentation act itself. This particular example highlights the strengths of the design philosophy of separating content from presentation.

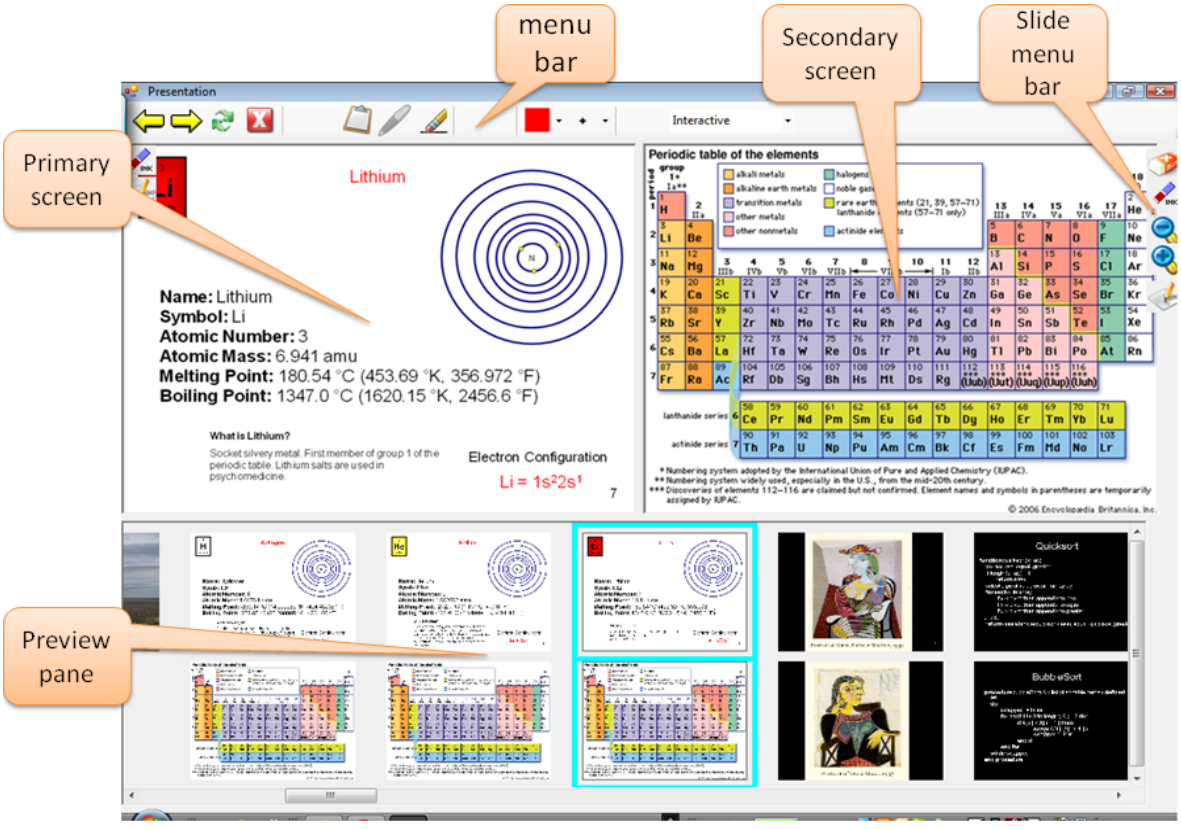


Figure 4.5 – Presentation view of the material shown in Figure 4.3

4.4.2 Presentation delivery

Figure 4.5 shows the *presentation view* that the presenter sees. The current two slides on display (the primary and the secondary screens) are shown in the two panels on top. The preview pane on the bottom shows the full presentation with the current location marked. The preview pane enables the presenter to navigate to different areas in the presentation. The presentation view gives the presenter a powerful set of tools that facilitate many of the presentation practices common to traditional presentations. The view also gives presenters the ability to dynamically manipulate the presentation of the content during the actual presentation.

Controlling the interface

The bottom panel in the presentation view shows the ready-made presentation. The presenter can go back or forth in the presentation using the scrollbar. A double click on any slide will jump to that slide and the accompanying slide on the other screen if one exists. Dragging a slide from the bottom pane to the upper pane will add that slide to the screen. If the screen is empty, then the added slide will fill it up. If one or more slides already appear on the screen, the system will automatically arrange all slides to fit on the screen.

Figure 4.6 shows the menu bars enlarged from Figure 4.5. The general menu is on the upper part of Figure 4.5, and the context slide menu is on the right side of Figure 4.5. The icons were purposely designed as large icons (32x32 pixels) to enable easy stylus access by TabletPC users. The upper menu bar is separated into 4 parts. Using the first part (the two yellow arrows), the presenter can move forward or backward through the slides (this can also be done using the arrow keys or the PageUp and PageDown keys on the keyboard), close the presentation (the red X icon), or exchange the contents of the two screens (the green double circular arrows icon). The latter is especially important because our software assumes that the presenter has a primary and a secondary screen. In many presentations (usually adapted from PowerPoint), the primary screen shows the stream of slides and the secondary screen will show auxiliary, or previous pertinent information. A similar ordering of screens occurs when the instructor shows one or more previous slides on the secondary screen. In the presentation view (Figure 4.5), the primary screen is always shown on the left and the secondary screen is always shown on

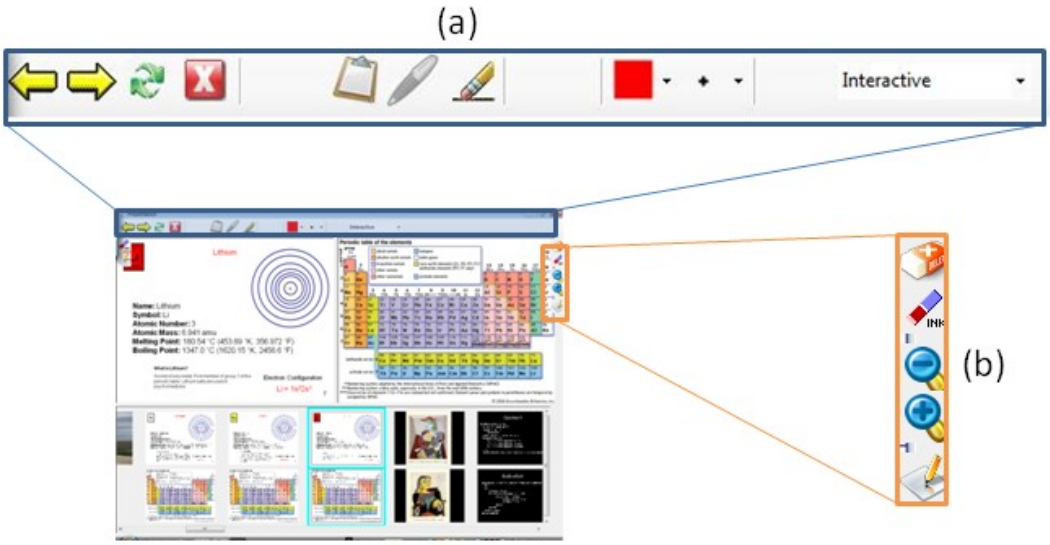


Figure 4.6 – menu bars extracted from Figure 4.5 and enlarged: (a) upper, general bar. (b) side, slide specific bar

the right (as can also be seen in Figure 4.3, when the user loads the presentation). However, this might not be the way the instructor wishes the audience to see the screens. For different reasons, such as projector quality, ease of gesturing on screen, geometry of the room, etc., the instructor might want to have the primary screen on one side or the other for the audience to view. Using the double circular arrows button, the instructor can easily exchange the screens without the need to change the cables connecting the projectors.

The second set of icons in Figure 4.6a control the cursor mode. The default is *clipping mode* in which the presenter can clip information from the primary to the secondary screen (explained later in this section). Pressing on the pen icon changes the mode to *ink mode* that enables ink annotations on the slides. Electronic ink can be used by TabletPC users by using their stylus to write on one of the two screens in the presentation delivery view. The pencil eraser icon is used to erase electronic ink (the back of the stylus can also be used for styli and TabletPCs that support this). To simplify erasing for the instructor, electronic ink is erased at the stroke level, meaning that if the instructor crosses the stylus over an ink stroke, the entire ink stroke is erased.

The third set of icons in Figure 4.6a is only active in ink mode and controls the color and size of the pen. The fourth and right-most part of the upper toolbar is a

dropdown menu that enables the instructor to change the presentation mode during presentation. The initial mode is set according to the dropdown menu in the authoring view (Figure 4.4) with the default being interactive (a dynamic presentation), but the presenter can change modes during the presentation. For example, the presenter can start with a dynamic presentation and change during the presentation to show the previous two slides and then change back to dynamic mode.

The sidebar menu (Figure 4.6b) supports functions for a single screen. The upper eraser button erases the entire screen, while the eraser with the word "ink" on it erases only the ink annotations on the screen. The plus and minus icons enlarge and reduce the size of a slide on the screen. This is useful when the instructor wants to make space for ink annotations or clips (see later in this section), while still keeping a slide visible. The bottom-most icon on the sidebar menu brings up a new window that consists of a full screen view of the slide without changing the view of the external screens. This view enables finer granularity of pen annotations on a single slide.

Figure 4.7 – Showing the two previous slides provides immediate context

Presentation modes

Figure 4.7 illustrates how the first screen can be used to show the regular slide deck while the second screen can be used to show one, two or four previous slides. As the presenter moves through the slide deck, the second screen is automatically updated, giving the audience automatic context for the current slide. The audience is kept aware of the order of the previous slides using animations that transition each slide to the new location on screen. This simple configuration allows presenters to use their existing slide decks and without any extra effort to use the second screen, giving the audience some context for what has been previously shown. As explained in Section 3.3.4, much of the information referred to during a presentation is recently shown information, so showing the previous four slides can give the audience the necessary context needed to understand the current slide and can also allow the audience to look at previous content they might have missed.

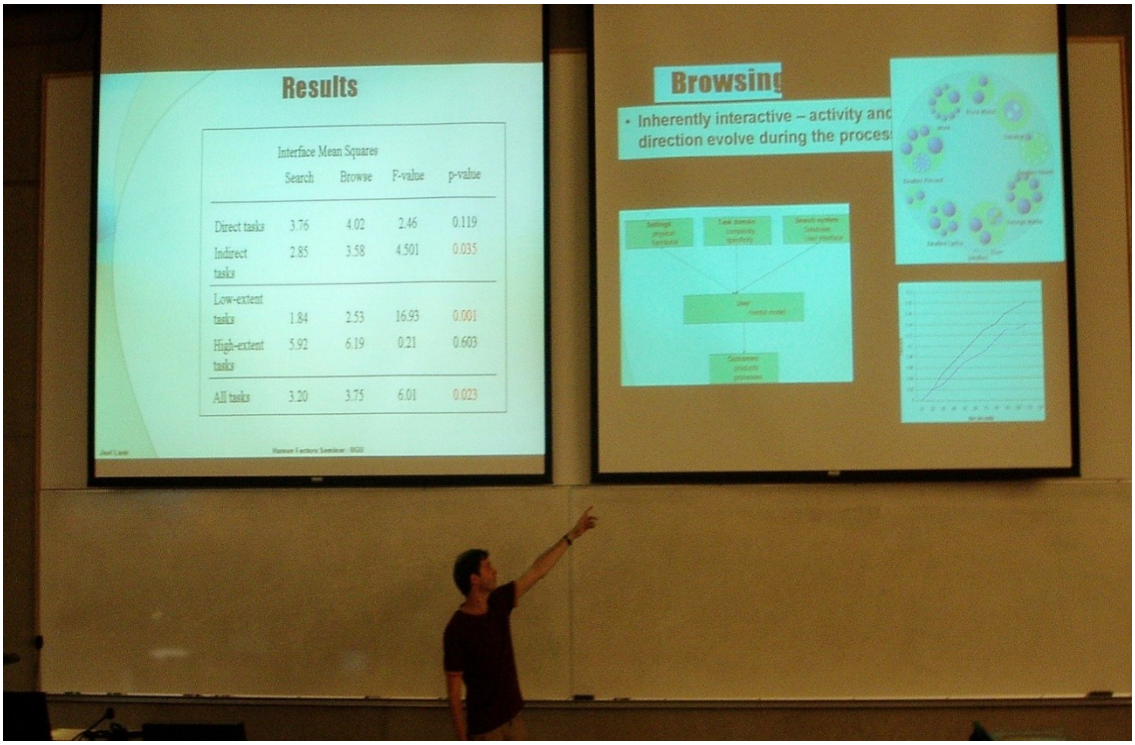


Figure 4.8 – Dynamically clipping content to the secondary screen

Figure 4.8 shows how MultiPresenter gives presenters dynamic, interactive control of displayed content. First, the presenter can at any time decide to select and display any

slide on the second projector, and this can stay on the display as long as the presenter likes. This affords using the second projector as a "reinforcing concept" that the presenter can return to throughout the entire presentation. Second, the second projector can be used as a "clipboard" of highly referred to content items that the presenter deems important to keep persistent. To modify this clipboard, the presenter can, at anytime, select a part of an existing slide (e.g., an important diagram or bullet point), an entire slide, or any number of slides to be added. Each added snippet is automatically laid out in size and location according to the number of existing snippets. The presenter can then move, resize or erase any snippet on the secondary screen. All interactions are shown on the presenter's laptop as well as to the audience to keep the audience aware of the origin of the information. Figure 4.9 shows an example of how a presenter would use this dynamic control during the presentation in order to keep important information available longer.

The presenter might want to keep certain data visibly grouped together to explain difficult concepts. In this case, the presenter can gather the important concepts from the stream of slides and put them on the secondary display, thereby providing the audience with a visual connection between related concepts. As explained in Section 3.3.8, instructors usually prefer to have some level of dynamics to perform ad-hoc explanations and to use visual aids to answer questions. In dynamic mode, the instructor is effectively given full control of how to use the second display.

Electronic ink adds another level of dynamics and allows the audience to follow a presenter's train of thought. Presenters who use TabletPCs can use a stylus in their presentations to add annotations to existing slides. Ink can be used by showing slides on one screen, and using the second screen as a drawing screen for ink alone. Electronic ink can also be used to gesture and emphasize important areas on a slide. Our system fully supports electronic ink in different colors and sizes. A presenter can add ink annotations to existing slides in the presenter's view, while the audience immediately sees the ink annotations. Erasing ink is also supported, as well as persistence of ink through time: when the presenter moves back and forth in the slide deck ink reappears each time an inked slide is shown again. Ink written on top of slides can also be saved after the presentation has ended, for future re-use of that presentation.

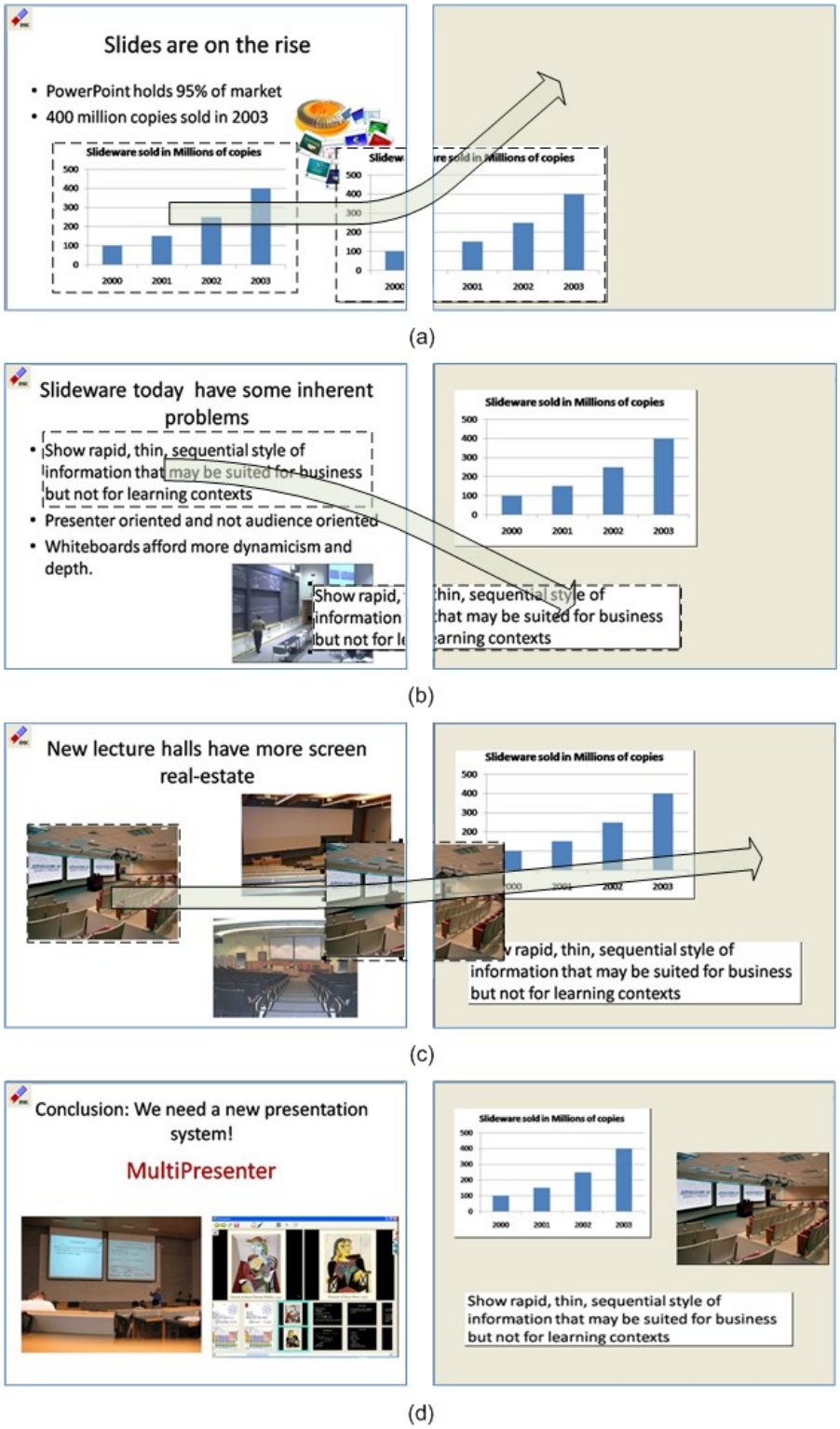


Figure 4.9 – Dynamic mode example. During presentation, the presenter drags content from the prepared slides on the left screen to the scratch screen on the right allowing long-term persistency of important content

4.4.3 System architecture

We have implemented MultiPresenter using C# under Windows. We use the operating system's extended desktop mode to control the external displays. Unlike a PowerPoint presentation, which usually uses mirror mode to clone the personal display onto the external display, in extended desktop mode the external screens are a logical continuation of the presenter's desktop. This not only enables us to control the external displays, but it also allows us to show the presenter a different view than the one the audience sees. Figure 4.10 shows MultiPresenter's system architecture.

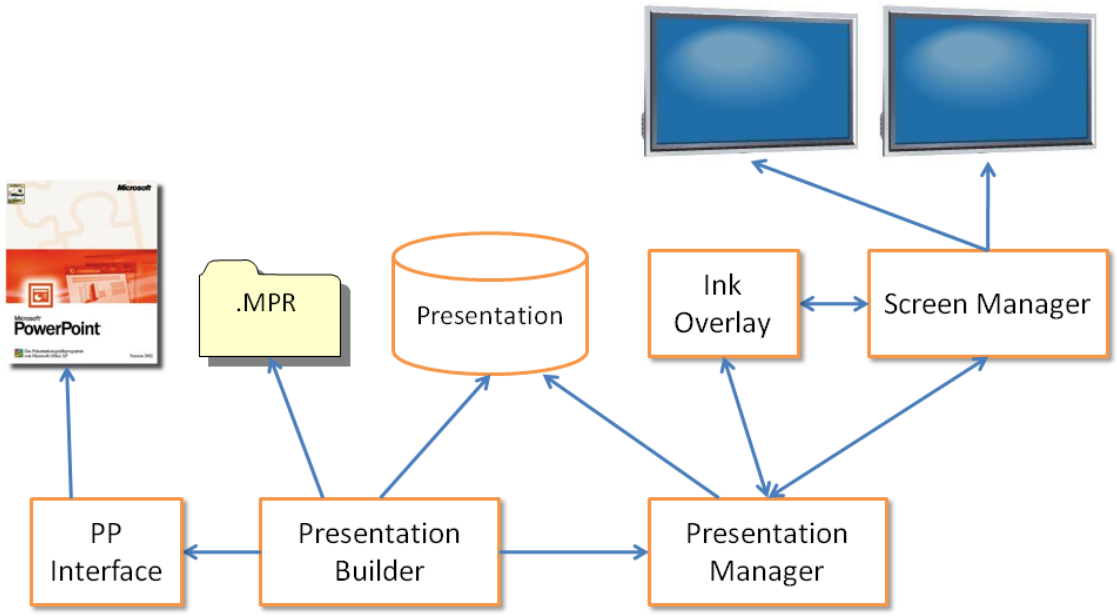


Figure 4.10 – MultiPresenter's system architecture

Presentation builder is the module that is responsible for building a pre-made two screen presentation. It gets control when the user starts MultiPresenter. The user can then load content either from a previously saved dual-screen presentation (saved as a .mpr file), or from a ready-made PowerPoint presentation. The user can then build a new dual-screen presentation from the loaded presentation using the authoring view shown in Figure 4.3. When the user decides to show the presentation, the Presentation builder invokes the Presentation manager module.

PP Interface is the component responsible for opening and interacting with an existing PowerPoint presentation. The Presentation builder can call the PP Interface to

open a PowerPoint file and load it as a Presentation. The PP interface uses the Microsoft Office Primary Interop Assemblies (PIAs) that contain the APIs for the Office library as a COM (Component Object Module) type library. Using the Microsoft .NET Framework it is possible to call these APIs using calls to a COM object.

Presentation – This is the representation that the system has of the actual slides. After the slides are loaded and authored as a two-stream presentation (or simply loaded as a one-stream presentation from PowerPoint), they are saved as a Presentation. This includes the slides, their ink-overlay that may have been drawn on top of the slides during a lecture, and their representation in the dual-screen lecture. This can be saved in an .mpr file as a simple data structure on disk that can later be re-loaded in MultiPresenter.

Presentation Manager – The Presentation Manager is invoked when the user starts presenting. It is responsible for the Presentation delivery view shown in Figure 4.4, in which the instructor can control the actual presentation during the lecture. It retrieves the content from the Presentation module, renders it as needed, and invokes the Screen Manager to control information presented on each screen. Whenever the user presses the next slide button, or performs any action that changes the information to be displayed, the Presentation Manager is responsible for taking care of that action, rendering it and sending it to the Screen Manager.

Screen Manager – The Screen Manager is responsible for detecting, controlling and drawing the information to be presented on an external display. It gets the information to draw from the Presentation manager and from the Ink Overlay modules.

Ink Overlay – Ink is rendered separately as another layer on top of the currently displayed information. When the user invokes a pen drawing, the Ink Overlay module is called. Using the Microsoft.Ink class the ink overlay module enables ink annotation with a TabletPC. These annotations are sent to the Screen Manager, displayed on the external screens, and saved with their corresponding slides by the Presentation module.

4.4.4 Infrastructure support

Our goal was to build a system that would be simple and usable. Simplifying the infrastructure support from what was required by prior work, which often relied on

complex technical setups (Chiu et al., 2003; Röüling et al., 2004), was also a core design goal to enable lightweight deployment: the system should be capable of running on a standard laptop connecting to existing projectors in any room. We believe that most presenters would like to retain control over their content and use either their laptop's or the room's PC to run their presentations. They should be able to come into any lecture hall that has two screens and use it with minimal effort to run their presentations. We definitely did not want to assume that major investments in new projector infrastructure would be made.

The primary requirement for MultiPresenter is for the computer to be able to control the entire display surface. If there are two displays, this means having two video outputs to control the two screens. Large lecture halls and conference rooms that have two or more projectors or displays set up in the room usually are accompanied by a dedicated computer that controls one or both of the screens. To accommodate the control of two screens by the room computer all that is needed is to add another graphic card to that computer (if it does not already have one) and to enable connection of the computer to the two screens via the control system for the room. This is a simple task that can be done in any room with existing infrastructure that controls two screens.

In order to run our software from a laptop, we needed the laptop to have two or more graphic cards to be able to control multiple screens (no laptops currently have dual-output cards). It is possible today to use various solutions to add another graphic card to a laptop. The VTBook™ [3] connects to the PCMCIA slot of a laptop and adds a graphic card that can connect to a DVI or VGA port. Matrox's DualHead2Go™ [4] or TripleHead2GO™ devices connect on one side to the laptop's VGA output and on the other side to two or three screens or projectors, allowing the laptop to have a multi-display capability by simulating one large surface of up to 3840X1024 pixels that spans all screens. The simplest and cheapest solution that exists today (less than $100) is to use a USB-to-VGA adaptor that adds another graphic card to the laptop with a simple plug-and-play USB interface.

[3] http://www.villagetronic.com/vtbook/index.html
[4] http://www.matrox.com/graphics/en/products/gxm/dh2go/

After a laptop is connected to two or more screens, the external screens should be set to work in extended desktop mode, with the screen used as the presenter's display (usually the presenter's laptop display) as the leftmost display. Figure 4.11 shows the Windows display settings appropriate for a two-screen presentation to be run with MultiPresenter.

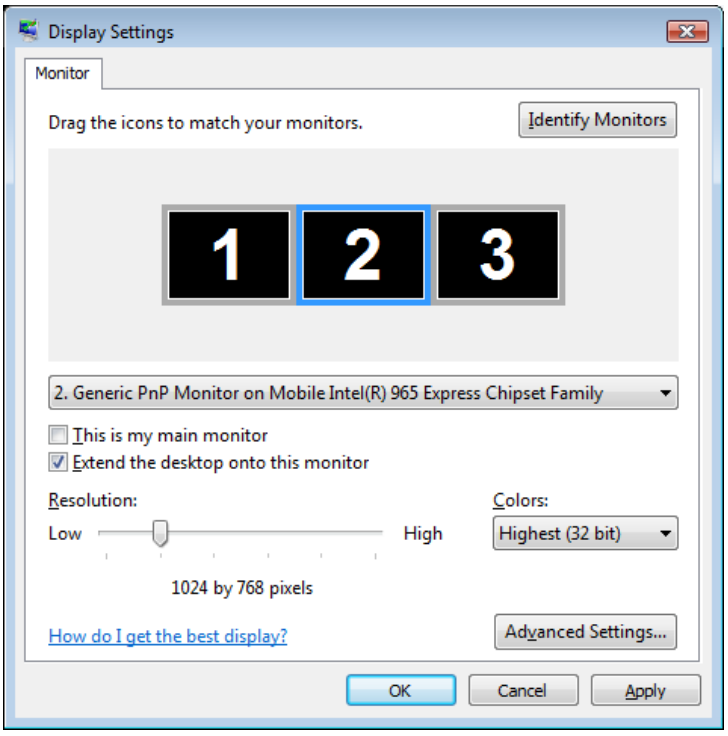


Figure 4.11 – Windows display settings appropriate for a dual screen presentation using MultiPresenter

As the resolution of graphics cards increase, it is possible for a single computer to control a large number of pixels. With continued development of networked projectors, and the increased resolution of projectors, future laptops will be able to control more projected pixels either on one or multiple screens. The real challenge is thus not the technical question of how the infrastructure will be realized, but rather how we can design tools that make use of this abundance of display space to create better presentations.

4.5 Limitations and possible extensions

We list here limitations and possible extensions to MultiPresenter. These are mainly limitations and extensions of the current MultiPresenter software. For longer-term issues related to future research questions, see Chapter 7.

4.5.3 Supporting more than two external screens.

MultiPresenter currently works only with two screens or a high-resolution screen that can be partitioned into two parts. This was a practical choice made as part of the initial prototype, because most lecture halls today have no more than two screens, so we wanted to focus our efforts on a tool that could be used in actual classrooms, not classrooms of the future. MultiPresenter's basic architecture is built so it will be easy to extend it to support additional screens. The majority of changes that would be needed in order to support multiple screens would be GUI changes to enable the authoring view to show and build more than two streams of slides, and the presentation delivery view to show and control more than two screens. It might be then more difficult to view slide details or use electronic ink for fine grain annotations in the presentation delivery view because the view of each screen would be scaled down according to the number of screens. This could be addressed by providing ways to view and annotate each screen separately. Dynamically controlling a 3- or 4-screen presentation is not necessarily a straight-forward matter. There are a myriad of choices to be made. Showing previous slides on 3 screens, for example, could show one previous slide on each of the two auxiliary screens or could show one previous slide on the first auxiliary screen and two (or more) other previous slides on another auxiliary screen. We will discuss the implications of building and controlling a general multiple screen presentation in more detail in Chapter 7.

4.5.4 Tighter integration with PowerPoint

Currently, it is only possible to load slides from PowerPoint into MultiPresenter. After they are loaded, it is not possible to change the content of these slides in MultiPresenter, because MultiPresenter saves these slides as bitmaps. If an instructor detects an error in one of the slides or wishes to change the content of one of the slides,

he or she needs to go back to PowerPoint, change the slide, import it to MultiPresenter, and insert it into the correct location in the authoring view of MultiPresenter. This is a somewhat cumbersome process that is difficult to manage. A tighter integration with PowerPoint would import the *semantic* content of the PowerPoint slides, enabling lower level access to objects on slides. This would allow control of individual objects during presentation time instead of only their bitmap image as is now implemented, because MultiPresenter would then operate on the content level.

Adding simple authoring tools (not competing with PowerPoint on the entire authoring spectrum), would enable instructors to make simple content level changes within MultiPresenter. The changed slides could then be sent back and saved as a PowerPoint presentation if needed. Integrating with PowerPoint on the content level would also enable us to address another current limitation in MultiPresenter: currently, animations in PowerPoint cannot be seen when transferred to MultiPresenter. Many instructors like to use animations, especially for showing one bullet point at a time. Using the PowerPoint COM APIs we could retrieve and save PowerPoint objects and thus enable transfer of animations from PowerPoint. An even tighter integration would be a plug-in to PowerPoint that would enable it to run a MultiPresenter presentation from PowerPoint. This would simplify things for presenters by having the authoring and presentation capabilities in the same platform, and would also enable them to easily run a multi-display presentation of existing presentations without any extra effort using standard representation templates such as “show the last four slides” or “show topic slides” on one or more additional screens.

4.5.5 Other extensions

Another set of features that can be added to MultiPresenter are a variety of gesturing tools. In a large lecture hall, with multiple screens far from the reach of the instructor, it may be difficult to show what part of a slide an instructor is referring to. As observed in Section 3.1.3, when using PowerPoint instructors sometimes use the mouse cursor to gesture at specific locations on slides, moving the mouse in a circular motion for gesturing. We can add some gesturing tools such as a flashlight highlighting tool, or a

temporal circle stroke to enable instructors to gesture at specific locations from within MultiPresenter's interface.

Other possible features include adding a dynamic text box widget to support text entry in dynamic mode for presenters without electronic ink capability or with poorly legible handwriting, and archiving of the dynamic mode interactions in the .mpr representation. The archiving of actions in dynamic mode is part of the separation of presentation style from the content. We plan to save objects seen on all screens, and the interactions of a presenter with all of the objects as part of the next generation archive format. Electronic ink annotations will be saved as a different layer, consistent with our earlier design decisions about its role at each stage of the process. We will discuss advanced archiving of presentations in more detail in Chapter 7.

Currently MultiPresenter only runs on Window OS. A version that supports Mac OS would be needed for Mac users, and another for the various flavours of Linux.

4.6 Enabling audience control

MultiPresenter, as well as most commercial slideware tools, supports a one-way presentation paradigm in which the instructor transfers information for students to absorb. We focused on this because it is by far the most prevalent way of teaching in higher education today, especially in classes held in large lecture halls. However, most educators today agree that it is important to more actively involve students in the process of learning (Bonwell & Eison, 1991). This section describes an extension for MultiPresenter that uses the extra screen real estate available with multiple and high-resolution displays together with laptop and handheld computers operated by students to enable a higher degree of student involvement and a stronger student-instructor interaction in classrooms. This extension was not used in the evaluations of MultiPresenter described in Chapter 5, but has been informally tested in classroom-like settings.

4.6.3 Motivation

Active learning refers to various techniques in which students do more than simply listen to a lecture. Bonwell and Eison (1991) state some characteristics of active learning:

> "Students are involved in more than listening, less emphasis is placed on transmitting information and more on developing students' skills, students are involved in higher-order thinking (analysis, synthesis, evaluation), students are engaged in activities (e.g., reading discussing, writing)" (p. 2)

Learners engaged in active learning practices have been shown to increase the degree to which they transfer their learning to new settings (Bransford, 2000). Most systems aiming to incorporate active learning techniques into the classroom using technology focus on encouraging student participation using back-channel types of communication by students using handheld or laptop devices. Participating in polls, question answering, or anonymous voting better engages students (Anderson et al., 2003; Dufresne et al., 1996; Ratto et al., 2003). While the current implementation of MultiPresenter focuses on enhancing regular lectures, we believe that the additional screen real estate available can also be used to support active learning techniques. Enabling students to control parts of the screen surface, and to bring their own content to be viewed by all, can be very useful in stimulating class interaction. Some projects have allowed students to annotate instructors' slides to be shared in the classroom (Peiper et al., 2005; Simon et al., 2004). However, in these projects the shared screen is always under full control of the instructor. With the extra screen real estate, we believe that new kinds of interactions can be facilitated. The screen could be shared by both instructor and students, and different screen areas used for different activities.

Many students today bring to class a computing device such as a laptop, PDA or smart phone. We might encourage student participation in learning activities by allowing them to bring content to the display, and to annotate and write on the shared display. In elementary school, for example, it is common for a teacher to ask a student to solve a problem on the board. That way, students are more involved and the entire class can see

the thought process of the student (although the down side is the pressure laid upon the student). Using the blackboard, a student who wishes to show his or her ideas, to visually ask a question, or to elaborate on the teacher's visuals, needs to approach the board, write on it and go back to his or her place. This takes time and stops the flow of the class, so it hardly exists in today's university teaching where large class sizes and relatively short lecture periods argue against such time-consuming approaches. With an extension to MultiPresenter we can allow students to present ideas on the board using their personal devices.

This has been implemented. Students can add or change existing content on the shared display. We envision a number of different pedagogical uses for this kind of interaction. A student can ask questions using his cursor to gesture on the display in a large lecture hall. Students can also bring up their content to share with other students in group activities. Some of the questions that we might ask when planning such a system include: How should we facilitate such interactions? What kinds of access control should we build in order for such a system to work well in actual classrooms? What kinds of pedagogical patterns are best to support student involvement?

4.6.4 Design

In our design of the extension to allow the audience to share control of the displays in MultiPresenter, we had several goals in mind:

- *Build atop MultiPresenter* – We wanted this to be an extension of MultiPresenter and not an entirely new system, so instructors would be able to still use MultiPresenter's rich feature set to control multiple screens while having new tools to enable audience control of the display. We envision a classroom with multiple screens, some used by the instructor to present learning material, while others are used by students to display relevant material, raise questions, or show results of polls.
- *Enable different pedagogical uses* – We wanted the audience to be able to control specific parts of the screen. This means that in a designated area, audience members could bring up a slide or parts of a slide from the current lecture slides, annotate in various ways, or bring up content from their personal devices. Although we had some pedagogical scenarios in mind, we focused on the interaction design and on

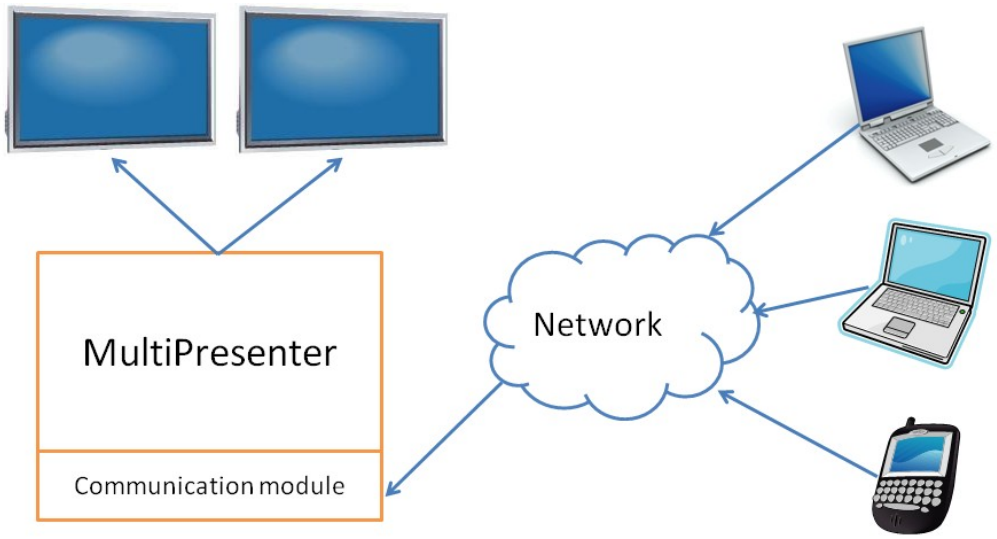


Figure 4.12 – System design: enabling audience control of the shared screen space

technological issues. Our assumption was that we should build a tool that would provide basic affordances for instructors assuming some basic constraints. This would enable instructors to devise different pedagogical patterns using the affordance.

- *Provide instructor control* – A presentation scenario, especially one given in a classroom, is not a symmetric situation. The instructor should usually have control of what is presented on the screen, be able to close windows, kick-off users who misuse the system, and decide which information could be under shared control and which should be restricted. Furthermore, the user interface to accomplish these actions should be intuitive, so it will not add to the cognitive load of the instructor.
- *Support a student queue* – While allowing simultaneous control of the screen for multiple students can enable interesting collaborative activities (Moraveji et al., 2008), we believe that in a higher education lecture approach, this might be too chaotic and that instructors would prefer more control. A better setting, in our opinion, would allow only one student to control the screen at one time using turn taking. While this may limit some interactions, it allows for a structured, clear way

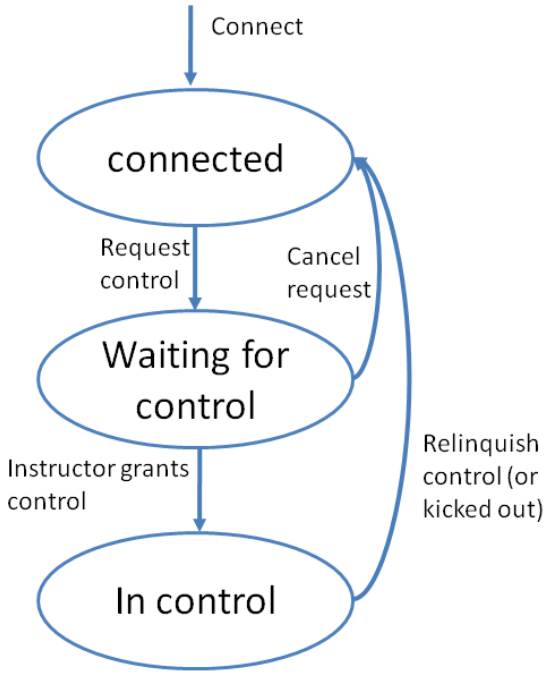


Figure 4.13 – State diagram describing a student's status when using the client. First the student connects and moves to the "connected" state. When wishing to control the screen the student requests control and moves to the "waiting for control" state. When the student is at the front of the queue and the instructor grants control the student moves to the "in control" state.

for students and instructors to understand how to use the system and for students to perceive a fair system of turn taking.

- *Require only simple infrastructure* – Similar to our arguments concerning the basic version of MultiPresenter, in order for the system to be usable in practice, the infrastructure to operate it should be simple. Many classrooms today are wirelessly networked, so a student with a laptop or PDA can easily connect to the network. The system should enable simple connection over HTTP or TCP, so any wireless device would be able to connect. A simple client (preferably using a web browser) should be implemented so students are able to easily run the client. To control the screens, the same infrastructure that was used with MultiPresenter should be used.

Figure 4.14 – The student queue on instructor's computer

4.6.5 Implementation

Figure 4.12 illustrates the design of the enhanced system that incorporates audience control. A communication module was added to MultiPresenter to enable incoming connections of students' personal devices. Students' personal devices use a dedicated client that connects to the communication module of MultiPresenter. The communication module accepts a TCP connection over a dedicated socket according to a predefined protocol. A set of commands, including cursor location and mouse clicks, is transferred from the communication module to the Presentation manager module (see Figure 4.10).

With these simple enhancements to the Presenters' view, an instructor can decide when to enable student control and when only instructor control of the screens is preferred. In the current implementation, student control is allowed only on the secondary screen. Student control of the secondary screen is determined according to a queue. Only one student can control the screen at a certain time. The first student to ask for screen control is at the beginning of the queue, and when the instructor allows interaction, the student gets control of the screen (Figure 4.13). When the student is finished, he or she relinquishes control using a "give" protocol and the next student in the queue gets control. The "give" protocol was shown to be more collaborative and to perform better with girls and provide a better distribution of time for boys than a "take" protocol in which a student takes control of the screen when desired (Inkpen et al., 1997).

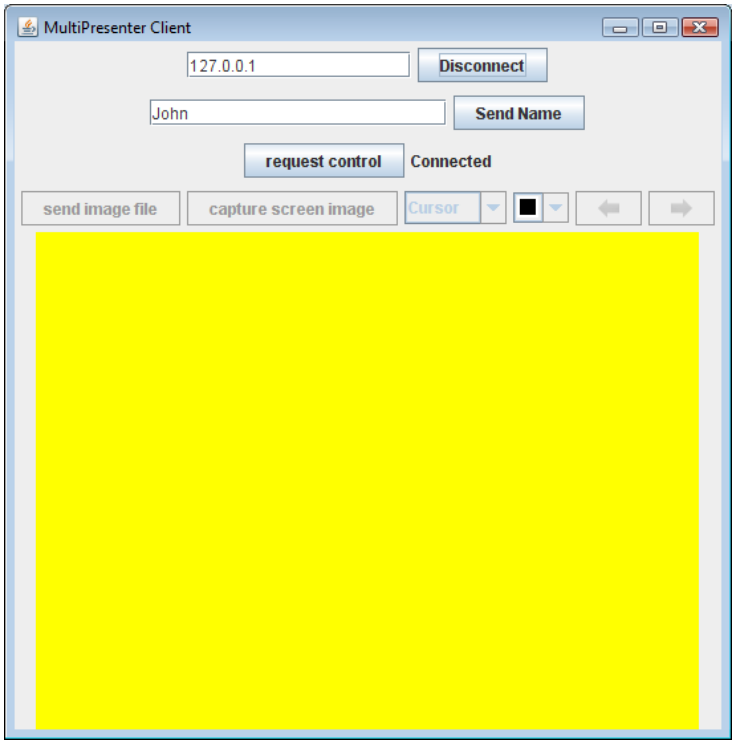


Figure 4.15 - Client to enable audience control of screen

The instructor can see the student queue (Figure 4.14), and at any given time can stop all student control, remove students, or change one or more students' locations in the queue. The analogy we made is to a group of students raising their hands in a classroom in order to ask questions. The instructor handles the turn taking, usually trying to allow the first student who raised a hand to ask the first question (take control). When the student has answered, the instructor gives control to the next student in line.

A simple client (Figure 4.15) was built to enable student control of the screen. Using the client, a student first connects to the instructors' computer. The student can then request to control the screen and is added to the queue. When the student gets control, she is notified and can then start interacting with the shared display using the client. The student can move her mouse in a set area (marked in yellow in Figure 4.15) that is mapped to the shared display where she sees her cursor on the screen. The student can move and resize clips, annotate, or highlight information using her mouse (a special highlight interaction was added that creates a partly transparent circle around the students' cursor lasting three seconds). The student can also move backward and forward through the slides in order to bring up previous information that she wants to highlight.

In addition, the student can bring images or screen captures from her computer to the shared screen. These images are transferred to MultiPresenter and added as clips to the secondary screen. The student (or instructor) can then interact with these clips by resizing, moving, or annotating them.

4.6.6 Experiences with audience participation

In order to informally evaluate the extension in a classroom-like setting we ran a demo session in our laboratory. The purpose of the session was to test whether our implementation was able to support a large number of users, to examine the utility of our turn taking protocol, and to get participants' impressions and initial feedback on our design and implementation. We invited people from the human computer interaction reading group in our department to participate in a one-time session. Fourteen faculty members, graduate students and undergraduate students, all with computer science or engineering backgrounds, came with their laptops and participated in the session. Participants downloaded the client prior to the session. After a brief introduction to the system and an explanation on how to use the client, we commenced with a 20-minute MultiPresenter lecture on multi-touch screens (a topic of interest to the reading group's participants) that was given by the author of this dissertation. Participants were encouraged to request control of the screen using the system and to contribute relevant information. Following the lecture, participants were given five minutes to browse the Internet and find related material to share with the group. We then conducted an open discussion on the lecture's topic, with each contributing member controlling the screen in turn.

Participants provided positive comments as well as constructive suggestions for improvements of the extension. We list here some of these suggestions and insights that stemmed from the session.

- The client must be easy to use and intuitive. If students are unsure about how to use the client they might be afraid to participate because of fear of delaying the class or looking foolish.
- One participant accidentally sent an image of his entire desktop instead of cropping a part of it as he intended. The student wanted to delete that clip in order to bring up

the correct one. However, currently students cannot delete a clip after posting it, so the lecturer deleted the clip for the participant. We plan to add the ability for students to delete their own clips, but not to delete clips that were posted by others.

- It is difficult to operate the client's interface in order to post content while simultaneously interacting with the instructor, or asking a question, or describing the content. A suggested improvement to the way the client is currently implemented would be to allow students to prepare material in advance and simply press the send when they get control. Another suggestion is to enable students to send content to the instructor's laptop and have the instructor post the content. This could be useful for students who wish to contribute, but do not want to be the center of class attention.
- Some participants commented on the security of the system and on the importance of denying different kinds of abuse of the system. In this implementation, we were concerned with the affordances and basic features available to students and instructors, so we did not handle security issues. We see security as an important topic tangent to our efforts. When deployed, the system could be integrated with a mechanism that authenticates users (possibly with a list of students in the course), so that we can know exactly who is controlling the screen at every minute. This is not very different than a student raising a hand during class.
- Students in the audience do not have a feedback on their place in the queue. It might be valuable to show the queue to the students, not only to just the instructor.
- There was much more participation in the open discussion part than there was in the lecture part of the demo session. During the lecture, participants focused on the instructor and did not use their laptops to look for related artefacts on the Internet. This gives us an indication that the tool might be best used to promote different types of class activities rather than used *during* a slide presentation. For example, we can imagine an instructor dividing the class into a number of groups and giving each group some sort of task. The groups could then show their work to the class using the shared screen (we could allocate a screen to each group if there are enough screens in the classroom).
- It was suggested to provide a view of the shared screen on the student's laptop. This may simplify students' interaction with content on the screen, allowing them to see

everything on their personal display (for example, it may help with annotating information). However, this may be technically difficult because updates to the screen would need to be sent to a large number of clients requiring a lot of network bandwidth.

The main research contribution of the enhanced implementation is in investigating a platform that gives presentation affordances that weren't possible before. The benefits and pedagogical implications of such a system are not obvious. While allowing audience members a form of interaction with the presentation surface not otherwise afforded, the way the presenter will use the system, the audience size, and the number of audience members with computational devices all have implications on the benefits of the system. In the classroom, the way that instructors will use the system is no doubt crucial to its success.

A formal evaluation of this system is beyond the scope of this dissertation. It is our opinion that an evaluation of the enhanced MultiPresenter system is best done in a real classroom. Evaluating such a system requires the use of the system in a classroom setting and requires a thorough examination of the best pedagogical approaches to engage students, while not distracting them from what the instructor is presenting. For example, an instructor might use the system only when he or she is answering students' questions, as an 'always on' place for students to add questions or post various data during the lecture, or as support for structured activities in which a group of students collaborates using the shared screen. These and other evaluations will require multiple sessions, possibly spanning multiple semesters.

4.7 Summary

We designed and implemented a prototype for MultiPresenter – a presentation system that allows users to author and show presentations on large display surfaces. In order for the system to be usable, we enable presenters to use existing presentations and, with simple infrastructure additions, to run MultiPresenter from their laptops. MultiPresenter supports both short-term and long-term persistence of data, enabling a presenter to keep important information visible longer, and it supports both static and dynamic

presentations. We also designed an extension for MultiPresenter that enables audience control of the shared screen. In the next chapter we describe the deployment of MultiPresenter (without the extension described in Section 4.6) in actual classrooms settings.

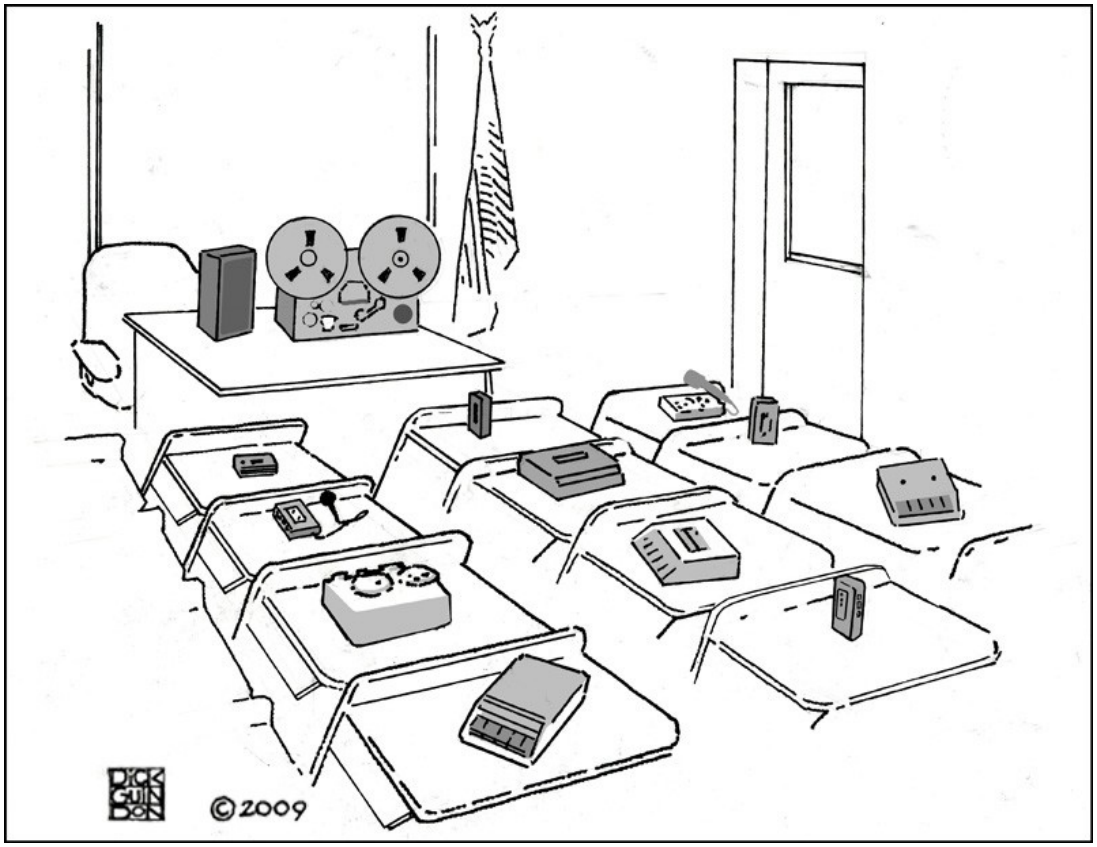


Figure 5.1: A cartoon by Richard Guindon that warns of the potential for depersonalization when technology is introduced into the classroom. The original caption read "Good morning, students". Used by permission.

Chapter 5

Using MultiPresenter in Classrooms

In the previous chapter we described the design and implementation of the MultiPresenter system. In this chapter, we discuss the evaluation of MultiPresenter in actual classrooms. We mostly used a design-based research methodology. Design-based methodology, originated by Ann Brown (1992) and further developed by Allan Collins (2004), is a quasi-experimental design that attempts to bridge theory and practice in education by defining interventions and implementing them in natural settings to examine assumptions and generate new bases of knowledge. The intervention we were interested in was using larger screen surfaces in classroom presentations. The implementation was with MultiPresenter in actual classrooms. Introducing technology to the classroom can be complex and may have many implications, some of which might be unexpected (Figure 5.1). We wanted to examine how the introduction of MultiPresenter would affect classroom interaction.

MultiPresenter was used by eight instructors in fifteen classes during most of the semester and was seen by 1013 students. We attended classroom lectures, interviewed instructors, recorded log files and screen images of the usage of MultiPresenter, and submitted questionnaires to students to get their subjective impressions. Based on this data, we examined how MultiPresenter was being used and we identified patterns of how instructors utilized two screens for educational purposes. We were interested in examining what kinds of pedagogical methods were employed when instructors were able to use multiple screens, how the usage of two screens affected classroom dynamics, and ultimately how these usage patterns affected students' learning. The data we collected on the usage of MultiPresenter provides insights into how the use of multiple screens affects both classroom interactions and student learning.

The deployment of MultiPresenter had two main goals. The first was part of our iterative design process to improve the usability and add required features to

MultiPresenter. Deploying MultiPresenter and receiving initial instructor and student feedback helped us attain this goal. The second goal was to evaluate the efficacy and understand the pedagogical implications of using two screens in general, and MultiPresenter in particular, in real classrooms. In particular, we were interested in validating and refining the design guidelines from Section 3.5.

5.1 Data gathering

We used various methods of data gathering to enable us to have different points of view on the usage of MultiPresenter so we would be able to "triangulate" data from different sources. We wanted to get data from both instructors' and students' perspectives, as well as making objective observations on usage.

5.1.1 Observations

We attended at least three lectures of each instructor using our system, and often many more. For each instructor, we attended the first lecture in which MultiPresenter was used in order to help with the initial setup and any possible technical problems. We usually attended the second or third lecture as well, until we were sure that the instructor was comfortable running the system. We then attended two more lectures during the middle and end of the semester. For many instructors, we attended more than three lectures in a semester to get a better feeling for and collect more information about how they used the system. During the lectures we took observational notes on how MultiPresenter was used. We focused on the visual content, and how the instructor related to that content.

5.1.2 Log files

MultiPresenter produces log files of features used. Instructors were informed that the software produces log files and were asked for a copy of the log files at the end of the semester. Examining the log files enabled us to get a quantitative assessment of the usage of different features.

5.1.3 Screen images

We recorded screen images of the MultiPresenter software interface from classes of two instructors (of four courses). These were instructors that received a TabletPC from us to

use in their classroom presentations. During these classes, a screenshot of the instructors' view that showed MultiPresenter's interface as the instructor saw it during the lecture was recorded every 30 seconds. The interface usually included an image of the two screens seen by the students. This allowed us to analyze most of what appeared on the screen during the class. We captured screen shots only for the instructors who received a TabletPC from us (4 out of 13 classes) because the screen shots took a lot of space on the hard-drive, a burden we did not want to impose on instructors using their own laptops.

5.1.4 Instructor interviews

During the first two semesters, we worked closely with the instructors to get immediate feedback and solve immediate bugs. Later, we met with instructors a couple of times before the semester to help install MultiPresenter and to explain how to use the software. With each instructor using MultiPresenter for the entire semester or only part of it, we conducted a half to one hour semi-structured interview after the first semester of usage to obtain the instructors' opinions and feedback.

5.1.5 Student questionnaires

We posted an online questionnaire to assess students' subjective opinions on the use of two screens in their classrooms. Questions included Likert-scale questions on agreement to various statements related to the effectiveness of the different MultiPresenter features, comparison questions between MultiPresenter and regular PowerPoint lectures, and open-ended questions. For most of the classes in which MultiPresenter was used, we contacted students in the last week of class and encouraged students attending the lecture to fill in the questionnaire. Completing the questionnaires was not mandatory.

5.2 Classroom deployment

We deployed MultiPresenter with a total of eight instructors in fifteen different classes held on the UBC campus. Table 5.1 summarizes the classes, instructors and types of data gathered for each class that deployed MultiPresenter. The course listings and lecture halls are listed in Appendix B.

Class	Instructor	Semester	Subject area	num of students	obs	log	scr	que	int
C1	I1	Winter 2007, term 2	computer science	88	✓			✓	✓
C2	I2	Summer, 2008	computer science	58	✓	✓		✓	✓
C3	I3	Summer, 2008	computer science	47	✓	✓	✓	✓	✓
C4	I2	Winter 2008, term 1	computer science	93	✓	✓		✓	✓
C5	I4	Winter, 2008, term 1	history	95	✓	✓	✓	✓	✓
C6	I4	Winter, 2008, term 1	history	35	✓	✓	✓	✓	✓
C7	I5	Winter, 2008, term 1	history	144	✓			✓	✓
C8	I5	Winter, 2008, term 1	history	21					✓
C9	I7	5/10/2008	Invited talk	~100					
C10	I4	Winter 2008, term 2	history	95	✓	✓	✓	✓	✓
C11	I6	Winter 2008, term 2	history	153	✓	✓		✓	✓
C12	I1	Winter 2008, term 2	computer science	89		✓			✓
C13	I8	26/2/2009	dentistry	~40	✓				
C14	I2	Winter 2008, term 2	computer science	91	✓				✓
C15	I2	Winter 2008, term 2	computer science	27	✓				✓
C16	I2	Summer, 2009	computer science	60					✓
C17	I2	Summer, 2009	Computer science	51					✓

Table 5.1: List of courses, course details and type of data gathered from each course that MultiPresenter was used in. Note that C9 and C13 were one-time presentations. obs=Observations, log=log files, scr=screen images, que=student questionnaires, int=interview with course instructor.

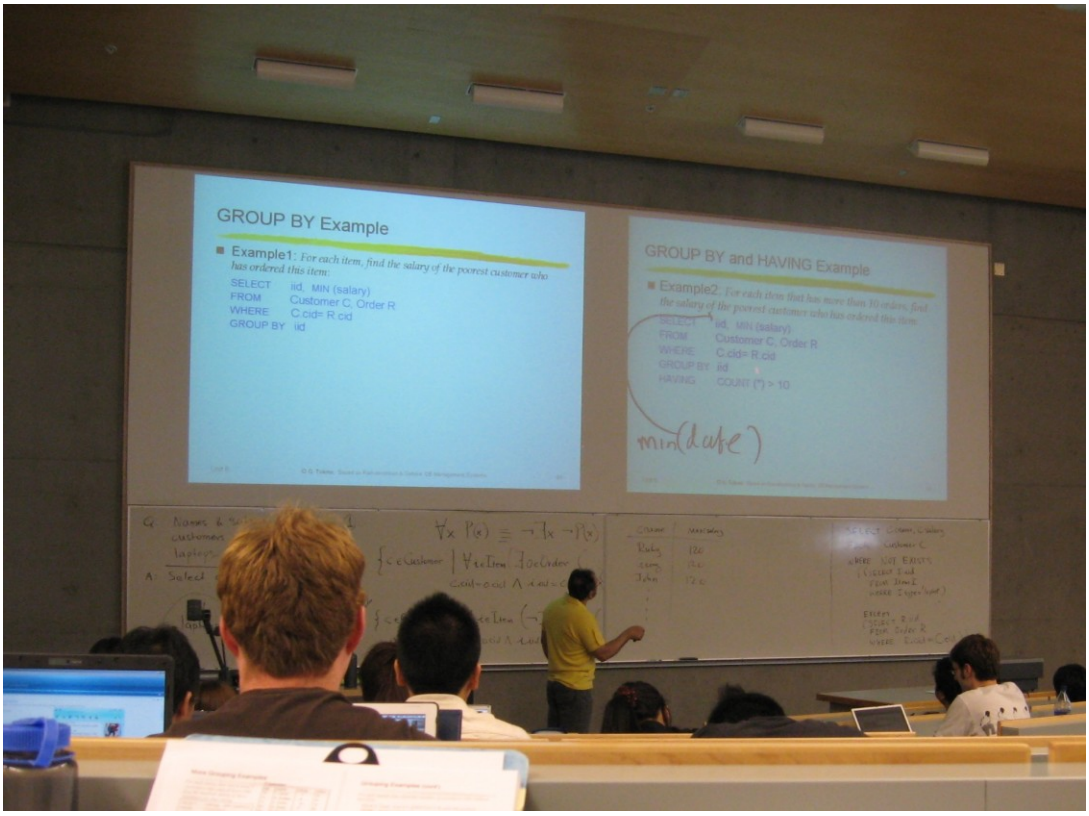


Figure 5.2 – I2 Using MultiPresenter in a computer science class explaining how the GROUP BY command works in an SQL database query by showing two different examples on separate screens with electronic ink used on one to augment the pre-made slide.

5.2.1 Deployment protocol

Our deployment protocol changed as MultiPresenter evolved. We started developing the initial prototype during the summer of 2007. We worked with a deadline of six months to develop a prototype to be used in classrooms for an entire 13-week term. The development was based on the guidelines outlined in Section 3.5 and our design goals described in Section 4.3. Finer design details were brainstormed with interested instructors and students during the development process.

We initially deployed MultiPresenter in a first year computer science course in winter 2007, term 2 (classes given Jan-Apr 2008). During this first trial, we were mainly concerned about improving the user interface, resolving existing bugs, tackling the technical problems arising from using MultiPresenter in classrooms with two screens, and adding needed features according to the instructor's feedback. This was part of our

iterative design process. The purpose of deployment, in this semester, was not to obtain much significant evaluation data (although we did gather some data for future analysis) but rather to improve the software and the user experience. The class had 88 students and was held in a large lecture hall with two projected screens (same lecture hall as in Figure 5.2). We worked tightly with the instructor, attending many of the lectures. The instructor of this class experimented with the capabilities of MultiPresenter, mostly using a dynamic style, and decided during class how to use the secondary screen. During the semester, we fixed many problems such as flickering when transitioning between slides, bugs with electronic ink, and more. We added some requested features such as better ink support (colors and sizes), and the possibility to change presentation modes during the lecture.

In the following semester of summer 2008, we approached two other computer science instructors in our department. We demonstrated the system to them, showing the different features and possibilities. After they had shown interest in using the system in their classes, we helped them install MultiPresenter on their laptops and showed them how to use their laptop computer to control the two screens in the actual classroom. We provided each instructor with a USB monitor adapter to enable them to control two screens from their laptops. We attended the first couple of lectures of each instructor, helping them to set the screens before the class. During this semester, we were still primarily concerned with the user interface and the technical problems, but we also started to observe how the instructors were using MultiPresenter, what tools and features in MultiPresenter they were using, and what kinds of pedagogical practices they used with two screens. Figure 5.2 shows I2 teaching with MultiPresenter during the summer 2008 semester.

Before term1 of winter 2008, based on feedback and bug corrections from the previous semesters, version 1.7 of MultiPresenter was complete. This was the basic version that was used for all following semesters, incrementing it only for small bug fixes. To this version, in addition to some small features and bug corrections, we added an interface to PowerPoint that allowed instructors to open existing PowerPoint presentations, a feature we thought was essential for non-technical instructors. We felt that this version was stable and robust enough to deploy with instructors outside the

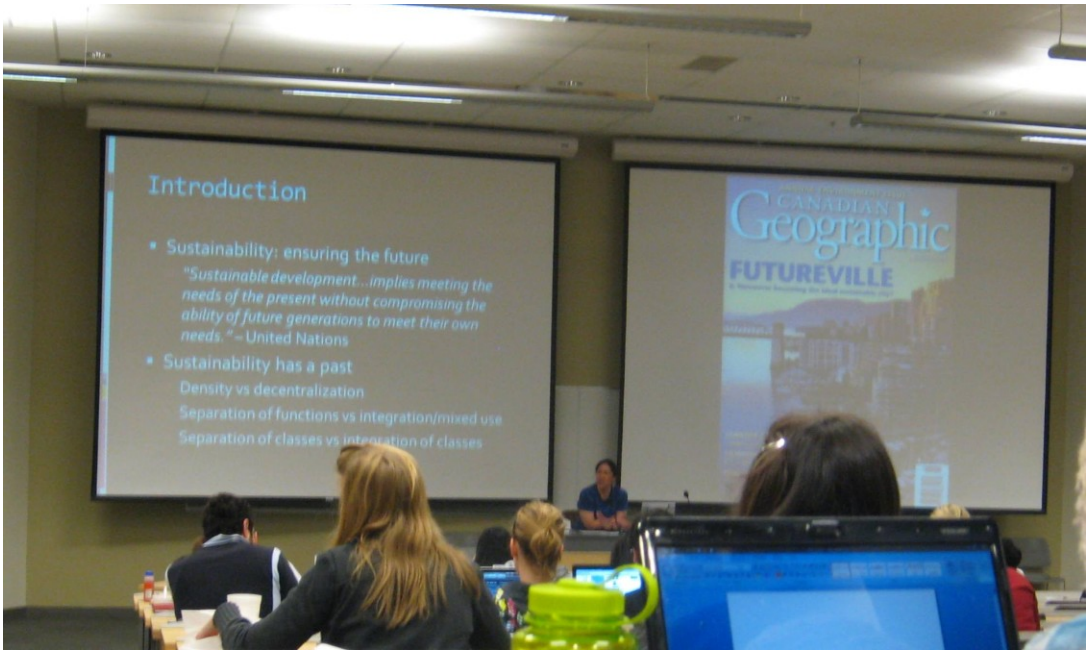


Figure 5.3 – I6 Using MultiPresenter in a history class using one screen to show the overview textual information and the other screen to show detail images

computer science department, who might be less technical or less tolerant of bugs and glitches in the software. We wanted to deploy MultiPresenter outside the computer science department to extend our observations to other topic domains. This, we thought, would help us both to identify cross-disciplinary commonalities in use of the system and to broaden our set of domain-specific usage scenarios. Additionally, because computer science instructors are "tech savvy" and are often accustomed to using new infrastructures and interfaces, we wanted to examine how less technically-oriented instructors would use the system.

In order to find interested instructors for deployment in winter 2008 term1, we contacted classroom services who sent a mass email to a list of instructors, describing the system and asking for volunteers. From about 20 responses we got, we filtered instructors according to availability for the term1 semester, classroom technology (the classroom that the instructor taught in needed to have two screens and the ability to connect to each screen separately), and type of class (we were interested in regular undergraduate classes). Since we only had six USB adaptors to give to instructors and a limited amount of time to support instructors, we ended up with six final candidates. Similar to the previous semester, we first demoed the system, and then helped install

MultiPresenter on the instructor's laptop. Because these were assumed to be less technically savvy people than the computer science instructors, we put more emphasis on explaining how to use the USB adapter to control the two screens in the classroom. We handed over a TabletPC to one of the instructors, to encourage usage of MultiPresenter with all of its features. Similar to the previous semester, we attended the first couple of lectures by each instructor until we were sure that the instructor was comfortable using the system. Three of the instructors ended up not using MultiPresenter (see Section 5.2.3), so during winter 2008 term1, we ended up with three instructors using MultiPresenter: two history instructors and one computer science instructor teaching a total of five courses. Before the start of the semester, we also developed a website (Appendix C) and a user manual (Appendix D) to provide support and enable easy download of newer versions of MultiPresenter.

During the next semester (winter, 2008 term2) we stopped our recruiting efforts. We felt we had gathered enough usage data for our evaluation. However, one history instructor and two computer science instructors who already had used MultiPresenter in the past wanted to continue using it during this semester. One new history instructor, hearing about MultiPresenter from her fellow instructors, asked to use it in her class as well (Figure 5.3). During this semester, we kept our observations and involvement with the instructors who already used MultiPresenter to a minimum because we felt that we had learned most of what we could during the previous semesters, although we did capture more log data.

5.2.2 Instructor styles

Different instructors have different teaching styles. An instructor's method of teaching in a specific course often depends on the subject taught, the classroom, the students in the class, and the instructor's specific teaching style. We did not observe how each instructor taught without MultiPresenter, so it is difficult to assess how MultiPresenter affected the style of each instructor that we observed. We tried to address this during the interviews we conducted with the instructors. All instructors who used MultiPresenter in this deployment were experienced instructors who had taught several courses in the past using other commercial slideware. We focused our analysis on classes in large lecture

halls. Although some classes were held in smaller classrooms equipped with two screens (C6, C8, C15), the predominant usage was in large lecture hall classrooms in which student-instructor interaction is often more difficult. Instructor's teaching styles varied. For example, I3 would often conduct class activities to engage students, while I4, I5, and I6 (all history instructors) mostly taught using a unidirectional style with little student interaction. The different instructor styles were reflected in the variety of styles that instructors employed when they used MultiPresenter.

5.2.3 Failed deployments

Not all deployments were successful. Some instructors who agreed to participate did not in the end use MultiPresenter in their lectures. However, once instructors did start using MultiPresenter for a few lectures, they kept on using it during the entire semester. Reasons for unsuccessful deployments were lack of features in MultiPresenter (e.g., no animation), lack of instructor time to engage with a new paradigm, and initial technical problems. We note that these problems are mostly caused by the prototype nature of MultiPresenter and could easily be addressed in a future commercial product.

Some instructors were from outset not interested in employing MultiPresenter in their classrooms. One instructor we approached said she liked the animation afforded by PowerPoint, and that she often uses animation in her slides, revealing one bullet point after the other. This is not possible with the current MultiPresenter version. Because she had all her course slides already prepared with animations, she did not want to redesign them to fit MultiPresenter. During winter 2008 term1, when we first deployed MultiPresenter outside our department, we had a few cases in which instructors ended up not using MultiPresenter in their classroom. One physiology instructor was impressed with MultiPresenter and told us he intended to use it in his classrooms. However, he ended up not using it, saying he did not have the time to try a new tool. An astronomy instructor had many difficulties with the installation of MultiPresenter. Most of his problems had to do with the integration of MultiPresenter with PowerPoint (opening PowerPoint files in MultiPresenter). He was using Office 2003 with Windows XP, a different configuration than the one we had tested. He encountered many technical difficulties opening PowerPoint files with MultiPresenter. After a few iterations in

which we tried to solve the problems with his installation, he gave up using MultiPresenter.

Another experienced computer science instructor often used a programming environment (Visual Studio) as part of his lecture, mixing a slide presentation with examples shown in a programming environment. Other software that he used during his classes included VMWare and iClicker. With the MultiPresenter configuration, he had to use an extended desktop mode, and thus could not see the programming or other software on his personal display. This required him to turn his back to the audience and look at the projected displays as he worked on his laptop. Normally he used mirror mode, so he could look at his laptop's monitor while the audience viewed all that was happening on his screen. Because he preferred to use mirror mode so the audience could see his desktop he was not able to use MultiPresenter.

One particularly interesting discussion we had was with art history instructors. We talked with several instructors from the art history department in our university who were very enthusiastic about trying MultiPresenter in their classes. The main reason was that their slides are usually images of art work, and they often compare two images during their lectures. One instructor told us in an email message "Since time immemorial Art Historians in North America and Britain have used two screens in lectures in order to show detail shots of images and in order to make comparisons or to provide images of architectural contexts." She went on to say that "PowerPoint has changed that by forcing us to squish our comparisons onto one narrow screen."

The old practice of art historians was to use two screens in their classes, with two 35mm slide projectors (or the equivalent), one for each screen. However, with the advent of digital imaging technology, which allows better storage, control, and acquisition of images, this practice has been lost as instructors switched to PowerPoint in their lectures, abandoning the two-screen approach that may pedagogically be better suited to their needs. However, this did not materialize into a deployment because the lecture halls in the art history department did not have two digital projectors. The instructor commented that she believes that with better infrastructure in their room, most art historians she knows would prefer having a dual-screen presentation. It is interesting to note that while two 35mm slide projectors had at one time been standard in the

classrooms used by art historians, the newer digital technology did not advance equally in terms of supporting both the authoring and the presentation of images: authoring became easier once digital photography was widespread, but dual digital projectors took much longer to appear in most classrooms.

5.3 Usage of software features

In this section, we describe how the different features of MultiPresenter where used. Usage data is based on our analysis of the log files, analysis of the screen images, and observations of the instructors using MultiPresenter.

5.3.1 Presentation delivery mode

Using MultiPresenter, instructors can author pre-made dual-screen presentations or they can show previous slides on the secondary screen. In both modes, instructors progress through the slides similar to the PowerPoint paradigm. Alternatively, instructors can decide dynamically during the presentation what to show on the secondary screen. We were interested in observing whether instructors would utilize the dynamic features of the system and whether they would shift between the different modes. We refer to a ready-made dual-screen presentation as *pre-made* mode, in contrast to showing previous slides in *slide-back* mode or to the ad-hoc placement of content during a lecture in *dynamic* mode.

Dynamic, ad hoc use vs. pre-made presentations

All three computer science instructors mostly used the dynamic mode. Figure 5.4 shows a timeline representation of a two-screen lecture by I3. Line A shows the primary screen, while line B shows the secondary screen. We can see how the instructor dynamically moved content from the primary screen to the secondary screen many times during the lecture (e.g. in minutes 1, 4, 14, 17). The three history instructors, on the other hand, used the pre-made dual-screen lecture option much more. I4 and I5 varied their presentation style and used both pre-made and dynamic mode. I6 solely used pre-made mode. She would usually put text information on one screen, normally a high-level overview, while going over many example content images on the other screen. Her style was similar to a keynote presentation in which there is a one-way transfer of information

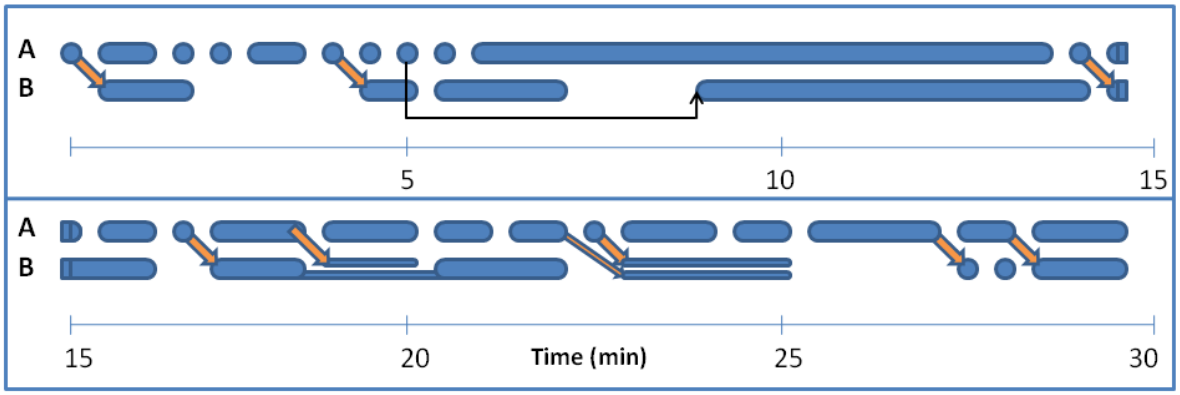


Figure 5.4 – A timeline representation of 30 minutes from one lecture of I3 that used two screens. Line A shows the primary screen, while Line B shows the secondary screen. Slides are shown as ellipses with the size of the ellipse depicting the length of time the slide appeared on screen. Arrows represent transitions of slides from the primary to the secondary screen.

with almost no involvement of the audience during the lectures. The pre-made usage of MultiPresenter fits this style because there is no need to dynamically alter the visuals during the lecture.

Shifting between pre-made and dynamic mode

I4 and I5 often used pre-made mode in their lectures. However, they would often still use the dynamic features, deciding during the presentation to put a certain slide on the secondary screen instead of the pre-selected slide, or leaving space in the dual-screen pre-made presentation to be used dynamically during the presentation. In a couple of instances, I4 used slide-back mode showing the previous slide on the secondary screen. Nevertheless, she did not use this mode for the entire lecture, but changed from that mode to interactive mode in order to have a slide with a map persist for a longer time, and then reverted to slide-back mode. We saw that even when using the "static" methods of presentation, the instructors reverted to dynamically deciding during the presentation what to display.

Using slide-back mode

Instructors seldom used slide-back mode. I4 used slide-back mode in two classes, but shifted between slide-back and dynamic modes in both of these classes. I5 used slide-

back mode in three classes, all of them near the beginning of the semester, when she experimented with the software. I8 was a dentistry instructor who used MultiPresenter only once and is therefore not discussed in detail in this analysis. He used slide-back mode, showing one previous slide on the secondary screen. No instructors used slide-back mode to refer more than one slide back.

In responding to questions about why this mode was not used, instructors commented that it can be a useful way of running their presentation, but they preferred having more control over what is displayed at any given time. It is interesting to examine these results in relation to other presentation systems that use multiple displays. Classroom 2000 (Abowd, 1999) and others (Chiu et al., 2003; Röüling et al., 2004) are restricted to displaying only previous slides on the other displays. Yet we saw that across the six observed instructors, this was nearly never preferred over pre-planned use of the space or dynamic use. We believe that this feature can be useful for other instructors, who prefer not to handle the interface during the presentation, yet MultiPresenter's deployment demonstrates the importance of allowing instructors full control of what is displayed on all screens.

5.3.2 Persistency of information

With MultiPresenter, instructors can present information spatially in parallel instead of sequentially over time. We were interested in observing how instructors would use MultiPresenter to show previous information. MultiPresenter supports various methods of showing previously shown information, from automatically showing the previous information in slide-back mode, to dynamically clipping information onto the secondary screen in dynamic mode. We were also interested in observing how long information persists on the secondary screen, and whether in fact it is used at all.

Spontaneously deciding what to keep persistent

Instructors often used the secondary screen to have selected information persist longer to use as a reference in the current theme. The information could be slides that were just shown, pre-set topics, or important slides (e.g. a map slide in a history class) that were designed to be shown longer, or it could be information that was seen earlier in the lecture (for example, in Figure 5.4 at around 8 minutes, a slide that was shown at minute

5 was brought back), or even slides that are later in the slide stream, breaking the linearity of regular slide presentations.

Many instructors spontaneously decided what to keep persistent on the secondary screen. In Figure 5.4, it seems that the most common practice was to move certain slides from the primary to the secondary screen after they were initially introduced on the primary screen (as in minutes 1, 4, 14 and others). This behaviour of moving the current slide from the primary screen onto the secondary screen while progressing to the slides that followed on the primary screen was common to all three computer science instructors. It suggests that instructors recognized the need for persistence as they went through a slide, or as they transitioned away from it.

Occasionally, instructors dynamically brought previously shown slides back to the secondary screen (as in minute 8 indicated by the black arrow in Figure 5.4), although this was less common. Bringing information to the second screen would usually be according to the instructors' immediate needs, such as explaining a concept that would be aided by previous information, comparing two pieces of information, or reacting to students' questions when the instructor might bring a relevant slide to the second screen. A common practice that I3 employed, often more than once during a single lecture, was to support in-class activities. He would usually put a slide describing the class activity on one screen and bring back a previous slide that provided related information on the other screen to support the activity.

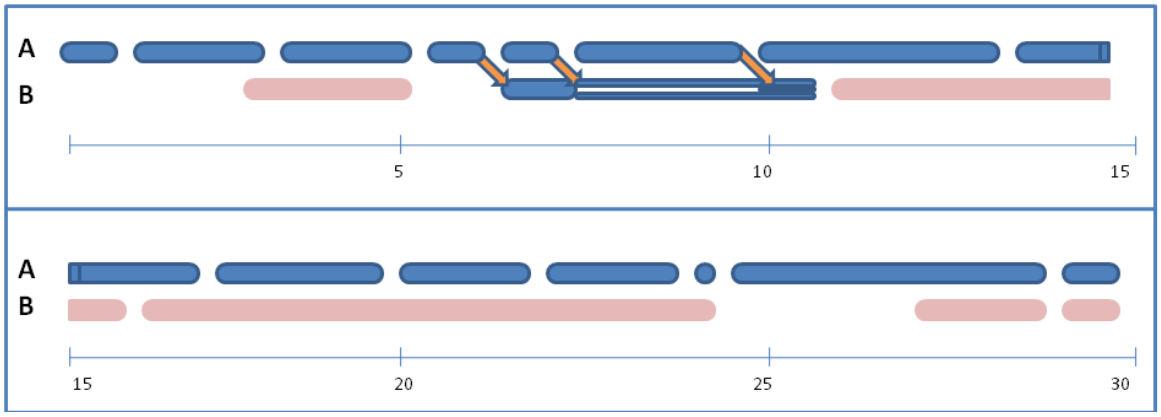


Figure 5.5 – A timeline representation of 30 minutes from a lecture of I3. Dark blue intervals represent individual slides that appeared on the primary screen or subsequently on the secondary screen, and light pink intervals represent slides that appeared only on the secondary screen. A white line within an interval indicates that multiple slides were shown at the same time.

Planning persistency

Some instructors planned ahead of time how information should persist longer. I6, for example, designed pre-made dual screen presentations that had overview text slides persist longer, while going over a sequence of slides. I4 used many maps in her lectures, and often arranged for a map to persist longer. She used dynamic mode, and dragged the map to the secondary screen before it was seen by students. We consider this to be planned, because the need for persistency was recognized apriori. We can see a similar example of this in Figure 5.5. Although the instructor used dynamic mode, we can see in minutes 3, 11, 16 and 23, 27 and 29 that slides (marked in red) "appeared" on the second screen. These were slides that were not seen before by students, but were brought to the second screen in an ad hoc manner by the instructor. We see in minutes 6, 7, and 10 examples of spontaneous persistency when the instructor dragged copies of slides from the first screen to the second.

5.3.3 One slide on one screen

Five of the six instructors almost exclusively used full slides on the second screen. I3 occasionally had two or three slides persistent on the second screen (as can be seen in Figure 5.5 in minutes 6 till 10, in which there were two, and then three slides on the

secondary screen). I3 and I4 were also the only instructors who used the clipping feature that enables cutting and pasting of pieces of information from one screen to the other, however, they each only used it twice. We believe the reason the clipping feature was hardly used is that its operation was too complex for the instructors to operate or plan during a lecture. In regards to the clipping feature, I3 commented:

> "It [MultiPresenter's feature set] has to remain simple. That might be one of the reasons I didn't use the "cut and paste", because it was a little too complicated to use, it was easier just to put the slides there."

Similarly, no instructors used the minus or the plus buttons in the slide menu bar to reduce the size of a slide on the secondary screen to enable space for ink annotations (Section 4.4.2).

Anderson et al. (2004) report similar trends of instructors making parsimonious use of Classroom Presenter's features. During class, instructors need to focus on their teaching task, and do not wish to spend cognitive effort operating a software interface or planning new pedagogical practices. Instructors are already used to the slide paradigm and build their slides as "whole" pieces of information. They therefore continue to use this paradigm when exploiting additional screen space by putting full slides on the second screen.

5.3.4 Electronic ink usage

Electronic ink was used extensively by the three computer science instructors. Two of the three history instructors had a TabletPC, but did not use the electronic ink features. One history instructor (I4) explained this as the novelty of using electronic ink:

> "I can see that in some cases it might be very useful, and I wish I had it in my hand, but I didn't. So part of it, I think, is just getting used to it, and keeping that in mind, thinking of ways to use it in advance, like knowing the exits in the room so when people shout "fire" you know exactly where to go without thinking. I hadn't gotten to that level of expertise."

Similar to Anderson et al. (2004), we found that the instructors who have used ink used it for attentional marks such as highlighting, emphasizing or connecting the spoken words

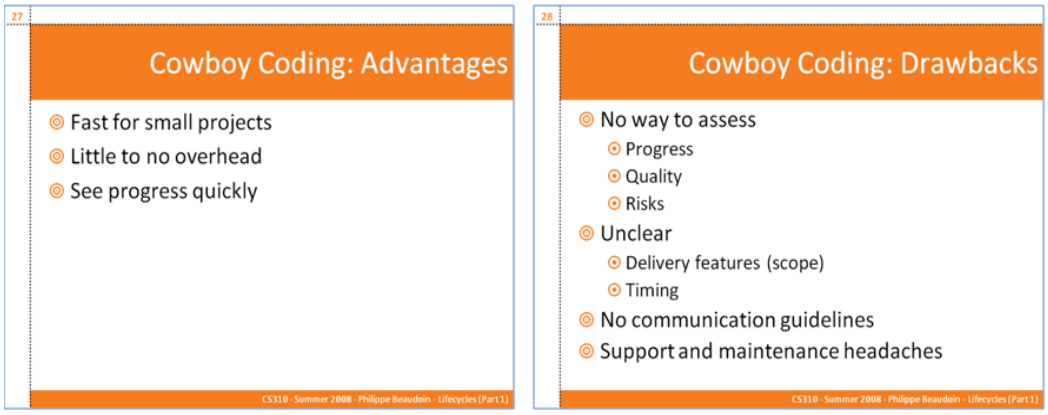


Figure 5.6 – Comparing two slides.

with the visuals, and for writing of content – usually in the form of text or diagrams. With the extended screen space available, instructors also used an empty canvas as a persistent writing space alongside the stream of slides. Instructors used different ink colors, however they rarely changed the pen size. One instructor commented favourably on being able to change the ink color using the interface with one step, rather than two steps with PowerPoint.

5.4 Usage patterns of two screens

We describe some of the usage scenarios and patterns we observed. All figures in this section are taken from actual slides shown in class.

5.4.1 Comparing two slides

A common teaching practice is to compare two items, to emphasize the similarities and differences between the items to the students. For example, a computer science instructor may wish to compare two algorithms side by side, highlighting the differences between them. Two different solutions for a problem or two definitions for the same idea might also be compared. Figure 5.6 shows an example in which the instructor compared the advantages and drawbacks of a technique being discussed during lecture. When using PowerPoint, the instructor either needs to flip back and forth between the slides to compare the two items, or needs to cram the two items onto one slide, making the items smaller. Using MultiPresenter, it is natural to compare two slides side by side, giving

students a visual comparison of the two items. Examples of making comparisons using two screens were comparing two algorithms, two pieces of code, or two programming styles by the computer science instructors, or comparing two maps in a world history course or comparing two legal documents in a medieval law course.

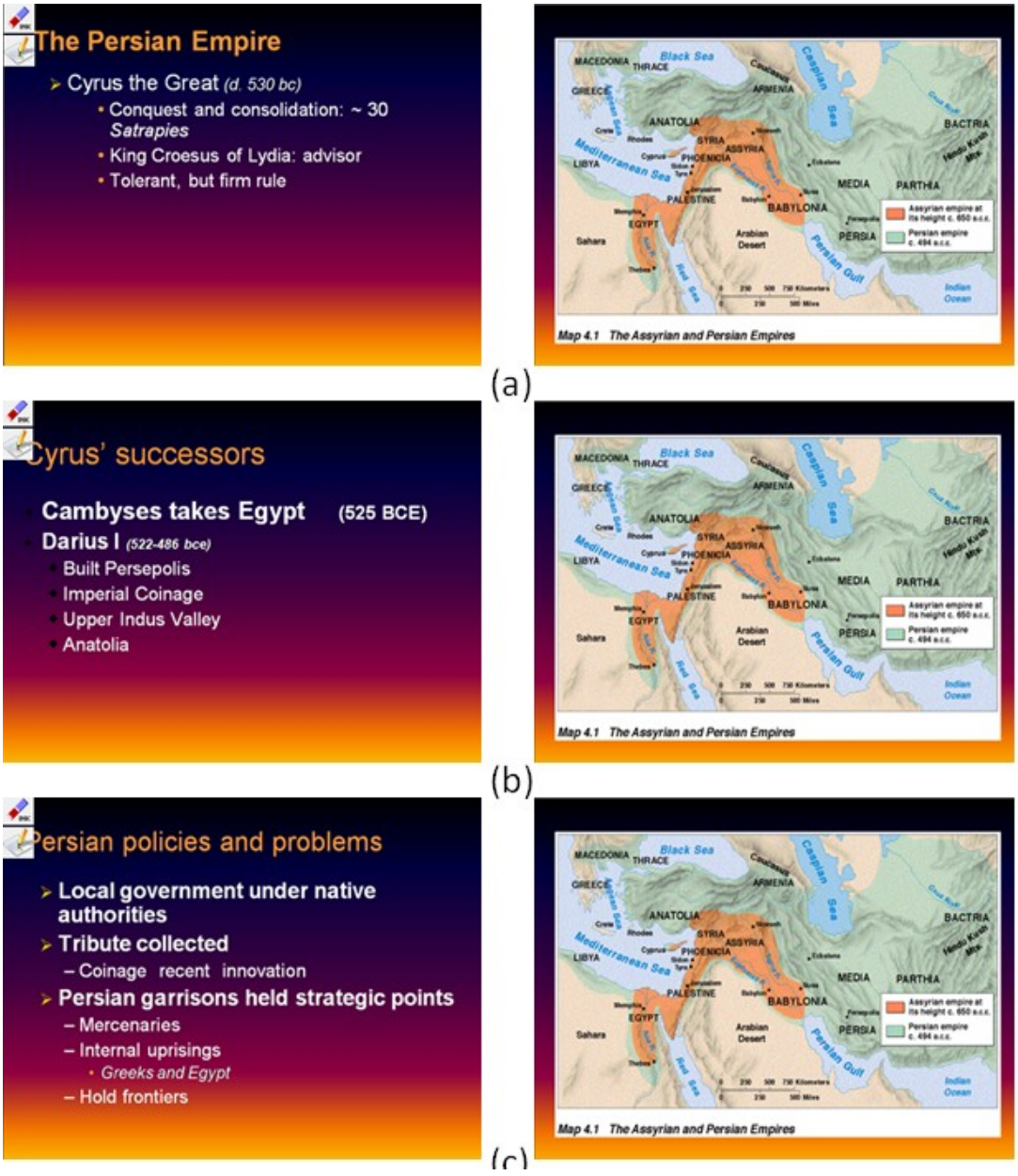


Figure 5.7 – Having a slide persist on the secondary screen

5.4.2 Having information persist longer

A common practice between all instructors was to use the secondary screen to keep an important slide persistent, while showing the regular stream of slides on the primary screen. This happened, for example, when the instructor wanted to have a definition slide available for the class to remember, or when having a problem slide persist while a stream of slides reveals the solution. This allows the students a view of the problem throughout the time the instructor spends on the solution, helping them remember the details of the problem. Figure 5.7 shows an example in which a history instructor kept a map persistent, while going over some technical information. Other examples include keeping a database schema or database table available while going over an example, and keeping an overview slide persistent while going over the details.

5.4.3 Referring to previously shown information

We observed that often during the lecture, when instructors referred back to previously shown information, they would put the previously shown slide on the secondary display. The instructor usually kept that information alongside the current slides until it was no longer relevant to the current theme, and then would either erase or replace it.

5.4.4 Unifying a topic area

Often, one slide is not enough to explain a single topic. This forces the instructor to either cram too much information onto a single slide, making it difficult for the students to read the slide and adding to the students' cognitive load, remove informative content to fit information on the slide or it causes the instructor to divide the topic onto two or more slides and then show them sequentially over time (Farkas, 2009). With MultiPresenter, we often observed instructors showing two slides on the same topic area side by side, thus allowing students to "see the whole picture" when a large topic is explained (Figure 5.8). When more than two slides describe a topic, often instructors show the latest two slides on the topic, or choose the more important slide of the topic to persist on the secondary screen. We might conclude that this suggests the benefits of having even more than just two screens, which is why the architecture for MultiPresenter is intended to extend to a larger number of screens.

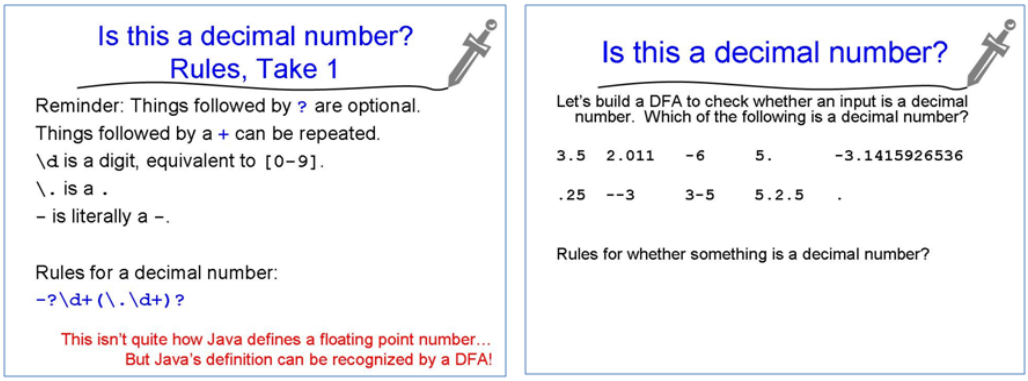


Figure 5.8 – Extending a topic on two slides

5.4.5 Showing overview slides

In many lectures, it is useful to give the audience some knowledge of the structure of the lecture: where in the whole lecture is the current point, and where are we heading. To achieve this, often there is an overview slide that is shown at the beginning of the lecture, and between each topic it is again shown to re-establish context. In his first lecture, one instructor used the secondary screen to show an overview slide of the lecture, while progressing in his slides on the other screen. The instructor used attentional gestures with electronic ink to mark each topic he was going over on the overview slide (Figure 5.9). Another example we observed was during a history lecture on the Persian Empire. The instructor had a set of slides describing each ruler. While showing the slide for one of the rulers as an overview on one screen, detail slides concerning the era in which that ruler lived were displayed on the other screen.

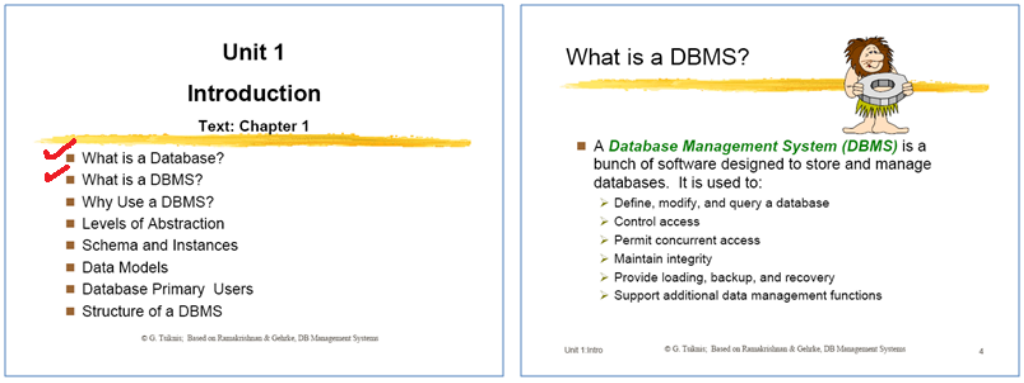


Figure 5.9 – Showing an overview slide alongside the context slides

5.4.6 Using ink and slides together

Electronic ink is also useful for adding dynamic interaction to classroom presentations. Electronic ink was often used as attentional gestures, to keep the audience focused on what the instructor was currently explaining. With the extra information available on the second screen, it was important for the instructors to sometimes focus the audience on specific areas. A common usage we observed was for the instructors to use the secondary screen as an empty canvas on which to write information (Figure 5.10). This allowed the instructor to use the screen as a whiteboard, providing more flexibility, while still having the slides viewable on the other screen for reference. As I3 commented about the use of ink with multiple screens:

> "[I]t really combines well with the dual screen, because otherwise you run out of space very quickly and you find that you cannot write that much. Also, now you can leave stuff on one screen and start writing on the other screen."

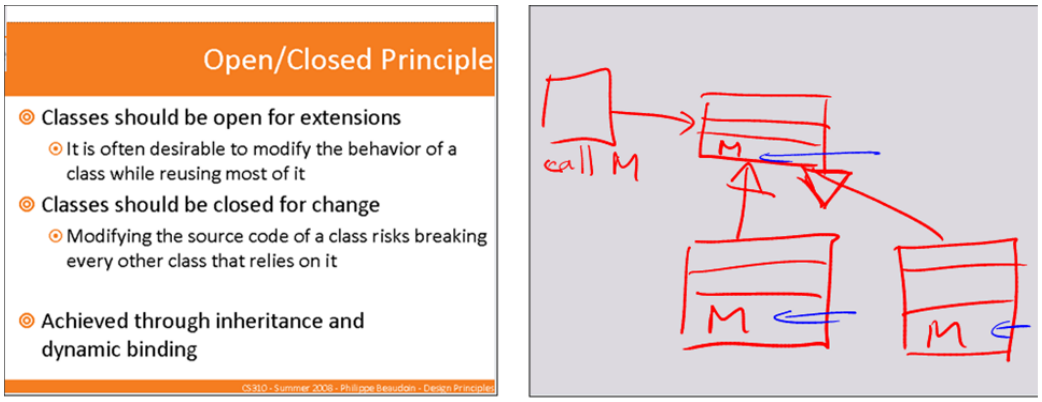


Figure 5.10 – Using ink together with slides

5.4.7 Using another environment along with slides

Using multiple screens, it can be useful to bring in content from different applications to show side by side. For example, an instructor can show a browser window or a document all from his or her laptop to display alongside the computer slides. An added benefit of using MultiPresenter's extended desktop configuration is that the audience does not see the instructor's desktop, so instant messaging and other notifications remain private. We have observed a history instructor show a movie on one screen alongside a slide

summarizing the major "take away messages" from the movie on the other screen. This can help show concrete examples that relate to the themes shown on the slides, while still seeing these themes summarized on screen.

5.4.8 Other inventive uses

On one occasion, we noticed that the instructor purposely put the same slide on both screens. The instructor then annotated two copies of the same slide in two different ways, emphasizing two different interpretations of the same diagram. On a couple of different occasions, instructors used the secondary screen to have an important notice (such as office hours, or cancellation of a lab) persistent during part of the class. Another use that one history instructor employed was to show a detailed image on one side (a map) with a section of it marked with a rectangle, and a zoomed view of the rectangle on the other screen. This provided the audience with an overview plus detail view of the map. Finally, one instructor used two screens to physically show a wide landscape image on both screens. This was in a classroom where the screens were located side by side without much space between them. The instructor had the landscape image partitioned across two slides and showed them side-by-side to create one wide image.

5.5 Instructors' interviews and feedback

We conducted interviews with six instructors that used MultiPresenter during at least one semester. We recorded the interviews, and transcribed five of the six. One interview was not transcribed because of technical problems with the recorder. Transcribed interviews are presented in Appendix E. We reviewed each interview's transcript at least twice. We report here on recurring themes and points of special interest revealed by our reviewing.

In general, instructors commented very favourably on the use of MultiPresenter and on using two screens for their presentations. All instructors said it was useful for them to use MultiPresenter, and they thought it helped students learn. All instructors said they would like to continue using MultiPresenter in classrooms that have two screens, and that they would recommend it to their peers. Most problems reported by instructors had to do with the technical difficulties of setting up the software to drive two screens, either due to problems with the video switches in the classrooms or with the Windows

OS selecting the proper display modes. While the computer science instructors had fewer problems with this, all history instructors encountered various levels of difficulties connecting their laptops to the screens in the classrooms they used.

Most instructors said they most often used dynamic presentations. I1, I2, I3 and I5 used dynamic mode almost exclusively, while I4 mixed her use, but used dynamic mode most and used dynamic mode and pre-made mode together (using the dynamic features on a pre-made presentation). Commenting on why they preferred dynamic mode, some instructors mentioned That using dynamic mode they did not need to put more effort into the class preparation process. Most instructors used existing PowerPoint decks, and using dynamic mode they could decide on-the-fly during the lecture how to convert the slides to two screens, not needing to decide ahead of time. Another reason given for using dynamic mode is that it is difficult to predict what will be needed in class. It is valuable to use the screen "as needed" *during* the lecture according to the way instructors perceive students' understanding. Some instructors also commented about being able to more easily address students' questions.

We asked instructors to comment about the ease and effectiveness of operating the software's interface. All instructors said that the interface was simple and intuitive to use. Nevertheless, a few mentioned that it did take them a while (a week or two) to get comfortable with the interface. More comments were received about getting used to teaching with two screens. A few instructors commented that it took them a while to get used to and to get the most out of using two screens. Some instructors had comments and suggestions about the interface that were noted and considered for subsequent versions. However, most problems that instructors encountered had to do with the technical difficulties of connecting the laptop to the two screens in the classroom.

We asked instructors whether they thought using two screens may be distracting or may convey too much information to students. All instructors said that in their experience they think this is not so. Most instructors said that they were aware of this possibility, and so they tried to minimize the amount of extra information on screen by having less information on each slide (I5 said "I think you should use it to display not that much more information, but to organize it better"), or to keep information on the

secondary screen longer and only keep relevant information up (I2 said "You always use the second screen for something relevant").

Finally, we present a comment from I6 about how MultiPresenter caused her to think about her lectures in a different way:

> "It actually changed the way I thought about my lectures. Which I thought was just an interesting pedagogical cognitive process for me to go to. Because when I used PowerPoint, or way back when I actually used slides or overheads there was one way that I would write my lectures. But given the capabilities of MultiPresenter to use two screens, I think that actually shaped the way that I structured the lecture. I would write the lectures, and I would often find that when I went to do the MultiPresenter presentation and thinking of the words and the slides that I wanted to use, that actually helped clarify some of the points in the lecture that I wanted to make. Because communicating, figuring out how to make that, how to convey a point on two screens would often make me clarify the point that I wanted to make in the lecture.... with PP there was one screen, so you would think a certain way, and you couldn't use too many images because you would also want to use some text. MultiPresenter kind of frees you from that.... I felt like I could do a lot more, and actually show maybe the process of how people drew conclusions."

5.6 Student survey

To assess students' subjective perceptions of the system, we asked students to fill out an online questionnaire about their attitudes and thoughts on the use of the presentation system in class. During the last week of the semester, we contacted students during class and asked if they would fill out an online questionnaire about the usage of the presentation system in their classroom. We also asked the instructor to post a link to the online survey in the class online teaching system. For further motivation, a $100 prize was awarded by a random draw between participants of the questionnaire.

The purpose of the survey was to get feedback and to help us evaluate MultiPresenter as well as to evaluate methods of learning with two displays. In

particular, the goals of the survey were to provide data about the *pedagogical* implications that MultiPresenter and using two screens had on learning (did students think it helped them learn, what features helped them learn, was it distracting), and to provide data about MultiPresenter's features (attitudes toward showing previous slides, "clipboard mode", etc.).

The questionnaire was divided into three sections:

1. A 5-point Likert scale to solicit students' opinions on nine statements that reflected students' opinions on the benefits and problems of MultiPresenter.
2. Students were asked to directly compare between MultiPresenter and PowerPoint presentations on a number of criteria using forced choice responses.
3. Unconstrained qualitative feedback was invited from participants of the survey.

The questionnaire was administered in nine classes taught by six different instructors. A total of 198 students filled out the questionnaire out of which 105 were male. Average age was 22.3 years (SD = 3.7). A copy of the survey is presented in Appendix F.

5.6.1 Likert scale questions

Questions and average Likert scores aggregated across the nine classes for the first section of the questionnaire are presented in Table 5.2. In the Likert scale, 1 represented strongly disagree, while 5 represented strongly agree.

Statement	Average	SD
1. Seeing two slides helped me understand the material better than a one-slide presentation	**4.05**	0.81
2. Having two screens helped the instructor present the material better	**4.24**	0.79
3. I would encourage other instructors to use two screens in a similar way	**4.24**	0.75
4. I had problems physically seeing one of the screens	**2.18**	1.20
5. It was good that the instructor had more space to write on (with electronic ink)	**4.01**	0.88
6. It was helpful for me when the instructor showed certain slides for longer periods on the second screen	**4.36**	0.75
7. It was helpful for me when the instructor used both screens to compare two slides	**4.27**	0.76
8. The presentation system helped increase my attention in the lecture	**3.52**	0.81
9. The presentation system helped me learn better	**3.85**	0.82

Table 5.2 – Student questionnaire results for section 1 (*N*=198 except for Question 6, where *N*=81 because only classes that used electronic ink were asked to answer.)

As seen in Table 5.2, students' general attitude toward MultiPresenter and the way instructors used the two screens was very positive.

5.6.2 Direct comparisons

In the second section, we were interested in a direct comparison of MultiPresenter with regular one-screen presentations. We first asked students to directly choose between MultiPresenter and PowerPoint as the preferred presentation system (students had to choose one or the other). As seen in Table 5.3, the vast majority of students preferred MultiPresenter over PowerPoint (159 vs. 14). Next, we asked participants to choose their preferred presentation system on four criteria. This time, they were allowed to choose "no opinion" if they had no opinion on their preferred system on that criteria. Results of the second section of the questionnaire are presented in Table 5.3. Due to an error with the online questionnaire, one class (with 17 participants) filled only the first part of the questionnaire. The number of participants in this part was therefore 173 instead of 198.

Statement	Multi-Presenter	Power-Point	No opinion
If you could choose one system as the presentation system in class, which one would you prefer the instructor to use?	159	14	
I learn better	109	14	47
The presentation structure is better for learning	133	12	28
The presentation is engaging	114	9	43
The presentation is more dynamic	142	10	20

Table 5.3 – Student subjective questionnaire, section 2 (*N*=173)

5.6.3 Unconstrained qualitative feedback

We gathered students' qualitative feedback using open ended questions to be able to classify data not only according to our pre-determined categories but also according to categories that might arise from students. To analyze these open-ended questions, we used a card sorting technique based on affinity diagramming (Figure 5.11). Affinity diagramming is a simple but powerful technique for grouping and understanding information (Preece, Rogers, & Sharp, 2001). It is used by having several people group pre-existing sets of information printed on cards or post-it notes on a surface. In our case, we first printed all student statements to a given open-ended question. Each statement was printed on a separate piece of paper. Two researchers then went over the statements one by one and grouped them according to similar themes. The groups were refined and rearranged during the process. Each new item had to be added to an existing group and agreed upon by the two researchers, which often led to further refinement of the groups. Finally, the categories were labelled according to the content of the group. Because we only wanted a rough categorization of students' feedback and did not perform any further analysis, we did not check for inter-rater reliability as we did in Section 3.2.5. A way to examine inter-rater reliability would have been to have one or more other people assign every statement to the list of categories we had developed and to then compare this assignment to our own.

Figure 5.11 – Card sorting: statements are printed and then grouped iteratively according to recurring themes. Groups are refined and rearranged during the process. Finally, groups are labelled to categories according to content.

Benefits of MultiPresenter

We performed an analysis on responses to the question: "What particular aspects of the presentation system or the way the instructor used the two screens did you like?" There were 136 answers to this question. Table 5.4 shows the main categories that arose from our analysis, sorted according to the number of comments. A single student response can include more than one comment so the total is more than 136.

Category description	Number of comments	Representative statement
Comparisons	39	"The instructor compared two different slides, which was very helpful"
Having image and text side by side	25	"It's nice to have a picture on one side and text on the other"
Overview and context	17	"... leaving up an overview slide while going more in-depth on the other screen"
Easier for note taking	17	"I don't have to rush to copy notes from the screen ... since I don't have to rush to copy notes, I can focus on listening to my instructor"
Referring to previous information	12	"When my instructor kept a slide up that had information that the other slide needed, it was helpful"
Having continuous information shown side-by-side (previous slide)	10	"In some cases, we need to look at pieces of code which resides on two (or more) pages. Because the next slide references the previous slide, MultiPresenter made the student's lives a bit easier"
Question and answer	10	"Having the question, or data for questions on one slide, whilst doing the work on the other projector"
Having longer time to view information	8	"I liked how it gave you a longer time to understand the slides"
Seeing more information	7	"We could see twice the amount of information at the same time"
More space	4	"I liked that there was more space, the individual slides were less jumbled"
More engaging	3	"It was more interesting having two images to observe, especially for comparing visuals"
Using electronic ink	3	"While showing a slide, the instructor was able to write notes on the other to give examples and such."
efficiency	2	"It saved time. We didn't need to move the slides repeatedly to see pictures and the articles; they were visible at once"
organization	2	"Information was organized in a better way that better communicated the content with two screens."
Untagged (no group)	3	"Something new I have never really seen before"

Table 5.4 – Categories of open-ended comments on the benefits of using MultiPresenter (*N*= 136 student responses. A single response can fit in more than one category)

The most predominant statement pertaining to the benefit of MultiPresenter was about the ability to compare two slides or two items (39 comments). Students mainly said it was helpful for them to see comparisons of slides or information, but also said it was beneficial to compare maps (3 comments), images (2 comments) and code (1 comment). Comparing information usually means examining two pieces of information in order to find similarities and differences between them. However, comparing two pieces of

information on two screens is similar to showing additional information on the second screen. As one student noted, it was useful to have "the ability to show more than one slide at a time, to compare or enhance what appeared on the other side".

Regarding using one display to enhance what appeared on the other side, many students (25) commented on having images and notes side by side as an aspect they liked about the use of the presentation system in their class. Many of these comments were from class C11 (see Table 5.1) in which the instructor (I6) used MultiPresenter in a distinct way. As discussed earlier, I6 solely used a ready-made dual-screen presentation style in which she had text outlines on one screen while going over a number of image or quotation examples on the other screen. This style also fitted the overview and context category (which had 17 comments).

The question and answer category, on the other hand, came mainly from the computer science courses. In computer science, unlike history, it is common to show a problem and then show the solution as a way to learn new techniques. In this category (10) students commented that it is useful to have the problem or question slide persist while one or more answer slides explained the solution.

Referring to previous information (12) and showing previous slides (10) were also categories that students commented about. Within the comments about referring to previous information there was a distinction between keeping information for subsequent reference, and bringing information back.

Drawbacks of MultiPresenter

We also performed an analysis on responses to the question: "What particular aspects of the presentation system or the way the instructor used the two screens did you dislike?" There were 105 answers to this question. Table 5.5 shows the main categories that stemmed out of our analysis, sorted according to the number of comments. A single student response can include more than one comment so the total is not 105.

Category description	Number of comments	Example statement
Technical problems	26	"Sometimes there were technical difficulties at the beginning of class"
Problems with software (bugs)	10	"The system sometimes seemed finicky and the professor had to spend time trying to figure out exactly how to use it"
Hard to pay attention	8	"Hard to pay equal attention to both slides simultaneously"
Too small	7	When three or more pages were put up at once they became too small to read easily
Unclear where the instructor is referring to.	7	"Having two different slides at once is slightly confusing since it could be difficult to tell which one the instructor is referring to sometimes"
Projector problems	6	"One of the projectors is darker than the other, hence it is difficult to see at times, especially if you're sitting at the far extremes of the classroom"
Too much information	5	"Sometimes there seemed to be too much information to take in"
Too fast	4	"Sometimes the instructor went too fast through the slides. It takes more time to look at two slides."
Problems with electronic ink	4	"The electronic ink lags in time"
Difficult to see both screens	3	"Seeing both screens can be hard from certain points in the room, especially from the sides"
Difficult to follow on laptop	2	"If I view the slide on my own laptop, sometimes it's hard to decide which page I should read on my laptop"
Having the same slide on both screens	2	"I disliked when both screens showed the same slide. I found it hard to read what it said, as I was jumping back and forth to confirm they were the same slide"
Difficult to take notes	2	"Sometimes it's hard to write down both things written on both slides when the instructor takes them both away"
Having two images	2	"I didn't find it very helpful when she used images on both the slides"
Instructor's learning curve	1	It was a bit frustrating when the instructor was still trying to figure the system out, but once he had a bit more practice it was fine
Nothing	21	"nothing"
Uncategorized / unclear	6	

Table 5.5 – Categories of open-ended comments on the down sides of using MultiPresenter (*N*= 105 student responses. A single response can fit in more than one category)

We can see from Table 5.5 that the top two categories had to do with technical difficulties (26 comments) and problems with the software (10 comments). Most of the comments about technical difficulties referred to the set up at the beginning of the class, and the wasting of time that accompanied it. This most probably refers to instructors'

problems with connecting the two screens to their laptop in extended desktop mode, either because of room setup problems (with the room controller) or Windows OS problems. Although during interviews instructors stated they did not think this was a big problem, students did not like seeing their instructor struggle with the technical arrangements. Projector problems (6 comments) are also considered technical difficulties. They were mostly from one class in which one of the projectors in the classroom was substantially darker than the other. Most of the comments from the 'Problems with the software' category had to do with software bugs, and with the instructor having difficulties with the software during class. Problems with electronic ink (4 comments) were bugs that were later fixed.

Some students (8) commented that it is difficult to pay attention when there is more information on the screen. Similarly, some found it difficult to know where the instructor was referring (7). Too much information, especially when the instructor changes two slides simultaneously was overwhelming to some students (5). This suggests that when the flow of the information on the screen is not clear, students may encounter difficulties in connecting the instructor's commentary with the visual aid and might not know where to direct their attention.

The "Too small" category (7 comments) refers to when the instructor puts two or more slides on the secondary screen (either dynamically or showing two or four previous slides). The system automatically scales the slides to fit more than one slide on the screen. This causes the slides, that were usually designed to be seen on an entire screen to be seen scaled down by a factor of around two. Students commented on it being difficult to read text slides that are scaled down, especially when sitting far away.

5.7 Discussion

In this section, we triangulate information from the different sources of data presented in this chapter and summarize and discuss the important findings from MultiPresenter's deployment. We found much support for the benefits of MultiPresenter's approach. Student responses were overwhelmingly positive, and all instructors who used MultiPresenter thought it was helpful and beneficial in their classrooms. We first discuss

the benefits of using MultiPresenter that we found, both those that were expected and those that were unexpected, and also detriments of using MultiPresenter with two screens. We then discuss limitations of our evaluation and of the MultiPresenter approach.

5.7.1 Benefits of MultiPresenter

We based the design of MultiPresenter on the design guidelines outlined in Section 3.5. We briefly discuss here the realization of the persistency and flexibility guidelines. We then discuss a few unexpected benefits that we found when using MultiPresenter with two screens. We will further discuss how our experience with MultiPresenter validated some of the design guidelines from Section 3.5. In Chapter 7 we refine these guidelines according to the findings from our deployment.

Persistency

One of biggest benefits of having a larger screen surface is the ability to have important or relevant material persist longer. Instructors extensively used the secondary screen as a place to hold persistent information. Students thought it was beneficial for information to persist. In student questionnaires, the statement: "It was helpful for me when the instructor showed certain slides for longer periods on the second screen" got a very high score of 4.36 in a 5-point Likert scale, and many students commented favourably about their instructor keeping information persistent. One student commented: "Having the main presentation material plus the secondary reference material available to look back at was extremely helpful for me." We observed three ways in which instructors caused information to persist.

The first way was when instructors brought back previously shown information. This was triggered by an instructor's need to show previous material, usually to help explain the current information or to answer a student's question. Often in a blackboard lecture, instructors refer back to previously written information, sometimes even to information written thirty minutes back. This is done to relate the current theme to a previously taught one, and to show how the current information relies upon the previous information. Visually referring students to the previously taught information presumably helps students integrate their knowledge by seeing the related information side by side.

Although possible using the presenter's view in PowerPoint, it is difficult to directly go to a previously shown slide without knowing its slide number. In the default presentation mode, the instructor needs to flip back through his or her slides, find the related slide, and revert to that slide. Also, when going back to the previous slide, students do not see the current slide and thus probably cannot visually integrate the two pieces of information as easily. That may explain why reverting to previous slides was observed to happen rarely if at all when using PowerPoint. Using MultiPresenter, the instructor simply brings the related slide to the secondary screen, allowing students to visually integrate previously taught information with the current theme. MultiPresenter affords simple navigation of slides using the instructor's view to easily see and jump to previous and future slides. Using MultiPresenter, we observed that often during the lecture, when the instructor referred back to previously shown information, he or she put the previously shown slide on the secondary display. The instructor usually kept that information alongside the current slides until it was no longer relevant to the current theme.

In the second way the persistence is achieved, an instructor would go over the stream of slides and decide *during* the lecture to keep the current slide available for longer. Instructors recognized the need for persistence as they went through a slide and spontaneously decided to keep it for longer viewing. For example, I3 commented: "It really helped me do things like emphasize the importance of something by leaving it there. I could then also easily use that information later on".

The third way that persistence is achieved, an instructor decides in advance that a certain slide such as an overview slide should persist for longer. This can be with a pre-made presentation in which the instructor sets a slide to be persistent alongside a stream of slides, or dynamically during the lecture when the instructor brings up a slide before it has been seen by the students.

Flexibility

Most instructors used MultiPresenter in dynamic mode. Instructors liked the ability to decide during the lecture how to use the secondary display, mainly to have more flexibility in the delivery of the lecture. I5 commented: "I often found that what I thought would work sitting here in the office didn't quite work in front of the students, and so that is why I would find it better to put it up on the fly". We saw that some

instructors recognized the need for persistence as they went through a slide, deciding only after they had used it that it should persist. Using electronic ink was another way for instructors to be flexible in their delivery. The need for a flexible use of the screen was emphasized by I4 and I5: Although they built pre-made dual-screen presentations, they still used the dynamic features during their lectures. Students seemed to appreciate the more dynamic nature of classes, rating MultiPresenter to be more engaging and more dynamic. I2 commented on keeping students engaged: "The power of the second monitor comes that it opens up for so much more interactivity during the course, and that is a key to keeping attention of the students longer".

Comparisons

Although our emphasis before deploying MultiPresenter was persistency and flexibility, we found out some added benefits afforded by MultiPresenter that our design guidelines from Section 3.5 did not predict, but nevertheless were very helpful for students and instructors. First, we found out that comparisons are a very powerful tool in teaching. MultiPresenter enables a more natural way to compare two items than PowerPoint, by simply putting the two items on the two screens, without the need to cram them both onto one slide. Comparisons were commented on very favourably by students who mentioned them in the open questions, and giving the statement "It was helpful for me when the instructor used both screens to compare two slides" 4.27 on a 5-point Likert scale. All instructors used comparison techniques and commented favourably on their utility.

Overview

Some instructors (mostly the history instructors) used an approach of having an overview slide on one screen while showing the detail slides on the other. This approach was liked by instructors and was highly appreciated by students as reflected in their open ended comments. This is not surprising: other researchers have also emphasized the advantages of having overview information available in multimedia learning (Mautone & Mayer, 2001; Shapiro & Niederhauser, 2004). The benefit of the approach taken by the history instructors is backed up by the literature. The segmenting principle (Mayer & Chandler, 2001; Mayer, 2005) states that people learn more deeply when a multimedia message is presented in learner-paced segments rather than as a continuous unit. By presenting each

segment as an overview slide on one screen and detail slides on the other screen, instructors were able to better segment and structure their talks. The overview slide was also used to list the main concepts such as the details about a Roman emperor when going over a summary of his accomplishments. The benefit of this approach is supported by the pre-training principle (Mayer, 2005) that states that people learn more deeply from a multimedia message when they know the names and characteristics of the main concepts.

Farkas (2009) notes the problem of keeping the hierarchy of a slide deck understandable. Because the title font attributes of each slide are often the same, it is difficult to understand the hierarchy of the talk when viewing it. This would be similar to trying to understand this dissertation's logical structure had all of the header styles been typographically the same. Farkas suggests having an overview slide or section slides appear throughout the talk, or to have category slides that introduce a grouping of a few slides, before those slides are shown. With multiple screens, showing an overview slide is simple and natural to do.

Images beside text

Many students liked the practice of showing images beside text. Specifically they liked how I6 added more slides and kept an overview text slide available alongside many example images. I4 and I5 used a similar technique. While this is a specific case of showing overview information, there is clear benefit in showing more image information. I6 commented that using a two-screen presentation allowed her to show more images, without losing the context of images to the theme. This is supported by studies that have found that using graphics in visuals increased recall attitudes toward the shown material (Benbasat & Dexter, 1985; Rossiter & Percy, 1980).

5.7.2 Detriments of using two screens

While there are many benefits for using multiple screens in classrooms, there are also some hazards that instructors should be aware of. We were concerned that using more screen real estate might be distracting to students. While instructors did not think this was the case, some students did comment on lectures being difficult to pay attention to, having too much information, and being too fast. Another concern some students noted

was that it was sometimes difficult to know which screen the instructor was referring to. With multiple sliding boards, this is usually not a problem. The current focus of the instructor is set according to the instructor's position and where she is writing, and her gestures at the different boards when needed. Moreover, the movement of the boards provides the audience with a positional memory of the sequence in which the writing took place. With sliding boards, information does not appear at once as it does with slides. We imitated this in MultiPresenter with the clipping feature and the slide-back feature. However, both of these features were seldom used by the instructors we observed. We believe that many of the student comments about attention difficulties refer to when both screens changed information simultaneously. Instructors should be aware of how much information is added at once. The problem of disembodiment of the instructor when operating slideware is something that MultiPresenter does not yet address, but suggestions for how this might be ameliorated are given in Chapter 7.

Other than one instructor, all instructors almost exclusively used full slides on both screens and did not put multiple slides or clips on the secondary screen, although this is possible to do with MultiPresenter. It is important not to overload instructors with possibilities and functions. During class, instructors need to focus on their teaching task, and cannot spend cognitive effort to decide how to use software. Instructors are used to working with the slide metaphor, and any change from this requires extra effort either before the lecture (by planning), or during the lecture. Presenting several slides on one screen may not be a good practice. Students commented on slides being too small in the class in which the instructor put several slides on the secondary screen. Slides that are usually designed to be seen on a full screen may not be legible when downsized.

5.7.3 Limitations

Most instructors used a ready-made PowerPoint slide deck from previous years as a basis for their MultiPresenter presentations. This, as they reported, affected the way that they used MultiPresenter. Some of the instructors made some changes to their PowerPoint slides prior to class so the slides would work better on two screens. Others simply used their existing slide decks and only decided during class how to best use them with two screens. An exception was I6 who taught a new class and designed her slides from the

outset for two screens. I6 commented (see Section 5.4) that this changed the way she thought about and designed her lectures. Indeed, her use of overview text slides beside detail image slides appeared to be very effective and was favoured by students. Although MultiPresenter is designed to support instructors using old PowerPoint slide decks, we believe that instructors building their presentations with more space in mind can benefit their students most from fully using its feature set.

We have seen clear differences between the way the computer science and the history instructors used MultiPresenter. The computer science instructors used mostly the dynamic features, used electronic ink, and often referred back to previous information. The history instructors often used pre-made presentations, and liked the practice of using an overview plus detail view or a text plus image view. While the history instructors did use dynamic mode as well, unlike the computer science instructors, they would rarely bring previously shown slides back, but rather they arranged the slides on the two screens as if it was a pre-made presentation. While some differences had to do with the higher technical abilities of the computer science instructors (the computer science instructors had less set-up problems), most differences stem from the inherent differences between the two subject areas and the ways instructors teach in these areas. While we believe that most of our results are generalizable, we should be cautious about generalizing them to other subject areas. Having more instructors from other subject areas use MultiPresenter might reveal other uses.

At least one interpretation of the Hawthorne effect refers to the fact that any intervention tends to have a positive effect merely because of the attention the experimental team give to participants (Brown, 1992). It is possible that student questionnaires were skewed favourably toward MultiPresenter because they knew they were evaluating a new tool that was chosen by their instructor. However, we believe that the extent of the results and the strong preference for MultiPresenter could not have been reached solely because of the Hawthorne effect. Our intervention in the classroom was kept to the minimum necessary to support instructors using the system. Students were oblivious to the software or the research and simply experienced a different kind of lecture. Instructors, however, were more involved in the research goals and might have

favoured MultiPresenter because of the Hawthorne effect. While this might be the case, it does not undermine their responses about the pedagogical benefits and does not explain why instructors continued to use MultiPresenter even after we stopped monitoring their classes. From our experiences with the instructors, we believe that in their interviews they spoke honestly about their experiences and opinions pertaining to MultiPresenter.

5.8 Summary

Based on our analysis of classroom usage, we believe that MultiPresenter is a powerful educational tool. We described how it was used in classrooms, and classified instructors' usage patterns when lecturing with two screens. Results from the deployment of MultiPresenter were very positive: both instructors and students thought the system was beneficial for learning. Despite the positive responses, in such a deployment it is difficult to empirically demonstrate that MultiPresenter improves learning. Usage data and questionnaires provides much insight and understanding, but do not constitute scientific evidence of pedagogical benefit. In the next chapter we present a controlled laboratory study that examines whether MultiPresenter actually improves learning over "conventional" slideware.

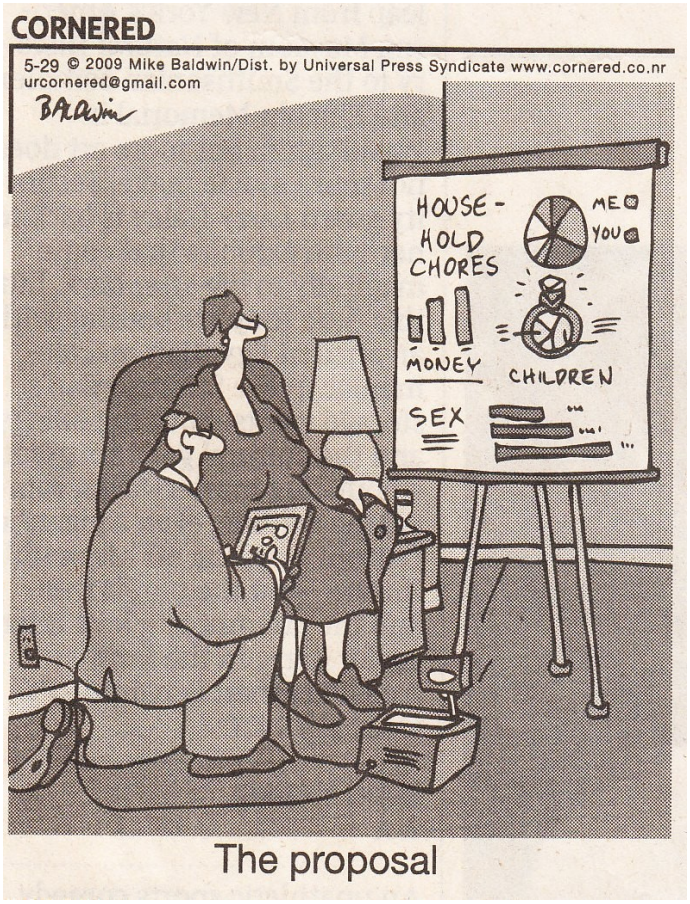


Figure 6.1 – A newspaper comic by Mike Baldwin poking fun at the widespread acceptance and ubiquitous use of slideware, especially in situations for which it was not intended. This raises the question of what benefits we can hope to provide with improvements to presentation software. Used by permission.

Chapter 6

Examining Learning with More Screen Real Estate: A Controlled Laboratory Experiment

In Chapter 5, we explained how MultiPresenter was used to utilize two screens in actual classrooms. We described our observations, the different usage patterns, and instructors' and students' subjective impressions of learning advantages using multiple screens in a classroom. In this chapter, we present a controlled laboratory study that we conducted in order to empirically assess the effect that increasing classroom screen real estate can have on students' learning. We first describe our objectives and the approach and methodology we used. We then present the results of this study and discuss the results' interpretation and implications.

6.1 Study objectives and approach

The primary objective of the study was to more thoroughly examine the relationship between screen real estate and learning in a typical classroom presentation scenario. Although in Chapter 5 we have gathered much subjective evidence on the utility that using more screens might have on teaching, both from the instructor's perspective and from students' perspective, this does not necessarily indicate that using more screens improves actual learning. For example, most students prefer that instructors use computer slides in their classrooms, although most studies haven't been able to show that computer slides improve learning over traditional visual aids (Levasseur & Sawyer, 2006). Our main objective in this study was therefore to first show that indeed more screens can improve learning. However, as we saw in Chapter 5, there are many ways in which instructors utilize two screens. A secondary objective was thus to drill down and examine in what cases does using a second screen improve learning, in which cases might more screen real estate not necessarily help, and might there be times in which it can even hinder learning.

With these objectives in mind, we designed a controlled laboratory study that simulated a classroom lecture with two conditions: (1) a "regular" *one-stream* lecture given with PowerPoint slides as the main visual aid, and (2) a *two-stream* presentation powered by MultiPresenter. The lectures were similar in all respects except for the use of the secondary screen in the second condition.

To drill down into how the usage of extra space can support or hinder learning, we examined several categories in which instructors used two screens in actual classrooms, as described in Section 5.3. We incorporated these categories into a controlled lecture setting, and assessed each category separately. The following three categories were based on usage we observed in actual classrooms:

Showing pertinent information from previous slides. As seen in Section 5.3.2 and discussed in Section 3.3.4, one of our main hypotheses is that showing pertinent information adjacent in space, instead of sequentially over time, is beneficial to learning. By presenting relevant information that was already seen in the lecture again, beside the current slide, students can use the previous information to better learn the information currently in focus.

Showing the previously shown slide. As seen in section 5.3.1, a usage pattern exhibited by instructors was simply to show the previous slide on the secondary screen. This allows students to see information longer, which can help students copy notes, and enables them to focus on information according to their needs. However, if the previous slide is not related to the current one, students might be distracted or lose track of the current theme.

Comparing information. As seen in Section 5.4.1, instructors often used two screens to compare two items, one on each screen. This separation, as opposed to forcing the two items onto one slide, can emphasize the differences between the two items.

In addition, based on the literature and on assumptions from our observations, we added the following two categories:

Verbal information. A study by Savoy et al. (2009) found that auditory information delivered in the presence of PowerPoint is more difficult to recall than in a traditional blackboard lecture. Therefore, it might also be the case that showing more information on two screens might hinder the verbal information conveyed by the instructor as opposed to a one-stream presentation. This category examines information that was only conveyed verbally and was not displayed on-screen.

Graphical vs. Textual information. Savoy et al. (2009) also found differences between how students learned from graphical and textual information on slides. We examined whether there is a difference when the previous information displayed on the secondary screen was graphical or textual.

In addition to the category-specific data, we were also interested in gathering user preference data regarding the use of MultiPresenter in comparison to a one-stream presentation, as well as users' opinions of the categories stated above.

6.2 Methodology

The experiment was a 2x2x2 mixed incomplete design with delivery style (one-stream or two-stream presentation) and lecture topic as within subject variables and lecture order as a between-subject control variable. The design is considered incomplete because each participant viewed each lecture topic with only one of the two delivery styles. We further describe the variables and experimental design in the following sections.

6.2.1 Participants

There were a total of 103 participants taking part in the study out of which 53 were male and 50 were female. The average age of participants was 23.6 years (*SD*=5.3). Participants were recruited via recruitment ads that were posted throughout the university, and recruitment emails sent to groups of students. Although we targeted the student population as our main audience for the study, we didn't limit participants to students. The majority of participants were undergraduates (82), while there were some graduate students (12) and a few non-students (8). Students majored in a wide variety of

subject areas including accounting, arts, biology, chemical engineering, civil engineering, commerce, computer science, creative writing, economics, electrical engineering, forestry, general science, geology, life sciences, nutrition, pharmacy, political science, and sociology.

Participants were asked about their familiarity with computer slides as visual aids in lectures. We asked them approximately how many courses they had attended in which the instructor used computer slides as the main visual aid. Most participants (72) indicated that they attended 7 or more such courses. Seventeen participants indicated attending 3-6 such courses, 9 participants indicated that they attended 1-2 such courses, and only 5 participants indicated that they hadn't attended any courses in which the instructor used computer slides as the main visual aid.

6.2.2 Independent variables

The main variable in which we were interested was ***delivery style***. There were two delivery styles used. In the *one-stream* condition, the lecture was supported by a regular stream of PowerPoint slides as in a regular PowerPoint lecture. In the *two-stream* condition the lecture was supported by two streams of slides projected onto two screens.

Lecture topic – There were two lectures presented to participants, one on the topic of the human *visual system* and one on the topic of the human *auditory system.*

Lecture order – The order in which the lecture topic was shown to participants was a between-subjects control variable to test any order or fatigue effects that might take place between the two lectures.

6.2.3 Materials

The lecture slides were adapted from two lectures in the same cognitive psychology course, one on the human visual system and one on the human auditory system. We chose a continuous subset from each of the original sets of lecture slides and made only minor changes to the slides, mostly to simplify concepts that had been explained in previous classes. Transcripts of the lectures were written to fit the slides based on available information on the web and from the course textbook. The visual system lecture started by explaining the basic characteristics of light and how we perceive light. The majority of the lecture described the anatomy of the eye including the function of the

various cells in the retina. The auditory system lecture first described what sound is and how we perceive it, and then described the anatomy and function of the ear, including the inner ear and the vestibular system.

For the one-stream delivery style, we simply used the lecture slides as described, and projected the same slide on both screens in the lecture hall. For the two-stream condition, we showed the exact same slides as in the one-stream condition on the left screen (the primary screen). However, on the right screen (the secondary screen) we showed selected slides that were previously shown on the first screen. Slides shown on the secondary screen were either the immediately previous slide from the primary screen, or older previously shown slides that related to the current slide on the primary screen. The basic concept in the two-stream condition was that the primary screen is the focus, and shows the regular visual support for the talk, while the secondary screen shows supporting material. Figure 6.2 shows an example of both lecture style conditions. The left image is the primary screen while the right image is the secondary. No new information was introduced on the secondary screen in the two-stream condition, although more information was shown at one time. The verbalized transcript for both conditions was exactly the same. The full set of lecture slides used in the study and transcripts for both lectures are presented in Appendix G.

To make this clearer, we will describe for a portion of one of the lectures what was presented on the secondary screen in the two-stream condition. During the first slide, the secondary screen was empty (because we didn't have information to put on it). For the next seven slides, the previous slide from the primary screen was shown on the secondary screen. Then, for the next four slides an important concept slide (that was shown on the primary screen in slide 7) remained on the secondary screen for reference.

Presentations were run from a Lenovo X61 laptop connected to the two projectors in the room. For the one-stream condition, Microsoft's PowerPoint 2007 was used to run the presentation. For the two-stream condition, we used the MultiPresenter software to run a ready-made two-screen presentation. To display information on the two screens from one laptop, an EVGA UV+ USB monitor adapter was used.

The visual lecture consisted of a total of 21 slides. The auditory lecture consisted of a total of 19 slides. Average time for the visual system lecture was 17 minutes and 33

seconds. Average time for the auditory system lecture was 19 minutes and 1 second. To ensure that there were no significant differences between the time the instructor spent on the different slides, we recorded the presenter's screen during the four sessions (see Section 6.2.5) and measured all slide times for each lecture. Significant correlations on slide times were found between all groups in both the auditory and the visual lectures ($p<.001$), suggesting that the verbal delivery was very similar across the four sessions in both lectures.

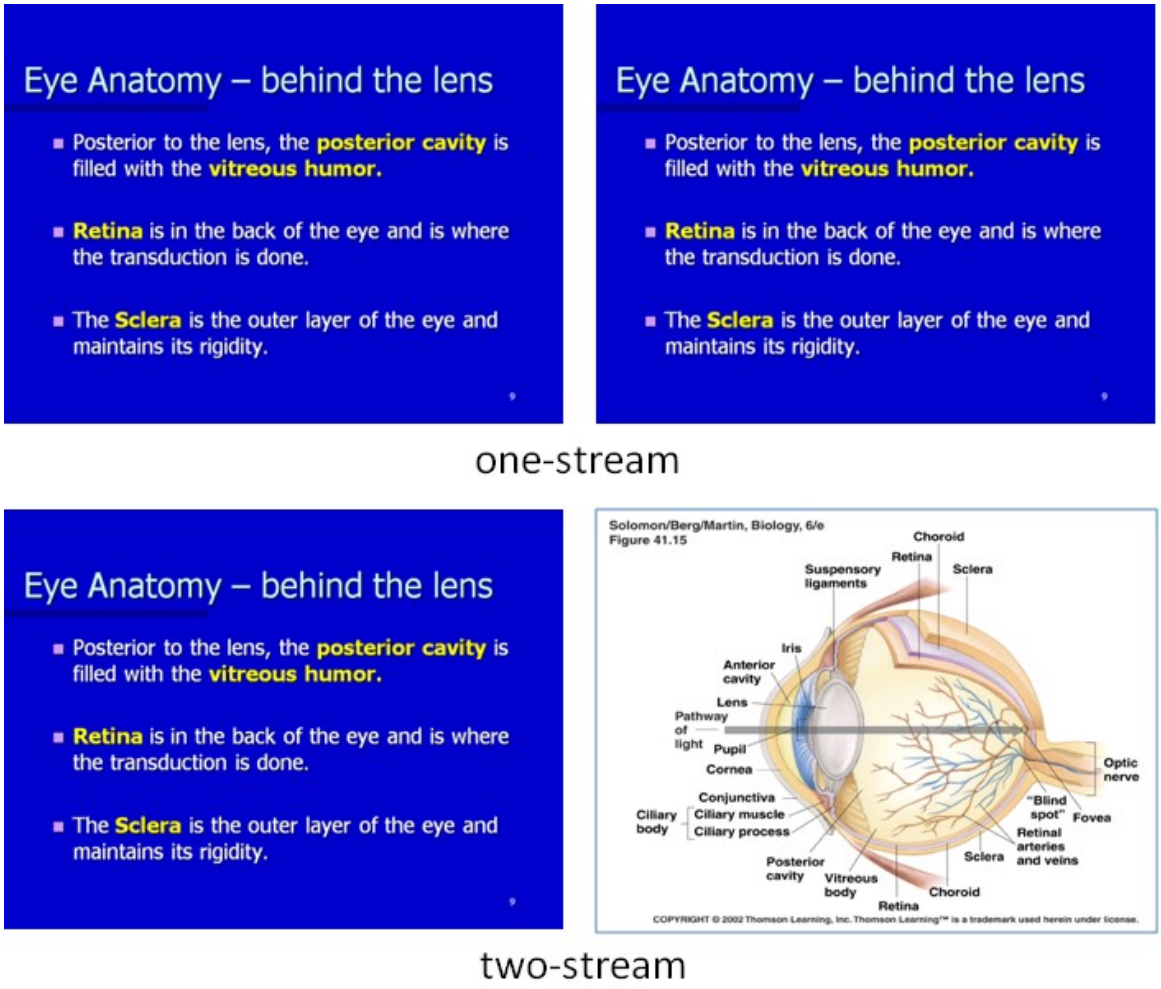


Figure 6.2 – Example of what was seen by participants in the one-stream (top) and in the two-stream (bottom) conditions.

6.2.4 Measures

To assess participant performance and to get subjective opinions, we administered several assessment quizzes. Table 6.1 presents the different quizzes administered in the study. As described later in Section 6.2.5, participants were requested to attend two sessions. During the first session they first completed the pre-test quiz. Then, participants experienced two lectures. After each lecture they completed an immediate retention quiz on the lecture topic. At the end of the first session they filled in a subjective questionnaire. Participants returned a week later for a second session in which they completed a deferred retention quiz that consisted of the exact same questions from both of the immediate retention quizzes of the first session. Then, participants completed a visual recall quiz. We will describe the details of these quizzes in the rest of this section. All quizzes are fully presented in Appendix H.

QUIZ NAME	SESSION	DESCRIPTION
pre-test	first	Ten multiple-choice questions, five on each topic. Questions were taken from the eye and ear immediate retention quizzes.
eye immediate retention	first	Fifteen multiple-choice questions on the eye lecture, three in each category.
ear immediate retention	first	Fifteen multiple-choice questions on the ear lecture, three in each category.
questionnaire	first	Subjective opinions of participants
deferred retention	second	Thirty multiple-choice questions on the ear and eye lectures. Questions were the same as the eye and ear immediate retention in the first session, but not in the same order.
visual recall	Second	Two quizzes, one for the ear and one for the eye, requiring matching between a diagram with empty labels and the corresponding text terms.

Table 6.1 – Quizzes administered to participants

Immediate retention quizzes

To assess participant retention immediately after the lecture related to the delivery style (one-stream vs. two-stream), we developed a multiple-choice paper-based quiz. Each

lecture topic had a quiz that consisted of 15 questions, each of which had four possible choices for answers.

Questions assessed basic information recall and were based on Bloom's taxonomy of learning objectives (Bloom & Krathwohl, 1956). Bloom's taxonomy identifies three domains of educational activities: *cognitive*, *affective*, and *psychomotor*. The cognitive domain is often used to describe questions in assessment quizzes (Savoy et al., 2009; Stephenson, Brown, & Griffin, 2008). The cognitive domain is divided into six major categories starting from the simplest behaviour to the most complex (Figure 6.3). Usually, Bloom's categories are thought of as degrees of difficulty. That is, the first one needs to be mastered before the next one can commence. The first category is *knowledge* which refers to recall of data. The second is *comprehension* which refers to understanding the meaning of the information. *Application,* the third category, refers to the use of previously learned information in new situations. The top three categories are *analysis, synthesis* and *evaluation*. Similar to Savoy's approach (Savoy et al., 2009), our assessment questions were chosen focused on the knowledge category within the cognitive domain of Bloom's taxonomy. We decided not to explore other categories because in a one-hour session it is difficult to reach a deeper level of learning; it is also more difficult to assess the higher categories. Future work can examine whether more space affects higher-level categories of learning.

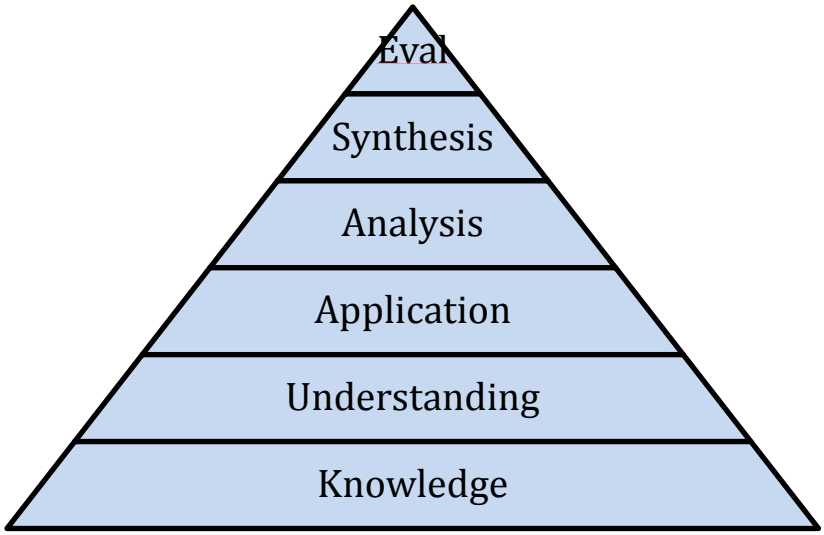


Figure 6.3 – Categories in the cognitive domain of Bloom's Taxonomy (Bloom & Krathwohl, 1956)

Immediate retention quiz categories

We were interested in categorizing the quiz questions according to the study objectives as listed in Section 5. In order to achieve that, we looked at several attributes of the two-stream presentations. First, we looked at the *temporal* attribute which refers to the temporal relationship between the information displayed on the primary screen and on the secondary screen. The secondary screen always shows information that was previously shown on the primary screen. However, this information can be recent or older. Second, we looked at the *modality* of the information. The information can be presented in graphic, textual or verbal-only form. The third attribute we looked at was the *spatial* attribute, which refers to whether the spatial relationship of information in a given slide has changed between the one-stream and the two-stream presentations.

Questions were categorized into five categories according to these attributes to examine the different ways in which two screens can be utilized. Because of the many possible permutations, we could not examine every combination of these three attributes. Future studies should examine the missing combinations (for example, examine long-term graphic vs. long-term text). For each lecture quiz, there were three questions of each of the following types:

Short-term text - The information necessary to answer questions in this category was presented in textual form (usually bullet point) on slides that in the two-stream condition were shown only once on the secondary screen. The slide with the answer was first shown on the primary screen when it was focused on by the instructor and then shown on the secondary screen as the instructor moved to the next slide (as the "previous slide").

Short-term graphic – The information necessary to answer questions in this category was presented in graphical form (usually a diagram) on slides that in the two-stream condition were shown only once on the secondary screen. The slide with the answer was shown on the secondary screen immediately after it was shown on the primary screen (as the "previous slide").

Long-term persistency – The information necessary to answer questions in this category was presented on slides on the primary screen. However, in the two-stream condition a slide that was previously shown in the lecture appeared again on the secondary screen (often, it simply persisted on the secondary screen for more than one primary slide). The information on the secondary screen was pertinent to the answer and reinforced or added another dimension to the answer. Information could be either graphic or textual.

Compare – The information necessary to answer questions in this category was in slides that compared two items. In the one-stream condition, the two items were presented side by side on one slide. In the two-stream condition, each item was presented separately on a single slide, and the two slides were presented side by side on the two screens. These slides are the only case in which the primary screen in the two-stream condition was not equivalent to what was shown in the one-stream condition.

Verbal – The information necessary to answer questions in this category was only presented verbally by the lecturer and was not present at all on the slides.

Pre-test and deferred retention quizzes

The pre-test quiz consisted of 10 questions, 5 questions on each lecture topic. The questions were selected from the immediate retention quiz of each topic, one question from each category mentioned above.

The deferred retention quiz, which was administered in the second session, included 30 multiple-choice questions, 15 on each lecture topic. It was comprised of the exact same questions from the eye immediate retention and ear immediate retention quizzes. However, question order and answer order were altered to minimize participants' priming of answers according to location in the quiz.

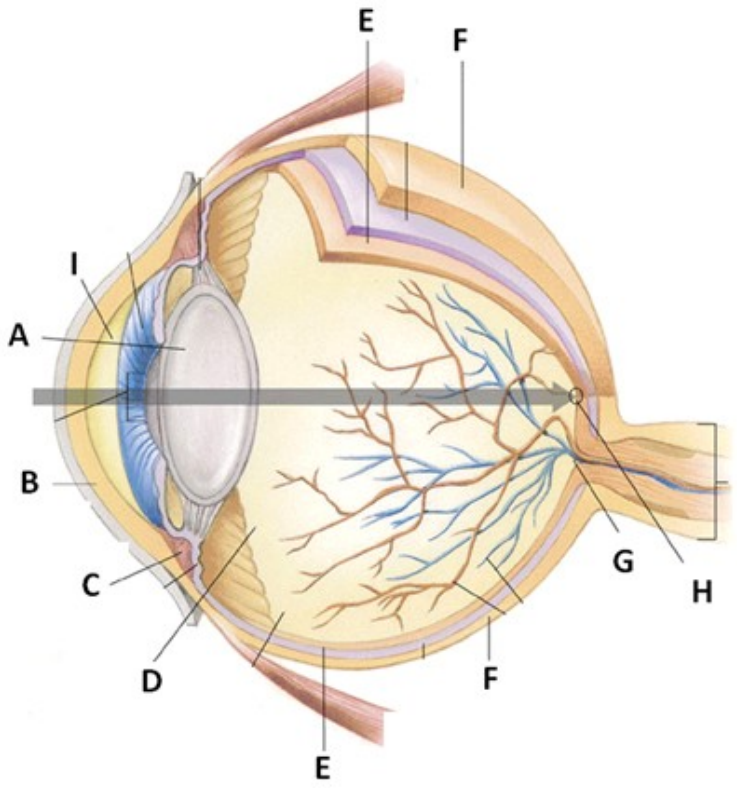
Questionnaire

A paper-based questionnaire was developed to gather information about participants' experiences and opinions. The first part of the questionnaire included personal information such as sex and age. The second part of the questionnaire asked participants to directly compare between the two lecture styles and to choose one of them (or "no opinion") for a set of criteria. The third part of the questionnaire asked participants for their opinions on different aspects of learning with multiple screens using a 5-point Likert scale.

Visual recall quiz

Figures 6.4 and 6.5 show the visual recall quizzes for the eye and the ear lectures. The visual recall quiz was developed to further examine the long-term persistency category, and was only administered in the second session. An image of the eye anatomy and the ear anatomy were presented to participants. Each image had nine areas on the image labelled from A to I. Participants were presented with six labels (e.g., retina, lens, cornea), and were requested to put the corresponding letter beside each label. These questions are considered long-term persistency categories because in both lectures, the ear or eye diagram was presented on the secondary screen alongside several other slides as a referral diagram.

Given the following Image:

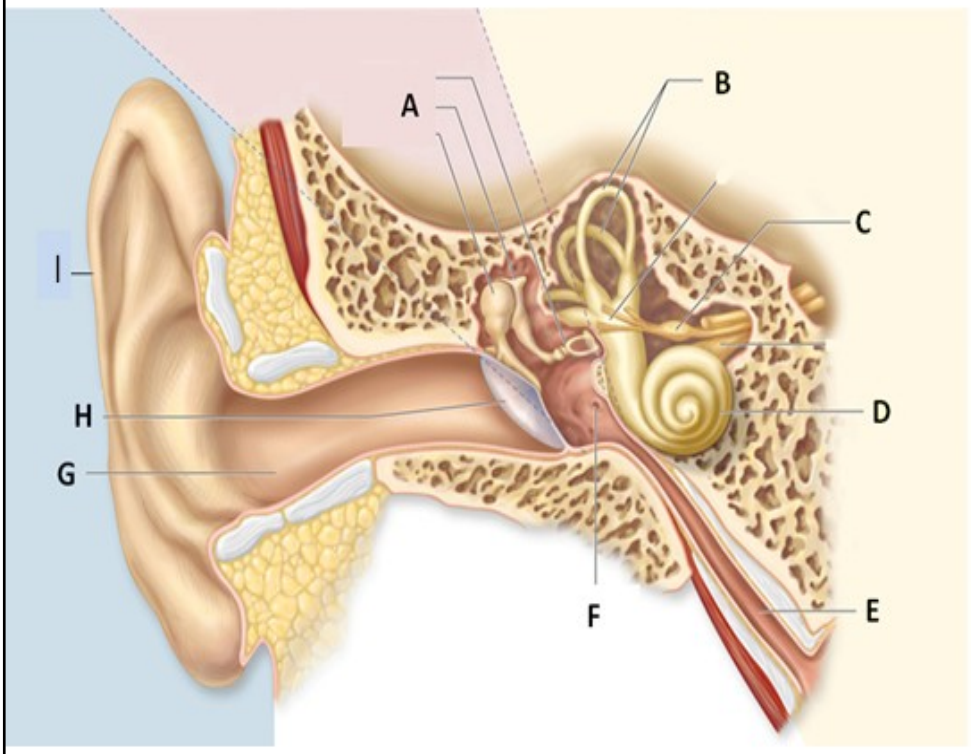


Please write the letter from the image above, beside each the organ names:

- Retina: _____
- Fovea: _____
- Cornea: _____
- Blind spot: _____
- Anterior cavity: _____
- Lens: _____

Figure 6.4 – Visual recall quiz for the eye lecture

Given the following image:



Please write the letter from the image above, beside each the organ names:

- Cochlea: _____
- Auditory canal: _____
- Semicircular canal: _____
- Ossicles: _____
- Auditory tube: _____
- Pinna: _____

Figure 6.5 – Visual recall quiz for the ear lecture

6.2.5 Procedure and experimental design

Participants were randomly assigned to one of four study groups. The groups differed according to the lecture order (visual system first, auditory system first) and according to the delivery style given for each lecture (one-stream, two-stream). Table 6.2 shows the four different groups in the study.

	NUMBER OF PARTICIPANTS	FIRST LECTURE	SECOND LECTURE
Group 1	28	V,1	A,2
Group 2	24	V,2	A,1
Group 3	27	A,1	V,2
Group 4	24	A,2	V,1

Table 6.2 – Experimental design. V=Visual system; A= Auditory system. 1 = One-stream; 2=Two-stream.

All lectures were given in the same lecture hall. The lecture hall could seat around 120 students. It had two large screens in the center of the room behind the lecture podium. Participants were seated in the front at the center of the room so they would have a good view of the screens. Lectures were delivered by an experienced instructor who read the prepared transcript for each lecture and progressed the slides in a preset way. The instructor was told not to gesture or gaze at the screens. Participants were requested not to use their cell phones and not to take any notes during the lectures. We requested participants not to take notes so participants would not use these notes during the quizzes and in order to equalize the learning conditions between participants as much as possible. To the best of our knowledge, these guidelines were kept by all participants.

Participants were required to attend two sessions. The first session started with the pre-test quiz. Following the pre-test, the two lectures were presented to all participants in a group. Following each lecture, the immediate retention quiz of 15 questions was administered. At the end of the first session, participants were asked to fill out the questionnaire. For the second session, participants returned a week later (plus or minus a day) and completed the deferred retention quiz that consisted of the same questions

from both the immediate retention quizzes from the first session. Participants then completed the visual recall quiz.

Participants were compensated $15 for their time. In addition, because this was not a class taken for credit, we wanted to motivate people to listen to the lectures and try to learn as best as they could. Therefore, four $100 cash prizes were drawn between participants. The draws were based on participants' results in the quizzes in such a way that a higher combined result in all quizzes gave a higher chance of winning the draw.

6.3 Hypotheses

Based on our assumptions and our study design, we established the following experimental hypotheses:

H1. Information displayed with MultiPresenter on two streams of slides can improve learning over a one-stream presentation.

H2. Showing pertinent information from previously shown slides on a secondary screen improves the retention of information.

H3. Showing the previous slide (i.e. showing the information for a longer time) improves the retention of that information.

H4. It is beneficial to compare two items of information on two separate screens rather than putting them on just one slide.

H5. Visibly showing more information (using two screens) does not have a negative effect on retention of verbalized information.

6.4 Experience gained in a pilot study

After the above protocol was designed, we pilot tested the protocol with five participants in one group session. The pilot was conducted with the exact same protocol as the study simulating group 1. The same instructor from the study was used in the pilot in order to familiarize the instructor with the scenario for the study and thus minimize any learning effect the instructor might have between the different study groups.

Some changes were made based on the pilot study. Most changes had to do with the assessment questions. The pilot participants got around 80% correct responses in

both of the assessment quizzes. We were concerned about a ceiling effect that could bias the results because of lack of sufficient variability, so we changed a few of the questions and a few of the possible answers to make the questions more difficult. We also made some minor changes in the transcript in places that we saw that the instructor was not comfortable or not "natural" enough with the verbal delivery.

6.5 Results

We first present results for the multiple-choice quiz administrated during the first lecture session (immediate retention). We then present results of the questions administrated after a week (deferred retention). Finally, we present the results of the subjective questionnaires.

6.5.1 Objective assessment of immediate retention

In this section, all results refer to the quizzes that participants filled out immediately after experiencing each lecture.

Analysis techniques

For most of the statistical analyses we performed both ANOVA and ANCOVA tests. ANCOVA, or analysis of covariance, is a statistical test used as an alternative, more sophisticated method for analysis of variance (ANOVA). It is based on the inclusion of additional variables (covariates) into the model. This allows us to account for inter-group variation and control the covariate variable and often get increased statistical power brought about by a reduction in the error variance. Because it is well known that previous knowledge of a domain affects learning ((Bransford, 2000)), when performing the ANCOVA analysis we used our pre-test score results as a covariant to control for participants' previous knowledge of the lecture topics. Pre-test or base results are often used as the covariant variable in ANCOVA analyses (Huck, Cormier, & Bounds, 1974). Whenever there is no substantial difference between the ANOVA and the ANCOVA results, we report only the ANOVA results as this test is more commonly used. When there is a difference, we report both results in order to enable the reader to compare and understand the impact of the covariance variable in the model.

General scores

The average score on the immediate retention quizzes was 20.4 correct answers out of 30 possible answers combined for both topics (68%). By only guessing, a person not attending the lecture would get an average of 7.5 correct answers out of the 30 possible questions (25%). We wanted to eliminate from the analysis data from participants who didn't listen to the lectures and only came to get the compensation money. Therefore, for all parts of the analysis, we removed any participants who had a sum of 10 correct answers or less. Five participants were removed for this reason (participant numbers 20, 29, 70, 80, 95). Another participant (#24) got slightly higher results than the cut-off (12 correct answers), but was removed because later on we found out that he was known to be a problematic subject based on previous studies he had attended. After this removal there were 26, 23, 25 and 23 participants in study groups 1, 2, 3 and 4, as shown in Table 6.2, for a total of 97 participants used in the analysis.

Order effect

To examine if there was an order effect between the first and second lectures (the participants might either get tired and do worse in the second lecture they experienced, or get used to the lecturer and do better), we initially conducted a one-way ANOVA and ANCOVA on lecture order (first, second). Because results were similar, we report only on the ANOVA results. We hypothesized that participants would perform better in the first lecture than in the second lecture because of a fatigue effect. However, results did not indicate an order effect, $F(1,192)=.06$, *ns*. This analysis assumes that the two test results of each participant are independent and compares between the means of the first lecture and the second lecture, relying on the counterbalancing. While this analysis is valid, it does not make use of the full statistical power possible, because it disconnects participants' scores in both topics.

In order to take into account the interpersonal variance of each participant performing two tests, we aggregated groups 1 and 2 from Table 6.2 into group α, and groups 3 and 4 into group β. We performed a 2x2 mixed ANOVA with the topic (visual or auditory) as the within-subject variable and group (α or β) as the between-subject variable. The groups were aggregated according to the order of lecture topic, disregarding the lecture delivery variable. That way we could measure a learning effect

by looking for a possible interaction between the aggregated group variable and the topic variable. Similar to the one-way ANOVA we presented before, the interaction effect was not significant, $F(1,95) = .270$, *ns*. Participants in the second lecture (m=10.15) didn't perform differently than those in the first lecture (m=10.28). The results of the analysis revealed an effect for lecture topic. Participants didn't perform equally on questions related to the different lectures. Participants did better in the visual lecture (m=10.68) than in the auditory lecture (m=9.72), $F(1,95)=14.59$, $p<0.01$.

Overall results

Because there was no order effect, for all of the following analyses we combined groups 1 and 4 from Table 6.2 into one group (group A), and groups 2 and 3 into a second group (group B). This grouping was done according to the delivery style variable, disregarding the order of the presentations. Thus, groups A and B differ by which delivery style (one-stream, two-stream) was used for each topic. Table 6.3 shows the topic and style used for the two lectures of both groups A and B (for example, we see that participants in group A saw the visual lecture in the one-stream condition, and the auditory lecture in the two-stream condition).

	Auditory	Visual
One-stream	B	A
Two-stream	A	B

Table 6.3 – Topic and style used for the two lectures of analysis groups A and B.

To examine the effect of lecture style on overall quiz scores, we performed a 2x2 mixed ANOVA with topic (auditory or visual) as the within-subject variable and group (A or B) as a between-subject variable. As previously found in the order analysis, results yielded a main effect for topic. Participants did better in the visual lecture (m=10.68), than in the auditory lecture (m=9.72), $F(1,95)=14.59$, $p<0.01$. More interestingly, the results also yielded a marginally significant interaction effect, $F(1,95)=3.76$, $p=0.056$. Participants in the two-stream condition performed better on their quizzes (m=10.42) than those in the one-stream condition (m=9.98). When participants' previous knowledge was taken into account using the more sensitive ANCOVA analysis with participants' pre-test results as a covariate, a significant effect was identified, $F(1,95)=4.03$, $p=0.048$. Figure 6.6 shows the differences in means between the two delivery styles over the two topics.

Results according to categories

For each category listed in Section 6.2.4, we performed a 2x2 mixed ANOVA and an ANCOVA with topic (auditory or visual) as the within-subject variable and group (A or B) as a between-subject variable. Mean differences between groups and statistical results are summarized in Table 6.4 and shown in Figure 6.6.

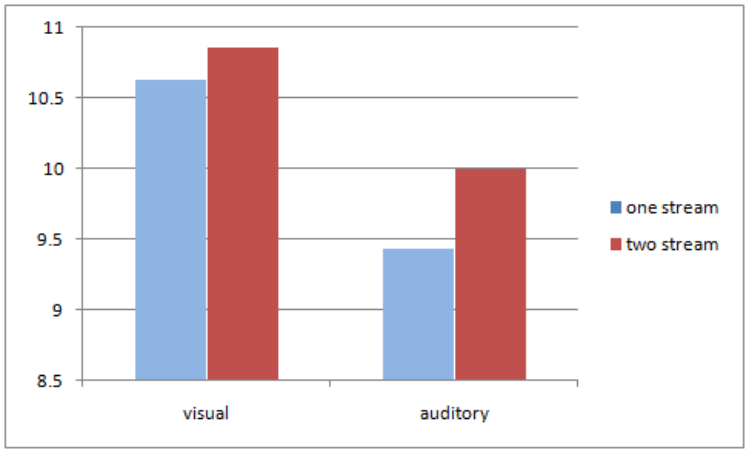


Figure 6.6 – Overall immediate quiz scores according to delivery style and topic (N=97).

	ONE-STREAM			TWO-STREAM			DIFF	ANOVA		ANCOVA	
	Mean	%	SD	Mean	%	SD	%	*F*	p	*F*	p
overall	10.0	66.7	2.62	10.4	69.5	2.42	4.2	3.76	.056	4.03	.048*
Text	2.26	75.3	.76	2.18	72.5	.79	-3.6	.67	.415	.717	.399
Graph	1.98	65.9	.94	1.93	64.3	.81	-2.5	.20	.654	.075	.785
Long-term	1.94	64.6	.87	2.19	72.8	.86	12.8	5.14	.026*	4.92	.029*
Comp.	1.91	63.6	1.02	2.07	69.1	.87	8.4	3.23	.075	3.46	.066
verbal	1.92	63.9	.92	2.02	68.7	.83	5.2	1.33	.251	1.20	.276

Table 6.4 – A summary of the results on the immediate retention quizzes (*N*=97).

As can be seen in Table 6.4, the overall interaction effect reported on before stems mostly from two question categories: the long-term questions and the comparison questions. Participants performed significantly better on the long-term questions in the two-stream condition than in the one-stream condition. Participants performed marginally better on the compare questions in the two-stream condition than in the one-stream condition. Answers to text, graph, and verbal questions were not significantly better in either delivery condition.

Pre-test questions

The pre-test questions consisted of a total of 10 questions, 5 questions for each topic. The 5 questions for each topic consisted of one question from each category (Section 6.2.4). We have used the pre-test results as a covariant variable for the ANCOVA analysis, as an indicator of participants' previous knowledge of the lecture's topic. In addition, the difference between how participants performed in the pre-test questions and how they answered these same questions after the lectures can indicate how much they learned from the lecture.

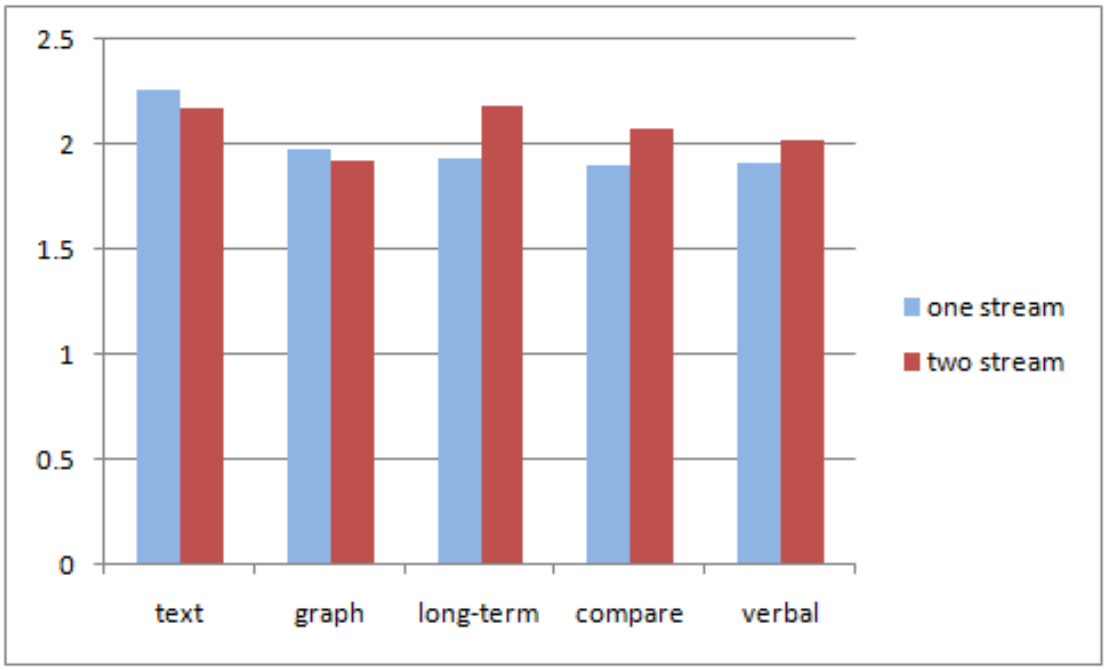


Figure 6.7 – Immediate assessment scores of the two delivery styles on the different categories (*N*=97).

On average, participants answered 35.6% of the pre-test questions before the lectures, and 65.2% of these questions after the lectures. Because the correct average response to all questions was higher (65.7%), it seems that there was no priming effect for the pre-test questions (a priming effect would occur if participants did better on these questions because they have seen them before the lectures). However, we still cannot totally rule out a priming effect, because these questions might have been more difficult.

We measured the increase in the number of correct answers for each participant in these questions. We then compared these between the two lecture style conditions (one-stream, two-stream). No significant difference was found between the two lecture styles, $F(1,95)=.147$, $p=ns$.

6.5.2 Objective assessment of long period retention

Participants returned a week later and completed the deferred retention and the visual recall quizzes. We excluded from the results the six participants who were excluded from the first session's analysis. In addition, three participants did not show up for the second part, leaving the total number of participants for this part of the study at 94.

Deferred retention quiz

The deferred retention quiz comprised of the 30 questions from both the visual and the auditory immediate retention quizzes completed in the first session. On average, participants answered 19.07 correct answers out of the 30 possible questions (63.6% correct answers). Participants still did better on the visual system questions (*m*=9.71) than on the auditory system questions (*m*=9.36), although this time the difference was not significant, $F(1,93)=1.66$, *ns*.

To examine the effect of lecture style on overall retention after a week, we performed a 2x2 mixed ANOVA with delivery style (auditory or visual) as the within-subject variable and group (A or B) as between-subject variable. Results of the analysis did not yield a significant interaction effect, $F(1,94)=1.05$, *ns*, even when using the more sensitive ANCOVA.

Table 6.5 shows the detailed results broken into the different categories. Only the long-term category showed a significant difference for the lecture delivery condition, $F(1,92) = 4.008$, $p<0.05$. For the long-term category, participants did better in the two-stream condition (*m*=2.09) than in the one-stream (*m*=1.84).

	ONE-STREAM			TWO-STREAM			ANOVA	
	Mean	%	SD	Mean	%	SD	F	p
overall	9.44	62.9	2.86	9.72	64.8	2.54	1.052	.308
Text	2	66.7	.86	2.01	67.0	.90	.009	.927
Graph	1.84	61.3	1.01	1.69	56.3	.93	1.428	.235
Long-term	1.84	61.3	.97	2.09	69.7	.90	4.008	.048*
Compare	1.69	56.3	1.01	1.78	59.3	.97	.523	.472
verbal	2.07	69.0	.87	2.15	71.7	.75	.570	.452

Table 6.5 – Summary of the results on the week-later retention quizzes (*N*=94).

Visual recall quiz

As described earlier, in the week-later deferred retention session we administered a visual recall quiz to further examine the long-term category. The quiz had a section on the visual system (Figure 6.4) and a section on the auditory system (Figure 6.5).

Participant scores for each section were between 0 and 6 according to the correct number of answers.

Figure 6.8 shows the results in this quiz according to delivery style and topic. On the auditory system, participants in the two screen condition had an average of 4.61 correct answers compared to an average of 4.04 correct answers in the one-stream condition (a difference of 14.1%). On the visual system, participants in the two screen condition scored an average of 3.62 correct answers compared to an average of 3.20 in the one-stream condition (a difference of 13.1%).

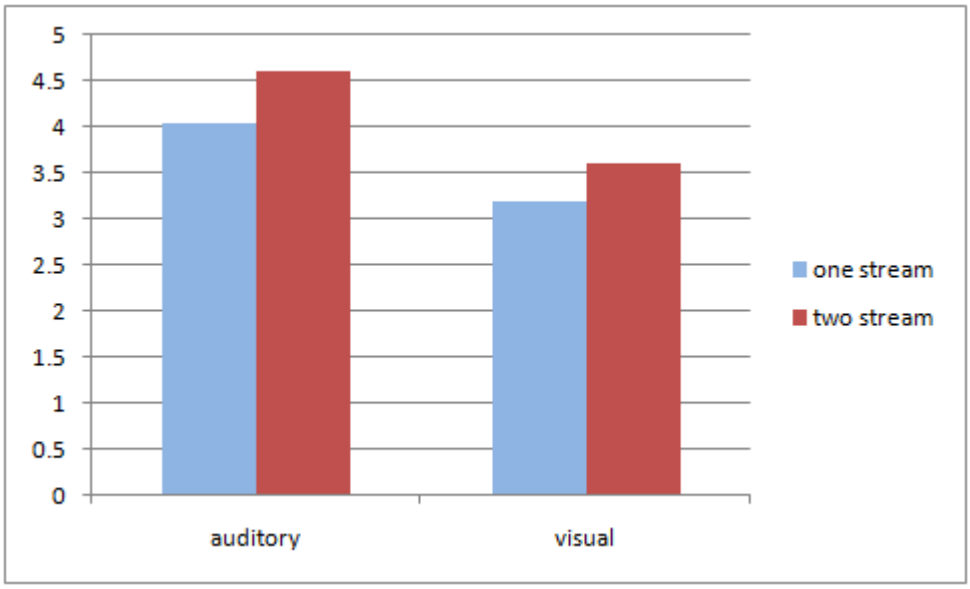


Figure 6.8: Visual recall quiz results according to delivery style and topic (N=94).

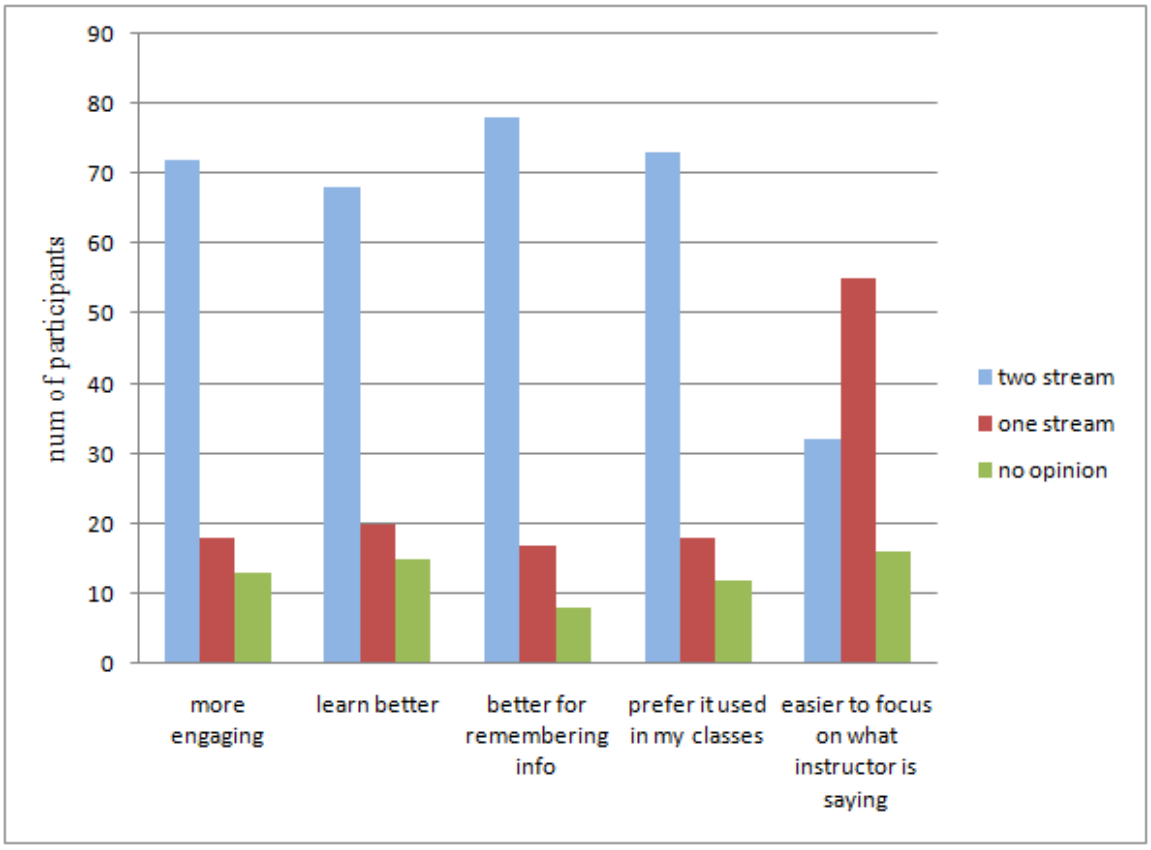


Figure 6.9: Delivery style preference data. For each phrase, participants were asked to choose between the two delivery conditions or choose no-opinion (*N*=103).

We performed a 2x2 mixed ANOVA with lecture (auditory or visual) as the within subject variable and group (A or B) as a between-participant variable. Results of the analysis yielded a significant interaction effect, $F(1,92)=6.84$, $p=.010$. There was also a significant effect of lecture, $F(1,92)=23.79$, $p<0.01$, indicating that in this quiz as in the immediate quizzes participants performed better on the auditory lecture recall diagram than on the visual lecture recall diagram.

6.5.3 Subjective questionnaires

In addition to the objective ratings based on assessment of participants using quizzes, we also administered questionnaires to gather information about participants' subjective preferences and opinions. In particular, our within-subject design allowed us to obtain direct preference information about the two delivery styles. Figure 6.9 graphically shows results of the direct comparison questions. Table 6.6 shows the full numeric results of the direct comparison questions.

Statement	one stream	two stream	no opinion
The presentation was more engaging	18	72	13
I learned better	20	68	15
The presentation was more effective for remembering lecture material	17	78	8
I would prefer it to be used in my classes	18	73	12
It is easier to focus on what the instructor is saying	55	32	16
The presentation was more effective for understanding lecture material	24	71	8

Table 6.6 – Delivery style preference data, tabular form (*N=103*).

We can see that participants found the two-stream condition more engaging, and they thought they learned better with it and it helped them to better remember information. They also preferred that it be used in their classrooms. An interesting exception for the clear preference for two-streams, was participants' response to the statement: "It is easier to focus on what the instructor is saying". Most participants (55 out of 103) indicated that they thought it was easier to focus on the instructor's words with the one-stream condition.

In order to better understand participants' subjective opinions, we presented participants with a second set of statements, and asked them to use a 5-point Likert scale to indicate how much they agreed with each statement, ranging from strongly disagree to strongly agree. Table 6.7 shows these statements and participants' responses. As seen from the table, and similar to the direct comparison results, on most scales participants preferred the two-stream condition. We discuss these results further in the next section.

Statement	Avg.	*SD*	Agree and strongly agree	Disagree and strongly disagree
The two-screen style gave additional value over the regular style	4.01	0.96	82	10
It was helpful for me when the previous slide was carried over in the two-screen style presentation	4.17	0.90	88	8
Having different information on the second screen in the two-screen style distracted me	3.01	1.18	39	39
It was helpful for me to see a single slide persist a long time on the secondary screen	3.65	0.92	65	13
It was helpful for me to see previously shown graphic slides in the two screen presentation	4.33	0.86	92	5
It was helpful for me to see previously shown text slides in the two screen presentation	3.40	1.08	52	20
It was helpful for me when two items were compared using the two screens in the two-screen mode	4.23	0.91	84	7
I looked at things on the second screen to remember earlier concepts.	4.05	0.99	82	7
I had problems physically seeing one of the screens	1.75	0.96	6	86
The two-screen style does not help me learn more than the regular style	2.21	0.99	14	71
The two-screen style decreased my attention to the lecture as compared to the regular style	2.55	1.19	27	55
The two-screen style helped increase my understanding of the material as compared to the regular style	3.72	0.91	70	12

Table 6.7 – Participants' subjective ratings of statements concerning the use of the two screens on a 5-point Likert scale (*N*=103).

6.6 Discussion

We first discuss the effect that the lecture delivery style had on learning, examining the hypotheses we made in section 6.3. We then reflect on the methodology we used and examine the trade-offs we had during the design of the study.

6.6.1 Effect of dual screen presentations on learning

Our results provide encouraging evidence that using multiple screens in classroom presentations can improve learning. On the overall retention scores issued immediately after the lecture, participants performed significantly better in the two-stream condition than in the one-stream condition. However, this general effect did not carry over a week later when participants were again tested. This may be because of higher variability and lower scores in this test. Drilling down through the different categories of the immediate retention scores, we see that this effect was driven by a significant effect for the long-term persistency questions, and a marginal effect of the comparison questions. H1 stated that with MultiPresenter, using the two streams can improve learning over the one-stream condition. The results of the overall assessments partly support this hypothesis.

Long-term persistency of information

The results support H2 that pertinent information that was previously shown, put alongside the current slide, promotes retention of information. Participants did significantly better on the long-term persistency questions both immediately after the lecture and a week later. This was reinforced by the visual recall quiz we administrated in the week later session, which also showed significantly better results for the two-stream condition. This coincides with Meyer's findings (2001) and with the split attention principle of Ayers and Sweller (2005) that states that when designing instruction, it is important not to split the attention of learners between multiple sources of information but rather material should be organized such that disparate sources of information are physically and temporally integrated. Participants' subjective questionnaires show that participants supported this notion, giving the statement "I looked at things on the second screen to remember earlier concepts" an average of 4.05 in a 5-point Likert scale.

Showing the previous slide

One of the common usages of MultiPresenter in real classrooms was showing the previous slide on the secondary screen. As stated in Chapter 5, students have commented favourably on this practice, saying it gives them more time to write notes, and allows them to see information longer if the instructor is rushing through the material. In this study, similar to the questionnaires administered in actual classes (Section 5.6), students also indicated that it was helpful for them when the previous slide was carried over in the two-stream style presentation (average 4.2 on a 5-point Likert scale). However, when examining the actual learning when immediate previous slides were shown, we found no results to substantiate these claims. On questions pertaining to the immediate previous slide, both for graphic and for textual slides, there was no difference between the one-stream and the two-stream conditions. Therefore, H3 conjecturing that simply having information shown longer on screen would improve retention of that information was not supported.

The reason why there was no effect may be because most of the slides had no connection with the slides before or after them. In order to answer the short-term questions correctly, it was sufficient to view and remember the information when it was the focus of explanation. Although a slide in this category was visible twice as long in the two-stream condition over the one-stream condition, remaining on screen when the instructor had moved to the next slide, information on it was not relevant to understand the following slide. Because the transcript was designed to focus on the primary screen, we believe that most participants did not look or focus on the information on the secondary screen, and kept their focus alongside the instructor on the new slide. It seems that in this case, *persistence* of information is less important than *pertinence*; that is, ***information should persist on the screen only if it is relevant to what is being taught by the instructor***.

Results might have been different if slides had a stronger connection with each other, if questions would have examined a deeper understanding stemming from this connection and not simply retaining information from one slide, and if the instructor fully used and referred to information on both screens. Future studies can examine these

issues. However, we now see that simply having information persist longer does not necessarily improve retention.

Comparing two items

Comparing two items on two separate screens as opposed to putting them both on one screen has the advantage of showing each item larger, as well as being able to more naturally separate between the items. In this category, results from the study show a marginally significant difference in favour of the two-stream condition in the immediate recall test. However, these results were not sustained in the deferred test in which there was no significant difference between the groups. H4, therefore, was only partial supported. Participants thought that it was beneficial for them to compare items on separate screens. Subjective ratings about the statement "It was helpful for me when two items were compared using the two screens in the two-screen mode" had an average of 4.23 out of 5.

Verbal-only information

Participants' subjective results in the direct comparison questions indicated a strong preferences for the two-stream condition over the one-stream condition as being more engaging, better for learning, and better for remembering information and participants preferred it to be used in their classrooms. Interestingly, the only category in which the one-stream condition was preferred over the two-stream condition was "it is easier to focus on what the instructor is saying" in which 55 participants preferred the one-stream condition while 32 preferred the two-stream condition. This finding was attuned to our concern that having more information on the screen might distract learners from the verbal information when it does not relate directly to the visuals. On the statement "Having different information on the second screen in the two-screen style distracted me" participants had an average of 3.01, which suggests that opinions were divided. The objective assessment results, however, did not coincide with participants' subjective feelings. Answers to verbal-only questions did not show a significant difference between the two groups in either the immediate or the deferred quizzes. These results support H5, which predicted that there would be no effect of showing more visual data on recall of verbal information.

Graphical vs. textual information

We did not find a difference between information shown graphically or textually across the two conditions. However, this may be because we only examined the difference between graphical and textual information within the previous slide category. Further research is needed to determine whether there is a difference between textual or graphical information that is pertinent and shown alongside the current information.

Visual recall

The visual recall quiz examined participants' long-term recall of visual information that was shown for a longer period of time in the two-stream condition. The results indicated that participants in the two-stream condition performed significantly better on the visual recall quiz than did participants in the one-stream condition. This has powerful implications. Keeping visual information on the screen for a longer time may improve long-term retention of that visual information. While it may seem clear in retrospect that giving students more time with what we want them to learn is a good way to help them learn it, it is not in fact obvious. We have already seen that showing the previous slide, when it was not related to the current topic, did not improve results. The information in the visual recall quiz was shown only when it was relevant to the lecture and as such was pertinent to current topic. We believe that students did not perform better just because they saw the information longer, but because they saw the information in context, and that gave meaning to its elements. However, further research is needed to examine how important it is for the information to be pertinent to the current topic, and whether simply showing unrelated visual information for a longer period of time can improve retention of that information.

6.6.2 Reflections on the experimental methodology

In this section, we will comment on some of our key design decisions for this study, and describe some of the lessons we learned and the limitations of our design.

The rational for a laboratory study

Our goal was to evaluate, using a laboratory study, how extra screen space affects learning. An alternative approach would have been to evaluate the usage of

MultiPresenter in a real classroom. This approach has been used by several researchers examining different delivery styles for classroom presentations. Some studies were conducted in which a few lectures in a certain class were given several times, one in each study condition (Savoy et al., 2009; Stephenson et al., 2008). Participants were instructed to attend one delivery style for each lecture. Other methods included examining two sections of a given course (different students were in each section) with each section viewing lectures with a different delivery style (Susskind, 2005; Susskind, 2008; Szabo & Hastings, 2000), having alternate delivery styles given to a same group during a full semester (Bartsch & Cobern, 2003), or comparing between two separate cohorts of students attending classes in different semesters with different delivery styles (Szabo & Hastings, 2000).

While these approaches have a higher ecological validity than a laboratory experiment, they all have certain drawbacks. In none of these prior studies were students randomly assigned to experimental treatments. Therefore, differences observed between groups may simply reflect pre-existing differences in academic ability or motivation. Second, there are many possible intervening factors during a semester that may affect one of the groups more than the other. Third, when delivering a lecture in a real classroom, the instructor must deliver the lecture in the best possible way. This constrains the ability to control the delivery of the lecture according to the needs of the study. Because of these drawbacks, and because we had already shown the utility of MultiPresenter in real classrooms (Chapter 5), we decided to conduct a laboratory study that would emulate a real classroom as best as possible, but to not sacrifice logical validity for ecological validity. This gave us better control over the intervening factors, allowing us to minimize differences between the two conditions except for the examined factor (one-stream vs. two-streams), as well as giving us the flexibility to design the lecture and questions in a way that would examine the different categories of learning in which we were interested.

Rationale for a within-subject design

We decided to have a within-subject design with two lectures because we wanted to obtain unbiased preference data. We felt that getting preference data in this study could further validate our results from the class questionnaires (Chapter 5). Data from

classrooms might be biased because students knew this was a new teaching tool and knew their instructors had chosen to use it. Preference data from a different source was therefore needed to fully validate the results in Chapter 5. We did find that the results of the subjective questionnaires in this study were mostly in favour of the two-stream condition, confirming the classroom results. We had two separate lectures in order to enable each participant to see both lecture styles and also to counterbalance the material and presentation style to see if there might be a difference between different material.

Reflections on the analysis

In our study design, every participant saw two lectures, one in each condition. This introduced several challenges. Because participants did not see each lecture in both conditions, it was not possible to perform a simple two-way ANOVA. This problem is quite common in experimental design. It can occur when comparing two interfaces or interaction techniques, for example, when a researcher wants to gather preference data (and therefore cannot perform a between-subject design), and the nature of the tasks prevents the tasks from being repeated. A possible solution is to design two or more tasks that are isomorphic, and to first test that there are no significant differences between the tasks (Bunt, Conati, & McGrenere, 2007 ; Zheng, Booth, & McGrenere, 2006). In our case, however, this was not possible because any two lectures are inherently different, and it is very difficult to design quizzes to be isomorphic in their level of difficulty. In order to examine the effect that delivery style had on the dependent variables across both lectures, we had to perform a mixed-design analysis and then test for an interaction effect. While this approach is not widespread, it has been used in other studies comparing two delivery styles for classroom lectures (Susskind, 2005; Susskind, 2008).

We presented the results of both ANOVA and ANCOVA tests. Although there was not much difference between the results, we saw that for the immediate retention quizzes, the ANCOVA managed to tease out a significant interaction that the less sensitive ANOVA did not. This result indicates that the pre-test had some predictive effect over the immediate retention results. In the deferred tests, this was not the case. The ANCOVA results were the same as the ANOVA results. We therefore conclude that in our case, the pre-test variable was not a great predictor of participants' abilities or pre-

existing knowledge. However, we believe that the ANCOVA analysis was worth doing and may be more useful when there is a clear intervening factor that needs to be controlled and brought into the model.

6.7 Summary

This chapter has described a controlled laboratory study that was conducted to formally evaluate the advantages that two-stream presentations have over one-stream presentations. The results indicate that, when used properly, a two-stream lecture such as with MultiPresenter can improve learning over a regular one-stream lecture. In particular, the two-stream presentation style was most useful when pertinent prior information was shown on the secondary screen alongside the current information. The study also provides some support for the benefits of using two screens to compare two pieces of information rather than putting them on a single screen, demonstrating the advantages of using more screen real estate. In addition, results of the experiment indicate that participants preferred a two-stream presentation over a traditional one-stream presentation, supporting our results in Chapter 5.

While there are many studies examining the effect that electronic presentations have in classrooms, our evaluation is the first study that we are aware of that examines the role that screen real estate has on students' learning in computer supported lectures. As such, it significantly contributes to the growing body of knowledge pertaining to the design, implementation and use of technology in classrooms.

Figure 7.1 – A newspaper comic by Mike Baldwin pointing out that sometimes new technology does not improve on traditional techniques. We argue that MultiPresenter does provide benefits, but also recognize the need for future research to explore these questions more fully (used by permission).

Chapter 7

Reflections and Recommendations

In this chapter, we reflect on the main ideas of the dissertation, discussing our methodological approach and outlining a framework for effective use of large display surfaces for classroom presentations. We summarize the dissertation's contributions, and recommend several avenues for future research that stem from the work we have reported.

7.1 Research approach

Our methodology used the classic human-computer interaction approach of iterative and human-centered design. Iterative design (Figure 7.2) is a methodology advocated by Gould and Lewis (1985), referring to the process of design and development as an iterative process. It includes cycles of design (or implementation), test, analysis (or measurement) and redesign repeated as often as necessary, so the design can be refined

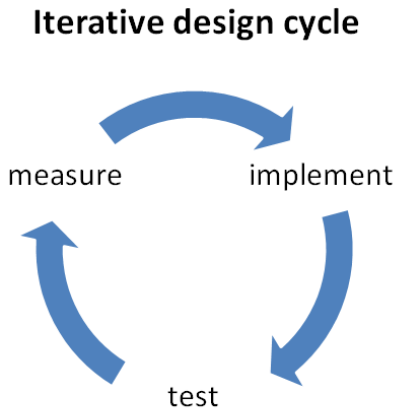


Figure 7.2 – The iterative design cycle approach taken in the implementation of MultiPresenter

based on feedback. The process is intended to improve the quality of the design by interacting with and testing successive versions. We engaged in iterative design when building MultiPresenter by continually redesigning the MultiPresenter prototype based on feedback by instructors and by co-workers before actual deployment, and later during the first two semesters of deployment.

Iterative design is often used in industry and in research as a process focused on the resulting end product or design artifact. While we were interested in improving MultiPresenter as much as possible, our main focus was on acquiring knowledge, not product development. The reason we designed and implemented MultiPresenter was not to build a practical and robust tool, but rather to enable us to formulate and validate some of our research hypotheses and to understand the design space for presentations using large display surfaces.

We see the process and methodology followed in this dissertation as a knowledge acquisition cycle (Figure 7.3), in which the goal is to gain knowledge. This approach is based on Schön's reflective practitioner model (1995) in which hypotheses are formulated, a prototype based on these hypotheses is implemented, and field studies or

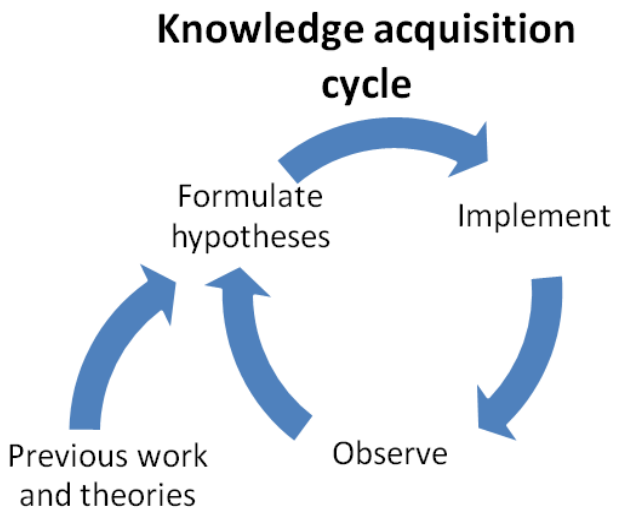


Figure 7.3 – The knowledge acquisition cycle used in formulating this research

experiments are conducted to re-examine the hypotheses in a cyclic way leading to refined hypotheses. Iterative design and the knowledge acquisition cycle closely resemble the spiral model first popularized in the software engineering community by Boehm (1988). Both have as key elements the iterative refinement of a theory or design artifact with each iteration governed by an assessment criteria. Boehm refers this to assessment as risk analysis in the spiral model, Gould and Lewis refer to it as evaluation in iterative design, and Schön refers to it as reflection.

In our knowledge acquisition cycle, we started by observing actual practices (Chapter 3). This, together with knowledge from previous work, led us to formulate hypotheses which we presented as design guidelines (Section 3.5). We then implemented MultiPresenter (Chapter 4) based on these hypotheses. We observed the use of MultiPresenter (Chapter 5) in order to re-examine the hypotheses and refine our theory. We present the refined hypotheses as a design framework in the next section (Section 7.2).

A model that we were not aware of during our work, but which describes our methodology well, is the design-based research (DBR) methodology, also known as design experiments (Brown, 1992; Collins, Joseph, & Bielaczyc, 2004). Design-based research tries to understand how educational innovations work in practice. Reeves (2000) summarizes the major characteristics of DBR:

- Addressing complex problems in real contexts in collaboration with practitioners.
- Integrating design principles with technological affordances to find solutions to these problems.
- Conducting rigorous and reflective inquiry to test and refine innovative learning environments and define new design guidelines.

Reeves notes that DBR emphasizes research and development through continuous cycles of design, enactment, analysis and redesign.

Our approach fits well within the DBR paradigm. We collaborated with instructors to examine our hypotheses in real contexts by deploying MultiPresenter in actual classrooms. Our design principles were integrated with the technological affordances of the large display surfaces in classrooms, and were rigorously examined and refined in that context. Wang and Hannafin (2005) outline five advantages of DBR that reflect the

advantages of the research approach taken in this dissertation: (1) it is pragmatic – the goals aim at solving current real-world problems, (2) it is grounded both in theory and real-world context, (3) the research process is interactive, iterative, and flexible. (4) it is integrative – researchers need to integrate a variety of research methods and approaches, (5) and it is contextualized – research results are connected to both the design process and to the setting.

7.2 A conceptual framework for effective use of larger display surfaces in classroom presentations

This framework aims at helping designers constrain and scope their design space. We describe a conceptual framework for effective use of larger display surfaces in classroom presentations (Figure 7.4). The purpose of the framework is to understand the design space for classroom presentation systems in terms that can be used for design. The framework has three major components: practices of using extra screen real estate, guidelines for designers and educators, and pitfalls to be aware of when using large display surfaces for presentation.

7.2.1 Practices

We list the different ways that instructors beneficially used large display surfaces during our classrooms observations. The list of practices is a combination of observed multiple blackboard practices with observed usage patterns instructors employed when using MultiPresenter to drive multiple electronic displays. When describing observed patterns with MultiPresenter, we take into account the possibility of larger display surfaces than only the two screens that were used during our deployment. Because they were elaborated on earlier in the dissertation, we only briefly describe the different practices we documented.

- *Unifying a topic* – having information on one topic appear side-by side in space rather than shown sequentially over time. We observed that many instructors put information related to one topic on two slides and used MultiPresenter to present those slides simultaneously. This can help with the content cutting problem of slides

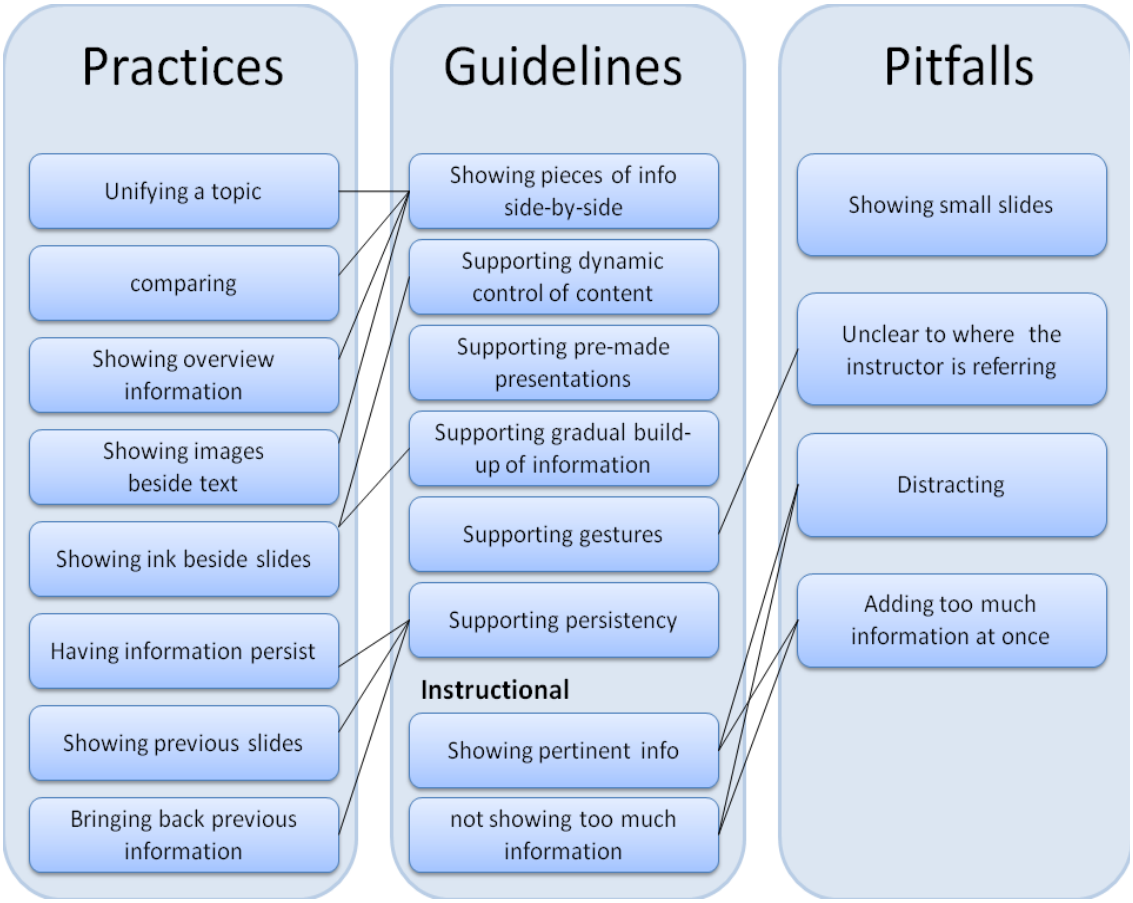


Figure 7.4 - Framework for effective use of larger display surfaces in classroom presentations

(Farkas, 2009) which refers to the removal of informative content by the author to respect the slide's boundary constraints.

- *Comparing* – comparing two (or more) pieces of information side by side. Many instructors used the two displays to compare information. This was said to be very useful by both students and instructors.
- *Showing overview information* – showing overview information alongside the detail information. Overview information, either of an entire lecture, or of segments of a lecture was useful to summarize information, and to keep students in context during the lecture. Students commented very favourably on this practice.

- *Showing images beside text* – separating text information and image information and displaying them together side-by-side. It was deemed useful for students to have the images separated from the text and shown side-by-side.
- *Showing ink beside slides* – having a space to use for writing (electronic ink) alongside electronic content provided instructors with a means to add dynamic content to compare or augment the topic being shown. Inking was also useful for gesturing at content, and for annotating existing content.
- *Having information persist* - having information persist for longer periods of time on parts of the display surface was useful for instructors and students. Instructors who left important information on the screen for longer periods of time could revisit that information and use it to support subsequent information.
- *Showing previous slides* – Showing a set number of previous slides (to be determined by the presenter) alongside the current theme. Although not common, some instructors showed previous slides on the secondary screen.
- *Bringing back previous content* – Often, instructors realized the need for previously shown information only after that information was replaced with new information. It was important to allow instructors to easily bring back content that was previously shown.

7.2.2 Guidelines

We provide a list of guidelines for effective use of larger display surfaces in classroom presentations. The guidelines were initially constructed after our observational study and listed in Section 3.5. We then validated them with MultiPresenter's deployment. Following the deployment, using insights gained from the laboratory study, we added some new guidelines and removed or de-emphasized a few others.

Guidelines for designers of presentation systems

- *Showing pieces of information side-by-side* – While this may be trivial and therefore was not included in the initial guidelines, allowing instructors to put pieces of information side-by-side is a basic functionality that supports many existing practices (Figure 7.4). It is therefore important to allow instructors to be able to easily present two or more pieces of information side-by-side.

- *Supporting dynamic control of content* – We re-emphasize the importance of dynamic control of content. Our deployment validated this guideline by showing that many instructors used the dynamic mode and that some used it exclusively. Instructors found it very useful to be able to decide during lectures what to put on the display.
- *Supporting pre-made presentations* – While it is important to support dynamic control, many instructors prefer to have a pre-set lecture in which they decide ahead of time what will be seen. We observed that some instructors often used pre-made dual-screen presentations. It is important, however, to still provide dynamic options to augment pre-made presentations.
- *Supporting gradual build-up of information* – Gradual build-up of information was observed in our initial observations, mainly when instructors used the logical progression and diagram content types. Supporting this guideline in MultiPresenter, we included electronic ink and the clipping feature. While clipping was hardly used (mainly because it was too complex for the instructors) we did note the usage of electronic ink to render diagrams. We note that logical progression was hardly used in the lectures we observed. We saw that it is difficult to support this guideline other than by including support for electronic ink. Another possible way to support this with electronic presentations is to allow animation, which MultiPresenter does not currently support. We believe that allowing instructors to gradually build-up information is important for better pacing and in-depth exploration of a diagram or a mathematical proof. This could be more general than the animation feature in PowerPoint, which has a pre-determined order of appearance for each element in an animation. It should be possible for instructors to determine on-the-fly the order in which the elements in a list appear, so that (for example) when asking students to identify the Ten Commandments in a course on the Bible the instructor can respond by revealing each correct answer as it is provided by the students in the class.
- *Supporting gestures* – we emphasized in our observational study the importance of gestures to show specific parts of the visuals and to connect the spoken words of the instructor with the visuals. This is even more important when the screen is larger and there is more visual information. MultiPresenter does not support gestures other than

by using electronic ink for attentional marks. We therefore could not validate this guideline. However, we believe that it is important to support gesturing and recommend this for future research.

- *Supporting persistency* – The deployment of MultiPresenter validated the importance of supporting persistency of information. We saw that all instructors used information persistency in one form or another in their presentations.

We removed one guideline from the original set of guidelines. We had thought that designers should help presenters focus on *rich* information such as information in the form of graphs, tables, diagrams and logical progression content. *Support* information which includes text and immediate visual aid content was recommended to be only peripherally supported. While this guideline might be useful, we saw when designing MultiPresenter that it is not practical to have the presentation software automatically control content type. We now believe that the responsibility for how to present different content types should lie with the presenter.

Guidelines for instructors

We have developed some guidelines for instructors. While there are plenty of guidelines in the educational literature and various teaching resources on how to use presentation software (such as PowerPoint) in classrooms, we provide some additional points on how to use extra screen real estate with electronic presentations. Section 7.2.1 states a few practices that were useful in classrooms that might be adopted by instructors. We mention here two important guidelines that were discussed in previous chapters.

- *Showing pertinent information* –in the laboratory study we concluded that learning is improved when showing pertinent information alongside the current topic. A large display surface affords putting a lot of information to be seen by students. While leaving old, unrelated information visible might not hinder learning, we have shown that it is good practice to present related information on the auxiliary screens. Instructors have agreed with this: most instructors usually showed related information on the two screens.

- *Not showing too much information* – with more screen real estate, instructors should be careful not to overwhelm students. Instructors should not present too much text or too much detailed information at once. Indeed, most instructors that used MultiPresenter were careful not to present too much textual information.

7.2.3 Pitfalls of using extra screen real estate

Although using extra screen real estate can have many benefits in classroom presentations, we list some of the pitfalls that occur when using extra screen real estate.

- *Showing small slides* – we have seen that students and instructors preferred to have one full slide on one screen. Students did not like it when slides were reduced in size to fit more than one previous slide on a screen, and instructors hardly used that feature. We recommend not to reduce the size of slides that were designed to be seen on a full screen simply to show more than one previous slide on a screen.
- *Unclear to where the instructor is referring* – with more information on screen, it may be unclear what visual information the instructor is currently referring to in a gesture or verbally. With multiple sliding boards, the instructor is usually near the screen and gesturing is a natural way to connect spoken words with the visuals. However, with the move to electronic visual aids, often there is a physical disconnect between the instructor and the visuals that can be more problematic with the increasing screen size.
- *Distracting* – the increase in screen size, alongside with displaying too much information on the screen can be distracting to students. Showing extraneous information can overload students' working memory, which hinders learning (Mayer, 2001). Some students commented on it being difficult to pay attention when there was more screen real estate.
- *Adding too much information at once* – with sliding boards, information is presented gradually, allowing students to visually see how information was created. When an instructor moves a board, the audience sees the movement of information and knows the location of the persistent boards. With an electronic display surface, it is possible to have all the information appear at once. It is also possible to move information without the audience being able to easily follow the movement.

Instructors should be careful not to have too much new information appear at once. Designers of systems should provide the audience with the ability to see the movement of information as it takes place.

7.2.4 Other reflections

We distinguish between *intentional* and *incidental* use of extra screen real estate. Intentional use is when the instructor deliberately arranges information on the entire display surface. This can be pre-planned or done spontaneously during a lecture. Incidental use, on the other hand, is when the instructor sets part of the screen to be automatically managed by the system (i.e., previous slides are automatically arranged by the system). Previous systems that used large display surfaces mostly provided incidental use of previous slides (Abowd, 1999; Chiu et al., 2003; Röüling et al., 2004). We have seen in our laboratory study that explicitly creating a use for the second screen by making side-by-side comparisons or showing long-term material improved learning outcomes, but implicitly using it by showing the previous slide did not show improvements. This reflected instructor's use of MultiPresenter. The previous slide mode was seldom used. Instructors preferred having more control over what was displayed at a given time. We therefore recommend that designers of presentation systems focus on intentional features that provide instructors with ways to decide how content is arranged, instead of incidental features that arrange content automatically. While incidental features are easier to use and may be useful in different presentation scenarios, we have not seen that they affect learning.

7.3 Contributions of the research

This research reported in this dissertation has made several contributions to the fields of educational technology, human-computer interaction and multimedia design. We discuss the main contributions in this section.

7.3.1 Examining visual aid usage

While the use of traditional whiteboards for synchronous activities such as brainstorming and conveying ideas, and asynchronous activities such as writing a task list or leaving messages had been studied within the computer-supported cooperative work (CSCW)

community (Cherubini et al., 2007; Mynatt, 1999; Tang et al., 2009; Teasley et al., 2000). Those studies focused on the whiteboard as a collaborative tool used in an office or common area setting, mainly to inform the design of interactive large-display tools. A whiteboard or blackboard in a classroom is inherently different. It is a visual aid used by an instructor to convey ideas to a large group of students, over a longer period of time. To the best of our knowledge, computer slide usage in classrooms or other domains has not been reported in the literature in the context of designing slideware tools.

Our observational study (Chapter 3) provides a first in-depth look at the usage of different visual aids in classrooms and in conference settings. Looking at slide usage, we found similar trends between the classroom and the conference setting, a finding that supports Tufte's claim about slides dictating a certain style of usage (Tufte, 2003). We then focused on classroom usage, and identified content categories that helped us better investigate how blackboards and slides are used for learning, and we distinguished between the advantages of each medium (slides and boards). The results from this study demonstrated the importance of persistency of information, showing that with blackboards instructors refer back to previously shown information – a practice that does not occur with electronic slides. We also emphasized the dynamic use of blackboards, enabling instructors to spontaneously add, control or remove content.

7.3.2 Developing design guidelines for classroom presentation systems

As explained in Section 3.5, our observational study provided six design guidelines for building classroom presentation systems on large, high-resolution displays. Some of those guidelines, such as short- and long- term persistency and support for dynamic content, have been implemented in our prototype systems. Other guidelines, such as supporting gradual build-up of information, have partly been implemented, while others, such as supporting gestures, have not. In Section 7.2, we examined how these guidelines evolved into a full comprehensive framework for effective use of larger display surfaces in classroom presentations. The guidelines outlined in the framework provide a practical contribution to designers and developers of presentation systems.

7.3.3 Designing classroom presentation tools

We described the design and implementation of MultiPresenter (Chapter 4), a novel presentation system that works on multiple displays. The main contributions of MultiPresenter are that it tells us *how* a presentation system for multiple displays can be realized, and allows us to validate the guidelines and assumptions on which its design is based. Unlike other presentation systems that only support showing previous slides and that require complex infrastructure (Abowd, 1999; Chiu et al., 2003; Röüling et al., 2004), MultiPresenter supports a wide range of presentation practices. Moreover, MultiPresenter is simple to use and can be run on a laptop in any classroom containing multiple screens. This enabled us to easily deploy it in order to understand how instructors would use it in actual classrooms.

One of the concerns when designing presentation systems is to not overload the presenter, who needs to focus on the presentation act. We have shown that it is possible to support a wide range of options, while still keeping a simple and usable interface. MultiPresenter enabled us to examine the feasibility of our design guidelines, including demonstrating a possible way of implementing them. In addition, MultiPresenter illustrated the approach of separating content and presentation style for presentation systems, and demonstrated the benefits of a robust system architecture.

We described an extension for MultiPresenter that enables audience control of parts of the screen. While this extension was not empirically validated in real classroom settings, we described the design goals and implementation details in order to explain how such a system could be designed.

7.3.4 Examining patterns of usage of multiple screens

The quasi-experimental deployment study presented in Chapter 5 allowed us to gather qualitative and quantitative data concerning instructors' use of two screens in actual classrooms. This allowed us to analyze the data for patterns of software usage (Section 5.4), by examining *what features* instructors used, and for patterns of pedagogical usage (Section 5.5) by examining *how* instructors used the extra screen real estate. The software usage analysis indicated that instructors used a variety of presentation styles, ranging from a pre-planned dual-screen presentation to a dynamic one, often shifting

between styles during the presentation. We also showed that instructors used the extra screen real estate for persistency of information, both by spontaneously bringing back previously shown information, and by deciding ahead of time that a slide should persist longer. The prominent pedagogical patterns we found included comparing slides, having an important slide persist, showing an overview slide alongside content slides, and unifying a single topic by presenting two related slides side by side.

7.3.5 Evaluating the efficacy of extra screen real estate

To evaluate the advantages and disadvantages of using larger display surfaces, we asked instructors and students for their subjective opinions of teaching and learning with extra screen real estate (Sections 5.5 and 5.6). Both instructors and students were very positive about using extra screen real estate. The 198 students that participated in the questionnaire showed a strong preference for MultiPresenter over regular PowerPoint presentations. Students indicated that they thought that MultiPresenter helped the instructor *present* the material better and it helped them to *understand* the material better compared to a one-stream presentation. All instructors indicated they thought MultiPresenter was very useful, it helped students learn, and they would like to use it again. In order to objectively evaluate the efficacy of learning with extra screen real estate we conducted a controlled laboratory study (Chapter 6). We examined how well participants learned from a two-stream presentation compared to a one-stream presentation. Data indicated that extra screen real estate can indeed improve learning. In particular, learning was best improved when pertinent prior information was shown alongside currently explained information. There was also some evidence to support the claim that comparisons are improved with extra screen real estate. Results gathered from subjective participant opinions from the laboratory study corroborate data from the classroom deployment. While there have been many studies that examined the effect that electronic slides have in classrooms (Bartsch & Cobern, 2003; Susskind, 2008; Szabo & Hastings, 2000), this is the first study that examines the connection between extra screen real estate and learning.

7.3.6 Revisiting the research questions

We re-examine the research questions from Section 1.2 and show how we addressed them in this dissertation.

The first research question asked how can we best combine the advantages of traditional visual aids with the advantages of electronic presentation systems. We answered this question in our observational study, by articulating the advantages of each medium and focusing on the practices that traditional visual aids have and those that were lost with the transition to electronic software. We showed that a system that is built based on the electronic medium and that added the notions of persistency of information, dynamic use of content, gradual build-up of information, and support for gestures would be able to combine the advantages of older and newer technologies.

The second research question asked how a presentation system that uses large, high-resolution displays can best support instructors and learners. We addressed this question by building and deploying MultiPresenter. We showed that using our design guidelines (Section 7.2.2) a presentation system can indeed support instructors and learners. We listed the design rationale and goals that we had when building MultiPresenter (Section 4.3). In addition, we have shown how instructors actually used MultiPresenter and discussed various pedagogical practices that instructors have used with MultiPresenter that were beneficial for students learning (Chapter 5).

Finally, the third research question asked if objectively there is benefit for learning using a larger screen surface. Our laboratory study (Chapter 6) showed that increasing screen real estate can improve learning, especially if pertinent prior information is shown alongside the current theme.

7.4 Recommendations for future research

We summarize our recommendations and suggest directions for future work that may be of broad interest.

7.4.1 Presentations on multiple screens (more than two)

The current version of MultiPresenter only supports two displays. Any extension to MultiPresenter would enable it to support more than two displays. MultiPresenter's

basic architecture is extendable to support three or four screen in much the same way as it supports two screens. In order to support more screen real estate, it would mainly require GUI changes to the instructors' interface. However, supporting more screens raises new questions. For example, when showing previous slide, an instructor might want to show one previous slide on each screen, or show more than one slide on a single screen. If the latter is the case, then there are many possibilities of showing two or four previous slides on two or three screens. The difficulty is how to effectively use an array of screens. We saw that one of the concerns students had was that it was difficult to pay attention when there is too much visual information. It may also be difficult to know where the instructor is referring. These problems are likely to increase if more information is on more displays. Another concern is for the authoring view. The authoring process enables instructors to construct a pre-made dual-stream presentation. Constructing a three or four screen presentation is more complex and would require better organization of the GUI interface.

7.4.2 Presentation on higher resolution, wall-size displays

MultiPresenter supports two screens, or a wide display surface that could be separated into two areas. This assumption was made because of practical reasons: most large lecture halls at our university today have no more than two screens. The screens in current lecture halls provide a natural seam that separates displays into two distinct areas. With the increase in graphical processing power of personal computers and the increase in projector resolution, we anticipate that higher resolution displays that might span over an entire wall will be more common in the future. While many of the principles outlined in this dissertation hold with these displays, designing for such a configuration is challenging.

One question that arises is whether we should partition the screen to some number of logical units and treat the space as we would with multiple screens, or use the entire display surface for effective presentations. Partitioning the screen is similar to having a presentation on multiple screens, which was discussed in Section 7.4.1. However, we need to understand how a display could be best partitioned, considering the size and locations of the partitions. Treating the entire screen as one unit brings up questions of

how to control and present information on large, wall-size displays. While there are several interaction techniques designed to control information on large displays (Baudisch et al., 2003; Guimbretière, Stone, & Winograd, 2001), few true large-display applications have been developed and tested.

The Fly system (Lichtschlag, Karrer, & Borchers, 2009) provides some ideas on how to present information on a large, unconstrained canvas. While they did not focus on large displays, their notion of a large infinite planar space could work well with a large wall display. Controlling a wall-size display in a lecture scenario can be quite complex. As we pointed out earlier in this dissertation, the way the instructor controls the interface must be intuitive and simple in order for the instructor to focus on the presentation task and not on the interface. We therefore believe that a static partition of the screen into several "display areas" is probably better. However, both approaches should be examined and compared. Novel design ideas and new applications might enable better control of information on a large display surface.

Large interactive touch sensitive display surfaces offer new opportunities. The advantages of interactive whiteboards for education have been shown in smaller classes (Glover et al., 2005; Smith et al., 2005). However, today's interactive boards are too small to be seen in large lecture halls. Research opportunities lie in examining how large interactive wall displays can be best used for presentations. With the instructor standing near the wall, controlling information may be difficult. Parts of the screen are unreachable by instructors. Interaction techniques with large displays such as shadow reaching (Shoemaker, Tang, & Booth, 2007) can be used to allow instructors to reach all screen areas while still providing the audience with awareness of the instructors' actions. Another possibility is to provide instructors with a world in miniature view (Stoakley, Conway, & Pausch, 1995) to control the entire screen standing near the screen.

7.4.3 Scalable presentation templates

Often lecture material is used more than once, and is presented at different times and on different venues. A presenter might want to use the same presentation in a small venue with one screen and a week later in a large lecture hall with four screens. Most of the instructors we worked with "recycled" their one-screen PowerPoint presentation to use

with two screens. One of the reasons for the success of MultiPresenter was that by using the notion of primary and secondary screens it provided full compatibility with a one-stream presentation. Instructors could use their one-stream presentations on two screens without any extra effort. Scalable presentation templates would be ready-made presentations that could be used according to the number of screens available in the room at the time of the presentation, not just the number of screens that were anticipated when the presentation was authored. This poses two main questions. First, expanding from a one-stream set of slides, how can we author a set of slides so that it could automatically be displayed on any reasonable number of screens in the room? Second, given an *n*-stream presentation, how can we use the presentation on fewer than *n* screens?

Starting with the first question, we believe that a combination of assigning meta-information to slides and using pre-defined templates could enable automatic expansion of presentations to fit the number of screens available. This would require more work from the presenter when authoring the presentation, but the presenter would need to mark the slides only once (when authoring the presentation) and yet could use this meta-information whenever he or she presented without having to worry about the number of screens available.

An additional benefit to adding meta-information is that this would require presenters to think more carefully about the structure of their presentations. When authoring a document, authors often think of the high-level structure of the document. However, many slide presentations do not have a set structure. Building a multiple-screen presentation in advance forces the instructor to rethink the structure of the lecture. As I6 stated: "It actually changed the way I thought about my lectures ... given the capabilities of MultiPresenter to use two screens, I think that actually shaped the way that I structured the lecture" Also, meta-information can be useful for archiving and retrieving of archived presentations.

Useful meta-information might be *grouping* and *attachment* tags. Grouping would assign a certain slide to be seen alongside a group of other slides. For example, a history instructor could mark the Roman Empire map slide to be presented alongside any slides that talk about the Roman Empire. This could also be used to mark positions for overview slides relative to the primary stream of slides. A second or third level of

grouping could also be marked, for example with higher-level overview slides on one screen and intermediate-level overview slides on another. Attachment might assign a certain slide to be seen with one or more other slides. This could be useful for comparing information, or augmenting a topic. If two or more slides are annotated as *attached* to each other, the system would try to show them side-by-side within the constraints of the number of screens available.

The rules inherent in the meta-information might be contradictory, requiring meta-rules to resolve conflicts. Attachments probably should have priority over grouping, so if three slides are attached to each other in a three-screen presentation, all three would be shown, temporarily replacing an overview slide that might otherwise have been shown in a four-screen presentation.

Different *templates* could be used to decide how to run a certain presentation in a specific situation using the assigned meta-information. For example, a template giving priority for showing the previous slide on at least one screen could be combined with meta-information to show a presentation on two, three or four screens. Showing the presentation on two screens would show a one-stream presentation on one screen with the previous slide on the second screen. Showing that same presentation on four screens would use one screen for previous slides, and the other three for a presentation based on the meta-information.

The second question was the problem of narrowing down a given *n*-stream presentation to a lower number of streams. This problem can be addressed by asking the presenter to mark a distinct order for the slides when building the presentation. This, however, is not necessarily trivial. A map slide marked for *grouping* may appear twice in a presentation, each time connected to a different set of slides. Therefore, when marking the order of the slides, the presenter should be able to mark one slide as being in more than one place in the presentation. Using templates, the presenter could then decide that when presenting on one screen whether the map slide should appear (for example) every third slide within its connected set of slides to remind the audience of the map, or appear only once in each of its marked locations.

This model for meta-information is certainly not complete. There are many more unanswered questions and many pitfalls, such as clashes of rules, that designers of such a

system will have to address. However, we believe that a solution based on the ideas of marking meta-information for slides, combined with pre-defined templates could be implemented and might provide a powerful way to easily author scalable presentations.

7.4.4 Extending our theoretical knowledge base

In Chapter 6 we examined how extra screen real estate affected learning in a controlled laboratory setting and we saw that extra screen real estate can indeed help learning. We found that showing pertinent prior information beside the current information increased learning outcomes. We had some support from our data for the hypothesis that comparing information is better when more screen real estate is used. In addition, we concluded that showing more information did not have a negative effect on retention of verbalized information. However, most of the extra information we showed was pertinent to the immediate theme. Other studies warn us that extraneous information can in fact hinder multimedia learning (Mayer, 2001; Mayer, Heiser, & Lonn, 2001). In order to better examine the negative effects large display surfaces might have, further empirical studies should be conducted to examine whether extraneous information presented on the extra screen real estate available with multiple displays might hinder learning.

We did not find a difference in learning with a larger display surface between information shown graphically or textually. However, this may be because we only examined the difference between graphical and textual information within the previous slide category, which did not show an overall general effect. In order to fully understand differences in learning with graphical vs. textual information when using larger display surfaces, a study that examines *pertinent* graphical and textual information should be conducted.

In our laboratory study, we assessed participants' basic information recall according to the knowledge category of Bloom's taxonomy (1956). The knowledge category examines the basic recall of data, and is the first building block in the taxonomy. Without mastering the basic categories of learning, one cannot continue to the next. Future work should examine whether more screen real estate affects higher-

level categories of learning, such as understanding the meaning of information and using learned information in new situations.

Finally, some of the reasons for conducting a laboratory study were to have better experimental control in order to help eliminate possible intervening factors, and to be able to randomly assign participants to experimental treatments. The drawback of this approach, however, is loss of ecological validity. A complementary study would examine the difference between a two-stream and a one-stream presentation in actual classrooms. A recommended way to conduct such a study would be to teach two sections of a given course with each section viewing lectures with a different delivery style similar to the methodology used by Susskind (2005; 2008).

7.4.5 Archiving presentations

Much effort has been made to enable archiving of presentations for later viewing. Some of the research focused on capturing the different streams of media of classroom or other presentations for later retrieval (Abowd, 1999; Hürst, 2003; Mukhopadhyay & Smith, 1999), while other research focused on capturing and transmitting to a large group of audiences via webcasting systems (Baecker, Moore, & Zijdemans, 2003; Baecker, Wolf, & Rankin, 2004). The dynamic nature of MultiPresenter makes it more difficult to archive than with regular "static" presentations. In order to capture the nature of a MultiPresenter presentation as it occurred in a classroom, we need to capture information presented on both screens, including the dynamic interactions that were used in class. Archiving at the semantic level is important for later retrieval; it is important to know *what* has been presented in order to later be able to return to that location in the material.

A compact representation of the lecture is also important in order to save resources. A MultiPresenter presentation could be archived using a two-level archiving scheme that saves the content of the slides in one level, and the time-stamped interactions during the lecture on a second level. Recent work by Chan (2009) has tested this in a prototype for webcasting archives. The lecture can then be reconstructed using these two levels. A viewer application could then be built that would enable viewing of the two screens at any moment in the presentation. Ideally, the viewer would enable access and viewing of the presentation according to semantic content. For example, a student interested in the

Roman Empire would be able to see in the outline of the lecture the times during which the Roman Empire overview slide (or the map) appeared on the secondary screen.

7.4.6 Gesturing

We have seen that gesturing is important for instructors to direct the attention of students to the visuals. Using blackboards, most instructors frequently gesture at the board to help connect the verbalized explanation with the visual one. I2 commented on using the blackboard together with MultiPresenter:

> "... I like still using the blackboard. I use the software when I want to write on top of the slides. When I present an example from scratch, I still use the board for the reason that it is more dynamic. I can point there, I can turn to the students and talk, I am also used to using the board. On the laptop, no matter how you do it, you need a pointer to point, and it feels more awkward. On the board I feel I can point there, I can draw things and point there with my hand and I can show from my gestures that **this** one is important."

Because of the positioning of the screen and the instructors, it is often more difficult to gesture at the visuals using electronic visual aids. This can create a disconnect between the instructor and the visuals, with the audience experiencing a feeling of a disembodied voice explaining what is seen on the screen. For these reasons, we have recommended in our guidelines to support gesturing as best as possible. However, it is difficult to support gesturing within a presentation system. With MultiPresenter, and with other commercial and research presentation tools, instructors control the presentation from a classroom computer or a personal computer. Because the instructor is standing near the computer, and the screen is usually high above the reach of the instructor, natural gesturing is difficult to achieve.

One way to add some gesturing capabilities is to provide instructors with tools to annotate or emphasize specific locations on slides. While this does not include the embodiment of the instructor, it does allow a finer granularity of gesturing to support pointing at specific areas on slides. Using electronic ink, instructors can do this kind of pointing. Indeed, as did Anderson et al. (2004), we have seen that many of the electronic ink annotations used were attentional annotations aimed at focusing students's attention

to specific areas on the screen. An enhancement that does not require a TabletPC could use ephemeral annotations. Using the spotlight technique (Khan et al., 2005), for example, instructors could highlight certain areas of the screen for a limited amount of time. A different approach, similar to seeing the shadow of the instructor's hand in an overhead projector, would use tracking of the position of the instructor to embed a part of the instructor's image with the visual aid to create an embodiment of the instructor within the projected image (Shoemaker, Tang, & Booth, 2007).

7.5 Concluding comments

The research reported in this dissertation investigated the potential for using large, high-resolution displays to enhance classroom learning. Our evaluations indicate that a system that integrates advantages of traditional and newer visual aids to make use of the larger display surfaces available in many of today's lecture halls to support classroom presentations can be effective for both instructors and students. We have shown many advantages that a multiple screen presentation has over the one-stream alternative. The success of the approach developed here provides persuasive evidence to continue using large display surfaces in large lecture hall presentations. This entails both further investment in large lecture hall infrastructure and development of adequate software support. MultiPresenter and the findings reported here are a first step in achieving this goal.

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Appendix A

Observational Study Interview Script

Background questions

1. How many years of teaching experience do you have?
2. Do you have formal teaching training?
3. What classes do you/did you teach?
4. What were the sizes of the classes in which you taught?
5. What kind of technological aids (how many projectors, microphones, other stuff) were there in the classrooms you taught in?
6. What technological aids do you use in the classroom? How do you use them? (laser pointer, projectors)
7. How does the class's physical settings (which kind or boards there are, where the projectors are screening) affect the lecture?

Comparison of different media

8. Do you use the blackboard or whiteboard in your classes? Slides? Overhead transparencies? Other visual aids?
9. If you use both, when do you use the blackboard and when do you use slides? (or OT?) Do you use more than one medium in the same lecture?
10. Are there courses or areas you prefer to use the blackboard? Why?
11. Are there courses or areas in which you prefer to use slides? Why?
12. Same thing if you use overhead transparencies, or whiteboards.

Questions about Boards

13. Can you try to explain in which cases you use the blackboard? How do you use it?
14. What types of data do you put on the board?

15. Do you come with prepared material that you intend to write down on the board, or do you use it spontaneously to support arising themes?
16. How do you generally organize information on the board? Do you have a regular way to lay down information?
17. When you erase the board, what do you erase?

Questions about slides

18. If you use slides, try characterizing your use of slides? How do you use them? What kind of information do you put on your slides?
19. Do you use animation in slides? Slide transition?
20. Do you feel that using slides you sometimes need to go back to previous slides? Does this happen with board use (need to go back to stuff you erased)?
21. Do you sometimes feel the need to compare two slides? When? Do you do that with boards?
22. Do you use another medium with slides? If so, what do you use the other medium for and what do you use the slides for?
23. How long does it take you to prepare a slideshow for a one hour lecture?
24. When you create your presentation, does the process help you structure your thoughts and thus better prepare for the class?
25. Do you feel that having computer generated slides gives the class a better structured lecture, or does it reduce the amount of freedom you might have to spontaneously drift from the current theme?
26. Do you hand over your slides to the class? Why? Why not?

Comparison questions

27. Do you think the pacing or the rhythm of the class is different depending on the medium used?
28. Do you think that students prefer when you use the board or when you use slides why? What gets students more engaged?
29. Did you get feedback from students on using either the board or slides?

30. To summarize our discussion, what are in your opinion the advantages and disadvantages of using slides verses a whiteboard or blackboard? What are some of the problems of each media?

Summary

31. Do you feel more comfortable explaining complex reasoning using the board? Slides? No difference?
32. I explain a bit about the mutli-monitor software.
33. Do you think that the software I described is useful? How could it be useful? Do you have other ideas I can implement?
34. Try to think of future classrooms and try to imagine any technological aid of any kind in the classroom that would help you in teaching. What would you want it to be?

Appendix B

Full Deployment Details

Class	Instructor	Semester	Subject area	num of students	class	Venue
C1	I1	Winter 2007, term 2	computer science	88	CS121	DMP110
C2	I2	Summer, 2008	computer science	58	CS 304	DMP 110
C3	I3	Summer, 2008	computer science	47	CS 310	DMP 110
C4	I2	Winter 2008, term 1	computer science	93	CS 211	DMP 110
C5	I4	Winter, 2008, term 1	history	95	Hist 101	West mall swing Space 122
C6	I4	Winter, 2008, term 1	history	35	Hist 476	Buchanan D219
C7	I5	Winter, 2008, term 1	history	144	Hist 104	IBLC 182
C8	I5	Winter, 2008, term 1	history	21	Hist 434	IBLC 182
C9	I7	5/10/2008	Invited talk	~100	Invited talk	Carlton university
C10	I4	Winter 2008, term 2	history	95	Hist 101	West Mall Wing Space 122
C11	I6	Winter 2008, term 2	history	153	Hist 105	West Mall Wing Space, 121
C12	I1	Winter 2008, term 2	computer science	89	CS 121	DMP 110
C13	I8	26/2/2009	dentistry	~40	DENT 420 (dentistry)	
C14	I2	Winter 2008, term 2	computer science	91	CS 304	DMP 110
C15	I2	Winter 2008, term 2	computer science	27	CICS 520	DMP110
C16	I2	Summer, 2009	computer science	60	CS 211	DMP110
C17	I2	Summer, 2009	Computer science	51	CS213	DMP110

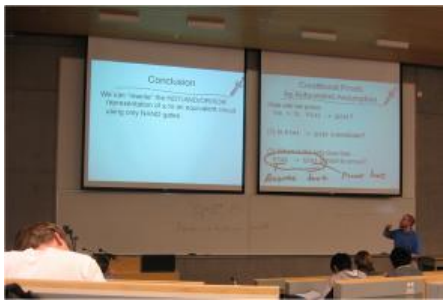
Appendix C

MultiPresenter's website

This appendix includes a copy of the MultiPresenter's website last updated June, 2009.

Joel Lanir

MultiPresenter



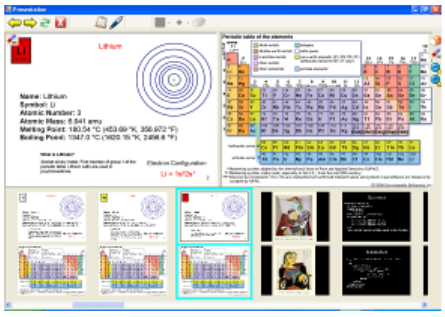
MultiPresenter is use in a classroom

Description

MultiPresenter is a novel presentation system designed to run on high-resolution or multiple displays. It allows the presenter to organize and present pre-made and dynamic presentations that take advantage of multiple projectors accessed from a personal laptop.

Using MultiPresenter the instructor can easily:

- compare between two slides
- Have an entire slide or selected clipped information persistent longer on one screen
- Easily refer back to previously shown information
- Have a problem slide on one side while showing the solution on the other side
- Show an overview slide on one side while going over the detail slides on the other side
- Show two or four slides back on the second screen

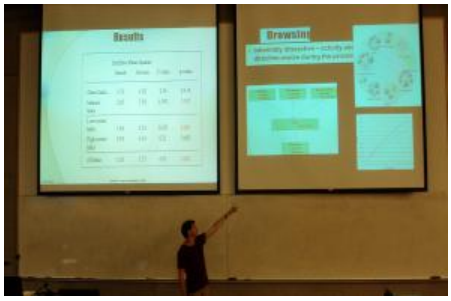


Interface of MultiPresenter when presenting

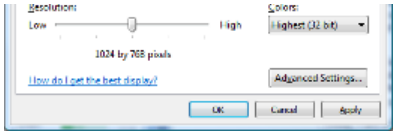
Hardware and Software Requirements

In order to run MultiPresenter, all that is required in the lecture hall are two projectors that can be accessed via two VGA (or DVI) cables. To connect to two projectors from a single laptop, a simple USB to VGA adapter is needed. One that I recommend is the UV Plus 16 by EVGA. You can buy it here.

Currently, MultiPresenter only runs on Windows XP or Vista operating systems. Before running MultiPresenter, you have to set-up the external screens to be in extended desktop mode, with the primary display (your laptop) the left most display. So your display settings window should look something like this:



Dynamically clipping content on the second screen



Download

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The software is granted in a nonexclusive license to use this software solely for the users' internal business purposes. The user may not commercially distribute, sublicense, resell, or otherwise transfer for any consideration, or reproduce for any such purposes, the software or any modification or derivation thereof, either alone or in conjunction with any other product or program.

This software is provided "as is". The author makes no warranties, either express or implied, with respect to this software and will not be liable for data loss, damages, loss of profits or any other kinds of loss while using or misusing the software.

Download MultiPresenter version 1.73 for office 2007

Download MultiPresenter version 1.72 for office 2003

Here is a user manual with instructions on how to use MultiPresenter:

web page , Download

Further information

If you have any other questions, want to try the software, or if you tried the system and have any comments, bugs to report, or any features you think should be added contact Joel Lanir at:

yoel @ cs.ubc.ca

Appendix D

MultiPresenter's user manual

We present a copy of MultiPresenter's user manual as was provided to the instructors using MultiPresenter and was available to download from MultiPresenter's website.

MultiPresenter User Manual

Written by: Joel Lanir

Contents

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4. Building a premade dual-screen presentation 225

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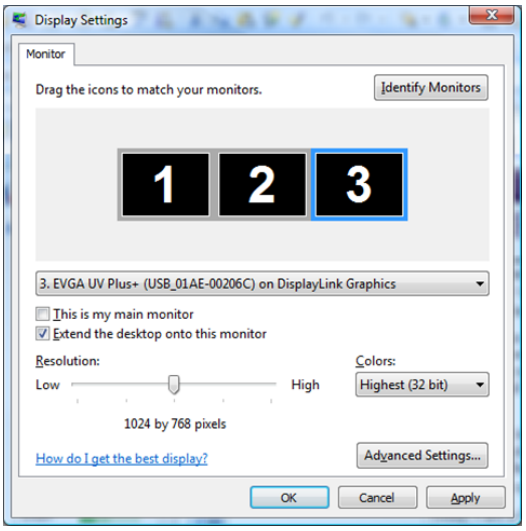
MultiPresenter is a presentation system built to work on multiple screens. It currently supports two external screens. This manual is a simple how-to-use manual which describes the different functions and features that MultiPresenter has. It does not describe how MultiPresenter can be best utilized, which is mainly dependent on the user.

1. Technical Requirements

In order to run MultiPresenter, all that is required in the lecture hall or conference rooms are two projectors or displays that can be accessed via two VGA (or DVI) cables. To connect to two projectors from a single laptop, a simple USB to VGA adapter is needed. One that I recommend is the UV Plus 16 by EVGA.

Currently, MultiPresenter only runs on Windows XP or Vista operating systems. Before running MultiPresenter, you have to set-up the external screens to be in extended desktop mode, so your display settings window should look something like this:



Please notice: in order for MultiPresenter to work, the laptop or primary display (the one the instructor is using) **must** be number one, and must be the left most display in the display settings dialog window.

2. Loading a presentation

After you start MultiPresenter, you get an empty application. First thing that is needed to do is to load a presentation. To load a presentation, press the following icon: . This will open a regular windows

file open dialog. The default file type to open is a PowerPoint file. Opening a PowerPoint file will load the PowerPoint slides as a single stream of slides. It is also possible to open an .mpr file which is a saved MultiPresenter two-screen presentation file. To open an .mpr file, the file type should be changed to .mpr MultiPresenter file. The third possibility is to open image file/s. One or more image files (by pressing cntl it is possible to select more than one file) can be selected and loaded to MultiPresenter as a single stream of slides by selecting the file type to be image files and choosing one or more image files.

3. Running a Presentation

After loading a presentation, you can either build a readymade dual-screen presentation (see section 4), or immediately run the existing presentation on the two screens. When running the presentation, there is a primary screen and a secondary screen. The primary screen is used to show the regular stream of slides, and the secondary screen is used to show different stuff that is decided either ahead of time or during the presentation to be useful for the audience and presented on the second display.

Starting a presentation

To start the presentation press: .

The dropdown beside the icon has the following possibilities for running the presentation:

Interactive: run an interactive presentation in which the presenter controls what appears on screen at any given time.

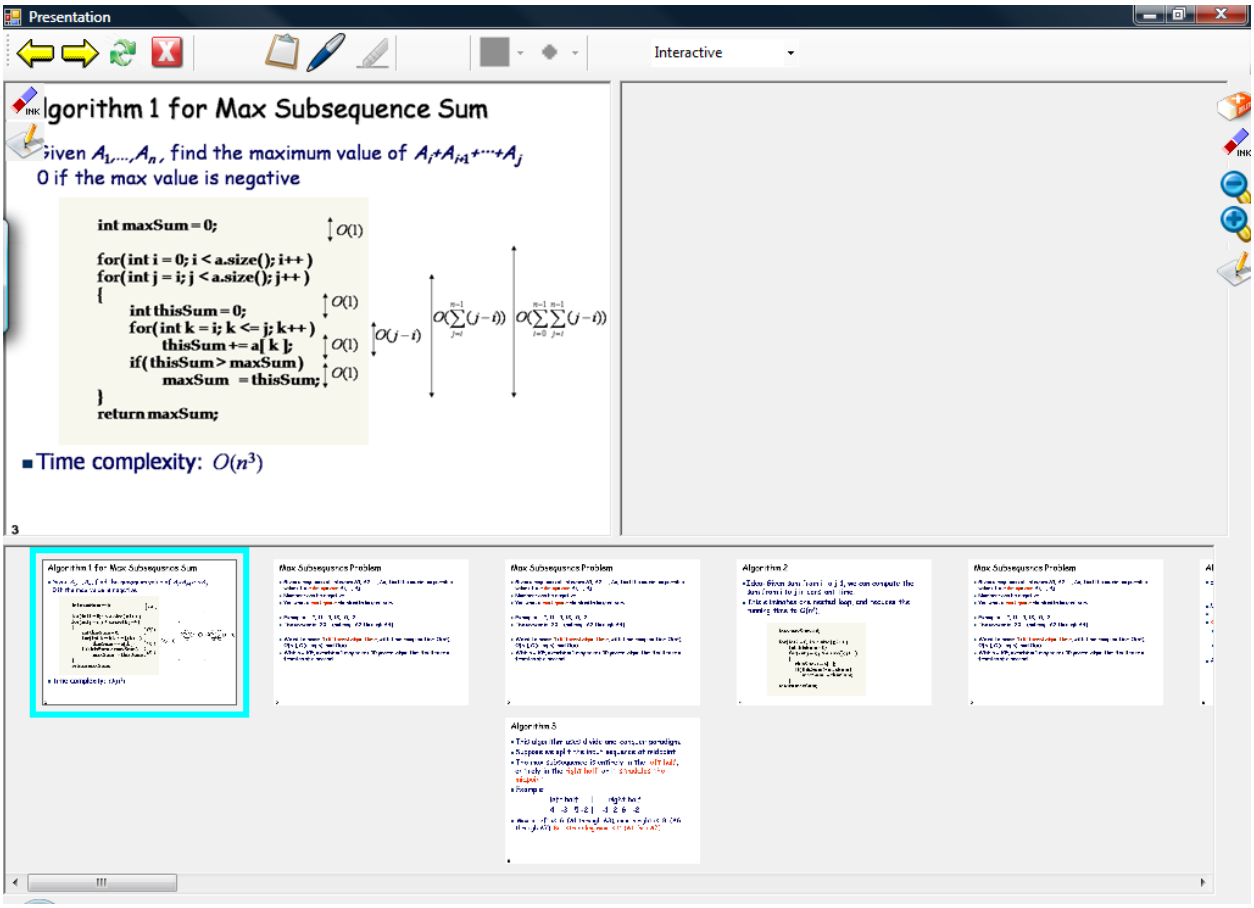
One slide back: The previous slide from the stream of slides is displayed at all times on the secondary screen.

Two slides back: The two previous slides are displayed on the secondary screen.

Four slides back: The four previous slides are displayed on the secondary screen.

During the presentation

The following is an example of the presentation control window:



The left pane shows what is currently shown on the primary screen. The right pane (empty in this screen shot) shows what is currently shown on the secondary screen. The bottom pane shows the stream of slides. The current position in the bottom pane is shown with a blue rectangle. (See image)

Progressing through the slide deck: to go to the next slide/s, it is possible to press the right arrow key, or the pgDn key on the keyboard, or press the yellow right arrow icon on the top left of the screen. To go to the previous slide, press the left arrow or the pgUp key on the keyboard, or the yellow left arrow icon on the top left of the screen. To go to any slide (or two slides set together) in the deck, it is possible to find the slide in the bottom pane, and double click on it to jump to it.

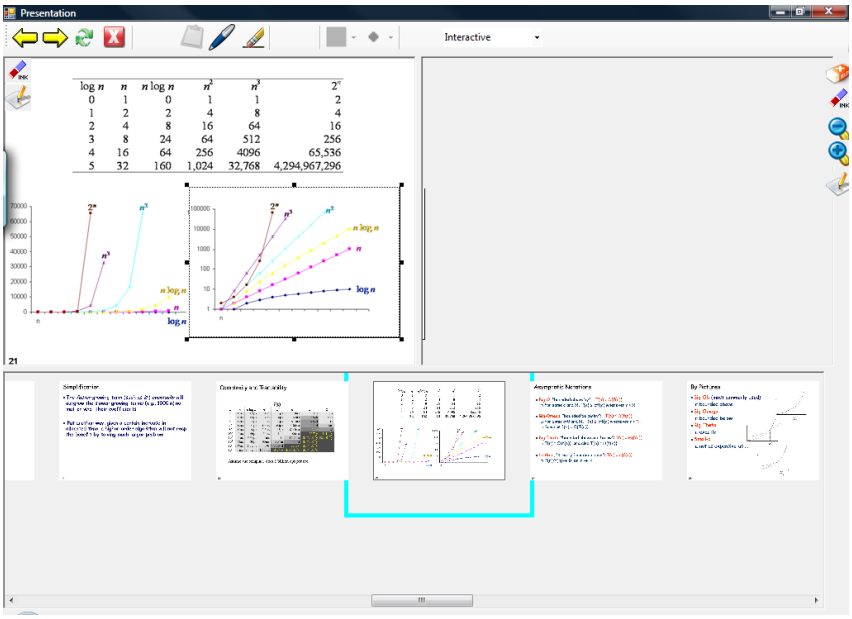
Putting a slide on the secondary screen: To put a slide on the secondary screen, simply drag any slide from the bottom pane to the right pane. If the right pane is empty, the slide will fill the entire screen. If there is already one or more slides on the secondary screen, the system will automatically position the slides on the screen so all slides can be seen. If you want the dragged slide to appear on the entire screen, you first need to erase what is on there, and then drag the slide to the screen.

Exchanging between the screens: Pressing the icon, will exchange between the two screens seen by the audience. Nothing will be seen in the presenter's interface, since the primary screen is always shown on the left pane of the interface regardless of which screen it is shown on to the audience.

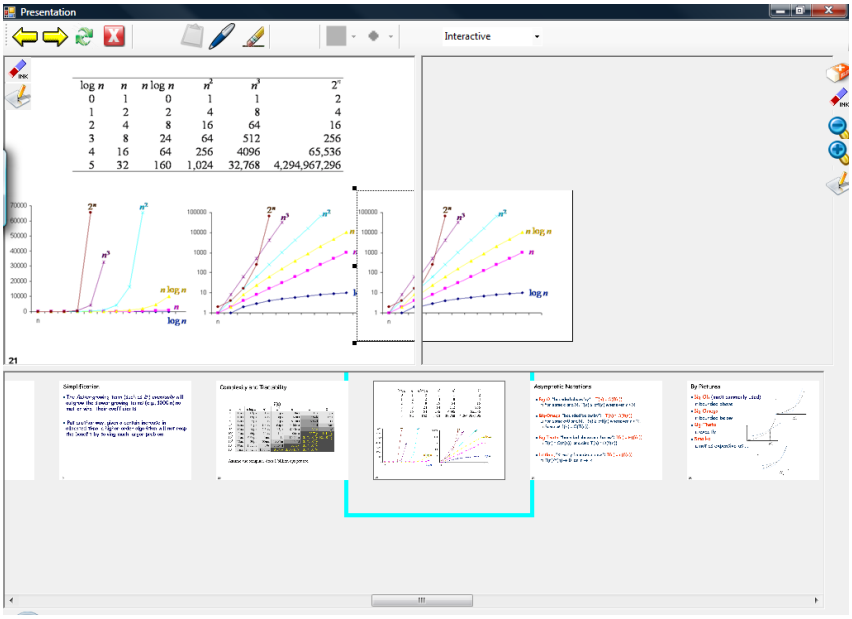
Finishing the presentation: Pressing the icon, or just closing the presentation window, will finish the presentation and return to the presentation-building window.

Clipping

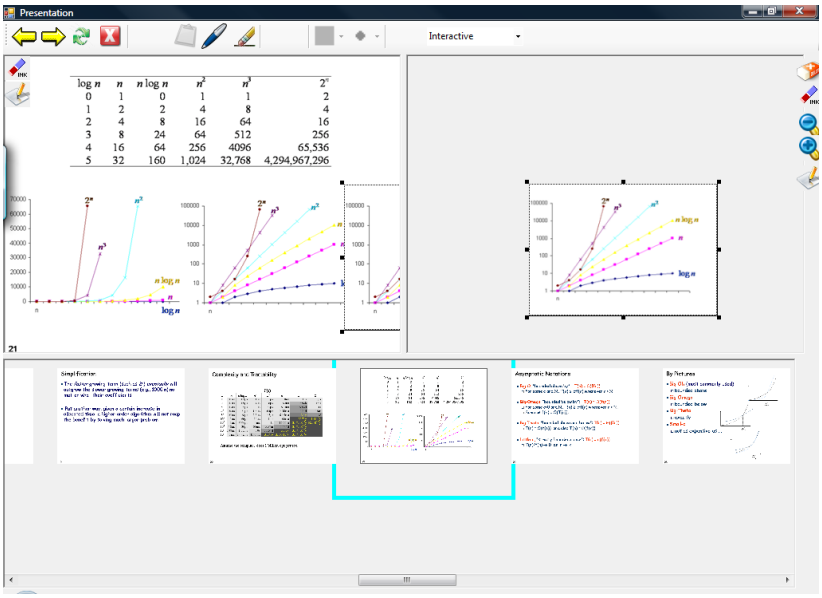
At any time during the presentation, it is possible to select any part of primary screen and "clip" it to the secondary screen. You are in clipping mode if the icon is greyed out. The following image shows the first part in which the presenter has selected the graph on the primary screen to be clipped:



The user then drags the clip to the secondary screen:



The clip is then positioned, and can be resized on the secondary screen:



At any time, any clip can be resized by clicking on it and using the dark dots to resize it. Any clip can be deleted by selecting it and pressing the delete button on the keyboard.

Using Electronic ink:

Presenters with tabletPC using their tablet's pen or presenters with regular laptops using the mouse (mainly for highlighting slides), can use electronic ink with MultiPresenter. To use ink, press the icon. This will change the cursor to indicate that you are in pen mode. Any touch on the slides either with the mouse or the tabletPC's pen on either screen will draw ink strokes. To use the secondary screen as an empty whiteboard, erase whatever is there and then use the pen mode to write on it. Pen can also be used to annotate on existing slides. To erase existing strokes, either use the icon and draw over any stroke, or use the back of the tabletPC's pen if your pen supports erasing.

Using the color and size icons: , the presenter is able to choose the color and size for the ink. These icons are only active in pen mode.

Only one of the , or icons can be selected at a single time. The one that is greyed out indicates which mode the presenter is currently using. After using ink, if the presenter wants to change to the clip mode, the clipboard icon should be pressed.

Screen toolbars

Both screens have a toolbar associated with them on the side of the screens. The primary screen has less functionality and is a subset of the secondary screen toolbar. The following toolbar is the secondary screen toolbar. Pressing any icon here will perform an action that only applies to the secondary screen:

The top eraser icon , erases the entire secondary screen.

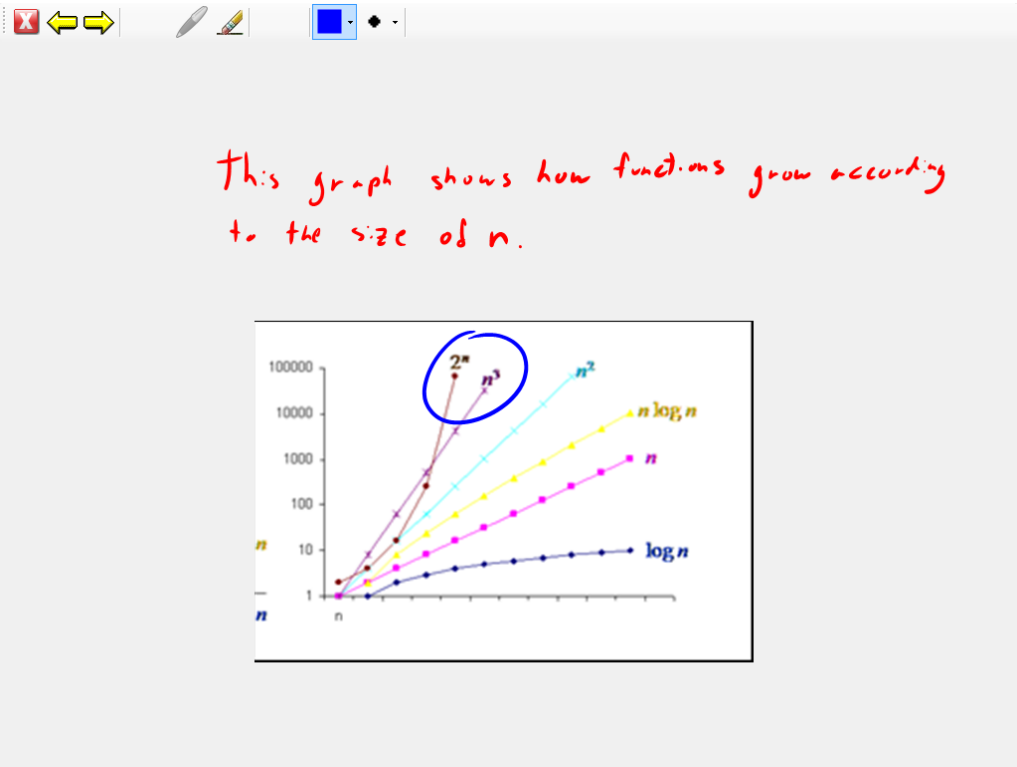
Underneath it, the eraser with the words ink on it

, erases only the ink from the screen.

The minus and plus icons , make the slide appear smaller or larger, to allow more space on the screen usually for either ink or for clips. Remember to make the slide bigger, if you made it smaller. The application will remember the previous size when you bring another slide, even if the slide is erased.

The most bottom icon (the writing icon) , will open a writing screen for the pressed screen. (the icon appears both on the secondary screen and the primary screen toolbar)

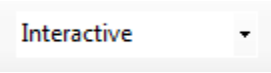
Writing screen



The writing screen is used to allow higher resolution writing for electronic ink. Using the writing screen, instructors can write on the empty screen or on a slide with higher resolution. (Since it covers the entire screen of the presenter's computer). On the top of the screen, the presenter can select the ink color and size, flip between the eraser and pen, or progress the primary screen slide (if this is the secondary screen), without leaving the writing screen. Pressing the close icon will go back to the presentation view window.

Changing modes during a presentation

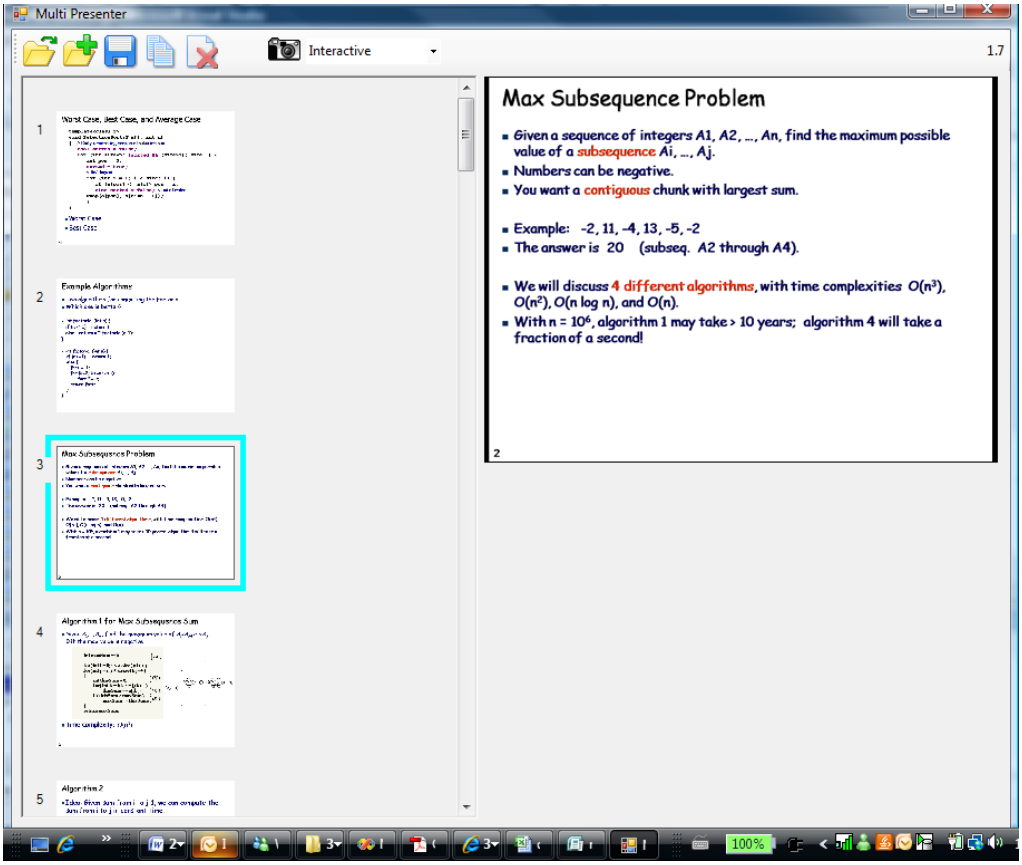
It is possible to change modes during the presentation. Using the following dropdown menu:



, the user can change between the interactive mode, and the slide-back mode in which one or four slides back are displayed on the secondary screen. For example, if the presenter is in slide-back mode, showing four slides back and wishes to use the secondary screen as a whiteboard for a while, the presenter needs during the presentation to change the drop-down to be interactive, then erase the screen and use it as a whiteboard. When the presenter finishes using the screen as a writing space, he or she can then revert back to the slide-back mode, again using this drop-down.

4. Building a premade dual-screen presentation

It is possible to decide ahead of time, which slides should appear on the secondary screen. This can be done using the presentation-building window:

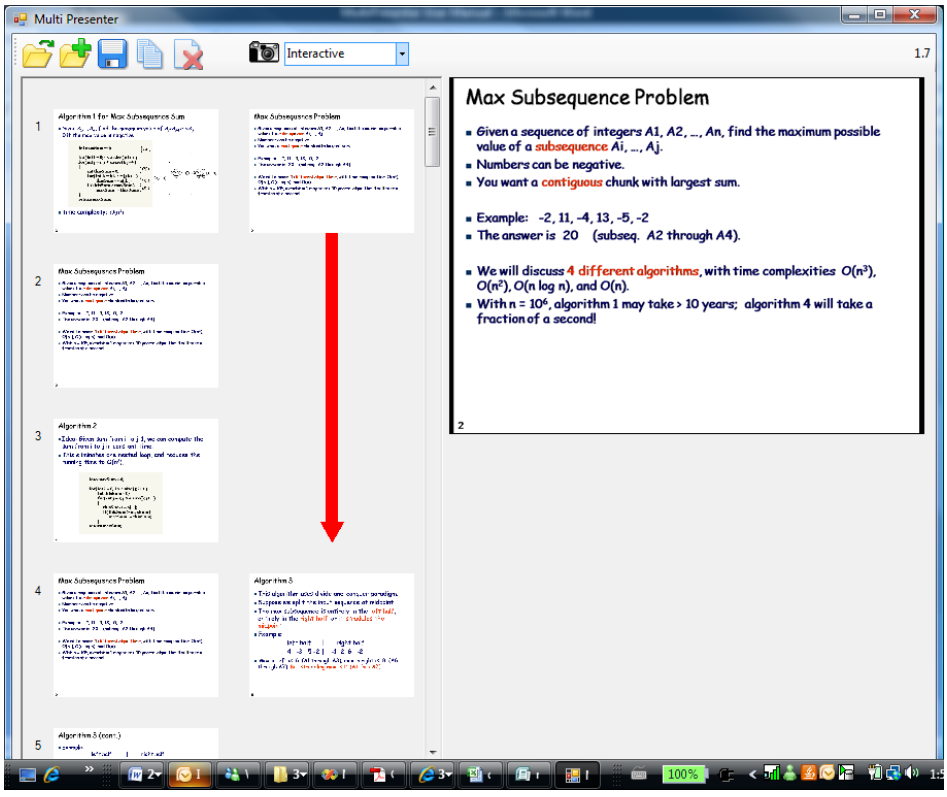


After loading a regular PowerPoint presentation, all slides will appear on the left side of the two streams. The left side shows what will be displayed on the primary screen, and the right side, shows what will be displayed on the secondary screen.

Moving a slide: It is possible to drag any slide to any position (on either side) to be displayed at that position. Two slides that are put one beside the other would be shown together during the presentation. If a slide is dragged to a position where a slide already exists, the two slides will be exchanged. If a slide will be dragged to the space between two slides, it will push the other slides downwards, and enter between the two slides.

Copying a slides: It is also possible to copy a slide by right clicking on the slide, then selecting copy. Then by clicking on an empty spot, right-clicking, and selecting paste, the copied slide would be copied to the empty spot.

To select a single slide to appear on multiple positions (if the presenter wants a certain slide to be persistent on the secondary display alongside more than one slide on the primary display during a presentation), the presenter can copy the slide to the first position on the secondary stream. Then the presenter should select the slide, and drag the blue edge of the slide downwards (or upwards) till the place to copy. The presenter should then press the copy slides button that appears. Another way to do this, is to choose the copy icon . This icon will open a dialog window asking to what range of slide places to copy the selected slide. After copying some slides to the secondary screen, it might look something like this:



Deleting a slide: Deleting a slide can be done either by right-clicking on it and selecting delete, or by selecting the slide and pressing the delete icon: .

Adding a new slide: To add a new slide to the presentation press the following icon: and select any image file. The image file will be added to the end of the presentation. This can be useful if a single slide needs to be updated, or some slides need to be added to an existing MultiPresenter presentation.

Appendix E

Deployment interviews

We present here the full transcripts of five out of the six interviews we did with instructors who used MultiPresenter in their classrooms. One interview was not transcribed because of technical problems with the recorder.

I2 interview transcript

Q: Did you like using MultiPresenter, did you think it was useful for you?

A: I thought it was really useful, ya. In many cases it saves a lot of time. I used two projectors in most of my courses. In one I use the slides and in another I print copies of my slides using the document camera, because I want to go back to give examples, so it really helps.

Q: how did you mostly use the software, can you explain in what cases you used it?

A: usually typical reference to the previous slides, two three slides before and so on. Most of the time I would have an example, or in the database course I would have on a slide the table we would have in an example, so when i present the example they can see the table throughout the example. Most of the time in the Database course I would use it like this. So keeping the schema or table on one slide when talking about the example in more detail.

Q: did you use it also to extend one topic to two slides?

A: that is a good idea, but I didn't do it. You have to get used to it. So, I used it to comparing things, but it was two not more. The features that you have that allows you to put multiple slides on the second screen i didn't use it.

Q: you did compare two slides?

A: yes.

Q: was the interface easy for you to use?

A: yes, the interface was fine. It took me a bit to understand how to use it, but after that it was fine.

Q: did it add any cognitive effort for you during the class to operate

A: there was a place where there was something like two pens on the main window. That was confusing at the beginning. The rest was clear. You had the main pen in which you choose the different settings, and then the actual pen that you write.

Q: is that maybe the eraser icons? There are two : one on the side which you erase the slide, and on top which you erase the pen

A: yes that could be it. It takes time until you get used to that. So, after you changed the magnified view of the icons that helped a lot. At the beginning I had problems with that, but after you changed it, it worked. If you want to improve on that, on the corner you can show the slide number. Sometimes you have a very busy slide, and you can't see the difference between many busy slide when you browse for slides. So the slide number can help, but now its fine. It is really nice.

Q: do you think that when using MultiPresenter you were more dynamic then when using PP?

A: well, it was easy to move from one slide to another, and move back and forth. From that case, it was more dynamic. Like I said, i was using two screens with a camera, so for the students, if you stay in one position all the time, it is boring. And so, because you don't move to the camera, there is less happening, so the students may feel it is more boring. But if you don't stay there, in front of your laptop all the time, and go around, then it is really more dynamic. It is more dynamic because you can find the slide you want and change it. I posted on the second window more pages that I use with the document camera.

Q: so, you used electronic ink in the past as well, was this software different in using ink?

A: After you fixed the pen, when you made the extra size, it was fine. The color is nice, you can go directly and change the color. On my laptop, the tablet (PP) in order to change the color of the stylus it is usually two clicks not one. You have to open the main

window which has the things about the stylus then you go to color, and then you set the color. This one (MP) I found really easy

Q: did you use sometime the second screen only for writing?

A: very few times, ya. For this course. For other courses, I use ink more. Because I like still using the blackboard. I use the software when I want to write on top of the slides. When i present an example from scratch, I still use the board for the reason that it is more dynamic. I can point there, i can turn to the students and talk, I am also used to using the board. On the laptop, no matter how you do it, you need a pointer to point. And it feels more awkward. On the board I feel I can point there, I can draw things and point there with my hand and I can show from my gestures that **this** one is important. The pointing on the laptop is the same, no matter how I do it, if I hit the board saying this is important, it is more clear.

Q: there are some things you can't imitate electronically

A: I agree, that is why i still like using the board.

Q: did you use the clipping feature?

A: no, I didn't do that one. I forgot about that. This one can be very handy. I forgot it completely. I think there were a couple of times where I would use it.

Q: do you think that having extra information on the second screen can sometime distract the students?

A: no, I don't think so. Initially when I started writing on the screen, that is dangerous, because then you underline things and you write a lot of things and that is bad for the students. If you go back and look at the screen, then you can say oh my goodness: what the student can keep track of from all this information. But if you do it right, very lightly it shouldn't bother. You always use the second screen for something relevant.

Q: did you have any technical problems with the software or the constellation of the two screens?

A: We had once, one problem with the second screen, that I don't remember. I don't remember if it was my fault with the extended screen or not. I couldn't get the second screen to show.

Q: do you think you would like to use this in the future?

A: yes, I would use it in all courses except the 213 course. The 213 has a lot of animatons. PP animations that you cannot copy to other slides. They are very important to the students, but the two screens are very important to the students, so I can do both together.

Q: do you have any other comments or suggestions?

A: well, it could be useful to be able to load two separate streams of slides, and to control each separately, I mean to be able to advance and to choose each slide separately. That way, if you have a PP with exercise slides, for example, you can show your regular stream of slides, and then from time to time use the second screen for the exercise. You don't need in advance, to think were the exercise fits.

Also, instead if you can add a highlighting feature it could be good, because sometime you don't want to clutter your slides with many highlighting.

I3 interview Transcript

Q: Do you think it was useful for you to use MultiPresenter:

A: Yes. I think it is a very good idea, I mean it is the first time I have been teaching with two projectors, and if I didn't have that, I would probably project the same thing on both screens. No, I think it is definitely a good idea, and I really enjoyed using it.

Q: so, what features did you mostly use? How did you use the software?

A: I used it only in interactive mode, I didn't design my presentation beforehand. At the beginning I wanted to do that, but I was too late preparing my slides to go through that, and I think that it is not that bad idea doing it like that because it gives the class much more interactivity since you are doing much more interactive stuff, so that is how i used it. I very often used one of the slides as a drawing board, just because I could do everything without leaving my computer. I could write there and it appeared very big and made a very efficient whiteboard, and also I kept referring to the other slide while doing that so this was very efficient. I also used it for storing slides while going forward, for example if a slide was important I put it there. And I used it for exercises: sometime i knew i had longer exercises so I designed my slides so I will have two slides instead of one and put both of them there. Or sometime i would have an exercise that needed reference to some material i had shown previously so i used one of the slides to hold the

material and one of the slides to hold the exercise. These are exercises being done by students during class. ... I didn't use the "cut and paste" thing. At first I really wanted to use it or parts of it, but I think it would have needed more forward design, so i should have designed my slides thinking of this, and I didn't do it. I couldn't see good ways of using it.

Most of the times i just put two slides there if I needed. Some students complained that it was too small but sometimes it was just to keep things in their minds. If it wasn't to hold information, just for them to keep in mind what was important it was useful. I also used it once or twice to design large canvas slides where stuff ran from one screen to the other and it worked really nicely. ... I also used a lot of "fill the blanks " slides where only bullet points are there, mostly i did that for the exam review, and I used the pen to fill it up. This setting made it very efficient, because you can have slides with very few text on them so it can be very efficient to write, but since you used two monitors you can really do that and not use too much screen space.

Q: was the interface easy to use? Did it work for you?

A: at the beginning I had some problems with ammm, so the fact that the pen selection and the tool selection for the pen are on the top, but you can still erase things with the tool bar on the right side, so I was confused at first, but after one week I had it figured out.

Q: do you think it added some load on you to operate the system while you were teaching?

A: no, not at all. It was really fast, just dragging a slide there was very easy. There was a problem I had that sometime I had to scroll too much to find a slide, because some of the slides i wanted were in the future, and i couldn't see them. It wasn't that bad, because the preview is big enough, so i always picked the right slide. Sometime i would drag a slide and it would stack with the one i had already there when i wanted just a new slide there. I think the way to do it is if the right hand side would be seen as a stack of slides, then when you add a new slide you see the other one moving toward the back using some kind of animation, then you have a button to display the two last slides, or parts of the stack, but that could be tricky to implement, but it would be closer to the way I saw this thing. But it could also be a problem because the second screen has many

different usages, and it is hard to combine them in a single unified interface. But the way it is now, you get used to that.

Q: Do you think this was helpful for the students?

A: I really think it was. It is hard for me to know, i didn't run a survey. I really think it helps from my perspective. From the students' perspective, i think it probably did. It really helped me do things like emphasize the importance of something by leaving it there, I could then also easily use that information later on. The drawback of it, is that i couldn't use animation, but then again I don't like using it. And the only kind of animation that i think can really work is ones in which i have stuff appear in short increments, because it helps students focus on what's there, and this i did by adding multiple slides that added to it. But I am still thinking that this metaphor is so new that i didn't use it fully, but the way that I would use it would be to have one slide display a single bullet point, and the other slide accumulate them in some way, so that you really focus on one, because most of the time what i have is a list of bullet points, and the last one i put with bold just to focus it, and i think the best way would be to focus it on one slide, and to have it add incrementally on the other slice. This could be done using the current system, but it adds a lot of work to me, but in any way it is better than trying to do the animation. So that might be the only drawback I see.

Q: Did you have any technical problems ?

A: my problems mostly related to the physical setup. I had the monitors automatically set off after three hours, and my course was three hours and a half, so it took me some time to figure that out, so i reset them during the brake and then i was good for the entire class. Also, one of the projectors was very dark in the beginning, and in the end they replaced the bulb and it was very bright. But it overheated and shut off automatically a few times. With the system itself, I had some minor bugs with the system. I was really using the tabletPC to write stuff, the best way to do that is to have the PC folded to write stuff, but then you cannot control the forward backward with the slides. You had to do that with the pen. If you could use the tablet buttons it could be great. Also, when i folded it, i would have problems with the display rotation, and the button to control that wouldn't always work. One problem I had was how text persisted on the slides,

sometime I wanted the text to stay there, but when I took the slide and moved it to the other pane, the text wouldn't follow.

Q: Do you think that having extra stuff on the screen can distract students, having too much information?

A: it depends on how you use it. I think you should use it to display not that much more information, but to organize it better. So this is the way i was using it. Most of the time i was using single slides. It could distract them, if you are using it just to increase the number of bullet points. I don't like to have too much information on one slide, but it helps because you can have the drawings, and the bullet points, and the drawing does not require too much attention from them ....

Q: would you use this system in the future?

A: ya, ya, definitely, definitely. You know, I would be really sad not to have it. I discovered two things at the same time, one was that using a tabletPC and a pen, and this I really liked too. I really liked to be able to write on my slides. This turns a very boring slide course into an interesting one. But it really really combines well with the dual screen, because otherwise you run out of space very very quickly and you find that you cannot write that much. Also now, you can leave stuff on one screen and start writing on the other screen. Also, I really liked the idea that you have the master view on your computer with the two slides side by side there. You can see exactly what the students are seeing.

Q: you have any ideas, things you would add or change?

A: I think it should strive to stay simple. I think there are two ways of using it, one would be a corporate presentation, where you pre-plan your presentation and you use the dual monitors for effect, and the other would be the course presentation, where you use the dual monitors for interactiveness. You don't want that in a conference presentation, but in a course the power of the second monitor comes that it opens up for so much more interactiveness during the course, and that is a key to keeping attention of the students longer. So, I think you should focus on both of that. If the prepared presentations came with a lot of features and things to make the presentation that would make a lot of sense, but for the class presentations, it has to remain simple. That might be one of the reasons I didn't use the "cut and paste", because it was a little too complicated to use, it was

easier just to put the slides there. So, unfortunately for you , I think you are pretty much done...

I4 interview transcript

Q: can you generally comment on using MP in your classroom?

A: well, I liked using MP very much and I think it got a very positive feedback from the class. I liked particularly being able to have the map and then being constantly being able to draw on that map when I have other things pertaining into it; keeping terms or brief outlines on one of the screens and then using the other one for images; or in the case of if you go through it, the retention of the last one was something the students particularly liked, as I think you mentioned before in the other teaching experiences. So, whether I used it by grabing the previous one, or just leaving the last one over, they found both of those very useful. And I usually used just one back instead of four simply because it was easier to move from that to the other mode.

Q. Did you ever use the four back?

A. a couple of times. But not as a usual thing, because often I was using it for the image or the map, and then it was easier to flash back and forth between the two techniques.

Q. did students comment on the four back mode? That it was too small?

A. no, they didn't did. Probably because I didn't use it that often, and secondly, in the classrooms where I used it in, it was probably not an issue, and I don't put on the slides that much of information. I wouldn't use it probably if I had a document with a lot of words

Q. What features in MP did you mainly use? For example, you can use it preparing the presentation ahead of time or dynamically during the class you decide what to put.

A. I did both of these things, depending how prepared I was before class. And how much I thought it was necessary. When I did use it during class dynamically , ahmm one thing you can easily do is skip ahead without them ever knowing you are skipping and leaving out a bunch of material when suddenly you realize that what you are doing now is not as important as what you need to get to or – this is not working very well, so lets go to something else. Or, they bring out a question that brings up something that you are going to present later on, so why not do it now. And that was very useful. The other

thing is that one thing I didn't use that much is the writing mainly because it required me to – I didn't walk around carrying the tablet, so it wasn't easy to do. And when I was up there at the podium, so I can see it as I moved around – I never stand still anyway. But a few times I did use it, particularly to write additional things down on the white screen. .....

Q. did you use if for example to mark areas on maps or gesturing at areas.

A. I did do that. I did use it to mark things. So as I talked about them. But not as a regular things, because I would forget about doing it. .... but particularily I can see that in some cases it might be very useful, and I wish I had it in my hand, but I didn't. So part of it, I think, is just getting used to it, and keeping that in mind, thinking of ways to use it in advance, like knowing the exits in the room so when people shout "fire" you know exactly where to go without thinking. I hadn't gotten to that level of expertise.

Q. How did you find the interface of the software? Was it intuitive or simple to use? Was it difficult or take you time to learn it?

A. Most of the things that I used, I got to be pretty good at, pretty quick. The thing that I had the most problem with was to remember to erase the screen when I was pulling pictures down. To remember to erase the existing picture before I would try to pull another one. I mean, it wasn't horrible, all it would do is shrink them, and put them both there, but then you know – I see I forgot to erase them. So, that was difficult. The other thing I found a little frustrating as I was going through it, was that even though you had a scroll on the bottom, you could see what was six I guess, slides at a time. Very often, I had to search the slides that I wanted, so, you know, if there would be two rows of them, or they were smaller, so you could identify the ones that you want them. With PP when you have the whole thing, you can see them bigger or smaller, but if you are looking for images that you have to scroll through. I guess, part of it is that it seemed to take me a long time to find the slides I wanted to, if there would be a way to move more quickly through the slides it would be nice. If you could just click a toggle where you can just see the next 20, without changing what was on the screen. That might be a little easier. On the fly in particular.

And the other thing, which was because the nature of the way it works, which gives you the ability to pull things down, and just cut off pictures if you want, and just leave them

up there or drag them over, I realized that what I wish is that there was someway to alter it, once you had it there, because of course once you had your slides and you want to change them, you have to go back to your original program. Change it, and move it back. If I noticed something in class that I wanted to change, I basically couldn't. I don't know if it can be fixed, and it probably can't be, of course you do have the option of simply writing it down there, which is what i did, but I often didn't think of it.

But, with that in mind, I really did like the ... having the two screens gave you that flexibility that you would not have otherwise had. That was worth that other inconvenience.

Q. did you use the "cut and drag" feature?

A. only occasionally. I used it when I wanted to retain a particular part of the slide when I went on to the next slide. But I only used it a couple of times, they thought it was pretty cool when I used it, but I often couldn't think of ways to use it while I was doing. So, I think that would come with a deeper level of knowledge and ease of use with the program to think of using it. So even though I used it in both terms, even by the end of it, I hadn't gotten to that point.

Q. did you have technical problems?

A. I think that most of my technical problems wasn't so much with the program but were with Vista and use of the PC cause sometimes it was just down to getting the displays right. For instance, there is no way you can get it ahead of time, and part of the problem comes with the fact that I couldn't get into the room more than a few minutes before to setup. And it takes a time for it to boot up and find itself, and if I didn't do it right the first time, I had to stop and reboot and do it all over again the second time. I mean a couple of days, I couldn't figure out what was wrong. And in one of my rooms, one of the projectors didn't work for a couple of weeks, so I went in with the idea that I would only use PP. Then, as far as having the time to setup and everything would have probably solve my problems cause when I showed up 15 minutes ahead of time I hardly ever had any problems. It is when I rushed in the middle of the day, having students in the classroom is when I had problems. But that is part of the thing. How many academic presentations have I been at when someone brings their own laptop and nothing works .....

Q. do you think that putting extra information on the screen sometimes distracted the students?

A. I don't think so. What it did is give me the opportunity to put less on one slide, and retaining it meant that they had more time even as you move something on the other slide, then they can refer back to the other one. If it was old information or if it was illustrative to what you were showing them now. Like very often, for instance, I was talking about characteristics of different types of phenomena, I would have the list of characteristics on one and I would have the different examples on the other one and just go through them, but I wouldn't have to have the labels on all of them. That way it was easy too to change the examples on each one of them that I use. And it was really useful, if we were analyzing a particular document, or we were comparing two documents and then they could see it. You know. In the past I would have two columns. If it was small, I could hardly put anything on each one, that kind of thing. So I didn't think it was a distraction. They watch MTV for Christ sakes...

Q. do you think your use of MP changed over time from first to second semester for example?

A. yes, I think I became more easily adapted to doing it on the fly, in other words, in the first term I always planned ahead what I would line up with each other. Or I didn't held on to the retention slide, but later on I was more free as to what I would pull to the second screen. I would reorder my lecture as I mentioned earlier as I was learning how to use the program.

Q. Did you change the slides because you knew you were going to use MP?

A. yes, I did. I changed the original slides by taking off , for instance, if I had both image and words on the same slide I put the image into one slide and the words on the other. And every year I have been cutting the number of words on my slides anyway, and I continued to do that because I didn't have to have so many words on one slide, so they wouldn't be hit with so many words. Even though on PP I did use the one line at a time appearing thing, which helped combat that problem.

Q. Did you miss that feature?

A. I did miss that, somewhat. And I adapted to that, putting fewer words to some slides in some cases, for example, having one or two lines on each slide. And then moving it

over. And that's when I used the four retention. Reducing each one to basically a bullet point. It caused me to do more work ahead of time to do that, but again, because of the two screen capability I still could do it, but you had to think about it differently when preparing it.

Q. would you like to use MP in the future?

A. yes, I think I would.

Q. do you have any other comments about using the system?

A. One thing as far as ease of use, even though the icons are very intuitive, nevertheless, I sometimes forget which eraser did which thing. So, I was wondering if there could be a one word text on the icons, so when you are in the middle of your flow you don't have to remember that. I think that at least for the learning curve it would help that. And pedagogicaly, probably it is just like practice. One has to have the time to set it up and knock it down. The part where I really missed it when the projector went out, for instance I was trying to teach them the concept of ritz – legal documents from the middle ages. And show them how I could identify different ritz and understand what sort of conditions generated the need for them, by comparing the words that was used in each. By just throwing both of these things up there at the same time, large enough that they can really see, and having them lined up, so the differences were highlighted was wonderful. I used to do that with two overheads which was a big pain. And also, I didn't get any of the "don't change that slide I have to write what's up there" comments. And using maps – I would always pull up a map, not only showing it with nothing near it but showing it in context to what was said, I liked that too.

Q. okay, thank you.

I5 interview transcript

Q: did you like using MP, and if you did what did you like?

A: I did like it, I thought it was really helpful. I liked being able to, for example have an image and a text at the same time without having to make one or the other very small, which you have to do if you only use one slide. I liked to be able to hold the outline up while moving through a series of examples. Or to have a map on one side and detail on the other, these were all very useful. I do have a TabletPC and occasionally I

experimented with writing on the screen, I think that was just a new thing for me and I didn't really get comfortable with that, I got the tablet at the end of last summer, so I am not really very used to using it, but I did do it a couple of times. I just felt it wasn't really naturally integrated into my style yet. I did find mostly, I used the interactive mode and did it sort of on the fly, sometimes I set up a slideshow, but I found I would often change my mind while I was speaking about the order I wanted to do things in, or exactly how I wanted to set it up so I found that doing it as I went along worked better for me.

Q. so using interactive mode, did you use a preset PP presentation? From a previous year?

A. yes. So I would have my PP presentation previously set up and I would convert it into the interactive mode, rather than converting it into a preset MP file. I did try that a couple of times, but I often found that what i thought would work sitting here in the office didn't quite work in front of the students, and so that is why I would find it better to put it up on the fly. And once that I got used to it, that worked quite well.

Q. how did you use it in the interactive mode, did you mostly drag slides as you saw them, like went through your slides saw an important slide and drag it, or would you go ahead or back in your slides?

A. I think probably the typical way I would do it would be to have some kind of outline slide that I would hold in one position, and then scroll through other ones, until I got to something where I felt that I wanted to have two at once, and then I would drag the one that wasn't moving into that other screen. That seemed to work quite well.

Q. did you put more than one slide on the screen?

A. I never did, I experimented with that in my office, but it just didn't seem to me that that would be something that I found particularly useful.

Q. did you use the previous slide feature?

A. a couple of times. But again, mostly i did that to configure my own arrangements of putting things together.

Q. did you use the clipping feature?

A. I did it a couple of times, I found that I had some, that the effect I really wanted from that, was difficult with the resolution. That when, so for example, I have a very high resolution map, that I wanted to clip some bits and move them over. But I really wanted

students to be able to see them better by enlarging them. And unless I was doing something wrong, what would happen was that it wouldn't enlarge properly. I had to actually go into my PP zoom in and cut an enlargement and put it on to another slide to make the resolution work properly. Because I was hoping to show the students the very fine details. So I would do that in PP and make that a new slide and show them at once using MP. But, I had to set it up on PP.

Q. could you elaborate a bit about the pedagogical ways you used it? You talked a bit about having images and text side-by-side what other pedagogical methods did you use?

A. I think the ability to have both the full slide and the detail was very useful, because it helped students not to lose site of the bigger picture. I would be able, if I set it up in advance, I could for example put a box on the full slide to show them where I was pulling the detail from, so they could always put the two things in mind. It was also very good for comparing things. Again, without losing the size of the image. If you want to compare two things on a PP slide obviously, you have to make them quite small. Cause you can only use half the slide. And this allowed me to use full size images when I was doing quite detail comparisons, so that was very useful. I think the students also found it very helpful to be able to have the outline up, as I moved through the lecture, so that I could say: now I am moving to the second of the major points, or if I was using a series of images or slides to illustrate a point, I could keep reminding them of where we were in the overall argument, I think that was very useful for students who sometimes find it difficult to follow. It also allowed me to keep sometimes complex information longer, cause I could keep changing the other slide allowing the more complicated information to stay up, and give them a chance to look at it again, and absorb it.

Q. did you use it to refer back to previous information? for example if you saw that you needed some previous information from the beginning of the lecture, would you bring it up?

A. that was one of the things that I felt that would be really helpful to use the interactive mode, especially if a student would ask a question that referred back to something, I could pull that other slide up so I could compare it to the point we were up now. So I felt that that was very useful .

Q. how did you find the interface?

A. the software itself, for running through the slide program seemed to work well. As I said, I didn't use the one where I would pre-create a slide show in advance very often. And partly because I didn't use that too often I found that confusing, but that wasn't a major problem. The major concern I had, the problem that came to me a lot was the issue of resolution and just getting it to work with the screens.

Q. do you think the interface added cognitive load on you during the presentation?

A. I think there was a step to start it that I stumbled on a few times. I just don't remember the interface well enough now. I think I forgot that I needed to press the camera to start the presentation. But that was relatively minor I think. In general it seemed relatively self explanatory.

Q. so let's talk about the technical difficulties, I think that was a major problem that you had.

A. I guess two problems. One I think I told you that I solved partially, which was the number of different steps you had to go through to actually get the three screens to get up. So having to pull up the preferences and then extend the monitor the right way and that became easier once i programmed in a MP setup on the screen so all I had to do was go into screen setup and click MP. And then as long as all of the screens got recognized it became quite easy to do. As soon as I had a problem with the screen I knew I had to do with ten minutes of rebooting things, and I did get complaints from students that said that the lecture started late sometimes because unfortunately in that big room I had somebody who persistently ran overtime on their lecture, which meant that I didn't get there ten minutes in advance.

Q. did you often need to reboot your machine?

A. I know for example, I talked with ------ [I4], who just got into the habit of rebooting every day before she went in, and I maybe should have ... I am trying to think, maybe one out of three, say, I would have trouble. And particularly in the big room and Irving Barber. I don't now if part of it is a problem with their setup. But I actually had fewer problems in Buchanan D room, in my smaller class?

Q. did you use it in that class as well?

A. I didn't very often, because that was a much smaller class. But I did use it there a couple of times.

Q. Do you think that having extra information on the second screen might have distracted some students?

A. I did get on my course evaluations a student saying they found there was too much information on the screen. I felt that that meant, that it was their problems, because I also gave them in that course summaries of the lectures, so they never had to write down everything that was on the screen. Anything in that format was also on their word document format. So, I think that that was a student who wasn't paying proper attention.

Q. it also depends, I guess on how much information you use in your slides

A. that's right, i would just be able to make the image and the text bigger and not add any other information.

Q. what things didn't you like about the system or about the user interface?

A. one was the technical difficulties, the other was that I would like to find some way of combining the flexibility of the interactive part with the ability to set it up in advance. So you would be able to set a general structure, but still be able to change it if you wanted to. Cause sometimes I would setup a version and then have an inspiration on my way to class. And say, okay, i would just do it interactively and just switch that order.

Q. is there any other features you think would be useful for you to have?

A. no, none that I can remember.

Q. did your use of MP change over time?

A. I think I got slightly bolder with it, I got more comfortable, I was able to experiment a bit more. And once I got more familiar with the setup I felt more comfortable about going with a plan.

Q. by the way, did you use more than two screens, cause in the room an IBLC it is possible to use four screens

A. they do have the desktop built in there, and two digital projectors. So there was an occasion where I had something on a digital projector, the MP up on the middle two screens. And that was about as multimodal as I have ever been. But it was actually useful to have that option of being able to put something on the digital projector while still having the two screens.

Q. you said you used electronic ink in a few occasions. Could you elaborate on how you used it?

A. partly it felt too gimmicky. So for example this is a slide I use, and as I was talking I would circle a few concepts I talked about. The alternative would be to use a laser pointer, so circling it on the screen is easier and more effective but I felt gimmicky in the sense it is not something they have seen – you can only do it with a TabletPC, so I just felt a bit awkward about it. Also, to try to write on the screen in that angle, is actually difficult. If you had it flat, then the only way to move the slides was with the stylus and it would be more difficult to see.

Q. do you think you would like to use MP in the future?

A. I would. I am not sure that I would use if for the smaller class. But especially for these big 100-150 students classes, I thought it worked very well, and i was very pleased to be using it. So that is definitely something I would do again.

I6 interview transcript

Q. How did you use the software, or how did you use the two screens?

A. I decided the first time that I would use it that I am going to keep it pretty simple, so essentially what I did was to have one screen be used for text, and by text I mean the outline of the lecture, and that would change according to which section of the lecture I would be in, so there would just be bullet points. I tried to keep the amount of text per slide quite low, cause student get anxious when they see too much text, and then I would have my other slide, the other screen, be an image. There might be a word or two on the image, but generally speaking that's how I did. I didn't in other words use the capability of extracting the... using the ink or something like that, I didn't use any of that. So it was pretty static, although clearly things moved, I moved through the slides, but I was using it in a pretty basic level.

Q. were all your lectures preset ahead of time for the two screens, or did you do anything during class?

A. no, I was totally un-spontaneous. I set them up in advance, and I pretty much, you know, went through them although I would go back and forth, but that is as exciting as I got. I would go back and forth or went back to something I said in advance, if there was a question I'd show the graph earlier on, I would go back to the graph and exchange it. But, that's about it. I found that it worked fine for that.

Q. so, how come you did not use more of the dynamic features?

A. to the extent that I would drag slides, things onto the second screen, I would do that with a video. I would take stuff from other sources and show a video, or an audio clip and use that. The reason I didn't do the other was the way which I lecture which was pretty... it's a big class and a new class to me, so I wasn't probably as comfortable as I may become in kind of winging it the way you would do can do with the dynamic functions in MP, but I think that I may do more of that in the fall when I teach the course for a second time, cause I will be just more comfortable with having got the structure of the lectures down and having a clear idea in my head of what I want to convey.

Q. What things did you like about using the two screens?

A. Maybe this is to get ahead a bit, but I think it actually changed the way I thought about my lectures. Which I thought was just an interesting pedagogical cognitive process for me to go to. Cause when I used PowerPoint, or way back when I actually used slides or overheads there is one way that I would write my lectures but given the capabilities of MP to use two screens, I think that actually shaped the way that I structured the lecture, I would write the lectures, and I would often find that when I went to do the MP presentation and thinking of the words and the slides that I wanted to use, that actually helped clarify some of the points in the lecture that I wanted to make cause communicating, figuring out how to make that , how to convey a point on two screens would often make me clarify the point that I wanted to make in the lecture. It was an interesting back and forth process, I would always start with the text, the lecture I wanted to give, and then I would think about how I could illustrate my points visually, and with PP there was one screen, so you would think a certain way, and you couldn't use too many images because you would also want to use some text. MP kind of frees you from that, and lets you keep the text static. You can go through a much more dynamic siries of images or graphs or things like that. I think that was the main strength of it for me, I felt like I could do a lot more, and actually show maybe the process of how people drew conclusions, by maybe showing them series of graphs rather than just the final graph that I might have just shown in the past.

Q. Did you also used it to compare two items?

A. yes, sometimes I would use that to compare, kind of before... after, or similar phenomena at the same time at different places in the world, and I think some of the student comments suggest that they found that quite effective. So I wouldn't have to flash that slide and flash the next one and go back to the first one, I would actually have two things there at the same time.

Q. When you built the presentation, did you start from a ready made PP that you already had, or did you start from scratch?

A. well, these were all new lectures, so I would start from scratch. So I would write the text and then I would figure out what images I wanted to use. It was a different process for me to think of how to lecture. I would write the lecture and when I thought about how I would present it, I would go back to the lecture and change it so it would kind of fit what I could do with MP.

Q. I wonder how would that be different if you would already had a one-stream PP presentation ready

A. ya, I think, part of it is aesthetic. I might have used the same slides in PP, but I'd have an image and then I would have some text overlaid on it, so it would obscure part of the image whereas this would simply , in someway it would just give me a bigger field to play with, i would have the image on one side and the text on the other. So they could see more clearly the graph or the photo or whatever it was that I was showing . umm.... and I think that clarity probably helps with the learning. I think it allowed me to show more images, cause I would keep the outline static and just go through a series of images in each section of my lecture so it really helped me divide my lecture into different sub-sections or units within an overall lecture cause it was an 80 minute lecture so it was quite long. Breaking it up that way into act 1 act 2 and act 3 also helps the students learn how to take notes, cause there would be kind of beginning and end in each section which you can convey visually in a way that would be a little bit harder to do if you would just be using a single screen.

Q. what would you say about the interface, so you haven't used the dynamic features, but you did use the features for building the presentation

A. I found it very easy to learn. I think that I imported, so ok I make my MP presentation in PP, so I would do all the image slides first, and then I would have all the text slides at

the end, the whole thing would get imported and turned into a MP presentation, and then I would copy the textual outline parts next to the relevant images, and that process was probably a bit clunky, just because moving things around, so you've got the right things being side by side. And sometimes when I was , there was one lecture which was an art lecture I was showing the photographs of a landscape photographer and often he would take pictures where there was a left and a right panel , so trying to figure out ... I could get the two panels lined up, but then when it came to make sure that the right and left projectors were part of the right and left ... would project right and left on the screen was another thing, but I managed to figure that out.

Q. you know there is a flip button in MP

A. yes. I did figure that out. So it worked and that was no problem. So I just think that importing the PP slides and copying them and moving them around so you get the presentation lined up properly is pretty straight forward to do maybe it could be

Q. Did you jump ahead or go back when you ran your presentations?

A. I would go sometimes ahead or back, usually by finding the slide and going to it, it worked fine. The only problems I would say that I had sometimes seemed to be simply with the getting the projectors and the computer talking to each other. There were a couple of times were I hooked it up and sometimes getting the two screens to display was a problem so I would have to unhook it and reboot my computer and then it was fine. I think that only once where it didn't work and i still don't know why it didn't work. So moments when students said: sometimes prof. Loo had problems setting it up – that's probably true, but I would say that that would be maybe a handful of times. No more than three or four times did it take me extra time. Mostly I was hooking it up and it was fine. I would always show up a bit early, and it would work.

Q. Do you think that having extra information on the screen might have distracted the students?

A. That's an interesting question, cause I thought about that. I got that from one of my TAs that was sitting in the audience, he said: well, when you are sitting in a lecture, you have to process what you are hearing, and if you are seeing two different things sometimes that is distracting, because you don't know what to focus on. And I think he decided that, for some of the times at least, what he was doing was listening to me and

writing – looking at his piece of paper. And he would only look up some of the time to see what was on the screens, and then he had to decide which screen he was going to look at. And he would look at ... he would want to look at the text screen cause that is where the information is, even though that screen would be up for a long time, and sometime would have miss the image. So I am wondering if at the end, having text up all the time, distracts from the picture – the graphical representation of what I am trying to say. I didn't get that from the feedback. But I can see how that would be possible and people learn differently

Q. I think in your case, your style of having images on one side with text on the other doesn't put so much information. that could be a problem when you have much text on both screens.

A. yes, even when PP, when it is just one screen and there is too much information. We have all seen bad PP presentations in our time where there is like – the whole thing is bullet points and it is exactly what the person is saying, so I try not to write down what I am saying. But, they needed to get used to that when they realize that I am saying something different than what is written on the screen. But I think the students adjusted relatively quickly. I don't think it was a distraction.

Q. did you get any comments from students on the visual aid used?

A. no, not directly. Indirectly through the TAs I think that most of the comments I got were positive, they felt like it helped them understand things better.

Q. Do you give them the slide before or after the class?

A. I do, but because I was doing these up to the last minute, they were posted afterwards on the Vista site. I just pdf the presentations, but what I pdf-ed was not all the images, just a couple of key images and all the text, cause the text is the outline. Perhaps once they figured out that I am going to get this later they calmed down a bit. Although I would say that, as they discovered, they wouldn't have been able to understand what the lectures were about just if they had the outline. Part of it is because the images help.

Q. did your use of the software change over time?

A. no, I don't think so, cause I stayed, I mean the way I used MP was pretty consistent. I might have used more video from the middle of the course to the end which means pulling it on to the second screen, which I left blank.

Q. how would you use the video?

A. sometimes when I knew it was a lengthy video I would put it on a blank slide with a text slide explaining the points from the video beside it. Other times, I would just drag the video over the existing slide. Students said that they liked those moments where I broke out of that and showed them something different on the screen, that there was something happening. One time – when you were there, I lost the cursor, it wasn't there and I wouldn't see it on the screen. Part of it is that the screens are right behind me it is hard because you are standing below to see where things are.

Q. do you have any more comments that you would want to add?

A. I have to say that I liked it a lot, and I am going to use it again. I would tell my colleagues about it but they would have to do that without your support ....

Appendix F

Student survey

The student questionnaire was posted on the Web in html format. We present here a view of that questionnaire

The following questions have to do with the method of using two screens and with the presentation system that was used by the instructor in your class to utilize these screens.

Please indicate the course you took for which you are filling this questionnaire:
_____

1. Did you notice that the instructor sometimes showed different slides on the two screens?

   □ Yes □□ No

2. Did the fact that the instructor showed two different slides on the two screens change the way the class was taught compared to a single-slide system?

   □ Yes, very much □□ Yes, a little □ No

The instructor has been using two presentation systems in this class

- Regular PowerPoint slides – you have probably also seen other classes using regular slide based presentations before
- MultiPresenter – The system the instructor has been using to utilize the second screen.

3. If you could choose one system to use as the presentation system in the class, which one would you prefer the instructor would use?

   □ □ PowerPoint □ MultiPresenter

4. There are a number of criteria listed below. Please select the version that would be your 1st choice *according to each of the criteria.* If you cannot make a choice for a given criteria please select "No opinion"

Criteria	**1st choice**
The presentation is engaging	□ PowerPoint □□ MultiPresenter □ No opinion
I learn better	□ PowerPoint □□ MultiPresenter □□ No opinion
The presentation is more dynamic	□ PowerPoint □□ MultiPresenter □□ No opinion
The presentation structure is more suited for learning	□ PowerPoint □□ MultiPresenter □□ No opinion

5. For each of the following statements concerning MultiPresenter, please indicate to which extent do you agree or disagree with the following statements:

SD = Strongly Disagree
D = Disagree
N = Neutral
A = Agree
SA = Strongly Agree

Seeing two slides helped me understand the material better than a one-slide presentation	□ SD	□ D	□ N	□ A	□ SA
Having two screens helped the instructor present the material better	□ SD	□D	□ N	□ A	□ SA
I would encourage other instructors to use the two screens in a similar way.	□ SD	□ D	□ N	□ A	□ SA
I had problems physically seeing one of the screens	□ SD	□ D	□ N	□ A	□ SA
It was good that the instructor had more space to use to write on (using electronic ink)	□ SD	□ D	□ N	□ A	□ SA
It was helpful for me when the instructor showed certain slides for longer periods on the second screen	□ SD	□ D	□ N	□ A	□ SA
It was helpful for me when the instructor used both screens to compare two slides	□ SD	□ D	□ N	□ A	□ SA
The presentation system helped increase my attention in the lecture.	□ SD	□ D	□ N	□ A	□ SA
The presentation system helped me learn better	□ SD	□ D	□ N	□ A	□ SA

6. What particular aspects of the presentation system or the way the instructor used the two screens did you *like*?

_____
_____
_____
_____
_____

7. What particular aspects of the presentation system or the way the instructor used the two screens did you *dislike?*

_____
_____
_____
_____
_____

Demographic Data:

8. Sex:
   □□ Male □□ Female

9. Age:
   _____

10. Approximately how many classes in which the instructor used computer slides have you attended?

    □ 0(this is the first) □ 1-2 □ 3-4 □ 5-6 □ 7+

Appendix G

Controlled Study Lecture Material

We present the lecture slides and transcripts used in both lectures and both conditions in the controlled laboratory study presented at Chapter 6. Please notice that because of space considerations all slides are presented here side-by-side even though in the one-stream condition they were presented each slide at a time. In the two-stream condition, they are presented side-by-side as was seen by the audience with the right side as the secondary screen. Slide numbers correlated to the transcript are presented below the slides.

Includes:

- Visual system one-stream slides
- Visual system two-stream slides
- Auditory system one-stream slides
- Auditory system two-stream slides
- Visual system transcription
- Auditory system transcription

G.1 Visual system one-stream

The Visual System

1

Sensing the world around us

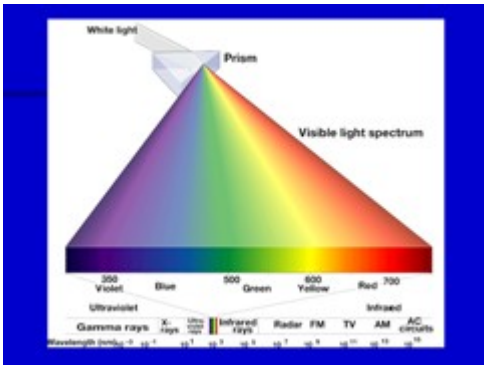
- **Stimuli** are energies in the environment that affect what we do.
- **Receptors** are the specialized cells in our bodies that convert environmental energies into signals for the nervous system.
- **Transduction**: the process of converting physical energy into neural activity

2

The Detection of Light

- **Light** is the stimulus that the visual system is designed to detect.
- Visible light is just one very small portion of the **electromagnetic spectrum**, which is the continuum of all the frequencies of radiated energy.
- The human eye is designed to detect energy in the wavelengths from about 400 to 750 nm.

3

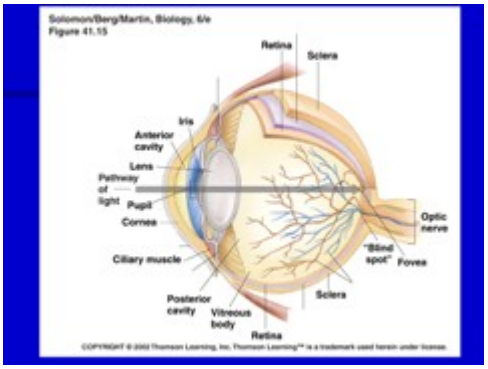


4

The Perceptual Characteristics of light

Perception	Physical Characteristic
Hue (color)	Wavelength
Brightness	Amplitude of the wave
Saturation	Wavelength purity

5



6

Vertebrate Eye Anatomy

- Similar to a camera
  - The **Cornea** covers the eye and lets the light in.
  - The **Iris** regulates light passing through the **pupil**
  - The **Lens** is located posterior to the iris and focuses light
  - The **retina** is where the image is projected on.

7

Eye Anatomy: in front of the lens

- The **cornea** refracts the light and covers the iris and the pupil
- The **anterior cavity** between the cornea and lens is filled with the **aqueous fluid**
- The **pupil** – regulates the light into the eye
- The **ciliary muscle** controls the lens and is involved in accommodation

8

Eye Anatomy – behind the lens

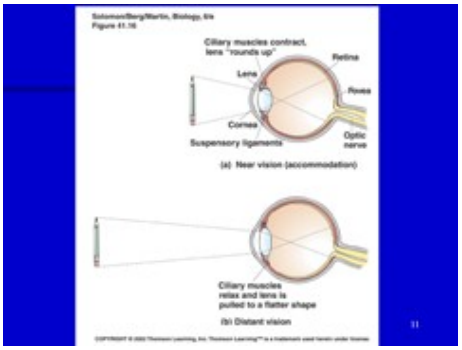
- Posterior to the lens, the **posterior cavity** is filled with the **vitreous humor.**
- **Retina** is in the back of the eye and is where the transduction is done.
- The **Sclera** is the outer layer of the eye and maintains its rigidity.

9

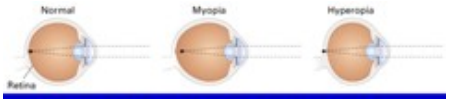
Accommodation

- A process by which the eye increases optical power to focus on an object
- Achieved by stretching the lens
- Done by ciliary muscle, part of the ciliary body

10

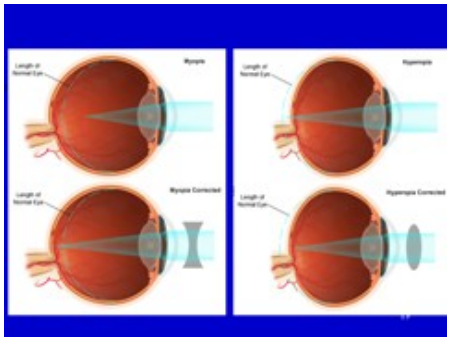


11



- **Presbyopia** develops as humans age, resulting in a reduced ability to focus on nearby objects.
- In **myopia** the person can focus well on nearby objects, but not distant ones. This condition is also called **nearsightedness**.
- In **hyperopia** the person can focus well on distant objects, but not on nearby ones. This is also called **farsightedness**.

12



13

The Retina

- The retina is specialized to convert light energy into neural signals.
- The retina has three layers of cells:
  - Photoreceptors
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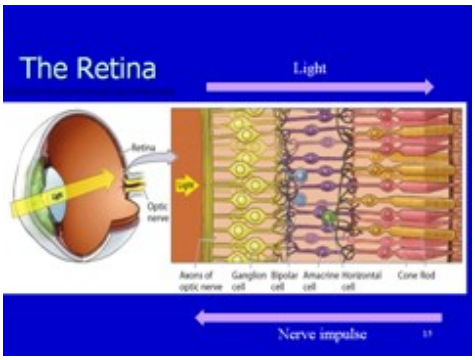
  - Ganglion Cells

14

The Retina



15

The Photoreceptors

- There are two types of photoreceptors
  - the rods
  - the cones
- There are 130 million rods and cones covering the back of the inner surface of the eye, except where the optic nerve exists.
- Rods far outnumber cones in the human eye.
  - Only 5-10% of the visual receptors in the human retina are cones.

16

16

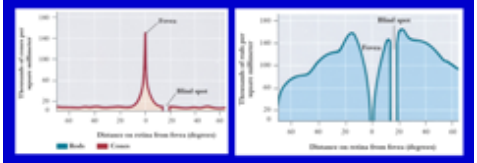
The Fovea

- The **fovea** is the center of the human retina, and the location of the highest proportion of cones.
- The lens focuses the visual image on the fovea.
- It is the area of the eye with the greatest acuity.

17

17

Distribution of Rods and Cones



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18

Major Differences between the Rods and Cones

- The cones are used for:
  - color vision
  - daytime vision
  - detail vision (visual acuity)
  - Most cones are in the fovea
- The rods are used for:
  - are adapted for vision in dim light
  - They are very sensitive to light rays
  - Sensitive to movement.
  - Rods are more plentiful in the periphery of the retina.

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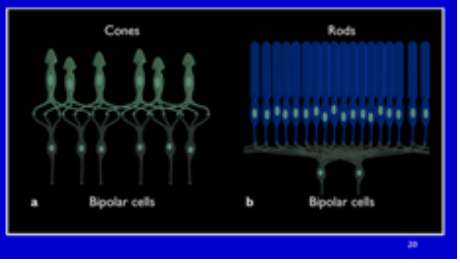
Convergence of Cones and Rods



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20

Why do rods and cones differ in terms of visual acuity and sensitivity?

- Sensitivity
  - Rods are more sensitive to light than cones (i.e. it takes less energy to cause them to respond).
- Convergence
  - The output of several hundred rods converges on a single ganglion cell. The output of only a few cones converges on a single ganglion cell

Rods = high convergence = high sensitivity = low acuity
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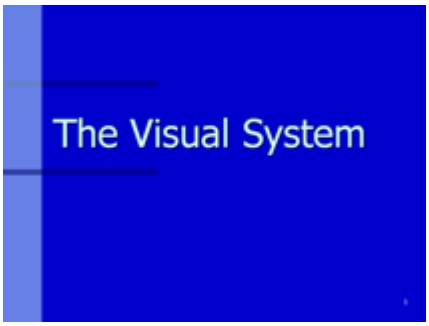
21

21

G.2 Visual system two-stream



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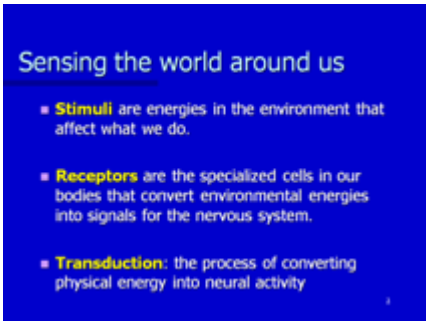

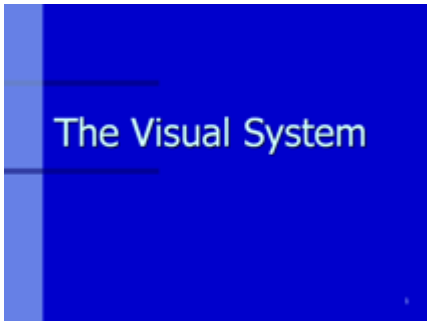

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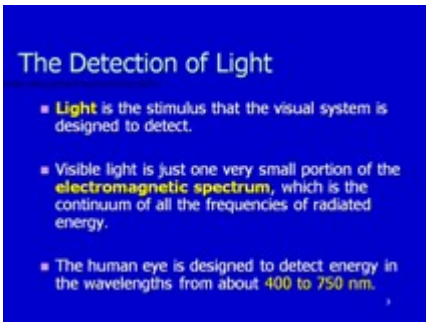

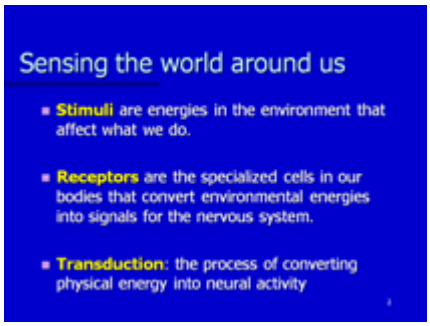

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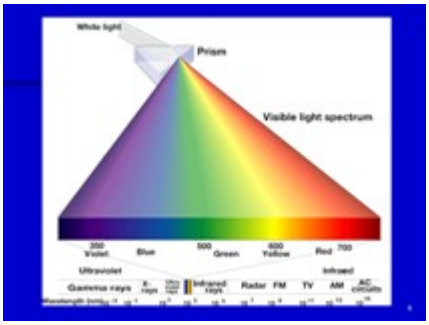

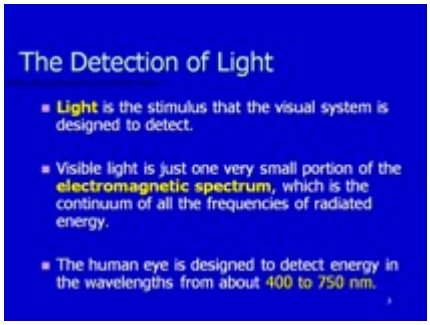

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The Perceptual Characteristics of light

Perception	Physical Characteristic
Hue (color)	Wavelength
Brightness	Amplitude of the wave
Saturation	Wavelength purity

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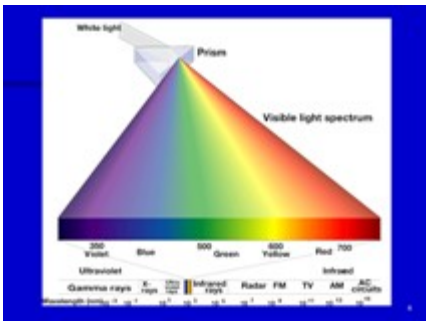

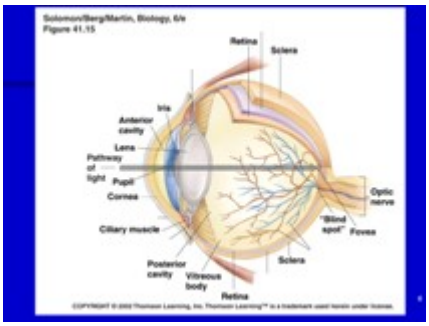

6

The Perceptual Characteristics of light

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Vertebrate Eye Anatomy

- Similar to a camera
  - The **Cornea** covers the eye and lets the light in.
  - The **Iris** regulates light passing through the **pupil**
  - The **Lens** is located posterior to the iris and focuses light
  - The **retina** is where the image is projected on.

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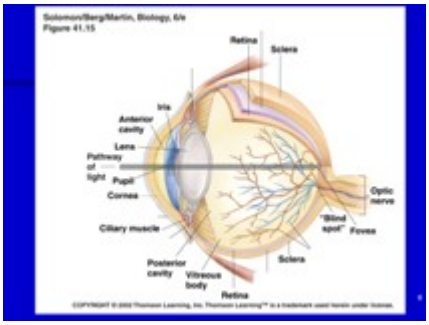

Eye Anatomy: in front of the lens

- The **cornea** refracts the light and covers the iris and the pupil
- The **anterior cavity** between the cornea and lens is filled with the **aqueous fluid**
- The **pupil** – regulates the light into the eye
- The **ciliary muscle** controls the lens and is involved in accommodation

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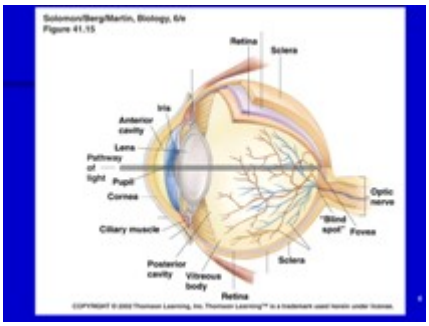

Eye Anatomy – behind the lens

- Posterior to the lens, the **posterior cavity** is filled with the **vitreous humor.**
- **Retina** is in the back of the eye and is where the transduction is done.
- The **Sclera** is the outer layer of the eye and maintains its rigidity.

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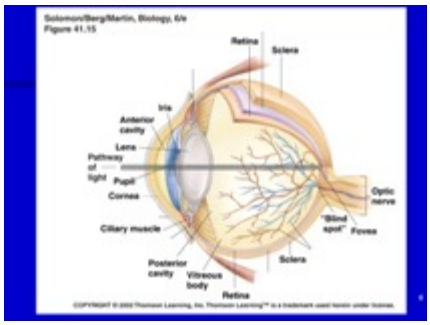

Accommodation

- A process by which the eye increases optical power to focus on an object
- Achieved by stretching the lens
- Done by ciliary muscle, part of the ciliary body

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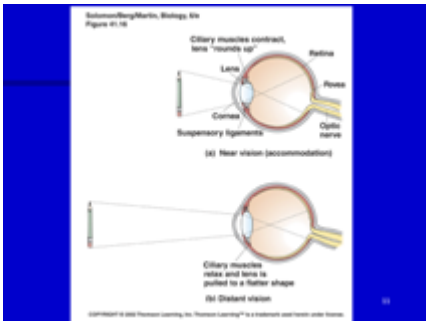

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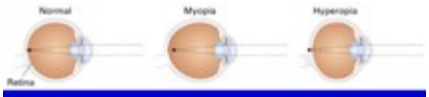

- **Presbyopia** develops as humans age, resulting in a reduced ability to focus on nearby objects.
- In **myopia** the person can focus well on nearby objects, but not distant ones. This condition is also called **nearsightedness**.
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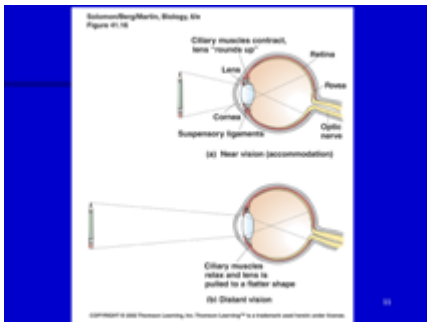

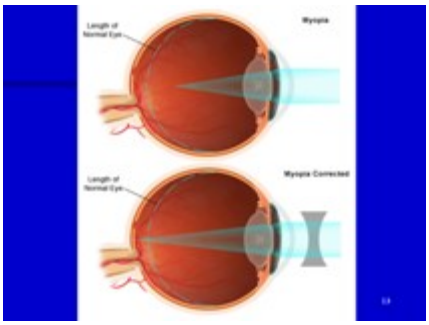

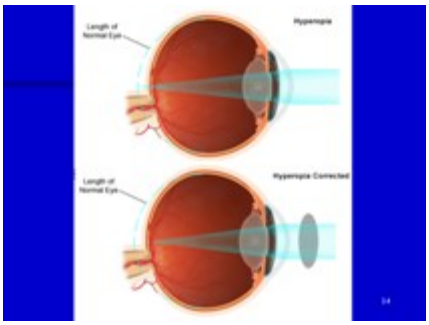

13

The Retina

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- The retina has three layers of cells:
  - Photoreceptors
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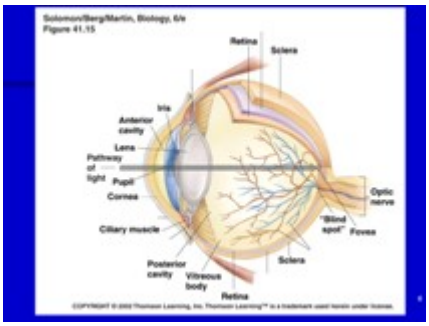

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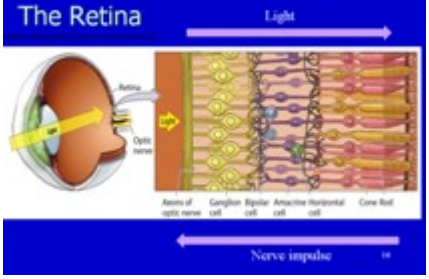

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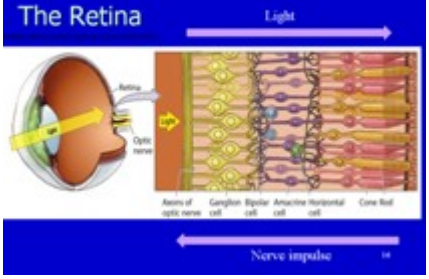

16

The fovea

- The **fovea** is the center of the human retina, and the location of the highest proportion of **cones**.
- The lens focuses the visual image on the fovea.
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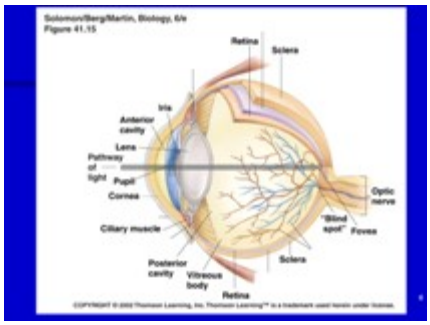

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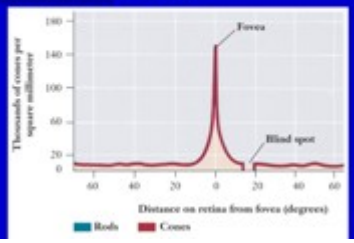
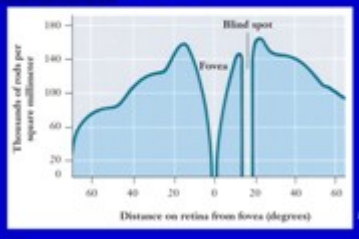
Distribution of Cones



Distribution of Rods



18

Major Differences between the Rods and Cones

- The cones are used for:
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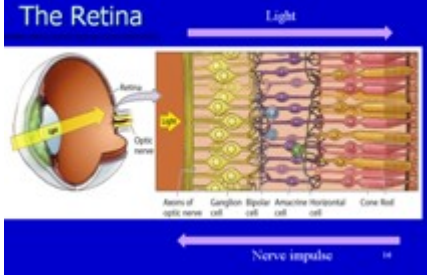
  - daytime vision
  - detail vision (visual acuity)
  - Most cones are in the fovea
- The rods are used for:
  - are adapted for vision in dim light
  - They are very sensitive to light rays
  - Sensitive to movement.
  - Rods are more plentiful in the periphery of the retina.

The Retina



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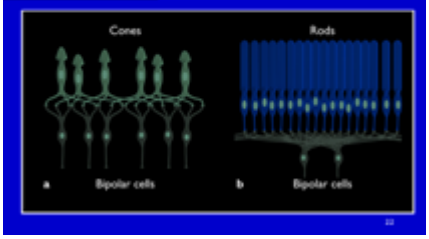
Convergence of Cones and Rods



20

Why do rods and cones differ in terms of visual acuity and sensitivity?

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- Convergence
  - The output of several hundred rods converges on a single ganglion cell. The output of only a few cones converges on a single ganglion cell

Rods = high convergence = high sensitivity = low acuity
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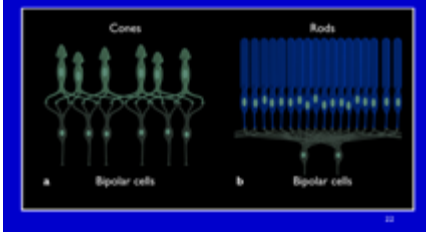
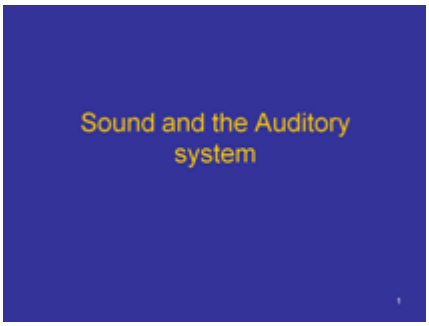
Convergence of Cones and Rods



G.3 Auditory system one-stream



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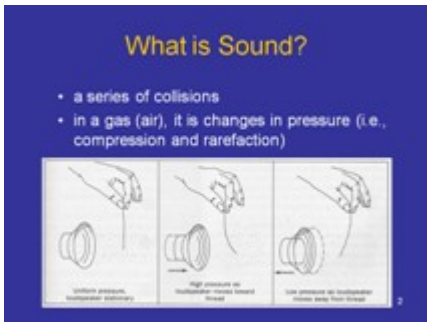

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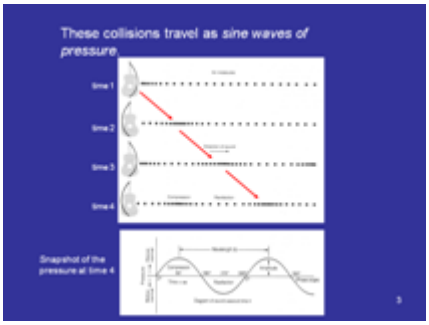

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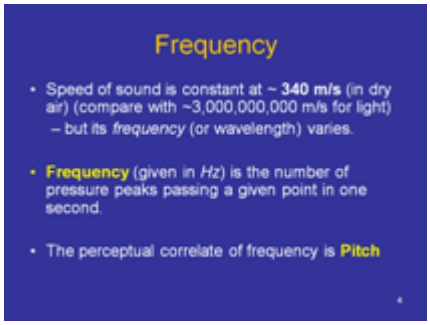

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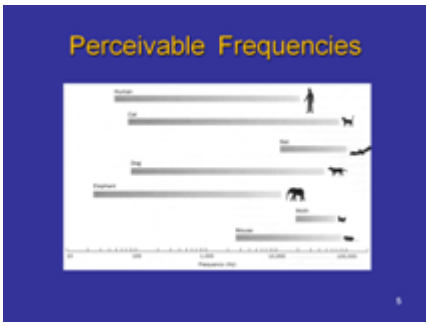

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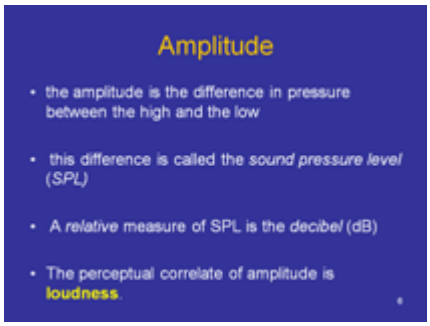

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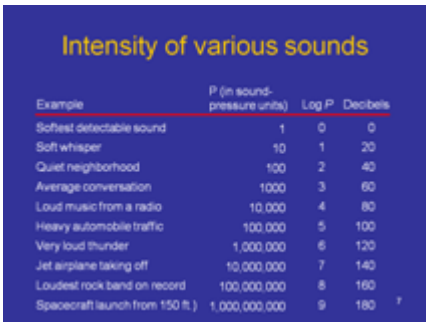

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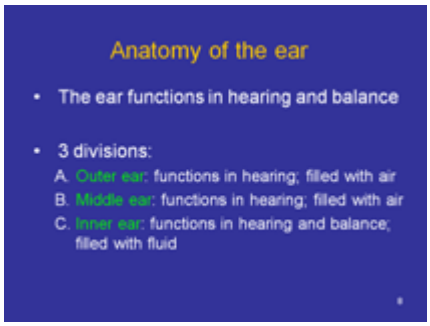

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The Ear

9

The outer ear

- Includes:
  - Pinna: the external ear flap that catches sound waves
  - Auditory canal: directs sound waves to the eardrum
    - lined with fine hairs and modified sweat glands that secrete earwax

10

The middle ear

- Eardrum (Tympanic membrane): membrane that vibrates to carry the wave to the bones
- 3 small bones called ossicles (malleus, incus, stapes): amplify sound waves
- Auditory tube: a tube that connects from the throat to the middle ear and is used to equalize pressure so the eardrum does not burst

11

The inner ear

- Important for both hearing and balance
- 2 areas: cochlea, vestibular system
- Stapes (middle ear bone) vibrates and strikes the membrane of the oval window causing fluid waves in the cochlea
- Vestibular system – responsible for keeping our balance

12

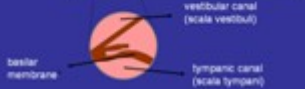
The cochlea

- Converts vibrations into nerve impulses
- Shaped like a snail
- Filled with liquid which vibrates
- Lined with tiny hair cells that transforms the movement of the liquid to neural energy

13

The Cochlea

The cochlea one (rolled up) tube divided into three chambers by two membranes



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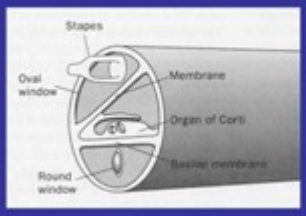
The Cochlea



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Vestibular system

- Responsible for our balance and sense of orientation
- The semicircular canals detect angular movement (rotational equilibrium)
- The Otoliths detect linear acceleration (gravitational equilibrium)

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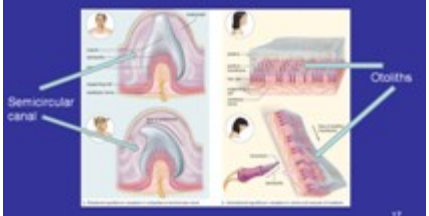
Rotational vs. gravitational equilibrium



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Hearing loss

- Conductive hearing loss: typically ossicles fuse together, or wax build up blocks canal
- Sensorineural hearing loss: Defect in or Destruction of the Hair Cells.
  - Caused by genetics, infection, toxic substances, loud noises, antibiotics.
- Central hearing loss: Caused by abnormalities in the central auditory system in the brain.

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18

Treatment

- Hearing Aid: amplifies sound waves to overcome conductive issues and mild outer hair cell loss
- Cochlear Implant: Insertion of electrodes into cochlea to directly stimulate auditory nerve endings.
  - 32 frequency discrimination

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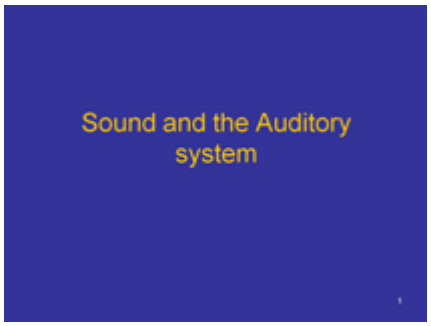
G.4 Auditory system two-stream



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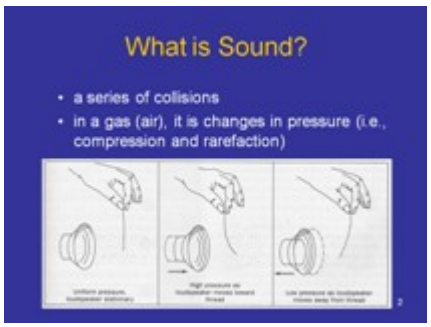

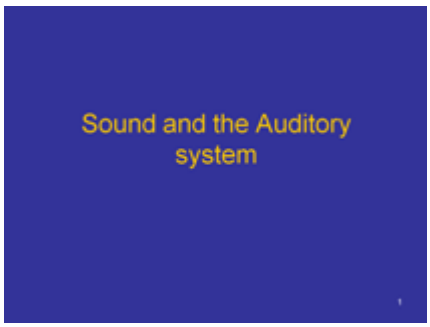

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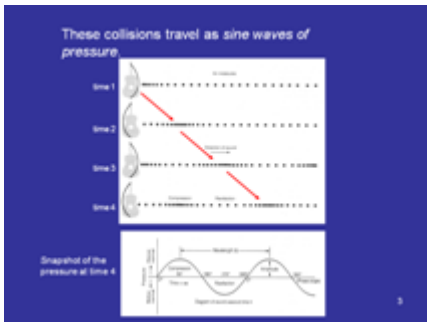

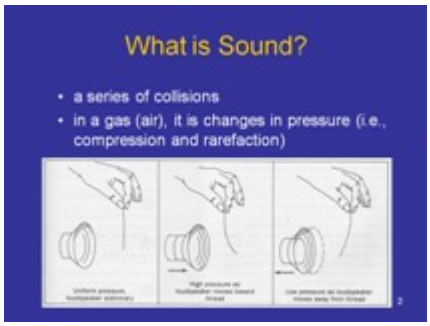

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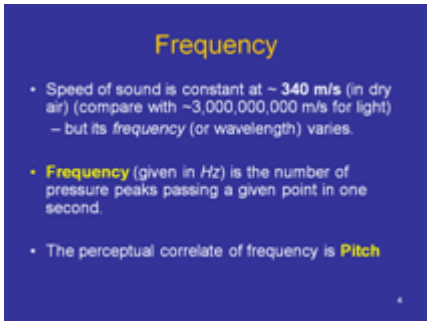

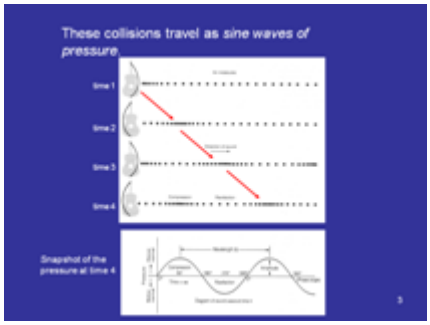

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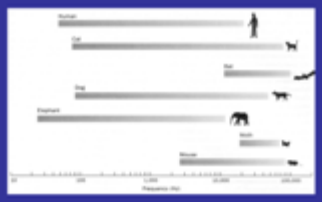
Perceivable Frequencies



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Frequency

- Speed of sound is constant at ~ **340 m/s** (in dry air) (compare with ~3,000,000,000 m/s for light) – but its *frequency* (or wavelength) varies.
- **Frequency** (given in *Hz*) is the number of pressure peaks passing a given point in one second.
- The perceptual correlate of frequency is **Pitch**

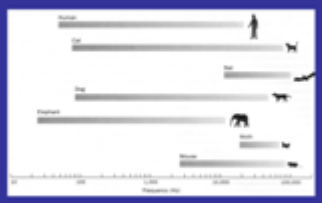
4

Amplitude

- the amplitude is the difference in pressure between the high and the low
- this difference is called the *sound pressure level* (*SPL*)
- A *relative* measure of SPL is the *decibel* (dB)
- The perceptual correlate of amplitude is **loudness**.

6

Perceivable Frequencies



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Intensity of various sounds

Example	P (in sound-pressure units)	Log *P*	Decibels
Softest detectable sound	1	0	0
Soft whisper	10	1	20
Quiet neighborhood	100	2	40
Average conversation	1000	3	60
Loud music from a radio	10,000	4	80
Heavy automobile traffic	100,000	5	100
Very loud thunder	1,000,000	6	120
Jet airplane taking off	10,000,000	7	140
Loudest rock band on record	100,000,000	8	160
Spacecraft launch from 150 ft.)	1,000,000,000	9	180

7

Amplitude

- the amplitude is the difference in pressure between the high and the low
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- The perceptual correlate of amplitude is **loudness**.

6

7

Anatomy of the ear

- The ear functions in hearing and balance
- 3 divisions:
  - A. Outer ear: functions in hearing; filled with air
  - B. Middle ear: functions in hearing; filled with air
  - C. Inner ear: functions in hearing and balance; filled with fluid

8

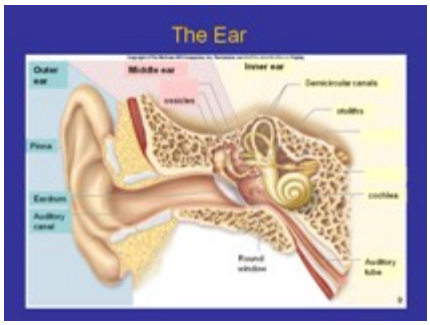
The Ear

8

10

The outer ear

- Includes:
  - Pinna: the external ear flap that catches sound waves
  - Auditory canal: directs sound waves to the eardrum
    - lined with fine hairs and modified sweat glands that secrete earwax



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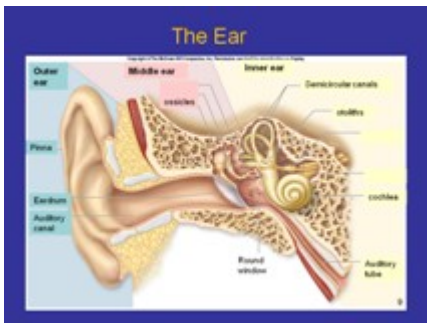
The middle ear

- Eardrum (Tympanic membrane) : membrane that vibrates to carry the wave to the bones
- 3 small bones called ossicles (malleus, incus, stapes): amplify sound waves
- Auditory tube: a tube that connects from the throat to the middle ear and is used to equalize pressure so the eardrum does not burst



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The inner ear

- Important for both hearing and balance
- 2 areas: cochlea, vestibular system
- Stapes (middle ear bone) vibrates and strikes the membrane of the oval window causing fluid waves in the cochlea
- Vestibular system – responsible for keeping our balance

13

The cochlea

- Converts vibrations into nerve impulses
- Contains the organ of Corti (spiral organ) sense organ containing hairs for hearing
  - Bending of embedded hairs cause vibrations that send nerve impulses to the cochlear nerve and then to the brain
  - Pitch is determined by varying wave frequencies that are detected by different parts of the organ of Corti
  - Volume is determined by the amplitude of sound waves

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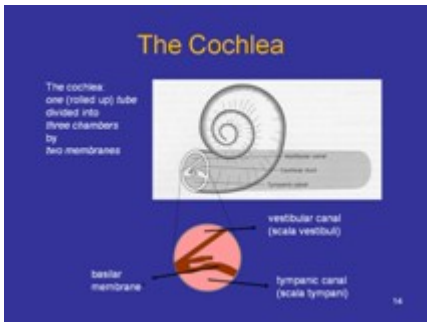

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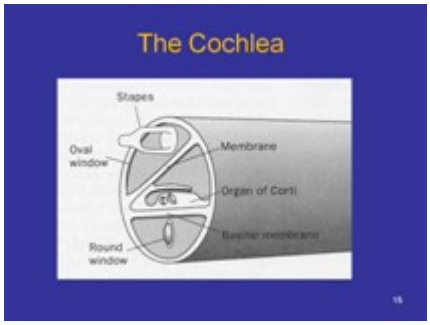

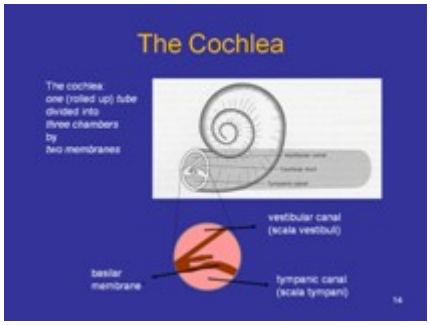

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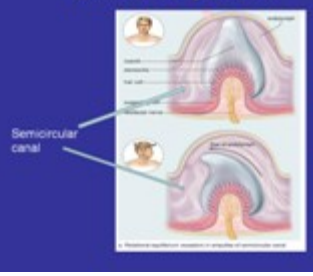
Vestibular system

- Responsible for our balance and sense of orientation
- The semicircular canals detect angular movement (rotational equilibrium)
- The Otoliths detect linear acceleration (gravitational equilibrium)

17

Rotational equilibrium



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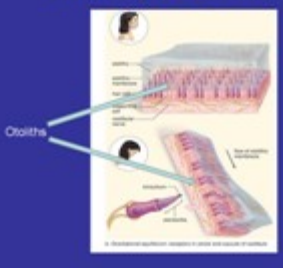
Gravitational equilibrium



Hearing loss

- Conductive hearing loss: typically ossicles fuse together, or wax build up blocks canal
- Sensorineural hearing loss: Defect in or Destruction of the Hair Cells.
  - Caused by genetics, infection, toxic substances, loud noises, antibiotics.
- Central hearing loss: Caused by abnormalities in the central auditory system in the brain.

18

19

Treatment

- Hearing Aid: amplifies sound waves to overcome conductive issues and mild outer hair cell loss
- Cochlear Implant: Insertion of electrodes into cochlea to directly stimulate auditory nerve endings.
  - 32 frequency discrimination

19

20

Hearing loss

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G.5 Visual system transcript

[slide 1]

In this talk, we are going to learn about how the visual system works.

[slide 2]

Using our senses, we want to understand what is happening around us. Most of what we experience is constructed internally in our heads. The world, provides us with certain forms of energy. This energy is the stimuli that we are sensing. Then, that energy has to be converted to something that the nervous system can work with. This is done by receptors. Receptors are cells that can convert the stimuli's energies to something that the nervous system can work with. For each of the sensory systems, we need to understand what information in the form of energy is provided by the universe. In the visual system, the energy that we are sensing is electromagnetic radiation.

So, in the visual system, electromagnetic radiation has to be converted to neuro-energy and in the auditory system, vibrations there have to be converted to neuro-energy and so on. That process - going from the external energy to neuro-energy is called transduction.

[slide 3]

The human visual system is designed to detect light. It is sensitive to only a narrow band of wave length of the electromagnetic spectrum. This band is about 400 to 700 nanometers and there'll be a picture on that in a second. Light is usually regarded as a wave or more precisely as having wave-like properties.

[slide 4]

So here is an image of the electromagnetic spectrum that the human eye is sensitive to. Humans can see from about 400 nano-meters to 700 nano-meters. Different colors have different wavelengths, with blue around 400 nm and red around the 700 nm. On the bottom of the slide, you can see that this spectrum of visible colors is only a small part of the full light spectrum, which starts with very short Gamma rays and ends with very long wavelengths of radio waves. As you can see, in the visible light spectrum, the colors go: red, orange, yellow, green, blue, violet. And that is exactly how our experience measures off against these wave lengths. Again, it's a very narrow band, there are a lot of other wave lengths, of electromagnetic radiation that produce other kinds of phenomenon; x-rays, you'll see television, radio waves, microwaves, and so on. So this very narrow band

of wave lengths that is bouncing around in our atmosphere produces chemical changes in the retina and those are what we use to produce the visual experience. Like we said, we look at light as a wave which has a known wavelength.

Slide 5

There are some other wave properties that affect how we see. One property is the wave length. We generally perceive objects to have hue or color, which as we explained previously corresponds to wavelength. A second wave property is the height or amplitude of the wave. This produces the brightness of the image as we see it. The third quality is purity, which really refers to the extent to which the quality gray or black is present in the experience. If you think about it, it's very important that the nervous system encode grays, because it is the gray or shadowing of most of our visual experiences that gives us information about texture. So, for example, a carpet has a lot of grays in it, because there's a lot of shadowing in it due to the tufts in the carpet. And that's important to us. It's important to us to know as we look at a building up close. If we can see the lines of the brick and that tells us something about the nature of that article, whether it's a single unit or multiple units have been put together and so on. So texture information is very useful and so the nervous system does encode texture information.

[slide 6]

We will now talk about the anatomy of the eye and the different components that make up the eye. The eye has been called the most complex organ in our body. It's amazing that something so small can have so many working parts. But when you consider how difficult the task of providing vision really is, perhaps it's no wonder after all. Here you see a picture of the eye structure with the many components that make it.

The main objective of the eye is to enable the light reflecting from different objects to enter the eye and to form an image on the retina. You can see in the center of the image the arrow showing the light wave entering the eye and falling on the retina which covers the inner part of the eye opposite the pupil. The retina is where the photo receptors are: the cells that give a response to the light. The light comes through the pupil and the image flips over and it hits the retina; it's upside down, but don't worry, your brain will

take care of that. There are two chambers of fluids; the anterior cavity filling the front of the eye in front of the lens and the vitreous body in the back of the eye behind the lens.

[slide 7]

The eye functions a lot like a camera. Light comes in through the cornea, a clear cover that is like the glass of a camera's aperture. The iris regulates light to pass through the pupil, an opening that opens and closes a little like a camera shutter. The lens which is located behind the iris focuses the light on the retina inside the eye where the receptors are. The retina is like the film in the camera and is where the image is "burned" on.

[slide 8]

The eye can be divided into two parts: in front and behind the lens. The Cornea is the first thing the light hits when it enters the eye. Its function is mainly to refract the light. It covers the iris and the pupil which like we said regulates the light into the eye. The anterior cavity is the space between the cornea and the pupil which is filled with fluid. It holds the "white of the eye". Part of it is the ciliary body which takes care of the fluid in the anterior cavity and the ciliary muscles which help in the process of accommodation which we will talk about later.

[Slide 9]

The lens then refracts the light once more, and the light goes through the posterior cavity which is the empty space between the lens and the back of the eye. That space is filled with a clear gel that keeps the form of the eye. The light passes through it and hits the retina on the back of the eye. That is where the transduction – you remember the translation of light energy to neuron activity is done. The Sclera is the outer layer of the eye and helps maintain the rigidity of the eye.

Slide 10

Accommodation is the process by which the eye increases optical power to focus on an object as it draws near the eye. Accommodation is done by the lens. The majority of the refraction of the light is done by the cornea. But the cornea is fixed and cannot flex. The lens does less refraction than the cornea but it is flexible. The flexibility is achieved by the ciliary muscle that is tied to the lens and stretches it when needed.

[slide 11]

Objects can be closer to us or farther away from us. So the lens has to change according to the distance of objects from us. Because of that, it has some flexibility, thinning out a little bit as objects are distant from us, and thickening a bit as objects get closer. The ciliary muscles or ciliary body surround the lens, so they actually wrap around the lens. And what happens is when those muscles are flexed, the lens gets fatter. It sort of squeezes around the edges of the lens and pooches it out and makes it a little bit thicker.
In the upper image, the object is close by, so the ciliary muscles contract making the lens round up which brakes the light more. In the bottom image the object is farther away, so the ciliary muscles relax which puts the lens in a flatter shape with less refraction.
[slide 12]
We will now learn what is happening when people don't see well and need correcting lenses. People who are near-sighted or far sighted usually have the object focus in front or behind the retina and not exactly on the retina.
During middle age, usually beginning in the 40s, people experience blurred vision at near points, such as when reading, sewing or working at the computer. There's no getting around it — this happens to everyone at some point in life, even those who have never had a vision problem before. This is called presbyopia. When people develop presbyopia, they find they need to hold books, magazines, newspapers, and other reading materials at arm's length in order to focus properly. Presbyopia stems from a gradual loss of flexibility of the lens. The lens cannot flex enough and subsequently, the object cannot focus on the retina. The solution is to have reading glasses that help focus close by objects.
Myopia is another name for nearsightedness. Nearsighted people typically see well up close, but have difficulty seeing far away.
Hyperopia is another name for farsightedness. Farsighted people usually have trouble seeing up close, but may also have difficulty seeing far away as well.
[slide 13]
In this image we see the Myopia or nearsightedness on the left. In the upper part we see how the focus of the projected image is on the center of the eye, and that is the problem with nearsightedness. With corrected lens the focus moves to be on the retina on the back side of the eye. We can also see why this can be caused by a larger than normal eye

size. The dotted line is a normal length of a normal eye. That is where the lens is aiming at. But since the eye is actually larger, the lens focuses the image before the retina. On the right side we see Hyperopia or farsightedness. In the upper part we see how the focus is behind the retina instead of on the retina. This can be caused by a shorter than normal eye as can be seen by the dotted lines which show a regular sized eye. In the bottom part we see how with corrected lens, the focus changes to be on the retina.

[slide 14]

We will now talk about one of the most important parts of the eye: the retina. The Retina lines the inner surface of the eye, and its function is to convert the light energy into neural signals. The light comes through the pupil, gets refracted by the lens and hits the retina where it is translated into neural signals that are sent to the brain. The optics of the eye create an image of the visual world on the retina, which serves much the same function as the film in a camera. The retina has three major layers: the photoreceptors which are the rods and cones, the bipolar cells and the ganglion cells

[slide 15]

This picture shows a cross section of the retina. The retina is a complex, layered structure with several layers of neurons interconnected by synapses. We can see the three layers of cells in the image. On your right side of the cross section, the first layer is the photoreceptor cells. They are the only neurons that are directly sensitive to light. These are mainly of two types: the rods and cones. They are in the back of the retina, so the light radiation filters through the other layers of cells to the photoreceptor cells. The second layer, in purple, is the bipolar cells which we can see in the middle of the image. The third layer is the ganglion cells that can be seen in yellow on the left side of the cross section image. The Ganglion cells form the optic nerve and send the message to the brain.

[slide 16]

The photoreceptor cells are the ones hit by the light. They are made of cones and rods. The rods kind of look like rods and the cones kind of look like cones, so that works out nicely. Rods and cones are receptive to the wave lengths of light that we showed on previous slides. There are about 130 million rods and cones in the human eye and there

are many more rods than cones – less than 10% of the photoreceptors are cones, and we will explain why this is so in a few moments.

[slide 17]

The Fovea is the place just straight behind the pupil, almost dead center in the retina. It is very rich in photo receptor cells, particularly cones, but it doesn't do anything, it's not a structure that has it's own function, it's just a geographic reference point. It is referenced because that is where the lens focuses the image and that is the place with the biggest visual acuity.

The blind spot is the place where all the signals from the photoreceptors are gathered. They all have to leave the eyeball, and at that point there are no receptors, so no vision is possible on that point. Now the brain compensates for this blank spot in the visual field by filling it using perception cues, filling in with information around the blank spot and mainly using the vision from both eyes to get one complete picture.

[slide 18]

There are many more rods than cones. The cones distribution across the retina can be seen on the left. They are located mostly around the Fovea, toward the center of the retina and get less frequent as you move toward the periphery. We can see the empty area in the blind spot where there are neither cones nor rods. The rods distribution across the retina can be seen on the right. They are much more evenly distributed and are more frequent in the periphery. They are also absent in the blind spot and also absent around the fovea where the cones are and there is no room for rods.

[slide 19]

The cones respond to bright light and mediate high-resolution vision and colour vision. They are used for daytime vision and provide good details and high visual acuity.

The rods work well in low levels of intensity, that is when it's kind of dark, and are used for vision in dim light. The rods will not pick up wave length information, and therefore the rods will not give you any color information. That is why you can't see colors in the dark. The cones also can pick up finer detail, so we have essentially two different systems on the retina. This rod system works pretty well when the levels of illumination are low and this cone system which requires a fair amount of illumination to work, but will give you finer detail and also color information.

Humans have three different types of cones that are sensitive to red, blue or green light and enable us to see colors. It is a lack of cones sensitive to red, blue, or green light that causes individuals to have deficiencies in colour vision or various kinds of colour blindness.

[slide 20]

Like we said, rod cells are responsible for night vision. This is because they are more light sensitive than the cones. A rod cell is sensitive enough to respond to a single photon of light, and is about 100 times more sensitive to a single photon than a cone cell. They are concentrated on the outer edge of the retina and therefore are also used for peripheral vision. The output of many Rod cells converges to a single ganglion cell, collecting and amplifying the signal. This convergence comes at a cost to visual acuity. Because the pooled information from multiple cells is less distinct than it would be if the visual system received information from each rod cell individually. The convergence of rod cells also tends to make peripheral vision very sensitive to movement, and is responsible for the phenomenon of an individual seeing something vague occur out of the corner of his or her eye.

[slide 21]

Cone cells, on the other hand, require tens to hundreds of photons to become activated, and are therefore much less sensitive to light. Only a few cone cells converge to a ganglion cell and therefore they are less sensitive to movement but enables them to have far better visual acuity. So, species that are active at night have few cones and many rods, giving them particularly good night vision, but less acuity.

So, that's it about the eye. Thanks for listening.

G.6 Auditory system transcript

[slide 1]

Hearing is one of the traditional five senses. It is the ability to perceive sound by detecting vibrations using the auditory system or the ear. In this talk we will explain first what is sound, and second how we use the ear to perceive it.

[slide 2]

We will start by explaining what is sound. Sound is a series of collisions or vibrations. These are transmitted through waves through solid, liquid, or gas, but are transmitted best through gas. They cannot be transmitted through vacuum , and that is why there is not sound in space. These waves change the regular air pressure causing local areas of compression and rarefaction. We can see in the image how a thread moves according to the changes in pressure from the loudspeaker. When the pressure is uniform, meaning neither high nor low, the thread doesn't move. When the loudspeaker moves toward the thread, it causes the air pressure to be high which moves the thread away. When the loudspeaker moves away from the thread, the pressure is low.

[slide 3]

These collisions, or changes in pressure, travel in the air as waves, or more specifically, sine waves of pressure. So if you look at the image, at time 1 someone has struck a chord on the guitar. This causes the regular neutral air pressure to change and we can see in time two that there is a compression in the air and that it is moving ahead in time three and four. The periods of compression and rarefaction repeat sequentially, and move through the air in the speed of sound, forming a wave which we can see in the figure on the bottom as a sine wave. The amount of compression or rarefaction is the amplitude of the wavelength, and the distance between each compression cycle is the wavelength.

[slide 4]

The speed of sound is much less than the speed of light and is around 340 meters per second. It is the same for all sounds, but the wavelengths of different sounds vary. When we talk about sound, we usually don't talk about wavelength but about frequency. The wave is moving, and so the length of the wave as it passes a unit in time, like wave lengths per second, gets us a measure of frequency. Frequency of sound is measured in Hertz.

The perceptual correlate of frequency is pitch, which is one of the fundamental basics of sound along with loudness and timbre. The difference between frequency and pitch is that frequency can be the physically measured with instruments, while pitch is a subjective sensation in which the listener assigns perceived tones to relative positions on a musical scale, based on this frequency.

[slide 5]

Here, we see a graph of the frequencies that different animals can perceive. We can see that dogs and cats can hear in higher frequencies than people do. And that cats hear higher frequencies than dogs. Bats also can hear in high frequency but cannot hear medium or low frequencies, which means that if you talk to a bat it is likely that it won't hear you. If you scream really high though, they might hear you – that is maybe why people scream when they see bats. Elephants and probably also whales, but they are not listed here, can hear in lower frequencies than humans.

[slide 6]

Another basic attribute of sound is loudness. The physical correlation to loudness is the amplitude of the wave. Each wave has an amplitude, or the wave's height, and in a sound wave it is the difference in pressure between high and low pressure. This difference in pressure is called the sound pressure level or SPL. Again, the sound pressure level is the physical measurable attribute, while loudness is correlated and is what we perceive according to this physical attribute. However, loudness is subjective, and can be affected by other attributes as well like the length of the noise, background noises, our ear condition etc. This basic deviation from the neutral pressure, is called sound pressure level or SPL, and it measures the amplitude of the wave. However, as we see in the upper red graph, it doesn't correlate well with our perceived notion of loudness. So, we take its logarithmic scale and call it decibels, which correlate linearly to our perception of loudness as can be seen in the bottom graph.

[slide 7]

Here we see the intensity of the different sounds. On the rightmost of the table you see the number of decibels, and in the middle we see the value in pressure units before the logarithmic scale. The scale starts with the softest detectable sound and that is 1 decibel. That was how decibels were defined. An average conversation is around 60 decibels, a

very loud sound like a thunder is around 120 decibel and can permanently harm your ears with a long time exposure and more than 140 decibles can cause pain and permanent loss of hearing with short time exposure.

[slide 8]

The ear is responsible for the detection of sound and for keeping our balance. In this lecture, we will focus on the hearing. The ear is divided into three main areas: The outer ear, the middle ear, and the inner ear. The outer and middle ear are filled with air, while the inner ear is filled with fluid. All the regions are involved in the hearing process which we will shortly explain.

[slide 9]

Here we see a general image of the ear. Like we can see in the image it is divided into the three parts. The outer ear is what we can see and easily reach and include the Pinna which is the outer ear part, the auditory canal which collects the sound and moves it to the eardrum. The eardrum separates between the outer and the middle ear. The middle ear consists mainly of three small bones that transform the sound from the eardrum to the inner ear. The inner ear consists of the cochlea which transforms the movements from the middle ear to neural activity and of the vestibular system that helps our balance. That's basically it, but if that was too fast, we are going to go over each part more slowly now.

[slide 10]

The outer or external ear's job is to protect the eardrum as well as to collect and direct sound waves through the auditory canal to the eardrum. The Pinna is the visible part of the ear that resides outside our heads. Its purpose is to collect the sound and direct it to the auditory canal. It also does some amplifying and filtering. For example, it boosts sounds with frequencies around 3kHz which is the frequency of human speech by 10-100 fold. The auditory canal is a tube running from the outer ear to the middle ear. It is about 3 centimetres long and contains modified sweat glands that produce earwax. Earwax is that gunky stuff that protects the canal. Earwax contains chemicals that fight off infections that could hurt the skin inside the ear canal. It also collects dirt to help keep the ear canal clean. So earwax isn't just gross. It's gross and useful. Too much earwax however can block sound transmission.

[slide 11]

So, after sound waves enter the outer ear, they travel through the ear canal and make their way to the middle ear. The middle ear's main job is to take those sound waves and turn them into vibrations that are delivered to the inner ear. To do this, it needs the eardrum or using its more official name the tympanic membrane. The eardrum is a thin piece of skin stretched tight like a drum. The eardrum separates the outer ear from the middle ear and the ossicles (say: ah-sih-kulz). What are ossicles? They are the three tiniest, most delicate bones in your body. They include:

the malleus (say: mah-lee-us), which is attached to the eardrum and means "hammer" in Latin

the incus (say: in-kus), which is attached to the malleus and means "anvil" in Latin

the stapes (say: stay-peez), the smallest bone in the body, which is attached to the incus and means "stirrup" in Latin

When sound waves reach the eardrum, they cause the eardrum to vibrate. When the eardrum vibrates, it moves the tiny ossicles — from the hammer to the anvil and then to the stirrup. These bones help sound move along on its journey into the inner ear. We need them because the inner ear is filled with liquid and air is too light to move liquid, so we need some way to transform the air movement into liquid movement.

You know the feeling when your ears pop when you are riding a plane or driving down a mountain? Well, changing altitudes changes the air pressure in the ears. To avoid having the eardrum burst, there is a tube that is called the auditory tube that connects the middle ear to the back of the nose. This tube acts like a pressure valve and opens to make sure air pressure is the same on both sides of the eardrum. When it opens, you feel a pop.

[Slide 12]

The most complicated part of the ear is the inner ear. It is most important for both our hearing and keeping our balance. There are three main parts for the inner ear: the Cochlea (say: **ko**-klee-uh), the semicircular canals and the vestibule.

Sound comes into the inner ear as vibrations from the ossicles that strike the membrane of the oval window on the cochlea causing fluid waves in the cochlea. The cochlea is responsible to transform the energy from its mechanical form as fluid waves, to neural energy, much like the retina in the eye. We will explain soon in further details how this

happens. The other parts in the inner ear include the vestibular system that is responsible for keeping our balance

[Slide 13]

The Cochlea is the part that transforms the sound energy to neural energy that is sent to the brain. It is shaped like the shell of a snail, a small, curled tube in the inner ear. The cochlea is filled with liquid, which is set into motion, like a wave, when the ossicles vibrate. The cochlea is lined with tiny cells covered in tiny hairs that are so small you would need a microscope to see them. They may be small, but they're awfully important. When sound reaches the cochlea, the vibrations (sound) cause the hairs on the cells to move, creating nerve signals that the brain understands as sound. The brain puts it together and hooray! You hear your favorite song on the radio.

There are approximately 16-20,000 hair cells (cilia) which poke up from a membrane called the organ of Corti. It is the organ of Corti that transforms the stimulated hair cells into nerve impulses. Because of the tapered design of the cochlea, waveforms traveling down the basilar membrane peak in amplitude at differing spots along the way according to their frequency. Higher frequencies peak out at a shorter distance down the tube than lower frequencies. The hair cells at that peak point give us a sense of that particular frequency—it is thought that a single musical pitch is perceived by 10-12 hair cells. Due the tapered shape of the cochlea, the distance between pitches follows the same logarithmic distance as our perception of pitch i.e. the placement of octaves are equidistant.

[Slide 14]

So let's take a closer look at the cochlea. The outer portion of the cochlea is actually bone – so it is rigid. Here is an image of the cochlea with a cross-section that shows what goes inside the tube. So the cochlea tube is actually divided into three chambers. The pink areas are where liquid is flowing. And the red coloured areas are membranes. The watery fluid that runs through the vestibular canal on the top is the fluid that vibrates via the oval window from the inner ear. The motion of this fluid vibrates the fluids in the other regions and also vibrates the basilar membrane on which sits the organ of corti.

[Slide 15]

So again, we see a cross-section of the Cochlea with the white areas in this image as membranes. So the staples is the bone that vibrates in the middle ear. It presses the oval window which causes the fluid to move which cause the membrane to shake. As the oval window membrane moves in, the round window membrane moves out, and this allows movement of the fluid in the vestibular canal which in turn, vibrates the basilar membrane and the organ of corti which rests on top of it. This causes the hair cells on the organ of corti to vibrate sending the vibrations as electronic neural signals to the brain. The hair cells in the organ of Corti are tuned to certain sound frequencies, being responsive to high frequencies near the oval window and to low frequencies near the end of the cochlea.

[Slide 16]

Ears do more than hear. They keep you balanced, too. In the inner ear, there are three small loops above the cochlea called semicircular canals. Like the cochlea, they are also filled with liquid and have thousands of microscopic hairs. When you move your head, the liquid in the semicircular canals moves, too. The liquid moves the tiny hairs, which send a nerve message to your brain about the position of your head. In less than a second, your brain sends messages to the right muscles so that you keep your balance. These canals detect rotational movements. The Otoliths sits on the base of these canals and detect linear accelerations.

Sometimes the liquid in your semicircular canals keeps moving after you've stopped moving. To understand this, fill a cup halfway with water. Now move the cup around in a circle in front of you and then stop. Notice how the water keeps swishing around, even after the cup is still? That's what happens in your semicircular canals when you spin in circles at the amusement park. When you stop spinning or step off the ride, the fluid in your semicircular canals is still moving. The hairs inside the canals are sensing movement even though you're standing still. That's why you might feel dizzy — your brain is getting two different messages and is confused about the position of your head. Once the fluid in the semicircular canals stops moving, your brain gets the right message and you regain your balance.

[Slide 17]

As the basis of our perception of a three-dimensional world, our vestibular system contains three semicircular canals. The semicircular canals are three canals that detect rotational movements. They are approximately orthogonal to each other to work with each dimension. We can see on the left side how the rotational equilibrium is happening in the semicircular canals. We see in the middle image of the left side that when the head is still the fluid in the canal is not moving, and in the bottom image we see how the fluid moves because of the rotation of the head. These fluid movements cause the hair cells within the canal to move, which sends the right signal to the brain. This is called rotational equilibrium.

On the right side we can see gravitational equilibrium that takes place in the otholiths. you can imagine this happening in a free fall for example. The acceleration causes the liquid in the corresponding canal to move because of the acceleration force as we can see in the bottom part of the right side image, leaving some cells behind due to the inertia. The cells in the tube's membrane can detect this fluid movement and informs the brain about it.

[Slide 18]

Deafness or hearing loss is the inability to hear sound. It has many causes and can occur at any age. People can go deaf suddenly as a side effect of a virus, or lose their hearing over time because of disease, nerve damage, or injury caused by noise. About 1 in 800 babies is born deaf, often because of genetic factors. Over two million people in North America cannot hear at all, and are considered profoundly deaf. Another 30 million have serious hearing problems.

Conductive hearing loss occurs when sound is not conducted properly through the outer ear, middle ear, or both. It is generally a mild to moderate impairment, because sound can still be detected by the inner ear. Generally, with pure conductive hearing loss, the quality of hearing (speech discrimination) is good, as long as the sound is amplified loud enough to be easily heard. It has a variety of causes: ear canal obstruction, problems with the eardrum or ossicles and more.

A sensorineural hearing loss is due to insensitivity of the inner ear, the cochlea, or to impairment of function in the auditory nervous system. It can be mild, moderate, severe, or profound, to the point of total deafness. Most sensory hearing loss is due to poor hair

cell function. The hair cells may be abnormal at birth, or damaged during the lifetime of an individual. There are both external causes of damage, like noise trauma and infection.

Sensorineural hearing loss that results from abnormalities of the central auditory system in the brain is called Central Hearing Impairment. Since the auditory pathways cross back and forth on both sides of the brain, deafness from a central cause is unusual.

[Slide 19]

Treatment for hearing loss varies depending upon the cause of the hearing impairment. Treatment may involve removing wax or dirt from the ear or treating an underlying infection. If there is damage or a structural problem with the eardrum or ossicles, surgery may help to repair it. If the problem is with the cochlea or hearing nerve, a hearing aid or cochlear implant may be recommended.

Hearing aids come in various forms that fit inside or behind the ear and make sounds louder. They are adjusted by the audiologist so that the sound coming in is amplified enough to allow the person with a hearing impairment to hear it clearly. Sometimes, the hearing loss is so severe that the most powerful hearing aids can't amplify the sound enough. In those cases, a cochlear implant may be recommended.

Cochlear implants are surgically implanted devices that bypass the damaged inner ear and send signals directly to the auditory nerve. A small microphone behind the ear picks up sound waves and sends them to a receiver that has been placed under the scalp. This receiver then transmits impulses directly to the auditory nerve. These signals are perceived as sound and allow the person to hear.

Appendix H

Controlled Study Quizzes

We present here the different quizzes administrated to the participants in our studies. The visual recall quiz was presented in Section 6.2.4

Includes:

- Pre-test quiz
- Visual system immediate retention quiz
- Auditory system immediate retention quiz
- Study questionnaire
- Deferred retention quiz

H.1 Pre-test

Please enter your participant number: _____

1. Please rate your current knowledge of the human visual system on a scale of 1 to 7 in which 1 is very low and 7 is very high:

   □ 1(very low) □ 2 □ 3 □ 4 □ 5 □ 6 □ 7 (very high)

2. Please rate your current knowledge of the human auditory system on a scale of 1 to 7 in which 1 is very low and 7 is very high:

   □ 1(very low) □ 2 □ 3 □ 4 □ 5 □ 6 □ 7 (very high)

3. What is the amplitude of a sound wave?
   a. Difference in the air pressure between high and low
   b. The wavelength of the sound wave
   c. The pitch of the sound
   d. The decibels of the sound

4. Where can you find the organ of corti?
   a. In the middle ear
   b. in the auditory canal
   c. In the vestibular system
   d. On top of the basiliar membrane

5. What path do the sound waves take until they are transformed to neural activity?
   a. Auditory canal, ossicles, eardrum, cochlea
   b. Auditory canal, eardrum, ossicles, cochlea
   c. Eardrum, ossicles ,auditory canal, cochlea
   d. Eardrum, auditory canal, ossicles, cochlea

6. What does the Pinna do?
   a. Collect the sound
   b. Direct the sound to the ear canal
   c. boost sounds with human speech frequencies
   d. All of the above

7. Gravitational equilibrium:
   a. Is detected in the semicircular canals.
   b. Is detected in the cochlea
   c. Is detected in the otholiths

d. Is detected in the oval window

8. What perceptual characteristic of the light causes us to see brightness?
    a. Wavelength
    b. Amplitude
    c. Wavelength purity
    d. Frequency

9. When seeing a nearby object
    a. The lens “round up”
    b. The lens flatten
    c. The lens stay the same
    d. The lens move forward

10. By which order would the nerve impulse go from the eye to the brain?
    a. Photoreceptors, bipolar cells, ganglion cells
    b. ganglion cells, bipolar cells, Photoreceptors
    c. Photoreceptors, ganglion cells, bipolar cells
    d. ganglion cells, Photoreceptors, bipolar cells

11. People suffering from Hyperopia (farsightedness) usually
    a. Their eye is larger than the length of a normal eye
    b. Their eye is smaller than the length of a normal eye
    c. Their eye is the same size as the length of a normal eye
    d. Don’t need corrected lens

12. The majority of the refractive power of the eye lies at the level of the
    a. Lens
    b. Cornea
    c. Retina
    d. Fovea

H.2 Visual system immediate retention

1. What is transduction?
    a. The way the nervous system encodes wavelength purity
    b. The process of receiving energy from the environment
    c. The process of converting physical energy to neuron activity
    d. The process of the detection of light by the eye

2. What perceptual characteristic of the light causes us to see brightness?
    a. Wavelength
    b. Amplitude
    c. Wavelength purity
    d. Frequency

3. The ability of the eye to focus on nearby objects is called
    e. myopia
    f. hyperopia
    g. Visual acuity
    h. Accomodation

4. When seeing a nearby object
    a. The lens “round up”
    b. The lens flatten
    c. The lens stay the same
    d. The lens move forward

5. By which order would the nerve impulse go from the eye to the brain?
    a. Photoreceptors, bipolar cells, ganglion cells
    b. ganglion cells, bipolar cells, Photoreceptors
    c. Photoreceptors, ganglion cells, bipolar cells
    d. ganglion cells, Photoreceptors, bipolar cells

6. What is the order that the light hits as it enters the eye?
    a. Pupil, lens, anterior cavity, cornea
    b. Pupil, anterior cavity, cornea, lens
    c. Lens, pupil, anterior cavity, cornea
    d. Cornea, anterior cavity, pupil, lens

7. Where is the sclera located?
    a. In the front of the eye, near the iris
    b. In the back of the eye surrounding the retina
    c. In the center of the eye behind the lens
    d. In the center of the eye in front of the lens

8. The Fovea is
    a. Located after the photoreceptors
    b. Located in front of the lens
    c. Located across the retina
    d. Located straight behind the pupil

9. In Myopia (nearsightedness)
    e. The light focuses in front of the retina
    f. The light focuses behind the retina
    g. The light focuses on the retina
    h. The light scatters around the retina

10. People suffering from Hyperopia (farsightedness) usually
    a. Their eye is larger than the length of a normal eye
    b. Their eye is smaller than the length of a normal eye
    c. Their eye is the same size as the length of a normal eye
    d. Don't need corrected lens

11. The cone distribution is:
    a. similar to the rod distribution
    b. High at the blind spot area
    c. Distributed about evenly around the retina
    d. centered around the Fovea

12. The majority of the refractive power of the eye lies at the level of the
    a. Lens
    b. Cornea
    c. Retina
    d. Fovea

13. Why is it important for us that the eye system encode different shades of grays?
    a. Because that gives us information about texture
    b. So we can see through the entire visible light spectrum.
    c. To ensure wavelength purity of light
    d. So we can see in different brightness levels

14. What does Presbyopia stem from?
    a. A longer than usual eye
    b. A shorter than usual eye
    c. Contraction of the ciliary muscles
    d. Gradual loss of flexibility of the lens

15. Rod cells converge such that
    a. each rod is connected to a single bi-polar cell
    b. many rods are connected to a single bi-polar cell
    c. few rods are connected to a single bi-polar cell
    d. each rod is connected to many bi-polar cells

H.3 Auditory system immediate retention

1. What is the perceptual correlate of frequency?
    a. Pitch
    b. Loudness
    c. Timbre
    d. Amplitude

2. Gravitational equilibrium:
    a. Is detected in the semicircular canals.
    b. Is detected in the cochlea
    c. Is detected in the otoliths
    d. Is detected in the oval window

3. Which animal can hear in the highest frequency?
    a. Human
    b. dog
    c. elephant
    d. mouse

4. What happens to the air when there is a sound passing through it?
    a. The sound moves the air forward
    b. The sound moves the air backward
    c. the air becomes a sine wave
    d. periods of compression and rarefaction repeat and move through the air

5. Where can you find the organ of corti?
    a. In the middle ear
    b. in the auditory canal
    c. In the vestibular system
    d. On top of the basiliar membrane

6. Rotational equilibrium:
    a. Is done using the same vascular tube as gravitational equilibrium
    b. Is done by detecting movements of the fluid in the semicircular canals.
    c. Is done by hair cells being left behind due to inertia of the fluid
    d. Is detected both in the semicircular canals and in the otoliths.

7. What is the amplitude of a sound wave?
    a. Difference in the air pressure between high and low
    b. The wavelength of the sound wave
    c. The pitch of the sound
    d. The decibels of the sound

8. What does the Pinna do?
    a. Collect the sound
    b. Direct the sound to the ear canal

c. boost sounds with human speech frequencies
d. All of the above

9. both gravitational equilibrium and rotational equilibrium
    a. happen in the semicircular canals
    b. are measured in the three dimensions of space
    c. are done using hair cells that detect when there is no fluid
    d. have fluid cover the hair cells when the head is not in motion

10. What can affect the loudness of a sound?
    a. Length of the noise
    b. Background noises
    c. Amplitude of the sound wave
    d. All of the above

11. Why do we feel dizzy when we step off a ride in an amusement park?
    a. Because the neurons in the hair cells continue to send some messages to the brain even after they don't move.
    b. Because the cochlea was under too much rotational equilibrium.
    c. Because the liquid in the semicircular canals continue to move even after we stopped.
    d. Because it takes time for the gravitational equilibrium to stop.

12. What separates the outer ear from the middle ear?
    a. The auditory tube
    b. The malleus bone
    c. The round window
    d. The eardrum

13. What path do the sound waves take until they are transformed to neural activity?
    a. Auditory canal, ossicles, eardrum, cochlea
    b. Auditory canal, eardrum, ossicles, cochlea
    c. Eardrum, ossicles ,auditory canal, cochlea
    d. Eardrum, auditory canal, ossicles, cochlea

14. Conductive hearing loss
    a. usually will require a cochlear implant
    b. Can often be treated with a hearing aid
    c. is often caused by an infection
    d. is caused by abnormalities in the central auditory system in the brain

15. The semicircular canals are:
    a. Located just in front of the cochlea
    b. Attached and just above the cochlea
    c. Attached to the auditory tube, below the cochlea
    d. Attached to the eardrum

H.4 Questionnaire

Part 1 – personal details

1. Are you a student?
   - □ Undergraduate student
   - □ Graduate student
   - □ No. Ocupation: _____
2. What year? _____
3. What is your major? _____
4. Sex
   □ Male ↑□ Female
5. Age: _____
6. Approximately how many courses in which the instructor used computer slides have you attended?
   □ 0 □ 1-2 □ 3-4 □ 5-6 □ 7+

Part 2

You have seen two lecture styles. In one, regular slides were projected on the two screens, with the same slide copied on both screens. We will call this style "**regular style**". In the second, different slides were projected on the two screens. We will call this style "**two-screen style**".

There are a number of criteria listed below. Please select the version that would be your 1st choice *according to each of the criteria* in regards to the different lecture styles (regular, two-screens). If you cannot make a choice for a given criteria please select "No opinion"

Criteria	**1st choice**
The presentation was more engaging	□ Regular □□ Two-screen □ No opinion
I learned better	□ Regular □□ Two-screen □□ No opinion
The presentation was more effective for remembering lecture material	□ Regular □□ Two-screen □□ No opinion
I would prefer it to be used in my classes	□ Regular □□ Two-screen □□ No opinion
It is easier to focus on what the instructor is saying	□ Regular □□ Two-screen □□ No opinion
The presentation was more effective for understanding lecture material	□ Regular □□ Two-screen □□ No opinion

Part 3

For each of the following statements concerning the **two-screen** style presentation, please indicate to which extent do you agree or disagree with the following statements:

SD = Strongly Disagree

D = Disagree

N = Neutral

A = Agree

SA = Strongly Agree

Item	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Agree**
The **two-screen** style gave additional value over the **regular** style	□ SD	□ D	□ N	□ A	□ SA
It was helpful for me when previous slides were carried over in the two-screen style presentation	□ SD	□ D	□ N	□ A	□ SA
Having different stuff on the second screen in the two-screen style distracted me	□ SD	□ D	□ N	□ A	□ SA
It was helpful for me to see a single slide persist a long time on the secondary screen	□ SD	□ D	□ N	□ A	□ SA
It was helpful for me to see previously shown **graphic** slides in the two screen presentation	□ SD	□ D	□ N	□ A	□ SA
It was helpful for me to see previously shown **text** slides in the two screen presentation	□ SD	□ D	□ N	□ A	□ SA
It was helpful for me when two items were compared using the two screens in the two-screen mode	□ SD	□ D	□ N	□ A	□ SA
I looked at things on the second screen to remember earlier concepts.	□ SD	□ D	□ N	□ A	□ SA
I had problems physically seeing one of the screens	□ SD	□ D	□ N	□ A	□ SA
Two screen style does **not** help me learn more than regular style	□ SD	□ D	□ N	□ A	□ SA
Two screen style decreased my attention in the lecture compared to regular style	□ SD	□ D	□ N	□ A	□ SA
Two screen style helped my understanding of the material compared to regular style	□ SD	□ D	□ N	□ A	□ SA

H.5 Deferred retention

1. What is transduction?
    a. The process of converting physical energy to neuron activity
    b. The way the nervous system encodes wavelength purity
    c. The process of receiving energy from the environment
    d. The process of the detection of light by the eye

2. What perceptual characteristic of the light causes us to see brightness?
    a. Wavelength
    b. Wavelength purity
    c. Frequency
    d. Amplitude

3. The ability of the eye to focus on nearby objects is called
    i. Accommodation
    j. Visual acuity
    k. myopia
    l. hyperopia

4. When seeing a nearby object
    a. The lens stay the same
    b. The lens move forward
    c. The lens flatten
    d. The lens “round up”

5. By which order would the nerve impulse go from the eye to the brain?
    e. ganglion cells, Photoreceptors, bipolar cells
    f. ganglion cells, bipolar cells, Photoreceptors
    g. Photoreceptors, bipolar cells, ganglion cells
    h. Photoreceptors, ganglion cells, bipolar cells

6. What is the order that the light hits as it enters the eye?
    e. Lens, pupil, anterior cavity, cornea
    f. Cornea, anterior cavity, pupil, lens
    g. Pupil, lens, anterior cavity, cornea
    h. Pupil, anterior cavity, cornea, lens

7. Where is the sclera located?
    a. In the center of the eye behind the lens
    b. In the center of the eye in front of the lens
    c. In the front of the eye, near the iris
    d. In the back of the eye surrounding the retina

8. The Fovea is
    a. Located across the retina
    b. Located straight behind the pupil
    c. Located after the photoreceptors
    d. Located in front of the lens

9. In Myopia (nearsightedness)
    i. The light scatters around the retina
    j. The light focuses behind the retina
    k. The light focuses in front of the retina
    l. The light focuses on the retina

10. People suffering from Hyperopia (farsightedness) usually
    a. Their eye is smaller than the length of a normal eye
    b. Their eye is larger than the length of a normal eye
    c. Their eye is the same size as the length of a normal eye
    d. Don't need corrected lens

11. The cone distribution is:
    a. Distributed about evenly around the retina
    b. centered around the Fovea
    c. similar to the rod distribution
    d. High at the blind spot area

12. The majority of the refractive power of the eye lies at the level of the
    a. Retina
    b. Fovea
    c. Cornea
    d. Lens

13. Why is it important for us that the eye system encode different shades of grays?
    e. To ensure wavelength purity of light
    f. So we can see in different brightness levels
    g. Because that gives us information about texture
    h. So we can see through the entire visible light spectrum.

14. What does Presbyopia stem from?
    a. Contraction of the ciliary muscles
    b. Gradual loss of flexibility of the lens
    c. A shorter than usual eye
    d. A longer than usual eye
    e.
15. Rod cells converge such that
    a. few rods are connected to a single bi-polar cell

b. each rod is connected to many bi-polar cells
c. each rod is connected to a single bi-polar cell
d. many rods are connected to a single bi-polar cell

16. What is the perceptual correlate of frequency?
    a. Timbre
    b. Amplitude
    c. Pitch
    d. Loudness

17. Gravitational equilibrium:
    a. Is detected in the otoliths
    b. Is detected in the oval window
    c. Is detected in the semicircular canals.
    d. Is detected in the cochlea

18. Which animal can hear in the highest frequency?
    a. elephant
    b. mouse
    c. Human
    d. dog

19. What happens to the air when there is a sound passing through it?
    a. the air becomes a sine wave
    b. periods of compression and rarefaction repeat and move through the air
    c. The sound moves the air forward
    d. The sound moves the air backward

20. Where can you find the organ of corti?
    a. In the vestibular system
    b. On top of the basiliar membrane
    c. In the middle ear
    d. in the auditory canal

21. Rotational equilibrium:
    a. Is detected both in the semicircular canals and in the otoliths.
    b. Is done using the same vascular tube as gravitational equilibrium
    c. Is done by hair cells being left behind due to inertia of the fluid
    d. Is done by detecting movements of the fluid in the semicircular canals.

22. What is the amplitude of a sound wave?
    a. The pitch of the sound
    b. The decibels of the sound
    c. Difference in the air pressure between high and low
    d. The wavelength of the sound wave

23. What does the Pinna do?

a. Direct the sound to the ear canal
b. Collect the sound
c. boost sounds with human speech frequencies
d. All of the above

24. both gravitational equilibrium and rotational equilibrium
    a. are done using hair cells that detect when there is no fluid
    b. have fluid cover the hair cells when the head is not in motion
    c. happen in the semicircular canals
    d. are measured in the three dimensions of space

25. What can affect the loudness of a sound?
    a. Amplitude of the sound wave
    b. Background noises
    c. Length of the noise
    d. All of the above

26. Why do we feel dizzy when we step off a ride in an amusement park?
    a. Because the neurons in the hair cells continue to send some messages to the brain even after they don't move.
    b. Because the cochlea was under too much rotational equilibrium.
    c. Because the liquid in the semicircular canals continue to move even after we stopped.
    d. Because it takes time for the gravitational equilibrium to stop.

27. What separates the outer ear from the middle ear?
    a. The auditory tube
    b. The malleus bone
    c. The round window
    d. The eardrum

28. What path do the sound waves take until they are transformed to neural activity?
    a. Eardrum, ossicles ,auditory canal, cochlea
    b. Eardrum, auditory canal, ossicles, cochlea
    c. Auditory canal, ossicles, eardrum, cochlea
    d. Auditory canal, eardrum, ossicles, cochlea

29. Conductive hearing loss
    a. is often caused by an infection
    b. is caused by abnormalities in the central auditory system in the brain
    c. usually will require a cochlear implant
    d. Can often be treated with a hearing aid

30. The semicircular canals are:
    a. Attached to the eardrum

b. Attached and just above the cochlea
c. Attached to the auditory tube, below the cochlea
d. Located just in front of the cochlea

Appendix I

Image references and permissions

Figure 1.1 is a photo by Robert Paz that originally appeared on the cover of the Caltech magazine Engineering and Science, Vol. 46, No. 5, May 1983. Used by permission of The California Institute of Technology.

Figure 2.1 is a photo by an unknown photographer that was annotated by Edward Tufte for the cover of his essay "The cognitive style of PowerPoint." The original photo was of a parade in Budapest on April 4, 1956, the 11th anniversary of the Soviet-backed regime. A statue of Stalin is the centerpiece as ranks of Hungarian soldiers parade in Budapest. Used by permission of AP Press (original photo) and Graphics Press (annotated version).

Figure 3.3 is a figure taken from the MIT Open Courseware website. Used by permission of The Massachusets Institute of Technology under the terms of a Creative Commons license.

Figure 5.1 is a cartoon by Richard Guindon. A similar cartoon by Guindon was published in Esquire in 1966. The version here was drawn in August 2009 and appears on his website. Used by permission of Richard Guindon.

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Appendix J

UBC Research Ethics Board Certificates

All of the research reported in this dissertation was conducted with the prior approval of the UBC Behavioural Research Ethics Board under certificate H07-00724. A copy of the most recent amended certificate is provided on the next page.

The University of British Columbia
Office of Research Services
Behavioural Research Ethics Board
Suite 102, 6190 Agronomy Road, Vancouver, B.C. V6T 1Z3

CERTIFICATE OF APPROVAL - MINIMAL RISK AMENDMENT

PRINCIPAL INVESTIGATOR:	DEPARTMENT:	UBC BREB NUMBER:
Kellogg S. Booth	UBC/Science/Computer Science	H07-00724

INSTITUTION(S) WHERE RESEARCH WILL BE CARRIED OUT:

Institution	Site
UBC	Vancouver (excludes UBC Hospital)

Other locations where the research will be conducted:
N/A

CO-INVESTIGATOR(S):

Joel Lanir

SPONSORING AGENCIES:

Natural Sciences and Engineering Research Council of Canada (NSERC) - "Collaboration technology and multi-user interfaces" - "Network for effective collaboration technologies through advanced research (NECTAR) - research"

PROJECT TITLE:
Network for Effective Collaboration Technologies through Advanced Research

Expiry Date - Approval of an amendment does not change the expiry date on the current UBC BREB approval of this study. An application for renewal is required on or before: February 18, 2010

AMENDMENT(S):	AMENDMENT APPROVAL DATE:
	March 16, 2009

Document Name	Version	Date
Consent Forms:		
Consent form - phase 3	2.0	March 16, 2009
Advertisements:		
Recruitment ad - Phase 3	2.0	March 16, 2009

The amendment(s) and the document(s) listed above have been reviewed and the procedures were found to be acceptable on ethical grounds for research involving human subjects.

Approval is issued on behalf of the Behavioural Research Ethics Board and signed electronically by one of the following:

Dr. M. Judith Lynam, Chair
Dr. Ken Craig, Chair
Dr. Jim Rupert, Associate Chair
Dr. Laurie Ford, Associate Chair
Dr. Anita Ho, Associate Chair