Use of Reading Strategy to Assess Reading Medium Effectiveness: Application to Determine the Effects of Reading Medium and Generation in an Active Reading Task

Kyunghui Oh

Dissertation submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

Doctor of Philosophy
In
Industrial and Systems Engineering

Tonya L, Smith-Jackson, Chair
Maury A. Nussbaum
Manuel Perez-Quinones
Woodrow W. Winchester

June 4, 2013
Blacksburg, Virginia

Keywords: reading strategies; medium; generation; reading comprehension, active reading; performance; subjective responses; cognitive load

Use of Reading Strategy to Assess Reading Medium Effectiveness: Application to Determine the Effects of Reading Medium and Generation in an Active Reading Task

Kyunghui Oh

ABSTRACT

Advances in computer technology have hastened the development and dissemination of a wide range of electronic media into the workplace and educational settings. Electronic media offer many advantages, including quicker access to information and easier information sharing among professions. However, electronic reading media have still not been well integrated into these settings, especially for non-routine cognitive tasks like active reading. Conflicting results from different measures (e.g., performance, preference) have been reported regarding their efficacy. Despite the fact that there are no significant performance differences between reading from paper and reading from electronic media, people still show a preference for reading from paper and resist changes in the workplace, which often results in the abandonment of electronic reading media. Therefore, in order to maximize the potential benefits from electronic reading media, researchers and designers need more valid ways to assess the effectiveness of electronic reading media than relying on existing methods using outcome-based measures of reading.

Although the act of reading is primarily a cognitive process, there are relatively few comprehensive empirical reports on how the use of different reading media impacts cognitive processes like reading strategies. Moreover, researchers have rarely considered generational differences, even though generation-specific reading practices could significantly affect readers' current reading practices using different media.

Therefore, the overall objective of this research was to develop and evaluate a new method to test the effectiveness of reading medium in terms of supporting design and evaluation. Specifically, this research examined how reading strategies can be used as a process measure. The research consisted of three parts: (1) investigating readers' use of reading strategies using different types of media, (2) identifying the relationship between readers' use of reading strategies and their performance and subjective response, and (3) identifying the relationship between readers' use of reading strategies and cognitive load. Resultant findings are expected to improve how we measure the effectiveness of electronic reading media.

First, readers' use of reading strategies for different types of media was examined and associated generational differences were investigated. A laboratory experiment was conducted in which three generations of participants (Baby Boomers, Generation X, and Generation Y) were asked to perform an active reading task (a simulated work-related reading task) with three types of media (paper, computer, and iPad). Readers' uses of reading strategies were identified from task

observation and Retrospective Think Aloud (RTA) sessions. Quantitative analyses revealed significant differences in readers' use of reading strategies, and which depended on both the type of media and individual attributes (generation). Detailed qualitative analyses were conducted to help explain the underlying reasons for these differences in the use of reading strategies.

Second, based on the identified reading strategies, the relationships between readers' use of reading strategies and their performance and subjective responses were examined. Such outcome measures have traditionally been used to assess the efficacy of different reading media. However, previous studies have generated conflicting results and did not clearly demonstrate the underlying aspects that influence readers' performance and subjective responses. The results of this study showed a clear association between readers' use of reading strategies and their performance and subjective responses. Accordingly, it was revealed that participants who used the reading strategies they developed in their formative period exhibited higher subjective responses.

Third, again based on the identified reading strategies, the association between readers' use of reading strategies and cognitive load was examined. Reading from electronic media has been regarded as requiring more cognitive resources than reading from paper. However, it has not been well understood precisely which aspects of reading from different media actually influence cognitive load in terms of cognitive and metacognitive perspectives. The results reported herein showed an association between reading strategies and cognitive load. Therefore, this study revealed that the use of reading strategies was critical to their cognitive load.

Overall, this research demonstrated how reading strategies could be used as process measures to assess the effectiveness of specific media for active reading activities. The way in which people interact with a text (readers' use of reading strategies) was affected by the medium, as well as by generation-specific reading practices. The extent to which reading strategies can explain reading differences was confirmed, by investigating the associations between readers' use of reading strategies and other measures. These findings can contribute to the design of reading media and help to determine the most suitable reading media for active reading activities (e.g., work-related reading activities). In addition, the findings also support the importance of culturally situated experience for non-routine cognitive activities and the use of an integrated approach that takes into account both cognitive and cultural aspects in designing human-computer interaction for non-routine cognitive activities.

ACKNOWLEDGEMENTS

I would like to give my sincere appreciation my advisor, Dr. Smith-Jackson, who provided guidance, critics, encouragement, and support through my dissertation work. I thank you for your insightful guidance that made this research much better. Without her support, this dissertation would not have been possible. I would also like to thank my committee members, Dr. Nussbaum, Dr. Perez-Quinones, and Dr. Winchester for their constructive feedback on my research.

Special thanks should go to Jessica Cooper and Julian Cooper. They encourage me to finish study and help me recruit participants. Without their support, I could not have completed this study. I would also like to acknowledge all participants of this research for their time and valuable feedback. I also thank all the Korean ISE students for their help and advice through my research.

I am very grateful to my parents and in-laws who have encouraged successfully finishing my study and have taken care of my little angel. I dedicate this work to my husband, Gyuhyun. Without your patience, encouragement and support, this effort could not have been completed. Most importantly, I would like to thank my little angel, Yoonhye. Thank you and love you.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1. INTRODUCTION

1. Background

Many activities in educational or workplace settings involve interacting with documents of some sort, whether printed or electronic. Within these document-related activities, reading—defined herein as seeing and comprehending words and sentences in a document—represents an essential activity. According to Mokhtari and Sheorey's (1994) study of the reading habits of 85 college students, the students spend an average of 14.45 hours per week engaged in reading activities, which typically breaks down into 4.75 hours of nonacademic reading and 9.7 hours of academic reading. Similarly, Adler, Gujar, Harrison, O'Hara and Sellen (1998) investigated daily reading activities of 15 people from a wide variety of professions and found that reading activities accounted for an average of nearly 82% of workers' time, ranging from 23% (nurses) to 94% (accounting assistants).

Many recent advances in computer technology have hastened the development and dissemination of various types of electronic media into the workplace and into educational settings. In the United States, for example, 55.5% of people who are employed use a computer at work, and an even higher percentage (80%) use a computer in managerial and professional specialty occupations. Moreover, 85% of students 18 years and older use a computer at school (U.S. Census Bureau, 2003). In particular, electronic media such as the personal computer and tablet are rapidly becoming mandatory devices on university campuses. The mobile workforce is also becoming increasingly dependent on hand-held electronic devices. Consequently, the growing use of computer technologies is impacting the way we read; where once we relied almost exclusively on paper documents, we now use electronic media with ever-growing frequency.

Also important for this study is that increasing numbers of older Americans are choosing to remain in the workforce—in part because of the increased birth rate after the Second World War (the so-called "Baby Boomers") and the declining birth rate after 1980. In the United States, there are 76 million Baby Boomers, while Generation X (those born after the post-WWII baby

boom) accounts for 46 million people (DeLong, 2004). According to the Bureau of Labor Statistics, the percentage of older Americans (55 years+) has increased in the workforce; in 2000 they represented 13.1 percent of the workforce, compared to 19.5 percent in 2010 and an anticipated 25.2 percent in 2020 (BLS, 2012). In addition, older people are likely to continue to participate in the workforce given improvements in medicine, economic uncertainties, and related policy changes (e.g., the delayed eligibility age for social security benefits) (Burtless & Quinn, 2002). Therefore, workers who perform reading activities in the workplace include diverse age groups, which makes the question of whether older workers can change their traditional reading practices with the introduction of new technology in the workplace an important consideration for employers and industrial designers.

2. Problem Statement

The use of electronic media in educational and workplace settings offers many benefits, such as rapid data processing and environmental advantages (i.e., reduction in paper use and printer/copier supplies). In particular, electronic media facilitates quicker access to information and easier information sharing among professionals (Cortada, 2008; Thomas, 2006). That can be especially beneficial when multiple users/readers review and revise a document in a collaborative process, which is an important reading activity in many settings. Thus, the use of electronic media can make reading activities significantly more efficient.

However, electronic reading media have still not been completely integrated into most workplace and educational settings, especially for non-routine cognitive tasks like active reading. As reported by Autor, Levy, and Murnane (2003), computer technology has mostly been adopted for routine cognitive tasks while non-routine cognitive tasks are still conducted in traditional ways (i.e., using paper) due to difficulties in effectively supporting these tasks with computer-based technologies. Several empirical reports (Haper & Sellen, 1995; Holzinger, 2011, Potthast, 2008; Sellen & Harper, 1997) have shown that people still prefer to read from paper and resist changes in the workplace, resulting in the abandonment of newer technologies with an associated waste of both time and money. In order to maximize the potential benefits from technology, researchers

and industrial practitioners need to discover the underlying causes associated with people's resistance to reading from certain media. Recent studies, however, have either failed to uncover significant differences associated with reading on different media, or they have found conflicting results from different measures (e.g., performance or satisfaction with the medium).

Existing studies have generally focused on outcome-based measures of reading (e.g., speed and accuracy) to evaluate media for reading activities, but these have largely been insufficient for elucidating reading differences associated with different media. A number of researchers have even reported no discernible differences in performance among media for reading activities (e.g. Noyes & Garland, 2008). Nonetheless, readers in the workplace continue to show a preference for either reading from paper or reading from an electronic medium and resist changing from one to the other (Gladwell, 2002; Holzinger et al., 2011). Although outcome-based measures can point to generalized reading differences across media, they do not provide detailed information about the act of reading using different media in terms of cognitive and metacognitive processes. For example, Hornbaek and Frokjaer (2003) found that people tend to prefer an interface that results in higher task completion time because it enables them to conduct a deeper exploration of a text, consequently helping them to perform the task successfully. Therefore, more valid ways of assessing the effectiveness of reading media in comparison to existing methods using outcome-based measures of reading are required.

The act of reading is first and foremost a cognitive process. Therefore, the ways in which the use of different reading media can affect those cognitive processes should be comprehensively addressed. Several studies have investigated the act of reading and have argued for the importance of process measures (Dillon, 1992; O'Hara & Sellen, 1997). While such studies have been instructive, they tend to focus on one specific strategy or function (e.g., annotation), rather than investigating how readers use diverse strategies for the successful completion of the assigned reading task.

Furthermore, existing studies have rarely considered generational differences, even though generation-specific reading practices could affect reader's current reading practices with

different media. Researchers (Galdwell, 2002; Potthast, 2008) have conceptually discussed how generational influences can override even the most advanced technologies for reading applications. Potthast (2008) also argued that people's highly trained reading and handling habits tend to withstand changes that are not accompanied by generational changes in the workplace. Therefore, investigating the reading strategies that people use was expected to provide detailed information to help reveal readers' underlying cognitive processes and any generational differences.

Reading strategies are defined as the cognitive and metacognitive strategies people utilize for the successful completion of reading activities, which are typically acquired during the formative period (Mokhtari & Richard, 2002; Pereira-Laird & Deane, 1997). When reading a document, people use different reading strategies for different purposes. These reading strategies may also differ depending on the medium used since reading from paper is different from reading with electronic media (Brown, 2001; Herath, 2010). Recent studies in the education field have also reported that readers can read as well with electronic media as they can with paper if they utilize different ways of interacting with that electronic media (Kol & Schcolnik, 2000; Murphy, Long, Holleran, & Esterly, 2003). However, it should be noted that those studies are primarily based on younger readers and do not take into account any generational differences. Therefore, assessing the reading strategies that people of different generations use for different media will be valuable not only for identifying media-specific reading strategies, but also for determining whether these strategies are associated with any specific reader/user attributes (in this case, generation).

3. Research Objectives

The overall objective of this research was to develop and evaluate a new method to test the effectiveness of reading media in terms of supporting design and evaluation. Specifically, this research focused on examining how reading strategies can be used as a process measure.

First, this research investigated reading strategies that people of different generations use when reading from different media. In so doing, whether reading strategies can reflect both cognitive

and cultural aspects was examined. Accordingly, this study looked at how reading strategies can be used to assess the effectiveness of reading media. A laboratory experiment was conducted in which three generations of participants (Baby Boomers, Generation X and Generation Y) were asked to perform an active reading task (work-related reading task) with three types of media (paper, computer, and iPad) in sequence. Readers' use of reading strategies was collected from task observation and RTA (Retrospective Think Aloud) sessions. Their choice of reading strategies depending on different types of media and their generation group was examined through both quantitative and qualitative analyses.

Second, this research investigated the relationship between readers' use of reading strategies and other existing measures—namely, performance, subjective responses, and cognitive load measures. Reading speed and overall comprehension were employed as the performance measures. Subjective responses were obtained using three constructs: usefulness, ease of use, and satisfaction with the medium. Three types of cognitive load were also examined: physiological cognitive load, mental efficiency, and subjective cognitive load. Consequently, the extent to which reading strategies can explain reading differences was examined by investigating the associations between readers' use of reading strategies and other measures. Specifically, the following research questions were explored.

- RQ1: To what extent does readers' use of reading strategies differ depending on different types of media and their generation?
- RQ2: What is the impact of medium and generation on performance?
- RQ3: What is the impact of medium and generation on subjective response?
- RQ4: What is the impact of medium and generation on cognitive load?
- RQ5: What is the relationship between readers' use of reading strategies and their performance, subjective response, and cognitive load?

CHAPTER 2. LITERATURE REVIEW

Reading has been the focus of research for many years, resulting in a considerable body of associated literature in diverse fields such as education, human factors, computer science, and psychology. While focusing on the basic act of reading and comprehending words, these study have focused on different aspects of reading, such as the structure of discourse, the purpose of reading, the medium for reading, and many others.

1. Reading Activity

Reading is a highly nuanced activity. People read a text for different purposes (Dillon & McKnight, 1990; O'Hara, 1996). There are many different reading purposes identified in the existing literature. Goodman (1994), for example, classified five reading types as follows:

- Environmental reading: environmental print read by choice and by necessity
- Occupational reading: reading done for an occupation during the workday
- Informational reading: the reading of certain information that cannot all be memorized or remembered such as phone numbers, and reading to satisfy longer range curiosity or personal needs
- Recreational reading: reading to pleasantly occupy leisure time
- Ritualistic reading: reading cultural or religious texts

Reading varies depending on text genre, task, or context that reflects detailed purposes. For example, Lorch, Lorch, and Klusewitz (1993) listed ten distinct reading categories or purposes regarding college students' reading contexts: exam preparation, reading for research, class preparation, reading to learn, reading to apply, search, reading to self-inform, intellectually challenging reading, reading for stimulation, and light reading.

Adler et al. (1998) identified a range of reading and writing activities regarding work contexts through participant diaries and from his interviews with people in varying occupations (Table 1).

Table 1. Reading and writing activities regarding work contexts (Adler et al., 1998)

Reading activities	Writing activities
- Reading in order to identify - Skimming - Reading own text to remind - Reading to search/answer questions - Reading to self inform - Reading to learn - Reading for cross-referencing - Reading to edit or critically review text - Reading to support listening - Reading to support discussion	- Creating - Note-taking - Annotation - Form-filling - Updating

2. Models of Reading Comprehension

The major goal of reading is comprehension, since reading a document implies processing and analyzing a document. In this section, reading theories (i.e., schema theory, construction-integration model, and constructionist model) will be reviewed. While a number of reading theories have been proposed, I chose three theories because each represents a particular perspective in an evolving body of reading research, and because they represent important theories in reading research (Butcher & Kintsch, 2003; Graesser, 2007; van den Broek & Gustafson, 1999). In particular, the concept of reading strategies (the focus of this research) is related to the latest model: the constructionist model.

(1) Schema Theory

In general, schema is defined as a mental representation or concept of past experience (Bartlett, 1932). Early models are chiefly based on schema and have emphasized top-down processes in which comprehension is considered as schema activation between existing schema in memory and new information from reading. Schema theory seeks to understand how the human brain organizes information, comprehends text, and constructs a mental representation of the text. This theoretical framework emphasizes the role of background knowledge in this process: how new

information interacts with already stored information in memory as represented by a schema (Anderson & Pearson, 1984).

Schemas play a crucial role in explaining reading comprehension. The following models of reading comprehension include schema and further describe its role within cognitive processes. However, under purely schema-based models, the reader's background knowledge and information within the text, such as how different types of text evoke different kinds of representation, tended to represent the main focus, while other aspects of cognitive process (e.g., bottom-up processes) were seldom incorporated.

(2) Construction-integration Model

The construction integration model (CIM; Kintsch & Van Dijk, 1978; van Dijk & Kintsch, 1983) is one of the most widely accepted models of reading comprehension. This model describes the bottom-up process of reading comprehension, especially explaining reading comprehension based on knowledge of perceptual and cognitive processes.

A three-stage process of reading comprehension characterizes the CIM. The first stage is the surface code, which is a record of the exact wording and syntax of the sentence. The second stage is the text-base. The text-base contains explicit propositions in the text that capture the core meaning of a sentence or a text. The third stage of the process is the situation model in which prior knowledge is integrated with new information from a text; during this stage the reader develops a referential mental model of what the text is about. In particular, Kintsch and Van Dijk (1978) characterized two levels of semantic structure (microstructure and macrostructure), and explained them based on the limitations of memory. The microstructure is defined as the structure of individual propositions and their relationships. In the text-base stage, propositions are formed and subsequently linked to other propositions. This activation process among propositions takes place in working memory and is restricted by the capacity of working memory. The macrostructure is the creation of a more general and complete meaning of the reading passage including the reader's knowledge (schemas). In this structure, schemas are retrieved in

parallel from long-term memory, and play a role in identifying the important propositions in a text and their relationships. Therefore, the CIM explains how the exact wording and syntax of a sentence are constructed in memory and how they are integrated into the reader's knowledge while considering human capabilities and limitations of cognitive processes.

Like this CIM, many models seek to explain reading comprehension based on the assumption that human attention resources are limited. Moreover, recent research on reading comprehension has placed more emphasis on describing dynamic aspects of reading. For instance, while the CIM assumes a fixed buffer with a limited number of slots of attention resource in working memory, recent models such as the Capacity-Constrained Construction Integration Model (CCCI; Goldman, Varma, & Coté, 1996) regard attention resources as a pool of activation that is distributed over multiple elements, with elements having different degrees of activation. The Landscape Model (van den Broek, Risden, Fletcher, & Thurlow, 1996) also assumes that the construction of a mental representation of a text is not all or none—but instead varies based on their strengths (i.e., coherence-based inference).

(3) Constructionist Model

The constructionist model also stresses the dynamic aspects of reading. Specifically, this model views the reading process as being indelibly linked with reading strategies (Graesser, 2007), which is the focus of this research. While the CIM regards reading as a rather automatic process, the constructionist model focuses on explaining how readers successfully read a text (Graesser, Singer, & Trabasso, 1994). Graesser et al. extended the concept of the situation model by proposing their referential-situation model in which "mental representation of the people, setting, actions, and events that are mentioned in explicit clauses in text or that are filled in inferentially by world knowledge" (p. 371). They argued that the referential-situation model is the key factor for successful reading, and that a reader's goal(s) play an important role in the development of this referential-situation model.

This model has three assumptions for explaining reading comprehension: reader goals, coherence, and explanation. First, the reader goal assumption is that readers read a text with certain outcome goals in mind. The coherence assumption is that readers seek to construct mental representations at both the local and global levels. Accordingly, readers actively think, generate inferences, and reinterpret the text in order to reduce the coherence gap. The explanation assumption is that successful readers seek to explain events, actions, and states in the text with respect to the assumption of coherence and the assumption of reader goals. That is, a reader with a goal tends to understand text by establishing coherence locally and globally and by addressing explanations of why things in the text occur. Therefore, this constructionist model emphasizes the role of reader goals in the process of reading comprehension, as well as addresses how a reader implements active comprehension strategies when reading texts.

A review of the literature regarding models of reading comprehension shows how perspectives regarding reading comprehension have evolved. In the workplace and educational settings (the contexts for this study), readers usually have a specific goal they want to achieve throughout a reading task. Consequently, recent models like the constructionist model that consider dynamic aspects of reading comprehension such as goal and reading strategies, would explain reading comprehension in such a context. As discussed in the constructionist model, reading strategy is the key aspect for explaining reading comprehension; therefore, this study will focus on reading strategies.

3. Reading Strategy

A reading strategy is defined as "a cognitive or behavioral action that is enacted under particular contextual conditions, with the goal of improving some aspects of comprehension" (Graesser, 2007, p.6). In other words, a reading strategy can be viewed as an acquired capability or set of capabilities for performing reading activities within a developmental process. For example, Graesser (2007) exemplified this notion by describing how students look up an unfamiliar word in a dictionary. In this situation, the behavioral strategy is to search and locate the word by

turning pages. The cognitive strategy is to read the definition of the word in the dictionary, and then reread the sentence with a fuller understanding of the meaning.

It is worthwhile to be aware of existing conceptualizations regarding reading strategies since other terms such as "reading skills" are also used to describe reading strategies. While the term reading skills has been used to describe reading behaviors for many years, the term "reading strategies" has been widely used in recent years along with an emphasis on the cognitive aspects of information processing (Afflerbach, Pearson, & Paris, 2008). In particular, studies in the education field (Garner, 1994; Paris, Lipson, & Wixon, 1994) state that reading strategies are conscious activities; in comparison, reading skills are more automatic activities. In fact, a reading strategy becomes a reading skill at the point of automaticity, thus reflecting a developmental view of reading strategies. However, researchers usually use those terms interchangeably, although there is a growing preference for the term reading strategies in recent studies.

Even though there is currently no unified classification regarding reading strategies, researchers in the education field have proposed different categorizations (Millis et al., 2004; Murray, 2003; Paris, Wasik, & Turner, 1991). For example, Paris et al. (1991) classified reading strategies into three groups: before reading, while reading, and after reading. Pugh (1978) identified five reading techniques based on studying how college students read: scanning, search reading, skimming, receptive reading, and responsive reading. Murray (2003) classified a number of active reading strategies from the literature into behavioral, cognitive, and metacognitive strategies as follows:

- Behavioral strategies: skimming, scanning, reviewing, bookending, big picturing, deepening, refocusing, exploring, writing
- Cognitive strategies: summarizing/consolidating, connecting, evaluating, questioning, predicting, planning
- Metacognitive strategies: monitoring coherence/understanding/effort/efficiency, setting goal/managing goal priority, deciding which behavioral or cognitive strategy to use next

Researchers in the education field further developed an instrument for assessing a reader's awareness and perceived use of reading strategies (Miholic, 1994; Mokhtari & Reichard, 2002; Pereira-Laird & Deane, 1997; Schmitt, 1990)—primarily since their focus has been on identifying ways to encourage a reader's awareness and usage of reading strategies through evaluating existing practices. For example, Mokhtari and Reichard (2002) developed the Metacognitive Awareness of Reading Strategies Inventory (MARSI), consisting of three types of reading strategies: global, problem solving, and support strategies (Table 2).

Table 2. The Metacognitive Awareness of Reading Strategies Inventory (MARSI, Mokhtari & Reichard, 2002)

Type	Items
Global strategies	- I have a purpose in mind when I read - I think about what I know to help me understand what I read - I preview the text to see what it's about before reading it - I think about whether the content of the text fits my reading purpose - I skim the text first by noting characteristics like length and organization - I decide what to read closely and what to ignore - I use context clues to help me better understand what I'm reading - I use typographical aids like boldface and italics to identify key information - I critically analyze and evaluate the information presented in the text - I check my understanding when I come across conflicting information - I try to guess what the material is about when I read - I check to see if my guesses about the text are right or wrong
Problem solving strategies	- I read slowly but carefully to be sure I understand what I'm reading - I try to get back on tract when I lose concentration - I adjust my reading speed according to what I'm reading - When text becomes difficult, I pay closer attention to what I'm reading - I try to picture or visualize information to help remember what I read - When text becomes difficult, I reread to increase my understanding - I try to guess the meaning of unknown words or phrases
Sub strategies	- I take notes while reading to help me understand what I read - When text become difficult, I read aloud to help me understand what I read - I summarize what I read to reflect on important information in the text - I discuss what I read with others to check my understanding - I underline or circle information in the text to help me remember it - I use reference materials such as dictionaries to help me understand what I read - I paraphrase (restate ideas in my own words) to better understand what I read - I go back and forth in the text to find relationships among ideas in it - I ask myself questions I like to have answered in the text

In the Human-Computer Interaction (HCI) field, researchers have also proposed different reading strategy categorizations (Dillon & McKnight, 1990; Harvey, Goudvis, & Graves, 2000; O'Hara,

1996). For example, through an extensive review of the empirical literature, O'Hara (1996) presented a typology of reading depending on three categories as shown below. In short, *how* a text is read and any support activities that accompany that process describe the range of reading strategies; in contrast, *why* a text is read explains the purpose of reading activities.

- How a text is read: receptive reading, reflective reading, skimming, scanning, serial/non-serial reading, and single/repeated reading.
- The support activities: underlining, note-taking, outlining, and networking.
- Why a text is read: reading to learn, reading to self-inform, reading to search/reading to answer questions, reading for research, reading to summaries, reading for discussion, proof-reading, reading while writing from multiple sources, reading for text revision, reading for critical review, reading to apply, reading for problem solving and decision making, reading for enjoyment.

Studies in the HCI field regard reading strategies as process measures of reading (further discussed in Section 6). They usually focus on specific ones among various reading strategies, and often subsequently compare differences between media according to one or two reading strategies. For example, O'Hara and Sellen (1997) qualitatively compared differences between paper and screen-based reading in light of annotating and note-taking activities as captured by video recordings of readers' tasks and subsequent oral interviews. Marshall and Brush (2004) also defined categories of annotation type (i.e., anchor only, content only, compound) based on investigating a reader's annotations on paper; the researchers then compared the number of annotation types between personal paper annotation and online public annotation.

Results from existing studies are limited to inclusively explaining the interactions between a reader and the type of media with regard to specific reading activities. Most available studies have focused on one or two reading strategies; however, how diverse reading strategies contribute to performing reading tasks using different media has not yet been considered. For example, if an annotation activity is difficult to accomplish using electronic media, what kinds of other reading strategies do people use to achieve the same goal (i.e., comprehension) since

reading strategies are cognitive and metacognitive activities are needed for successfully performing reading tasks. Accordingly, this research focused on how diverse reading strategies are used depending on different types of reading media.

4. Cognitive Processing and Reading Comprehension

As reviewed in the section on reading theories (Section 2), knowledge of perceptual and cognitive processes plays an important role in explaining the process of reading, as well as human capabilities and limitations in reading comprehension. In this section, working memory, cognitive load theory, and metacognition will be reviewed.

(1) Working Memory

Working memory plays a central role in human information processing such as reading comprehension, learning, problem solving and many others (Haberlant, 1997). Traditionally, researchers have classified human memory into short-term memory and long-term memory. Although this arrangement represents an important basic difference with respect to information storage, it ignores concurrent processing aspects. Baddeley and Hitch (1974), however, proposed a more detailed model of working memory that incorporates the importance of dynamic cognitive processes in storing information. In their model, working memory is defined as the system responsible for processing and storing information on a temporary basis, while long-term memory represents a permanent memory store. When new information is processed, it is transferred from working memory into long-term memory, and then integrated with existing long-term schemas and stored in long-term memory. Therefore, the interaction between working memory and long-term memory plays a crucial role during reading comprehension.

Baddely and Hitch (1974) described the components of working memory and how working memory functions. Baddeley (2003) further defined these components as shown in Figure 1.

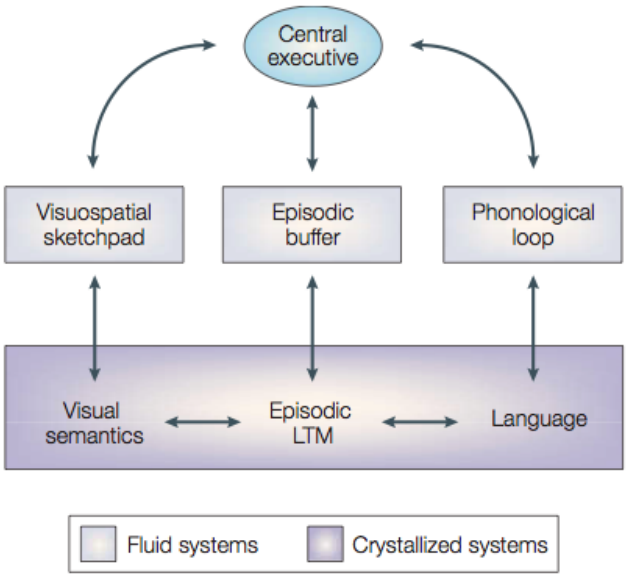


Figure 1. The multi-component model of working memory (used with permission of Baddeley, 2003)

This model is comprised of four main components: the central executive, the visuospatial sketchpad, the phonological loop, and the episodic buffer. Each of these components has limited capacity. The central executive allocates attention resources for storing or processing new information, as well as information from long-term memory. This central executive is connected to three other sub-components and is responsible for controlling those factors. The visuospatial sketchpad holds visual information, which is retained in the form of a visual/spatial representation whereby each item can be displayed simultaneously. The phonological loop holds auditory information, which is retained in serial order and then rapidly decays. The episodic buffer, which Baddeley later added to the model, plays a role in developing mental models of information that integrates schemas from long-term memory with information in working memory. As mentioned, auditory information is stored in linear sequential order on the phonological loop; visual/spatial information is stored holistically and concurrently on the visuaospatial sketchpad. That is, the episodic buffer in working memory bounds those two sub-components and integrates them with information from long-term memory.

In addition, this model has two shaded areas: fluid systems (fluid intelligence) and crystallized systems (crystallized intelligence) (Horn & Cattell, 1967; Schaie, Rosenthal & Perlman, 1953). Fluid intelligence represents the capacity to think logically and solve problems in unfamiliar situations—thus it is distinct from acquired knowledge. The three components described above (visuospatial sketchpad, phonological loop and episodic buffer) require the utilization of fluid intelligence. In contrast, crystallized intelligence represents general knowledge and the capacity to use skills, knowledge and experience. This crystalized intelligence is the product of educational and cultural experience, which increase with age.

When considering this model in light of a reading activity, every component plays a critical role. Both the visuospatial sketchpad and phonological loop are involved in reading comprehension. Specifically, when a reader reads a text he or she receives visual information and creates a visual representation of the page and its layout (visuospatial sketchpad). A reader would also make a visual representation to comprehend imagery prose. In addition, since reading could also be described as processing verbal information, a reader therefore subvocalizes visual information (phonological loop). Therefore, the retention of information is based on both phonological and visuospatial characteristics, with the episodic buffer integrating those two components.

The central executive serves the role of managing the reading activity, including maintaining task goals, ignoring irrelevant information in text, and retrieving information from long-term memory. For example, certain readers will focus on the main content and skip extra visual information (a figure or table). Such a reader will search the main content (i.e., using the visuospatial sketchpad), and check whether the content is accurate (i.e., employ the phonological loop). The central executive is involved in controlling sub-components in a dynamic way. Therefore, readers' use of reading strategies—the focus of this study—would result from how the central executive manages the reading activity and how the sub-components work. Reading from electronic media would affect limited working memory capacity, which effectively hinders a reader's use of reading strategies. For example, since each component has limited capacity, the difficulty of visually searching the main content (visuospatial sketchpad) would influence one's comprehension of verbal information (phonological loop). Reading from electronic media also

hampers the central executive's simultaneous controls such as receiving information, retrieving relevant information, recalling information previously read, and anticipating where the passage is going.

Two types of intelligence play a role in explaining reading comprehension: fluid intelligence and crystallized intelligence. As mentioned, three main components (the visuospatial sketchpad, the phonological loop and the episodic buffer) are involved in fluid intelligence and function as explained above. Crystalized intelligence represents one's lifetime intellectual achievement and is based on experience and culture. Accordingly, crystallized intelligence would explain the extent to which a particular reading medium would be appropriate for utilizing the collective intelligence that a person possesses. For example, reading from electronic medium is affected by a person's fluid intelligence, which is the basic capacity to process, but it also depends on factors that are learned and acquired through experience. This crystalized intelligence will be further explained in Section 8. As reviewed in this section, the working memory model can effectively explain cognitive processing of reading activities. Therefore, based on this model of working memory, this research will explain readers' use of reading strategies using different media. To assess such cognitive aspects this research will include cognitive load measures, which are explained in the following section.

(2) Metacognition

In general, metacognition is defined as "thinking about thinking" or "cognition about cognition." More specifically, metacognition refers to one's knowledge of how to oversee and regulate one's own cognitive processes (Flavell, 1976). Metacognition involves cognitive activities such as planning, monitoring, and evaluating the processes or outcomes for learning, problem solving, and decision-making tasks. Metacognition is extensively linked with the whole cognitive process; in particular, it is highly related to the role of the central executive (Cox, 2005; Shimamura, 2000).

According to Flavell (1979, 1987), metacognition consists of metacognitive knowledge and metacognitive experience or regulation. Metacognitive knowledge refers to knowledge about cognitive processes, while the metacognitive experience involves the use of metacognitive strategies. Specifically, metacognitive knowledge is classified into three categories: knowledge of (1) person variables (i.e., individual characteristics), (2) task variables (i.e., task demands), and (3) strategy variables (i.e., cognitive and metacognitive strategies). For example, a reader may know that he/she (person variable) has difficulty reading long passages quickly (task variable). Thus, he/she will first scan the whole passage, self-question about the contents, and then re-read the important paragraph(s) to accomplish the goal (strategy variable).

Metacognition plays a crucial role in reading comprehension. It involves a reader's awareness of his/her reading process and knowledge about when and how to use certain strategies for reading to ensure that the goal has been met (Harvey, Goudvis, & Graves, 2000). Ultimately, this metacognition enables people to be successful readers. For example, Pressley and Afflerbach (1995) noted that skilled readers are aware of what they are reading and why they are reading; skilled readers use a tried-and-true set of reading strategies. In contrast, unskilled readers have limited metacognitive knowledge about reading; nor do they use appropriate reading strategies while reading. Therefore, the reading strategies that people use are representative of cognitive and metacognitive activities.

(3) Cognitive Load Theory

As discussed, reading comprehension is a task that requires perceptual and cognitive processes and is affected by human capabilities and limitations with respect to those processes. Specifically, reading from different media (the focus of this research) can be affected by reading tasks, reading media, and individual characteristics. Therefore, understanding what contributes to a user/reader's cognitive load while reading is imperative for understanding how the use of different media can impact the act of reading in terms of cognitive and metacognitive process.

Cognitive load in Cognitive Load Theory (CLT) is defined as "a multidimensional construct representing the load that performing a particular task imposes on the learner's cognitive system" (Paas, Tuovinen, Tabbers, & Van Gerven, 2003, p. 64). Cognitive load impacts both task characteristics and individual characteristics, while mental workload, which is often mentioned along with cognitive load, is more focused on the demands placed by the task itself. Mental workload is generally defined as the amount of information processing resources (limitations) used for task performance (Wickens & Hollands, 2000). That is, while mental workload describes processing capacities and limitations of working memory, cognitive load considers them across working memory as well as long-term memory. This research is grounded in cognitive load theory since it focuses on reading processes that are involved in both working memory and long-term memory.

Cognitive Load Theory (CLT) (Sweller, 1988), is based on an understanding of human cognitive architecture and argues that instructional design has to be adapted to the structure and functions of human cognitive architecture. CLT has three components consisting of intrinsic cognitive load, extrinsic cognitive load, and germane cognitive load. Since they are additive, their total load must not exceed available resources if the task is to be completed successfully. Specifically, intrinsic cognitive load refers to the inherent level of difficulty regarding the task being performed (e.g., instructional material). Extrinsic cognitive load is caused by external factors (e.g., the design of the instructional material). Germane cognitive load, which was introduced later (Sweller, Van Merrienboer, & Paas, 1998), refers to the processing capacity used to construct schema in performing a task. While intrinsic cognitive load is generally believed to be immutable, since it is imposed by the intrinsic aspects of a task, extrinsic cognitive load can be manipulated by adjusting external factors (e.g., different instructional designs). Germane cognitive load is the remaining mental resource that can be used to enhance task performance. Accordingly, CLT generally recommends a way to decrease extrinsic cognitive load and promote germane cognitive load within a human's cognitive processing capacity.

Furthermore, Schnotz and Kürschner (2007) recently reviewed the concept of CLT and proposed that germane cognitive load as the "conscious application of learning strategies (i.e. strategies,

which are not automated yet), conscious search for patterns in the learning material in order to deliberately abstract cognitive schemata (i.e. mindful abstraction) and create semantic macrostructures, restructuring of problem representations in order to solve a task more easily (i.e. by insight), meta-cognitive processes that monitor cognition and learning" (p. 496). Reading strategies, the focus of this research, are significantly related to germane cognitive load. However, as discussed in Section 3, the differences between reading strategies and reading skills are based in part on whether it is automatic or conscious—and even researchers cannot fully distinguish between them. Therefore, considering both automatic and conscious aspects, it can be assumed that readers' use of reading strategies would be related to both extrinsic cognitive load and germane cognitive load.

CLT researchers have investigated the relationship between a particular instructional format and the learner's expertise (Kalyuga, Ayres, & Chandler, 2003; Kalyuga, Chandler, & Sweller, 1998). In fact, Kalyuga et al. reported that the appropriate type of instructional design depends on the learner's level of expertise. Depending on the level of expertise, the most appropriate instructional design was different from the one integrating multiple sources of information (i.e. diagram and text), as well as from the one that separated the presentation of information. Although existing studies have tended to include an examination of a learner's level of expertise, they can be expanded by investigating the relationship between the format of the media and the reader's cultural experience. In short, it is important to consider how one's level of expertise is influenced by personal cultural experiences. This is the concept that was used to explain generational differences on participants' use of reading strategies according to different media (see Section 8).

CLT has been widely applied to instructional design in educational settings, but it can also be applied in the workplace—for example, in the design of workstations or training systems. For example, Wallen and Mulloy (2006) used CLT to determine the effectiveness of three versions of computer-based respiratory safety training for older and younger workers. Therefore, this theory was determined to be applicable for explaining the effectiveness of reading media in both the workplace and educational settings (the contexts for this study).

In summary, it was expected that readers' use of reading strategies on different media and associated generational differences could be explained using CLT and the model of working memory. For example, when a reader reads from electronic media, the difficulties of manipulating electronic texts would hinder sub-component processing in working memory (visuospatial sketchpad and phonological loop) and place a higher extrinsic cognitive load on the reader. Those difficulties would further influence the central executive's functions (e.g., effective use of reading strategies), which results in lower germane cognitive load. Furthermore, if readers' use of reading strategies is related to personal cultural experiences (as this study investigated by looking at generational influences), it may explain more complicated issues relating to cognitive load by looking at the relationship of different media and a reader's cultural experience. In summary, this study used CLT to investigate how reading strategies can be affected by the use of different media by investigating the relationship between readers' use of reading strategies and cognitive load. The measurements for cognitive load are explained in Section 6.

5. Reading Across Media

This section will review how existing studies in this area have been changing. A review of the mental model and affordance is included since they represent concepts that should be considered in designing reading media.

(1) The Focus of Existing Studies

Early studies in the 1980s and early 1990s focused mostly on factors related to visual quality. Studies compared reading between paper and screen or among different types of screens (e.g., CRTs vs. LCDs); factors such as text display format, luminance, contrast, color, and density of text were also considered (Dillon, 1992; Muter & Maurutto, 1991; Schlick, Ziefle, Park, & Luczak, 2008) In terms of elucidating essential differences across media, outcome measures such as efficiency and effectiveness are usually targeted, since they tend to be sufficient in revealing differences between reading from paper and reading from an electronic screen.

As early studies predicted (Gould, Alfaro, Finn, Haupt, & Minuto, 1987; Muter & Maurutto, 1991; Noyes & Garland, 2003), comparative differences in reading performance caused by poor screen quality began to decrease with advances in technology. Therefore, as discussed in Section 3 recent studies have begun to focus on how text is read (reading strategies). For example, Toms (2000) examined browsing activities on different types of interfaces (i.e., traditional hierarchical menu, menu with automatically suggested items). Hornbæk and Frøkjær (2003) also investigated reading activities in three different types of interfaces (i.e., linear interface, fisheye interface, and overview + detail interface). With the introduction of various new reading media (e.g., PDAs, Tablets, and e-book readers), scholars renewed their focus on the reading efficacy of using these media. For example, Morris, Brush, and Meyers (2007) compared paper to three alternative media: (1) a dual monitor desktop system, (2) a pen-enabled horizontal display surface, and (3) multiple tablet computers. They found that reading from electronic media is as effective as reading from paper. In another study, Schilit, Price, Golovchinsky, Tanaka, and Marshall (1999) argued that electronic devices based on a paper-based metaphor could be better than computers with a desktop metaphor for reading activities. Therefore, researchers began to focus more on identifying an appropriate interface or medium for reading activities rather than relying on the dichotomy of paper versus digital (Dillon, 1992; Nielsen, 1989; Noyes & Garland, 2008; Sellen & Harper, 2001). Given this situation, measures used to gauge reading efficacy have also changed. As discussed in Section 3, researchers argued for the importance of other measures such as process measures and cognitive measures (Dillon, 1992; Noyes & Garland, 2008; O'Hara & Sellen, 1997).

(2) Mental Models

In order to understand how readers read using different media, one must consider a user's thought processes with a given system—which represents the concept of the mental model. The concept of the mental model originated with Craik (1943), who suggested that people have their own personal model of reality in their minds. This mental model plays a role in anticipating, explaining, reasoning and other cognitive processes, and has been widely researched in the psychology field (Collins & Gentner, 1987; Gentner & Gentner, 1983). With regard to the HCI

domain, this concept has been also widely applied in other fields. For example, Norman (1983) observed people's calculator usage and found that their beliefs (mental model) about the calculator mechanics were not the same as how the calculator actually worked. Norman (1983) provided the following descriptions regarding mental model terminologies.

- The target system: The system that a user is using.
- The conceptual model of the target system: The model represented by designers or researchers.
- The system image: The impression of the system represented by users.
- The user's mental model of the target system: The model created by users as they interact with the target system.
- The scientist's conceptualization of the mental model: A designer's or researcher's understanding of a user's mental model.

Ideally, the scientist's conceptualization of a mental model needs to be consistent with a user's mental model of the target system. A user's understanding of a system's mechanisms includes being able to predict and interpret the actions of a system based on his or her mental model. Hence, it is important to design a system that can be matched with a potential user's mental model. This concept has been widely applied in order to improve software usability in the HCI field (Kurniawan et al., 2003; Norman 2005).

According to several studies, mental models significantly affect the way people cope with novel problems—although they have little effect on routine problems (Borgman, 1986; Halasz & Moran, 1983). For example, Halasz and Moran (1983) investigated the use of the calculator and found that a problem space search used for solving non-routine problems was affected by a user's mental model; in contrast, skilled methods, problem reduction strategies, and conversion algorithms used for solving routine problems were not dependent on a user's mental model. Similarly, with regard to reading with different media, it was also expected that one's mental model would only play a role with novel problems such as active reading tasks (work-related

reading activities). Therefore, this research focused on active reading tasks, as explained in Section 7.

Different cultural groups have different cultural meta-schema containing specific mental models (Smith-Jackson et al., 2011; Smith-Jackson et al., 2013). With regard to reading with different media, no studies to date have considered cultural aspects, despite the fact that different generation groups would be expected to have different mental models of reading practices according to concepts about cognitive affordance and "technology generation." The concept of affordance is discussed in the following section, and technology generation is explained in Section 8.

(3) Affordance

As mentioned in the previous section, the closer a designer can get to a user's mental model of a system, the better. An important design principle that applies to reading from different media is known as "affordance." This term generally refers to the properties of an object or the potential of a system as being readily identified and accessed. As discussed in existing studies pertaining to reading from different media, some studies have described the advantage of applying paper-based design principles to electronic media (Schilit et al., 1999). A recent example of this concept is the development of tangible user interfaces (TUIs) that rely on touch (touch screen) to advance text. A number of studies have stressed the importance of incorporating paper-based interactions in electronic media. In these arguments, the concept of affordance plays a critical role (Chen, Guimbretiere, Dixon, Lewis, & Agrawala, 2008; Morris et al., 2007; Wightman, Ginn, & Vertegaal, 2010).

Affordance originates from the work of Gibson (1977), and was first defined as the corresponding relationship between an actor and the physical artifacts in the world in which actors (e.g., humans and animals) can instinctively perceive the artifact's physical properties that then offer certain behavioral possibilities and functions to them. For instance, once an animal perceives the properties of a terrestrial surface (slope, smoothness, etc.), it will behave

differently in how it traverses that surface (e.g., walk, jump, run, or avoid altogether) Gibson, 1977). This concept of affordance has been further extended and applied in the HCI domain (Gaver, 1991; Hartson, 2003; McGrenere & Ho, 2000; Norman, 2002), which has since diverged from Gibson's original concept.

Researchers have used different terminologies to define the concept of affordance. Hartson (2003) reviewed existing studies and categorized them into four types of affordance: physical affordance, sensory affordance, functional affordance, and cognitive affordance. First, physical affordance is defined as "a design feature that helps, aids, supports, facilitates or enables physically doing something" (Hartson, 2003, p. 319). The physical properties (e.g., size and form) of the physical action are included in this type of affordance, which most closely resembles Gibson's original concept. Other researchers refer to this as real affordance (Norman, 2002) or simply as affordance (Gaver, 1991; McGrenere & Ho, 2000).

Cognitive affordance is defined as "a design feature that helps, aids, supports, facilitates, or enables thinking and/or knowing about something" (Hartson, 2003, p. 319). Norman (2002) referred to it as perceived affordance in that it refers to characteristics of a device that provides clues for its appropriate operation. While physical affordance is the relationship between the physical properties of object and a users' physical abilities, cognitive affordance is based on a users' experience, knowledge and cultural convention (McGrenere & Ho, 2000; Turner & Turner, 2002). For example, users know the meaning of operations such as pushing buttons and turning knobs because of learned experiences. With regard to symbols, Hartson (2003) also argued that they can effectively convey the function of a product because of people's prior knowledge and experience with using images and icons.

Functional affordance is defined as a design feature that helps, aids, supports, facilitates, or enables users to accomplish work (i.e., the usefulness of a system function) (Hartson, 2003). For instance, although a chair can have various functional affordances (e.g., sitting, stepping object), the chair's function is dependent on a user's goals; the physical affordance of a chair enables one to access those functionalities. Accordingly, while functional affordance is linked to an object's

perceived usefulness, usability is related to the effectiveness of cognitive affordance, physical affordance, and sensory affordance (Hartson, 2003; McGrenere & Ho, 2000).

Sensory affordance is defined as "a design feature that helps, aids, supports, facilitates, or enables user in sensing (e.g., seeing, hearing, feeling) something" (Hartson, 2003, p. 322). Sensory affordance plays a role in supporting cognitive affordance and physical affordance when interacting with products and design features that are related with human sensation such as visual, auditory, haptic, and tactile. As Hartson explained the relationship among the four kinds of affordance under the interaction cycle (i.e., Andre et al (2001)'s User Action Framework), the concept of affordance is critical in linking interactions between users and products and is regarded as guiding design principle of HCI artifacts.

While the concept of affordance is regarded as an important factor in the design of electronic media for reading activities, no existing studies have explicitly delineated how affordance occurs while reading. The concepts of sensory affordance and physical affordance can be applied to elucidating how reading occurs with different media. For example, when a reader goes back and forth in the text to find relationships among ideas of interest, the types of affordances in performing such an activity would be very different depending on the reading media. Compared to reading from electronic media, a "paper reader" is able to access significant levels of sensory affordance and physical affordance, which would effectively support cognitive affordance. Existing studies that are mainly focused on imitating paper-based interactions may include such assumptions about reading activities. Cognitive affordance in terms of a user's experience and cultural conventions—which has not yet been considered critically in existing reading studies—could elucidate differences in reading from different media, as well as take into account generational differences.

Typically, there are several possibilities when considering a user's strategy for accomplishing a certain task. A user's decision to operate a given way is dependent upon how the individual perceives the affordance, which as noted, is highly dependent on personal experience and cultural conventions. For example, relying on a specific reading strategy regardless of the type of

reading media, while at the same time perceiving greater difficulties by not employing that particular strategy, could be due to that person's previous experience and cultural conventions. In other words, an individual's cognitive affordance for reading activities (regardless of the media) may be significantly dependent upon established cognitive affordance in terms of a user's experience and cultural conventions. And as discussed in the previous section, different cultural groups may have different cognitive affordance as established cultural mental models. Therefore, this study will investigate the reading strategies that people use, as well as generational differences in those strategies, under the broad umbrella of physical/sensory and cognitive affordance. The notion of "generation" as an important cultural aspect for this study will be further explained in Section 8.

6. Measurement for Reading on Different Media

In this section, the measurements that have been utilized in existing studies will be reviewed. In general, researchers characterize measures for assessing reading behavior with different media in two ways: as outcome and process measures (Dillon, 1992; O'Hara & Sellen, 1997; Schumacher & Waller, 1985).

(1) Outcome Measures

As discussed, earlier studies have tended on focus on outcome measures such as efficiency and effectiveness. While reading efficiency includes speed and accuracy, reading effectiveness includes comprehension. Outcome measures are defined as follows:

- Speed: Reading speed is mainly considered as an outcome or performance measure, and early studies found a performance deficit when reading from a screen due to the format of the textual display (e.g., line lengths), the density of text information, and the time that text information is presented on the screen (Muter, Latrémouille, & Treurniet, 1982; Kruk & Muter, 1984; Muter & Maurutto, 1991).
- Accuracy: Accuracy usually refers to an individual's capability to identify errors in proofreading tasks. For example, Wilkinson and Robinshaw (1987) descrbied errors of

five types: missing or additional spaces, missing or additional letters, double or triple reversions, misfits or inappropriate characters, and missing or inappropriate capitals.

- Comprehension: While scholars have long debated an appropriate means for quantifying or measuring comprehension, the number of correct answers on a reading comprehension test is typically used to measure comprehension (Dillon, 1992). Studies found few differences between paper and screen in terms of attained levels of comprehension, except in certain cases. For example, Belmore (1985) reported reduced comprehension levels when participants were required to read from the computer *first*, which he asserted reflected their lack of familiarity with computers.

(2) Process Measures

Along with advances in technology, studies incorporating other measures such as process measures and cognitive measures (Dillon, 1992; Noyes & Garland, 2008; O'Hara & Sellen, 1997) have become increasingly important. For example, Noyes and Garland reported that traditional outcome measures such as reading speed, reading accuracy and comprehension have been replaced with more sophisticated measures such as mental workload and memory measures. O'Hara and Sellen also argued for a focus on "process" rather than "outcome" —i.e., how readers look at text in terms of eye movement, how they manipulate it, and how they navigate through it. According to Dillon, process measures for reading activities are defined as follows:

- Eye movements: Eye movements are characterized by a series of saccades and fixations; these physiological differences could explain reading difficulties and comprehension variations (Mills & Weldon, 1986).
- Manipulation: Manipulation is related to manual dexterity such as using one's fingers to turn pages, flicking pages to browse a document, and fingering to locate a specific page.
- Navigation: Navigation is defined as finding one's position by browsing through text—e.g., flipping through the pages of a book (Dillon, 1990; Dillon & McKnight, 1990).

While process measures are effective for explaining certain differences between media, they are more difficult for quantifying and revealing the differences between media (Dillon, 1992; Nisbett & Wilson, 1977). For example, a measure of eye movement is easily affected by factors other than reading. Moreover, the equipment and procedures for measuring eye movement are intrusive for some users, and therefore may produce unreliable results. Examining manipulation and navigation could also interfere with the normal processing of reading activities, thus necessitating additional considerable effort such as verbal protocol analysis and video analysis. Hence, studies have typically focused on specific aspects of process measures (among several), as previously discussed. The drawback of this approach is that by focusing on specific aspects of process measures as indicators of manipulation (for example, annotation), one cannot account for important differences between media types. Furthermore, existing studies usually focus on paper-based interactions and therefore overlook important aspects associated with novel ways of interaction that new electronic media provide. Therefore, as discussed in Section 3, these factors necessitate a fresh investigation of how people use diverse reading strategies to accomplish reading tasks and their differences across media.

(3) Cognitive Load Measures

The measures for cognitive load are classified into three types: subjective measure, performance-based measure, and physiological measure. Some measures for cognitive load correspond with outcome and process measures, which prior studies have employed.

Performance-based measures can be categorized into two types. The first is an assessment of task performance, which corresponds to outcome measures as explained above. The second involves the use of a dual task method, which assesses the performance of a secondary task that is performed concurrently with the primary task. This methodology is based on the assumption that both tasks use the same resources, and performance of the secondary task reflects the level of cognitive load cased by the primary task. While performance-based measures have the advantage of sensitivity and objectivity, they require an experimental setting to assess cognitive load imposed by the primary task.

Psychophysical measures are based on physiological states such as heart rate variability, galvanic skin response (GSR), and pupillary dilation. Heart rate variability (HRV) originates from the assumption that cognitive processing is related to a specific HRV power spectrum band (Mulder, 1992). In short, HRV has a demonstrated relationship with task demands. The GSR is based on skin resistance and is regarded as a relatively simple method for measuring measure cognitive load. The use of pupillary dilation is based on the assumption that the diameter of the pupil increases as load increases (Van Gerven, Paas, Merrienboer, & Schmidt, 2004). Even though such physiological measures are effective in collecting continuous data with a relatively high degree of sensitivity, they are nonetheless sensitive to physical effort or emotional arousal, both of which can make interpretation difficult (Brünken, Plass, & Leutner, 2003; Paas, 1992; Paas & van Merrienboer, 1994).

Subjective measures refer to a user's estimate of cognitive load. They are based on the assumption that individuals are able to examine their own cognitive processes and thus can self-report their cognitive load with some reliability. Subjective measures usually involve a questionnaire that has one or multiple semantic differential scales to assess the experience level of the cognitive load. The subjective cognitive load measure (SCL), which is a one-dimensional scale, has been widely used in existing studies (Paas et al., 2003; Paas, 1992; Paas & Merrienboer, 1994). Through their extensive review of empirical literature, Paas et al. described 24 existing studies that used either a 7- or 9-point SCL scale.

As discussed, the various different types of measures for cognitive load generally explain total cognitive load rather than individual subclasses of cognitive load. This discrepancy represents a critical drawback for deciphering a multidimensional construct of cognitive load. Paas and Merrienboer (1994) suggested using a combination of performance, mental load, and mental effort, in which mental load and mental effort are subjective data using rating scales, and performance data results from performance-based measures. Specifically, the researchers proposed the term "mental efficiency," which combines measures of mental effort with measure of performance. Since its introduction, many studies have widely applied this method. The formula is as follows:

$$E = \frac{Z_{Performance} - Z_{Mental\ Effort}}{\sqrt{2}}$$

Researchers have used multidimensional subjective measures in order to assess individual subclasses of cognitive load (i.e., intrinsic cognitive load, extrinsic cognitive load, and germane cognitive load). Gerjets, Scheiter, and Catrambone (2004, 2006) evaluated three types of cognitive load based on a modified version of the NASA Task Load Index tool (NASA-TLX) (Hart & Steveland, 1988). The first is intrinsic cognitive load, which assesses task demands—how much mental and physical activity is required to accomplish a given learning task. The second is extrinsic cognitive load, which assesses navigational demands—how much effort a person must exert to navigate a learning environment. The third is germane cognitive load, which corresponds to overall effort—how hard a person has to work to understand the content of the learning environment. In a subsequent study, Cierniak, Scheiter, and Gerjets (2009) measured the three types of cognitive load using subjective rating scales: intrinsic cognitive load (How difficult was the learning content for you?), extrinsic cognitive load (How difficult was it to learn with the material?), and germane cognitive load (How much did you concentrate during learning?).

In contrast, there is considerable controversy over the use of multidimensional subjective measures (Kalyuga, 2011; Paas et al., 2003). Paas et al. argued for the inability to obtain differentiated knowledge of cognitive load components; instead, they suggested using a combination of analytical (e.g., task analysis) and empirical measures (e.g., mental effort, performance). Kalyuga also criticized those approaches and stated that existing studies with different types of cognitive load tend to measure overall cognitive load rather than individual subclasses of cognitive load. In particular, among the three types of cognitive load, germane cognitive load is difficult to measure quantitatively; therefore, most existing studies explain germane cognitive load in a post hoc manner (e.g., post hoc explanations of learning effects) (Kalyuga).

With regard to assessing cognitive load measures, this research will use both approaches—measuring total cognitive load *and* measuring individual subclasses of cognitive load. Although there is some disagreement about individual subclasses of cognitive load (intrinsic cognitive load, extrinsic cognitive load, and germane cognitive load), it is important to understand individual subclasses of cognitive load quantitative and qualitatively. This study focuses on both extrinsic cognitive load and germane cognitive load. Consequently, it will include all three types of measures discussed above: outcome measure, process measure, and cognitive load measure. Specifically, task completion time (efficiency), comprehension (effectiveness) and subjective responses will be used as outcome measures and subjective measures. Reading strategies that participants use will be regarded as process measure for explaining how to navigate and manipulate the document. Lastly, in order to measure cognitive load, a physiological measure of cognitive load (pupillary response), mental efficiency, and a subjective measure of cognitive load (unidimensional scale and multidimensional scale) will be used. This design is intended to elucidate how readers' use of reading strategies can be employed as a process measure for explaining reading on different media by investigating reading strategies and identifying relationship between readers' use of reading strategies and other measures.

7. Task: Active Reading

Reading activities can be broadly classified into active reading and passive reading. According to Schilit et al. (1999), "Active reading combines reading with critical thinking, learning, and decision making, whereas passive reading is less careful and requires less effort" (p. 65). Schilit and coworkers further categorized reading situations into two dimensions: the nature of engagement with a text, and the breadth of the activity across texts (Table 3). The nature of engagement with a text is divided into two types, active reading and passive reading. The breadth of the activity across text is classified into single text and multiple texts. Depending on the category, different reading strategies are required. For example, active reading tends to require note taking and annotation. With regard to breadth across texts, reading a single text involves bookmarking and navigation, while reading multiple texts includes sorting, filing, and navigating.

Table 3. Categories for reading situations (Schilit et al., 1999)

		The nature of engagement with a text	
		Passive	**Active**
The breadth of activity across texts	**Single text**	Enjoying a novel, reading a poem aloud (Possible problems) Understanding the text	Studying a textbook, reviewing a proposal, diagnosing with a manual (Possible problems) Understanding the text, finding information within a text, summarizing
	Multiple texts	Keeping up with e-mail, browsing the newspaper, surfing the Web (Possible problems) Understanding the text, carrying lots of documents, finding interesting documents	Researching a problem, surveying a field, keeping up-to-data professionally (Possible problems) Understanding the text, carrying lots of documents, finding relevant documents, structuring lots of information

As indicated in the literature, electronic reading media are less effective in supporting active reading compared to passive reading. Many studies have investigated differences in reading behaviors between media; their results indicate that digital reading tends to be "one-time reading" and discontinuous reading rather than continuous and deeply immersed reading (Liu, 2005; Liu & Huang, 2007; Macfadyen, 2011; Marshall & Ruotolo; 2002). For example, Liu investigated the electronic-based reading behaviors of people aged 30 to 45. He characterized screen-related reading behaviors as browsing, scanning, keyword spotting, one-time reading, non-linear reading, and selective reading, which was based on a survey on perceptions about reading behaviors (e.g., percent of time spent on keyword spotting). Marshall and Ruotolo conducted a field study in which students utilized Pocket PCs to read various types of course material during a semester. The researchers reported that handheld devices such as small computers and PDAs are good for reading secondary materials, excerpts, and shorter readings. Reading from pocket PCs was mostly related to such activities as searching, skimming and scanning rather than continuous and deeply immersed reading. These studies have shown that paper has more advantages in terms of continuous reading and deeply immersed reading (active reading) that demand sustained

attention while reading. These advantages are associated with the flexibility of the spatial layout, and the efficiency of performing annotation and note taking from paper.

Reading strategies, the focus of this research, play an important role in explaining active reading. As mentioned in Section 3, reading strategies are goal-oriented actions to improve reading comprehension. The use of reading strategies typically occurs during active reading activities since they require attendant thinking and efforts. In particular, diverse use of reading strategies is useful for elucidating continuous reading activities (rather than discontinuous reading). Therefore, active reading is appropriate for explaining the use of reading strategies in terms of cognitive and metacognitive processes. Furthermore, active reading is related to goal-related reading activities that generally occur in the workplace and educational settings, which is the context for this research. As discussed in Section 1, Adler et al. (1998) described ten distinct reading activities in the workplace, with reading for cross-referencing, reading to support discussion, and reading to search for and answer questions among the most important.

Active reading is also appropriate for explaining the mental model and cognitive load. As discussed in Section 5, the mental model is involved with deciphering novel problems rather than routine ones. With regard to cognitive load, it is also important to have a task with some difficulty in order to determine differences in germane cognitive load according to the use of different media. Cognitive load theory assumes that intrinsic cognitive load, extrinsic cognitive load, and germane cognitive load are additive (Sweller, 2005). When intrinsic load is low, it is possible to increase germane load even if extrinsic load is high. When intrinsic load is high and extrinsic load is high, both can interfere with promoting germane load. It should also be noted that germane load may not occur even in the case of simple tasks. These relationships were summarized by Schnotz and Kürschner (2007), as follows: “Whereas it is possible to solve very difficult task (high intrinsic load) without deep metacognitive reflection (low germane load), it is not possible to reflect deeply (high germane load) about a very easy task (low intrinsic load)” (p. 497). That is, germane load cannot be increased even if there is available capacity due to low intrinsic load. Therefore, this research will focus on active reading as the experimental task.

8. Generation-specific Reading Practices: the Cultural Aspect of Generation

Considering the reading experiences of different generation groups—and, as noted earlier, the fact that older Americans are remaining in (or even re-joining) the workforce in greater numbers (DeLong, 2004)—it is important to investigate reading activities in the workplace and educational settings. Moreover, training and re-education are generally required throughout a worker's employment lifespan. This is particularly true of older people who will be required to update their skills to keep up with advances in knowledge and technology-based industries. Therefore, as the target users for reading media in the workplace, different generation groups should be considered. This is not to say that existing studies have ignored age-related factors, but most have tended to focus on age as a gradual decline in an individual's capability. However, age-associated differences can also result from generation-related experiences (i.e., from cultural factors) since generation is also based on a person's year of birth. In this section, the concepts of age, generation, and culture will be discussed.

(1) Age

Physiological aspects of aging such as visual acuity and visual performance (Oetjen & Ziefle, 2007; Ziefle, 2009) have been investigated. Studies have also examined age differences relative to computer experience (e.g., familiarity) in using different media for reading activities (Czaja & Sharit, 1993; Meyer & Poon, 1997). For example, Meyer and Poon identified age-related differences in reading comprehension between paper versus computer screen. They concluded that young and older adults differ in their familiarity with computers and showed performance differences. Thus, they viewed aging as a gradual decline in an individual's capability (i.e., lack of experience) to perform a given task.

(2) Generation

A generation is defined as a group of people who were born during a certain period. People of the same generation tend to show similar behaviors and share norms based on sociological environments throughout their life course (Mannheim, 1985). Depending on the viewpoint of

sociological environments, researchers have proposed different classifications. For example, Becker (2000) identified five generations based on important socio-historical events (e.g., wars, economic depressions) that occur during a person's formative years (i.e. before the age of 25): the Pre-war Generation (1910-1920), the Silent Generation (1930-1945), the Baby-Boom Generation (1946-1954), the Lost Generation (1955-1969) and Generation X (born in 1970 or later). Howe and Strauss (2009) identified a generational cycle in American history and provided the following classifications: Baby Boomers (1943~1960), Generation X (1961~1981), and Generation Y (1982~2004). Such generation-related divisions take into account cultural attributes that define user variations, and have also been used to explain differences in the use of products and systems (Smith-Jackson, Artis, Johnson, & Resnick, 2013).

While no reported studies have examined generational differences with regard to reading from different media, related reports have envisioned generational changes in using different media for reading activities. For example, Potthast (2008) investigated the use of traditional paper strips that delineate flight route information for current air traffic controllers; results indicate that paper strips will disappear as generation shifts occur in this workplace. *The Economist* magazine also noted, "A new generation of workers, who have grown up with technologies such as e-mail, word processing and the internet, felt less of a need to print documents out than their older colleagues did" (The Economist, 2008).

The concept of "technology generation," which originated in sociological studies (Sackmann & Winkler, 2013; Weymann & Sackmann, 1994), could apply to explain generational differences with regard to reading from different media. The technology generation is defined as the group of people who began to use various electronic devices routinely during their formative years (i.e. before the age of 25); as a result, they may show greater facility and behaviors in their use of current technology (Weymann & Sackmann, 1994). Since first proposed, many scholars have investigated aspects of the technology generation (Czaja, 1996; Docampo Rama et al., 2001; Lim, 2010; Salthouse, Hambrick, Lukas, & Dell, 1996). For example, Docampo Rama et al. classified generational differences based on the type of user interface experienced during the formative period, with three resulting groups: the Electro-mechanical Generation (1930-1960), the Display

Generation (1960-1970) and the Menu Generation (born in 1970 or later). Therefore, these studies clearly suggest that differences in performing a given task results from generation-specific experiences—not because of age-related declines in capability over time.

(3) Culture

Culture has been defined as the characteristic ways that people perceive their environment (Triandis, 1972). As mentioned, generation effects can be an attribute of culture since people of the same generation tend to share a number of common experiences during a specific period of time. Based on these shared experiences, people can exhibit similar behaviors, attitudes, norms, and values (Smith-Jackson, 2011).

Several researchers have discussed how culture can be situated in cognition such as thinking and action. Semin (2008) described complex relationships among language, culture, and cognition, and explained how culture is embedded in language, and how language shapes cognition. The Sapir-Whorf Hypothesis, which describes the interrelatedness of cognition, language, and culture, might also explain cultural influences with respect to cognition and language. In particular, Oyserman (2011) proposed culture as a situated cognitive model. In this model, culture is situated in a specific meaning-making framework (i.e., mindset) and that a cultural mindset (e.g., individual and collective cultural mindsets) can influence cognitive processes. In addition, researchers such as sociocultural theorists have emphasized socially and culturally situated experience (Dewey, 1938; Vygotsky, 1978; Kakar, 1981). They believe that individuals are socially and culturally situated and these sociocultural contexts influence individuals' behaviors, beliefs and actions.

As mentioned in Section 4, the intellectual abilities associated with the model of working memory can also explain culture-based influences in cognitive processing. While fluid intelligence is mostly biology based and can decline with aging, crystallized intelligence depends on experience and knowledge and therefore increases with age (Horn, 1968; Schaie et al., 1953).

Both biological and cultural influences play a role in information processing mechanisms (Li et al., 2004).

When people of different generations read, both biological and cultural factors jointly act on reading processes. Specifically, in terms of reading from different reading media, cultural factors would be important for explaining thinking and actions with respect to the use of different types of reading media. Different generations would have generation-specific reading experiences that are culturally based, and those experiences would be situated in cognitive processes. As mentioned, reading strategies represent cognitive capabilities acquired during adolescence; therefore a person's mental model would be based on his or her experiences with different types of technology at that time. Thus, those established mental models might affect how that individual currently interacts with different media as cultural schema. Existing studies in the education field have reported that reading strategies do differ according to different media. (Altun, 2000; Kol & Schcolnik, 2000; Murphy et al., 2003). For example, Murphy et al. noted, "The strategies requisite for comprehending traditional printed text are not the same strategies required to comprehend computerized text" (p. 17). Kol and Schcolnik found that training could help to improve the use of reading strategies. However, since their results were mostly based on younger readers (i.e., undergraduate students), their results may not be applicable to all age groups, and especially older readers. For example, older persons may rely more on reading strategies that they developed with paper, whereas younger persons may be more adept at using reading strategies required for electronic media.

In summary, this research focused on generation as a factor in examining reading strategies, performance, cognitive load, and satisfaction with medium. Specifically, this study investigated the role of generation-specific reading practices acquired during adolescence in reading activities. This research targeted three generations: Baby Boomers, Generation X and Generation Y (Net Generation). While no literature exists regarding environmental differences for reading activities, these three generations are regarded as being "products" of different environments (see Table 4), which has and will continue to impact teaching and learning strategies in various educational fields (Oblinger, 2004).

Table 4. Product of the environment by generation (Oblinger, 2004).

Baby Boomers (1946~1960)	Generation X (1961~1981)	Generation Y (Net Generation) (1982-2004)
- TV generation - Typewriters - Telephone - Memos - Family focus	- Video games - PC - Email - CDs - Individualist	- Web - Cell phone - IM - MP3s - Online communities

(4) Generation Effect Vs. Age Effect

In analyzing generation effects, researchers have investigated differences between the age effect and the generation effect, since both generation and age are essentially measured by a person's birth year (Glenn, 1977; Docampo Rama et al., 2001). Glenn noted that a discontinuous trend is considered a generation effect, while a continuous trend indicates an age effect across age groups. This research will follow Glenn's convention and investigate trends across age groups.

Investigating reading strategies is also meaningful for distinguishing between age effects and generation effects. For example, Baltes, Reese, and Lipsett (1980) investigated performance comparisons between younger and older adults. The researchers showed that when the same strategies are used to assess both generational cohorts, age-related cognitive decreases could be confirmed with some certainty. This study is applicable to the current investigation since it assumes that reading strategies used to perform active reading tasks will differ between younger and older adults. Accordingly, it will be not based on age-related decreases in cognitive capability, but rather on generation-related experiences (i.e., a cultural factor) acquired during the formative period.

9. Summary

This review of the literature has found that prior studies are distinctly lacking in their ability to explain reading using different media in the workplace and educational settings in terms of two aspects. First, while cognitive aspects such as reading strategy are critical for explaining recent

reading models and reading activities in the workplace and educational setting, such aspects have not been considered in any comprehensive way. The majority of existing studies have focused on outcome measures. However, with advancements in technology, traditional outcome measures are deficient in their ability to explain differences between reading from paper and reading using electronic media. Second, even though the workplace is characterized by workers of various ages (and increasingly by older workers), the cultural aspect of age has not yet been considered. Prior studies mostly regard age as a gradual decline in an individual's capability. Instead, the effects of generation as a cultural aspect should be taken into account when considering reading strategies, as well as when looking at concepts such as the mental model, affordance, and the technology generation.

For these important reasons, this research was designed to investigate how reading strategies can be viewed as a process measure for assessing the effectiveness of reading media. Specifically, this research investigated reading strategies that people of different generations use when reading from different media, and explored whether reading strategies can explain cognitive and cultural aspects. This research also sought to identify the extent to which reading strategies can explain reading differences by investigating the relationship between readers' use of reading strategies and other measures employed by existing studies. Figure 2 shows research approaches and research questions.

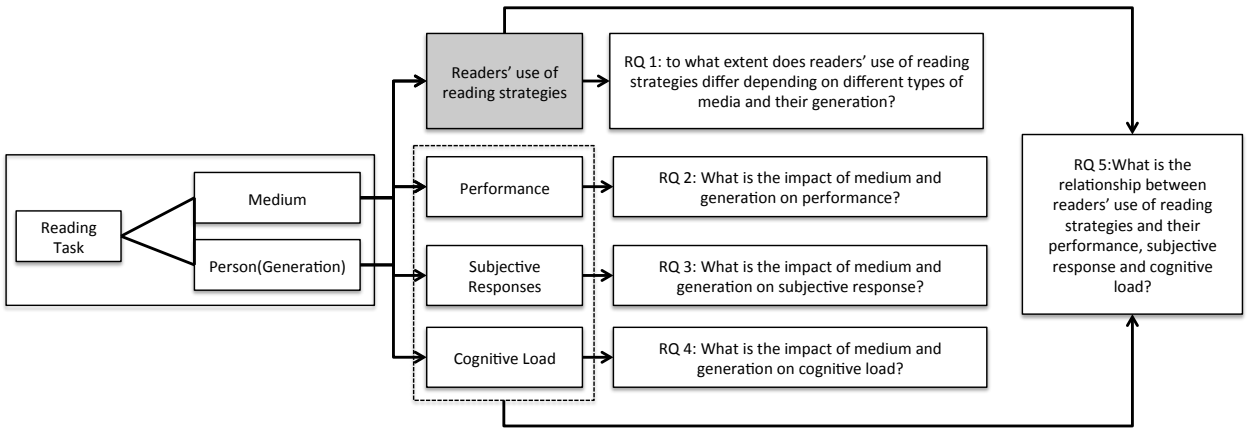


Figure 2. Overview of this research

CHAPTER 3. INVESTIGATION OF READERS' USE OF READING STRATEGIES FOR DIFFERENT TYPES OF MEDIA IN AN ACTIVE READING TASK

Abstract

With ongoing advances in computer technologies, various types of electronic reading media have been developed and are widely used in the workplace and educational settings. Although researchers have compared different reading media using traditional outcome measures (e.g., speed and comprehension), there is a lack of scholarship concerning the cognitive and cultural aspects of designing human-computer interactions for reading activities. This study investigated readers' use of reading strategies for different types of media; associated generational differences were also investigated. Thirty-six participants evenly split between three generations (Baby Boomers, Generation X and Generation Y) participated in an active reading task with three types of media (paper, computer, and iPad) in a controlled laboratory setting. Readers' use of reading strategies was identified from task observation and Retrospective Think Aloud (RTA) sessions. Quantitative analyses revealed significant differences in a reader's use of reading strategies depending on media and generation. Detailed qualitative analyses were conducted to help explain the underlying reasons for observed quantitative differences among readers' use of reading strategies.

1. Introduction

The use of electronic media offers many advantages, including quicker access to information and easier information sharing among professions. However, electronic reading media have still not been integrated into many workplace and educational settings, and conflicting results from different measures (e.g., performance, preference) are reported regarding the efficacy of electronic reading media. For example, Holzinger et al. (2011) examined differences between reading from paper and reading from a screen (an LCD monitor) for 111 medical professionals (clinicians) in an actual work setting. They found that medical professionals showed a preference

for reading from paper regardless of there being no significant differences in reading performance between the two media.

Most existing studies on different reading media have focused on standard outcome measures of reading—namely, speed, accuracy and comprehension (Noyes & Garland, 2008). However, as technology advances, traditional outcome measures are becoming limited in their ability to explain differences between reading from paper and reading using electronic media. These limitations are causing researchers to consider the use of more sophisticated measures, such as reading patterns (Hornbeck & Frokjer, 2003) and critical thinking skills (Eshet-Alkalai & Geri, 2007). In particular, reading strategies can be an important factor in elucidating complicated issues of reading from paper vs. reading from an electronic reading medium in terms of cognitive and cultural aspects.

Reading strategies have garnered considerable interest among researchers in the educational field, not only for elucidating the ways that readers manage their interactions with documents as cognitive and metacognitive processes, but also with respect to identifying evidence of effective reading comprehension (Alexander & Jetton, 2000; Pressley, 2000). The act of reading is a cognitive process and reading strategies are the cognitive strategies people use for the successful completion of reading activities (Mokhtari & Reichard 2002; Pereira-Laird & Deane, 1997). This is a complex undertaking, since the reading strategies that people use can differ according to a reader's personal traits (Jiménez, García, & Pearson, 1996), the task type, the specific reading situation, and other variables. Lorch et al. (1993) investigated the relationship between a person's specific reading situation and his or her choice of reading strategy; in doing so, they detailed the role of conditional knowledge on the use of reading strategies in different situations.

Since the properties of the various available media differ and require specific types of interactions when conducting tasks, a reader's use of cognitive and metacognitive strategies can also differ according to media type. For instance, Haas (1989) showed how different text-editing technologies influence cognitive processes associated with the writing process; specifically, he reported differences in planning and rereading processes when using different media. Hornbæk

and Frøkjær (2003) investigated reading patterns in three types of electronic reading interfaces and revealed that each had a particular effect on the way readers read. Therefore, understanding whether a certain reading medium effectively supports a reader's use of cognitive and metacognitive strategies and how it assists or hinders task performance will be essential for the successful design of a medium, and will determine the most appropriate medium for reading activities.

Although reading strategies represent a set of cognitive capabilities usually developed during adolescence, existing studies have rarely considered generational differences. As mentioned, there is a sizable body of educational studies that have investigated reading strategies. Most studies that have looked at reading strategies with different media have been conducted with younger readers (Kol & Schcolnik, 1997, 2000, Murphy et al., 2003). For example, Kol and Schcolnik (1997) found that readers who lack computer experience have difficulty making effective use of their reading strategies. In their subsequent study, the authors concluded that training could improve the use of reading strategies (Kol & Schcolnik, 2000). However, these results can differ among different generations, which highlight the significance of investigating generational reading differences—particularly in light of the aging workforce.

There are relatively few comprehensive empirical reports on how the use of different reading media affects a reader's use of reading strategies. Several studies have looked at differences in reading behaviors using different media as reported through a survey questionnaire (Liu, 2005; Liu & Huang, 2007). However, self-reported information might not actually represent authentic processes that people employ while performing a reading task. Other studies have utilized field observations and interview data to explore how readers actually read (Marshall & Brush, 2004; Marshall & Ruotolo, 2002; O'Hara & Sellen, 1997). It should be noted, however, that most of these studies focused primarily on examining the differences across media based on a single reading strategy—nor did they consider generational differences. Thus, reported findings cannot necessarily be extrapolated to determine how readers of different generations use diverse reading strategies for the successful completion of a given reading task depending on the type of medium involved.

Therefore, the primary objective of this study was to investigate how reading strategies can be used to assess the effectiveness of reading media as reflecting both cognitive and cultural aspects. Specifically, this study investigated readers' use of reading strategies depending on different types of media and according to their generation cohort.

2. Background

2.1. Reading Strategies

In simple terms, a "reading strategy" refers to how a text is read. Afflerbach et al. (2008) defined the term as "deliberate, goal-directed attempts to control and modify the reader's effort to decode text, understand words, and construct meaning out of text" (p. 15), and they are regarded as acquired capabilities through the developmental process. Diverse classifications regarding reading strategies have been proposed. For example, Pugh (1978) identified five reading techniques that college students tend to utilize: scanning, search reading, skimming, receptive reading, and responsive reading. Other researchers have categorized reading strategies in terms of a multi-level cognitive process. Murray (2003) broadly classified reading strategies into behavioral, cognitive, and metacognitive strategies. Similarly, Mokhtari and Reichard (2002) grouped reading strategies into three types (global, problem solving and support strategies) and also developed an instrument to assess a reader's awareness and perceived use of reading strategies.

Reading strategies play a critical role in explaining dynamic aspects of reading comprehension, such as a achieving a specific reading goal, which is typically involved in active reading (Schilit, 1999). Active reading requires attendant thinking and reflective processes, which are typically required of readers in the workplace and in educational settings. When people are engaged in active reading activities, they are thinking about what they would like to get out of a reading exercise (e.g., locating specific information), as well as how they plan to accomplish it in light of a specific reading goal and other situational factors. For instance, Lorch et al. (1993) found that

college students select and use particular reading strategies, and further coordinate and organize the use of a variety of reading strategies to successfully accomplish a given task. In this situation, the choice of reading strategy could vary considerably according to the way a particular medium supports or constrains those processes, consequently affecting reading comprehension. Therefore, investigating readers' use of diverse reading strategies is required to comprehensively explain cognitive processes in active reading activities.

In particular, human capabilities and limitations in memory play a critical role in explaining reading comprehension, while working memory is greatly related to readers' use of reading strategies. According to Baddeley and Hitch (1974), working memory is a temporary storage facility that performs concurrent processing of information; in contrast, long-term memory represents a permanent storage unit. Working memory is comprised of four main components: the central executive, the visuospatial sketchpad, the phonological loop, and the episodic buffer. The central executive manages task goals and controls three sub-components, the visuospatial sketchpad for visuospatial information, the phonological loop for phonological information, and the episodic buffer for integrating the other two sub-components. A reader's use of reading strategies can be interpreted as the result of how the central executive functions and how the sub-components work.

Technology continues to evolve—presumably in response to human need and demand. Nonetheless, the extent to which newer technologies can successfully promote reading activities for diverse age groups is as yet unclear. Electronic reading media introduced in recent years are greatly improved in terms of product quality (e.g., resolution, image signal processing), and also encourage more natural interactions between the person and the device. Tangible user interfaces (TUIs) such as touch screens have become more prevalent as alternatives to traditional graphical user interfaces (GUIs) that require input from a keyboard or a mouse. Therefore, in order to progress further, it is necessary to determine whether newer technologies can support readers' cognitive processes effectively considering diverse age groups in the workplace. For example, in thinking of appropriate reading strategies, what is causing these differences so that the workplace

can be designed to magnify the benefits of these new technologies (i.e., electronic reading media)?

2.2. Generation-specific Reading Practices: the Cultural Aspect of Generation

Reading strategies are usually developed and inculcated through developmental processes, but as noted, no studies have yet considered generational differences with regard to reading on different media. Several studies envisioned the influence of generation-specific experience on reading activities (Gladwell, 2002; Potthast, 2008). For example, Harper and Sellen (1995) showed how air traffic controllers' work practices have been shaped by the use of paper through ethnographic fieldwork in air traffic control centers. The authors concluded that it would be difficult to change these workers' ingrained paper-based habits into the use of electronic media without generational changes. Since they represent people's trained reading habits, reading strategies can be essential to explain generational differences.

Age has long been regarded as one of the key attributes for explaining any variations in reading with different media. Several age-related aspects, such as physiological changes (visual acuity) (Oetjen & Ziefle, 2007; Ziefle, 2009), cognitive changes (Stine, Cheung & Henderson, 1995), and lack of experience with certain media (familiarity) have been investigated. For example, Meyer and Poon (1997) showed that younger and older adults tended to differ in their familiarity with computers. They argued that the resulting age-related differences in computer experience were responsible for performance variations between reading from paper versus reading from a computer screen. Thus, these studies have generally considered aging as a gradual decline in an individual's capability to perform a given task.

Age-associated differences could also result from generation-related experience as a cultural aspect rather than an age-related decline, since generation is also determined by a person's year of birth. Culture is the framework that explains one's interactions with the real world and generation is an important cultural attribute (Hofstede, 1997; Smith-Jackson et al., 2013). In general, a generation is defined as a group of people born during a certain period. People of the

same generation tend to show similar behaviors and share norms based on sociological environments throughout their lifetime (Mannheim, 1985). With respect to reading practices with different types of media, the concepts of technology generation, the mental model and affordance can explain generational differences.

The term "Technology Generation" originated in sociological studies (Sackmann & Winkler, 2013; Weymann & Sackmann, 1994) and has been applied quite widely (Czaja, 1996; Docampo Rama et al., 2001; Lim, 2010; Salthouse, Hambrick, Lukas, & Dell, 1996). According to Weymann and Sackmann (1994), a technology generation is a birth cohort that shares similar technology experiences. In other words, they tend to exhibit similar current technology usage patterns based on the types of technology they experienced during their formative years. Docampo Rama et al. (2001) examined the performance of four age groups with respect to software user interfaces and found that people who had prior experience with specific software user interfaces outperformed those who had no such experience during their formative period, regardless of age differences. In defining the formative period, the researchers operationalized the period as being between 10 and 25. Overall, these studies indicate that generation-specific technology experiences during the formative period could play a major role in a person's facility with current technology usage.

The "Mental Model" describes a person's understanding of the things (e.g., content, system) with which they are interacting; this concept has been widely adopted for improving software usability in the field of Human-Computer Interaction (HCI). For example, Norman (1983) observed people's calculator usage, and found that people's beliefs (mental model) about the calculator mechanics did not coincide with actual calculator mechanics. In order to improve system usage, it is important to design a system to be congruent with the prospective users' mental models. With regard to culture, according to Smith-Jackson et al. (2011), different cultural groups have cultural meta-schema containing specific mental models developed through shared experience. Hence, different generation groups would be likely to have different mental models for reading practices (i.e., their understanding of how they need to behave to do a certain

reading activity) through their generation-specific technology experiences; accordingly, the use of reading strategies would be different among different generations.

Specifically, affordance can explain the effective use of a reading medium as a principle for designing a system that corresponds with a user's mental model. The concept of affordance was originated by Gibson (1979) to explain an artifact's properties that a person first perceives and then interacts with. Affordance describes how design features enable users in physically doing, sensing and accomplishing the task. This affordance is also dependent on user experience and cultural convention (McGrenere & Ho, 2000; Turner & Turner, 2002). With regard to the cultural aspect of age, different generation groups would have different affordance when using reading media based on their cultural convention. This affordance can be equated to their mental model in their cultural schema.

Consequently, it was expected that differences in readers' use of reading strategies would not be due to age-related decreases in an individual's capability, but to generation-specific reading experiences during the formative period. While no studies in the education field specify the formative period with respect to reading strategies, for this study it was operationalized as the period corresponding to K-12 education (i.e., before 18 years old), since people tend to acquire reading skills at school and at home during these years. In order to dissociate generation effects from age effects based on performance differences between younger and older adults, knowing whether both cohorts use identical strategies was essential. As noted by Baltes et al. (1980), "Memory growth and decline do not reflect increasing and decreasing efficiency of performing a fixed set of encoding, storing, and retrieving processes, but rather reflect the development of qualitatively different processes (operations) for encoding, storing, and retrieving" (p. 86). Therefore, investigating a reader's use of reading strategies for different types of media and exploring generational differences in readers' use of such strategies will be also beneficial in distinguishing between an age effect and a generation effect.

3. Methods

3.1. Overview of the Experiment

The experiment was conducted in a controlled laboratory setting. A mixed-factor design was used to determine the effect of READING MEDIUM (within-subject) and GENERATION (between-subjects) on readers' use of reading strategies. By comparing each participant's reading strategies under identical experimental conditions (i.e., using the same three media and following the sequence given in Table 7), this study was expected to provide a better understanding of the effect of the reading medium on reading behaviors. Three generations of participants (Baby Boomers, Generation X and Generation Y) were recruited, and participants were asked to perform an active reading task with three types of media (Paper, Computer, iPad). Reading strategies were identified from task observation and RTA sessions using protocol analysis method. Based on coded protocols, quantitative analysis was performed. Qualitative analysis was also conduced based on data from the RTA sessions and the subsequent semi-structured interviews. In addition to the protocol data, other measures were obtained—outcome-based measures (performance, subjective response), and cognitive load measures—which are described in Chapters 4 and 5. In summary, independent and dependent variables considered in this study are listed in Table 5.

Table 5. Independent and dependent variables

Variable	Component
Independent variables	• Reading medium (paper, computer, and iPad) • Generation (Baby Boomers, Generation X and Generation Y)
Dependent variables	• Readers' use of reading strategies : Eight reading strategies code (Table 10)

3.2. Participants

In order to investigate the effects of the reading medium on an "active reading activity" (Adler & van Doren, 1972; Schilit et al., 1999) of the sort that typically occurs in an educational or workplace setting, all the participants selected were involved in active reading in their

professions. Thirty-six participants were recruited using the SONA experiment management system from the Psychology Department at Virginia Tech and from the general community. All participants were native English speakers (self-reported) and had at least a college degree or were current college students. They represented diverse professions, including students, engineers, managers, and teachers. Of the 36, 13 were male and 23 female.

In addition, the researcher ensured that the participant group was age diverse so that they could be classified into three generation groups: Baby Boomers (those born between 1943 and 1960), Generation X (those born between 1961 and 1981), and Generation Y (those born between 1982 and 2004). This classification is based on Howe and Strauss (2009)'s generation cycle in American history and Oblinger (2004)'s view that different generations are a "product of environment." Accordingly, the three generation groups in this study were expected to have been exposed to different environments for reading activities during their formative periods. In order to distinguish between age effects and generation effects, trends across age group were examined as discussed in Chapter 2 (Section 8).

The mean age of the participants was 39.7 years (SD=16.4; Min=20, Max=74). Detailed demographic information is shown in Table 6 below. Participants were compensated for their time by receiving research credits or monetary compensation.

Table 6. Participants' age and gender distribution

Generation	Baby Boomers (1943~1960)	Generation X (1961~1981)	Generation Y (1982~2004)	Total
# of Participants (Male/Female)	12 (3/9)	12 (5/7)	12 (5/7)	36 (13/23)
Age Mean (SD)	59.5(7.7)	37.5(5.5)	22.2(1.8)	39.7(16.4)

3.3. Medium Conditions

To investigate readers' use of cognitive and metacognitive reading strategies for different types of media, three reading media were selected: paper, computer, and iPad, as shown in Table 7. The applications used with the computer and the iPad are representative software from those media. Figure 3 shows experimental setup.

Table 7. Overview of the experiment session

	Paper Session	Computer Session	iPad Session
Medium	Paper	Mac notebook	iPad
Application		Preview	iAnnotate PDF
Accessory	Pencil/pen/highlighter/ Post-it/blank paper	Mouse/ Blank paper	Stylus pen/ Blank paper

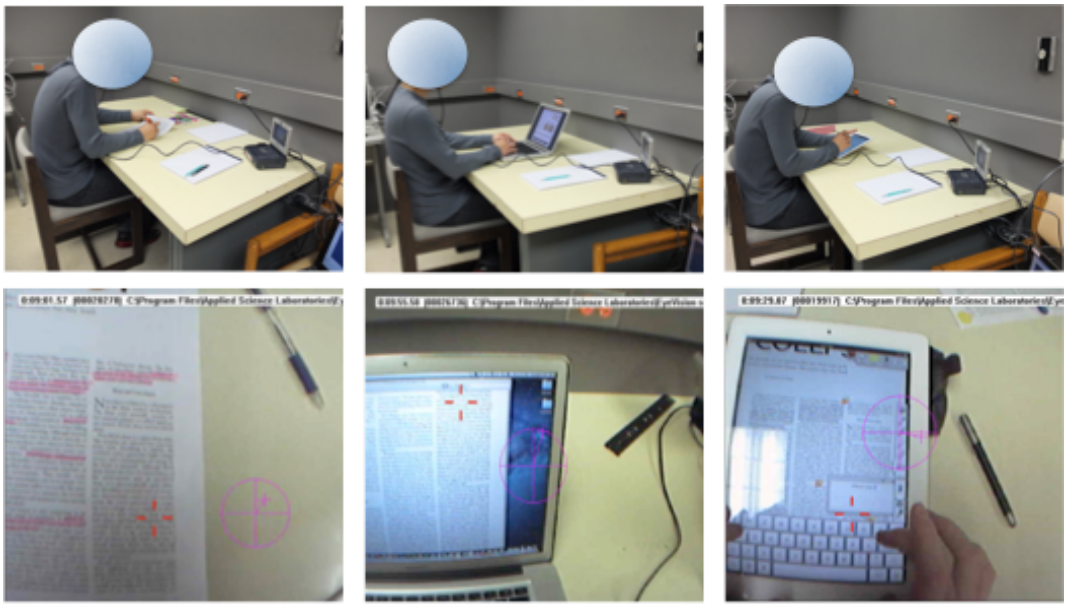


Figure 3. Experimental setup

3.4. Reading Task and Materials

The active reading task for this study was selected based on findings from prior studies (Adler et al., 1998; Lorch et al. 1993). For instance, Adler et al. (1998) investigated document-related activities within the context of people's working lives and found "reading to learn" to be a standard reading task. Earlier, Lorch et al. (1993) also identified reading to learn as a normal reading situation encountered by college students. For this study, participants were asked to read

an article to learn its main contents. Afterwards, with access to the article, participants were required to make a written summary of the contents as the final outcome. This reading and summarization task represented an essential undertaking that would normally occur in an educational or workplace setting. The task instruction for the reading task is shown in Appendix C (Section 6).

Participants had 30 minutes to complete this reading task (i.e., reading and creating a written summary). It should be noted that in order to encourage participants to favor comprehension against speed in a trade-off of task demands, the written and verbal instructions stressed the importance of comprehension (Campbell et al., 1981).

Three 6 to 8-page articles (between 3500-4000 words) of similar subject matter and readability were selected from the magazine, *Scientific American*. The three articles resulted in a Flesch Reading Ease score of between 36 and 43 and a Flesch-Kincaid Grader Level score of 12. The selection of these specific articles was based on the presumed reading level of participants. As noted above, all participants in this study had at least a college degree or were current college students. Thus, a Flesch reading ease score of between 0 and 30 was considered to be appropriate for participants, In addition, when considering cognitive load aspects such as germane cognitive load, the articles had to have some degree of difficulty. As Schnotz and Kürschner (2007) stated, "Whereas it is possible to solve a very difficult task without deep metacognitive reflection, it is not possible to reflect deeply about a very easy task"(p. 497). This statement highlights the importance of selecting an appropriate level of task difficulty in order to promote cognitive and metacognitive processes.

Pilot experiments with six participants were conducted. Based on the results from the pilot experiment, experimental settings were modified as needed—including reading task, task time, article, and procedures. Throughout the pilot experiments, the researcher verified appropriate articles based on the likelihood that they would engage the readers intellectually and stimulate their innate reading strategies. Based on the participants' task completion time and their written

summary, the researcher determined the task time during which participants would perform a given reading task without sacrificing comprehension.

3.5. Procedures

A Graeco-Latin square design was used based on medium and document conditions. A representation of this design is shown in Table 8. The overall procedure for the experiment is shown in Figure 4.

Table 8. The Graeco-Latin Square design based on medium and document conditions

Participants	Order		
	1	2	3
12 (4:Y, 4:X, 4:B)***	A*a**	Bb	Cc
12 (4:Y, 4:X, 4:B)	Cb	Ac	Ba
12 (4:Y, 4:X, 4:B)	Bc	Ca	Ab

* Medium condition: A = Paper, B = Computer, C = Ipad
** Document condition: three different articles (a, b, c)
*** Generation group: Y = Generation Y, X = Generation X, B=Baby Boomers

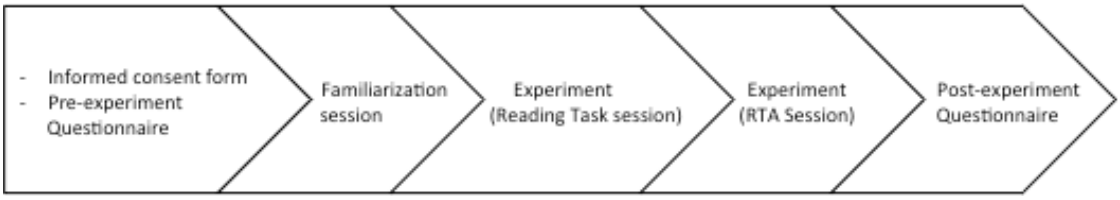


Figure 4. Procedures for the experiment

Upon entering the lab, participants completed an informed consent document and a demographic questionnaire, which included a survey of the kind of media they routinely used for their reading activities (i.e., active reading or work-related reading activities and passive reading or casual reading activities) (Appendix C).

Prior to beginning the experiment, participants had a familiarization session, during which they received instructions about using the electronic media (i.e., computer and iPad) and then performed trial tasks. Once the participants had completed the trial tasks with all media and felt comfortable performing the tasks with the different types of media, they began the actual experiment.

The experiment consisted of two sessions: the task session and the Retrospective Think Aloud (RTA) session. In the task session, participants were asked to perform a reading task (i.e., reading and making a written summary of the contents) with each of the three media (i.e., paper, computer, and tablet). During the task, participants wore an eye tracker to record their reading processes and pupil radius. Upon completing the reading task, the RTA session followed immediately. The RTA method with probing questions (Ericsson & Simon, 1993) was administered with video-playback of observed data. Participants were asked to verbalize what they were thinking as continuously as possible as they carried out the reading tasks. When they did not do so for more than 30 seconds, the researcher reminded participants to verbalize their thoughts. The researcher also asked probing questions regarding "probing events," defined as predefined codes (*a priori* codes) for reading strategies based on existing studies. The RTA session was recorded with a fixed camera. The instructions used in the experimental session are provided in Appendix C.

After the experiment, a post-experiment questionnaire (Appendix C) designed to assess text familiarity, subjective responses, and cognitive load was administered to the participants. Each medium condition was expected to take one hour to complete, with the entire experiment (three media conditions) lasting three hours.

3.6. Data Analysis

Data analysis for this study was composed of three parts: protocol analysis, quantitative analysis and qualitative analysis. First, protocol analysis was conducted based on data from the task observation and RTA sessions. Second, based on coded protocols, quantitative analysis was

conducted. Third, qualitative analysis was conducted based on data from the RTA sessions and the subsequent semi-structured interviews.

For the data analysis portion of this study, two coders and one judge were recruited from the Grado Department of Industrial and Systems Engineering at Virginia Tech. The two coders were undergraduate students and the judge was a doctoral candidate with expertise in HCI and qualitative data analysis. The two coders were involved in protocol analysis, and they were trained in how to identify reading strategies and code them. The judge was involved in protocol analysis and qualitative analysis. The judge was required to validate the codes that coders made during protocol analysis. The researcher and judge performed the qualitative analysis.

3.6.1. Protocol Analysis

Protocol analysis is the method that makes inferences about the cognitive processes of human beings (Ericsson & Simon, 1993). A protocol includes behaviors and verbalization. In order to comprehensively understand the cognitive processes that underlie certain tasks, the physical behaviors of participants as well as their verbal accounts were analyzed. Protocols can be collected by two kinds of methods: concurrent think aloud and retrospective think aloud. In order to minimize interruptions during the reading task due to concurrent verbalization, this study collected a participant's physical actions from task observation session, and then collected retrospective verbal reports from the RTA session. Protocol analysis involves protocol segmentation and coding.

3.6.1.1 Segmentation and Transcribing

Segmentation is the process of dividing protocols into units, which are then assigned a code. This segmentation was conducted under consideration of changes in participants' behavior, thoughts, and intentions. The recorded data from task observation session were first segmented according to changes in readers' behavioral activities over the duration of the task. Verbal protocols from the RTA session were transcribed and matched with behavioral activities.

Table **9** shows an example of the data processing.

Table 9. Example of segmentation and trascribing

Time*	Page	Task Observation (Behavioral activity)	Retrospective Think Aloud (Verbal Protocols)
0:00:50-0:01:07	Page 1	Reading	I started to read the article.
0:01:07-0:01:09	Page 1	Symbol: ?	I'm reading this, it took me a little while [to understand]. So I put the question mark
0:01:09-0:02:10	Page 1	Reading	I kept reading.
0:02:10-0:02:17	Page 1	underlining	I'm going to go ahead and underline stuff that looks important to me.
0:02:17-0:02:22	Page 1	Reading	I am reading again.
0:02:22-0:02:30	Page 1	Note (how know?)	At this time, I have thought, "how do you [author] know that" from this content. So I just wrote that comment there. That seems kind of skeptical a little bit.
0:02:30-0:02:50	Page 2	Reading (pointing at a sentence using a pen)	[Pointing at a sentence using a pen?] Yes. It helps me to read the content.

* measured from start of test

3.6.1.2. Coder Training

The training was standardized through the use of a coding manual, predefined behaviors, and decision rules (see Appendix D). The researcher instructed each coder individually regarding codes (*a priori* codes) and coding procedures by using a coding manual. After receiving instructions, the coder practiced data coding by watching a ten-minute sample video with the researcher. It should be noted that even though the research asked the participants to use their normal reading behaviors, participants might have altered their reading strategies under experimental conditions. Accordingly, the researcher trained the coders to confirm each code based on both the behavioral activities from the task session and verbal protocols from the RTA session. After the coders felt comfortable with the coding work and process, they were able to code the data independently.

3.6.1.3. Coding Process

Once the coders had completed their individual codes, a final protocol coding was achieved by process of arbitration. Two coders independently read the segmentation and transcripts, and

coded them based on *a priori* codes generated by the primary researcher based on a review of the literature (see the list of literature and *a priori* codes in Appendix D). Coders were also free to suggest additional codes that emerged during the coding process.

After each coder completed the coding, the researcher and coders had a reconciliation meeting to present their codes. When there was disagreement, each coder first explained the reasons for his or her decision, and then the team discussed that item with reference to the video and transcripts to clarify a participant's actions. Thus, an arbitrated decision was achieved through consensus. Figure 5 shows a typical coding process.

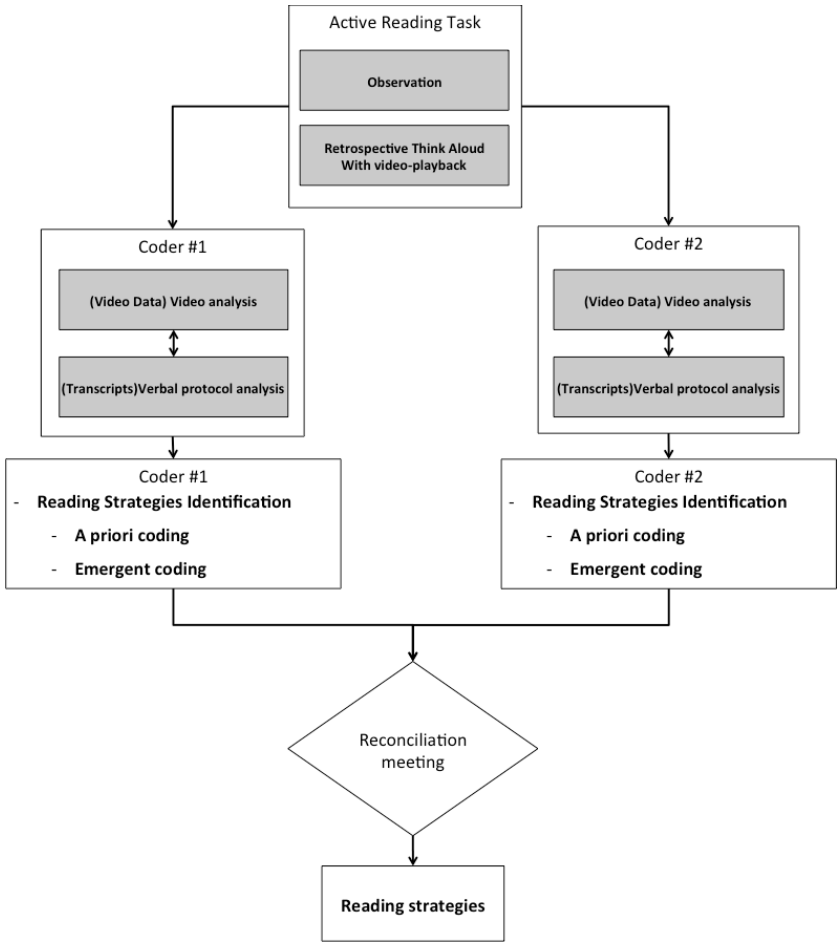


Figure 5. Coding process

The reliability of the coding process was measured by calculating the Kappa values between the coders as shown below. The initial Kappa value was 0.67 and the Kappa value after the reconciliation meeting was 0.92. This Kappa value is larger than 0.75, which indicates that the reliability of the coding was high (Fleiss, Levin, & Paik, 2003).

$$Reliability = \frac{Number\ of\ Agreements}{Total\ Number\ of\ Agreements + Disagreements}$$

Throughout the coding process and reconciliation meeting, reading strategy codes were revised, which resulted in the set of final codes shown in Table 10. For example, among the *a priori* codes (Appendix D), any code that was difficult to define from the video, from task observation, or from verbal protocols from the RTA session was eliminated (i.e., receptive reading, reflective reading, skimming, scanning and immersive reading). Codes that were similar in terms of the purpose of the behavioral activity were combined (i.e., rereading, reviewing, networking, and local process of reading), while codes pertaining to annotation were differentiated further, reflecting their rationale. The final coding results are as follows. The annotation category had four codes: Highlighting, Note, Symbol, and Paper note. The movement category had two codes: Networking and Jumping based on references. The monitoring category also had two codes: Micro-monitoring and Macro-monitoring. A detailed description of each, including the relevant decision rules, is shown in Appendix D. Table 11 shows an example of data coding.

Table 10. Final reading strategies codes and descriptions

Category	Code	Description
Annotation	Highlighting	Highlighting or underlining the text.
	Note	Making a note in the margin of the paper or using the tool on the electronic media
	Symbol	Making a symbol on the paper or using the tool on the electronic media (e.g., !, |, ?, {}, *, √)
	Paper note	Making a note on a separate piece of paper.
Movement	Networking	Re-reading or reviewing documents in order to make relationships within the text (e.g., going back to a previous page or looking at different parts of multiple pages)
	Jumping based on references	Locating specific information based on references in the text (e.g., directly moving from one part to another part of the text (referenced part))
Monitoring	Macro-monitoring	Broadening the focus beyond the present page in order to determine current progress (e.g., quickly skimming the remaining pages by counting them or using the navigation panel on electronic media)
	Micro-monitoring	Narrowing the focus in order to extract information (e.g., pointing/following sentence using the hand, pen, or stylus, pointing/following sentence using the cursor)

Table 11. Example of data coding

Time	Page	Task Observation (Behavioral activity)	Retrospective Think Aloud (Verbal Protocols)	Code
0:00:50-0:01:07	Page 1	Reading	I started to read the article.	
0:01:07-0:01:09	Page 1	Symbol: ?	I'm reading this, it took me a little while [to understand]. So I put the question mark	**Symbol**
0:01:09-0:02:10	Page 1	Reading	I kept reading.	
0:02:10-0:02:17	Page 1	underlining	I'm going to go ahead and underline stuff that looks important to me.	**Highlighting**
0:02:17-0:02:22	Page 1	Reading	I am reading again.	
0:02:22-0:02:30	Page 1	Note (how know?)	At this time, I have thought, "how do you [author] know that from this content." So I just wrote that comment there. That seems kind of skeptical a little bit.	**Note**
0:02:30-0:02:50	Page 2	Reading(pointing at the sentence with a pen)	(Pointing at the sentence using a pen?) Yes. It helps me to read the content.	**Micro-monitoring**
0:02:50-0:03:10	Page 1	Reading	I went back up and read this part again.	**Networking**
0:03:10-0:03:30	Page 2	Reading	I kept reading	
0:03:30-0:04:00	Page 8	Reading	I went to the end, I read this part [grey part]. It was referring to it. So I went back to see it. I read that, and I went back to the beginning (2nd) page again.	**Jumping based on reference**
0:04:00-0:04:30	Page 2	Reading	I went back and read this part.	
0:04:30:0:04:50	Page 3	Reading	I finished reading the 2nd page and started to read the 3rd page.	
0:04:50-0:05:10	Page 3	Reading	I looked at this picture after reading all the words. I was having a hard time to find a good stopping point. So I just read all the text and then looked at the picture	**Jumping based on reference (no)**
⋮	⋮	⋮	⋮	⋮
0:35:30-0:45:00		Summarization	I definitely went back through the article again. I kept rereading the annotated parts. I sequentially went through the annotated parts and wrote my summary.	

3.6.2. Quantitative Data Analysis

As preliminary analysis, participants' computer experience and media usage were examined. Data for participants' computer experience and medium usage were initially tested for normality using Shapiro-Wilk test. Distributions were normal; consequently, parametric data analyses were conducted. In terms of participants' computer experience, a one-way ANOVA was used to compare participants' computer experience for the three different generation groups (Baby Boomers, Generation X and Generation Y). With regard to media usage, a repeated-measure ANOVA using the Greenhouse-Geisser correction was used.

In terms of readers' use of reading strategies, quantitative analyses were performed to determine the READING MEDIUM effect and the GENERATION effect on each of the coded reading strategies (Table 10). With regard to quantifying the reading strategy codes, a dichotomous response whether each participant showed a particular reading strategy or a continuous response how many times each participant used a particular reading strategy could be used. Both approaches have drawbacks. In the case of continuous response, the number of behaviors (i.e., frequency) could be affected by individual characteristics that are unrelated to reading comprehension. That is, even though the use of reading strategies has been linked to improved reading comprehension, higher usage of reading strategies cannot necessarily be assumed to confirm higher reading comprehension. On the contrary, a dichotomous response shows whether each participant used a particular reading strategy with the different types of media, this type of response does not reflect changes in reading strategies, thus introducing the potential for distorted results. For example, one participant did use his/her reading strategies with satisfactory results, while a second participant started to use his/her familiar reading strategies but then decided to not use them due to difficulties with the particular reading media. Nonetheless, in both cases the dichotomous response was the same for both participants (appearing: 1). Given this ambiguity, this study employed the continuous response method for quantifying the reading strategy codes. Among a total of eight reading strategies, the following six strategies were quantified with respect to the number of behaviors (frequencies): highlighting, note, symbol, paper note, networking and jumping based on reference. For two reading strategies (micro-

monitoring and macro-monitoring) for which it was difficult to discern the number of behaviors (frequencies), a dichotomous response (1: appearing, 0: not appearing) was assigned.

For six reading strategies (highlighting, note, symbol, paper note, networking, and jumping based on reference), the following quantitative analyses were conducted. A Shapiro-Wilk test was first conducted to test for normality; distributions were found to be non-normal. Accordingly, nonparametric data analyses—specifically Kruskal-Wallis and Friedman's analysis of variance—were conducted. To examine the interaction of generation and medium, an Aligned Rank Transform (ART) test was conducted (Sawilowsky, 1990; Wobbrock, Findlater, Gergle, & Higgins, 2011). For the post-hoc paired comparison, a planned F-test was conducted. Effects were considered "significant" with an alpha level of 0.05.

For two reading strategies (micro-monitoring and macro-monitoring), the following statistical tests were used to examine the READING MEDIUM effect and the GENERATION effect: (1) a Chi-Square test (exact p-value of Pearson Chi-Square) to determine differences between independent samples of small size expressed in a nominal scale (GENERATION effect), and (2) the Cochran Q test for verifying repeated measures of dichotomized ordinal data (READING MEDIUM effect). For the post-hoc paired comparison, the Fisher exact test and the McNemar change test were used. Effects were considered "significant" with an alpha level of 0.05.

3.6.3. Qualitative Data Analysis

Qualitative analysis was conducted based on the data from the RTA sessions and the subsequent semi-structured interviews. The researcher and one judge read all transcripts and examined the underlying reasons for a reader's use of reading strategies using thematic analysis. Participant excerpts that represented common reasons were included. In addition, graphical approaches, which have been used in existing studies (Goldman & Saul, 1990; Hornbaek & Frokjer, 2003), were also used to show reading processes.

4. Results

Before examining the READING MEDIUM effect and GENERATION effect on readers' use of reading strategies, the order of media and document was tested. As a result, media order effects and document order effects were non-significant.

The research question in this study is as follows:

Research Question (RQ1): To what extent does readers' use of reading strategies differ depending on different types of media and generation?

4.1. Participants' Computer Experience and Media Usage

In terms of participants' computer experience, there was a significant difference in participants' computer experience depending on their generation group ($F_{(2, 108)}$=7.43, p=0.0022). Additional post-hoc paired comparison indicated that Generation Y (M=11.75, SD=3.62) had significantly lower levels of computer experience than either Baby Boomers (M=20.25, SD=7.86) or Generation X (M=18.67, SD=4.91).

With regard to media usage, there were significant differences among media usage for the reading activities (i.e., active reading or work-related reading activities and passive reading or casual reading activities), p <.01. In both active and passive reading activities, participants more frequently used paper and computer over the iPad. Neither GENERATION effect nor the interaction effect of GENERATION x READING MEDIUM was found with respect to media usage for active reading and passive reading activities (Figure 6).

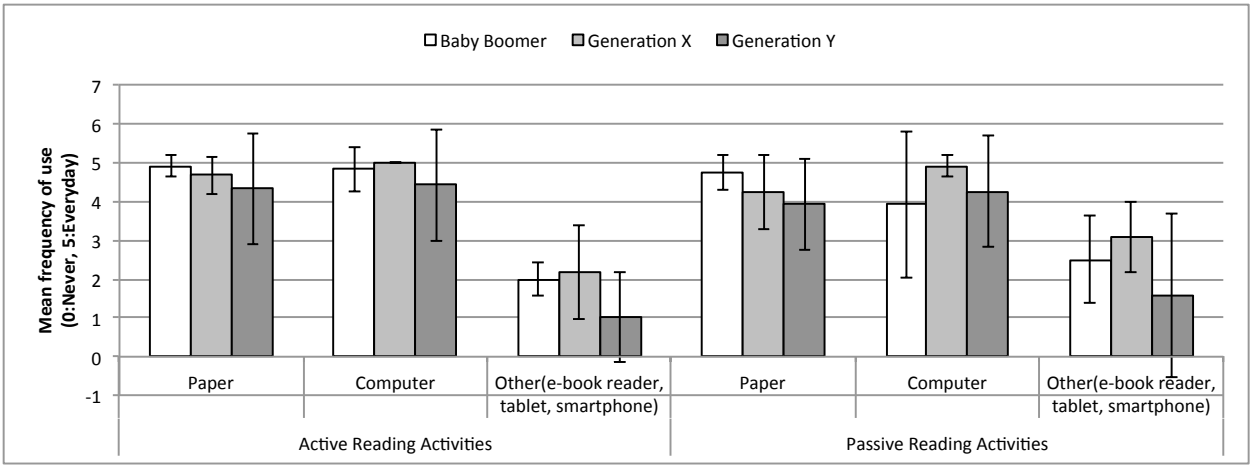


Figure 6. Media usage by reading activities and generation groups

4.2. Annotation

In general, annotation refers to markings made on a text, as shown in Table 10. Participants used a range of annotation strategies, including highlighting, notes, symbols and paper notes. During the semi-structured interview, participants specifically mentioned that annotating enhanced their active interaction with a text and played a critical role in helping them to understand the content. In addition, the act of annotation served to single out important information that a participant might wish to revisit at a later time. These points are conveyed in the following participant statements:

> *P13: I am more like to remember something if I highlight it.*
>
> *P15: Sometimes when I underline text, I am really doing it not just because this is an important point. That particular point perhaps helps me keep on track with the author's main point. It was complex, so what I want to do is basically simplifying some complexity of ideas.*
>
> *P30: In case I need to add extra information. I knew I could pull it from there [the annotation]. I can reread that to find what is important.*

In terms of different types of annotation, participants indicated that they used them for different purposes, for example to explicate certain content, or for singling out information for later use. As commented by one participant,

P11: Highlighting was used for the main idea or main concepts and then my notes are more bullet points. So, highlighted things I thought are more important for my summary and my notes are just kind of back up examples.

4.2.1. Quantitative Results

(1) Any Type of Annotation

H_a: Participants' use of annotation (any type of annotation) will differ between reading media.

H_a: Participants' use of annotation (any type of annotation) will differ between generations.

The total numbers of all four types of annotations (highlighting, note, symbol, and paper note) made by each participant were examined to discover whether there were significant differences depending on the type of media and the specific generation. As shown in Figure 7, participants tended to make more annotations with the paper than with either the computer or iPad media. However, no statistically significant results were found in terms of the interaction effect of GENERATION x READING MEDIUM, the GENERATION effect and the READING MEDIUM effect.

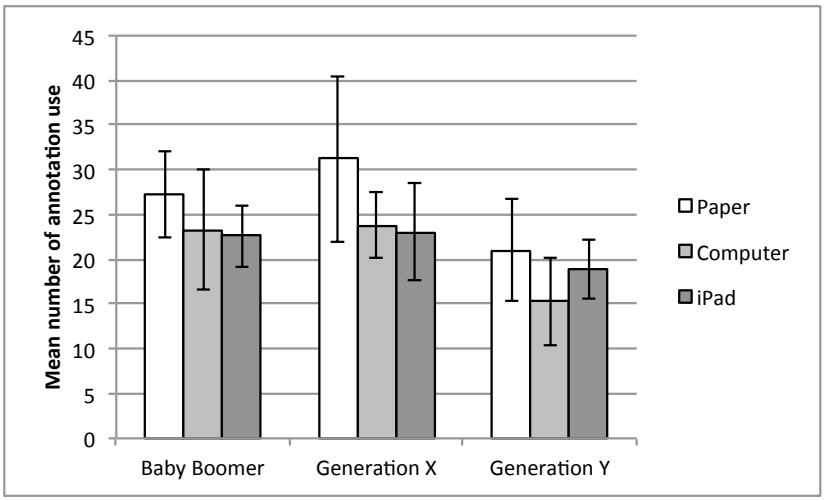


Figure 7. Mean number of all four types of annotations (error bars: 95.00% confidence interval)

(2) Highlighting

H_a: Participants' use of highlighting will differ between reading media.

H_a: Participants' use of highlighting will differ between generations.

Highlighting refers to when users either highlight or underline portions of the text, as shown in Table 10. Various types of pens were supplied for the paper condition and both a mouse and a stylus for the electronic media conditions were available for participants.

The interaction effect of GENERATION x READING MEDIUM on highlighting was not statistically significant. The GENERATION effect was not significant and the READING MEDIUM effect was also not significant.

(3) Note

H_a: Participants' use of note will differ between reading media.

H_a: Participants' use of note will differ between generations.

Note refers to when users make a note in the margin of the paper or use the tool to make notes directly on the electronic media, as shown in Table 10. The applications used for the computer and iPad conditions utilized tools for making a note within an electronic document.

The interaction effect of GENERATION x READING MEDIUM on notes was not statistically significant. The GENERATION effect was statistically significant (Kruskal-Wallis test; $X^2_{(2)}$ =7.67, df=2, p=0.02) and the READING MEDIUM effect was also significant (Friedman one-way ANOVA: $X^2_{(2)}$=6.49, df=2, p=0.04). Additional paired comparisons showed that the use of note was higher among the Generation X group than the use of note for both Baby Boomer group (p=0.01). Participants' use of note also differed between the paper and computer conditions (p<0.0001), and between the paper and iPad conditions (p<0.0001), and between the computer and iPad conditions (p<0.0001). As shown in Figure 8, participant's use of note was highest for the paper condition, following by the iPad and computer conditions.

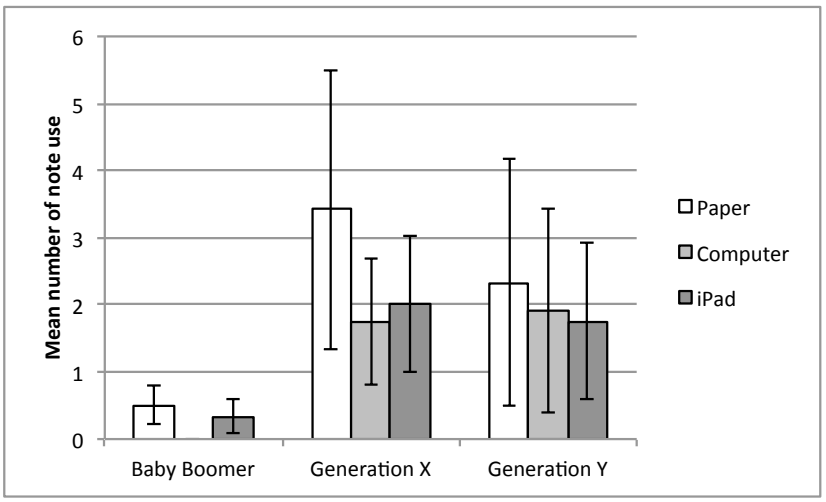


Figure 8. Mean number of note use by media conditions and generation groups (error bars: 95.00% confidence interval)

(4) Symbol

H_a: Participants' use of symbol will differ between reading media.

H_a: Participants' use of symbol will differ between generations.

Symbol refers to when users make a symbol on paper or use a tool on either of the electronic media (e.g., !, |, ?, {}, *, √), as shown in Table 10. For the electronic media conditions, participants could make a symbol using a tool within the software application or by hand through manipulating a mouse or stylus.

The interaction effect of GENERATION x READING MEDIUM was statistically significant, $F_{(4, 108)}$=5.13, p=0.0012. Additional paired comparisons on the interaction effect showed that the use of symbol for the iPad condition differed significantly between Baby Boomers, Generation X (p=0.01), and Generation Y (p=0.01). For the computer condition, participants' use of note differed significantly between Generation Y and Baby Boomers (p<0.0001) (Figure 9).

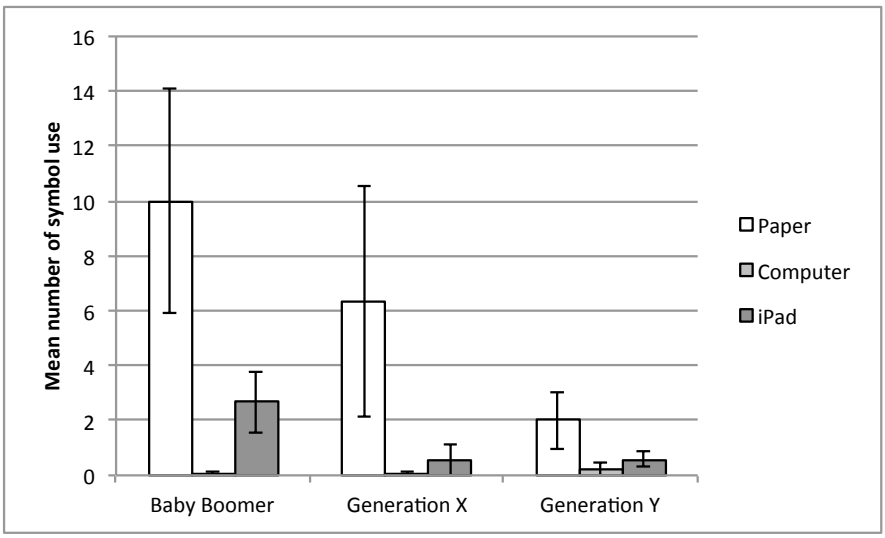


Figure 9. Mean number of symbol use by media conditions and generation groups (error bars: 95.00% confidence interval)

(5) Paper Note

H_a: Participants' use of paper note will differ between reading media.

H_a: Participants' use of paper note will differ between generations.

Paper note refers to when users make a note on a separate piece of paper as shown in Table 10. For all three media conditions, a blank sheet of paper was provided.

The interaction effect of GENERATION x READING MEDIUM was statistically significant, $F_{(4, 108)}$=2.68, p=0.04. As shown in Figure 10, paper note was only used with electronic media. Additional paired comparisons on the interaction effect showed that the use of paper note for the computer condition differed significantly between Baby Boomers and Generation X (p=0.004), as well as between Baby Boomers and Generation Y (p=0.03).

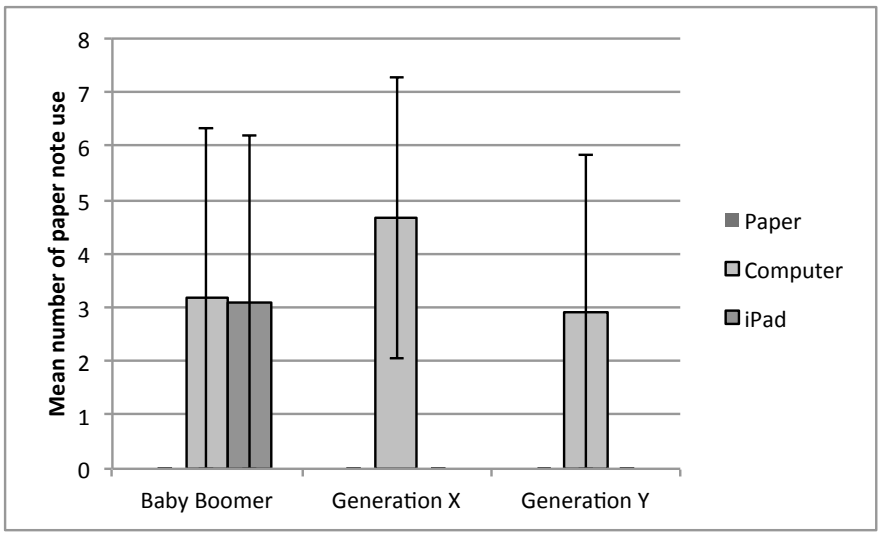


Figure 10. Mean number of paper note use by media conditions and generation groups (error bars: 95.00% confidence interval)

4.2.2. Qualitative Results

The quantitative results showed that there were significant differences in readers' use of annotation strategies depending on reading medium and generation. Further qualitative analyses were conducted to identify the underlying reasons for these differences.

(1) Simplified and Even Changed Annotating Strategy on Electronic Reading Medium

As the quantitative results for the annotation strategies showed, participants' use of note and symbol largely decreased when moving from paper to electronic media; in contrast, there was no difference in participants' use of highlighting, and their use of paper note increased when moving from paper to electronic media.

The qualitative data indicated that the quantitative results were due to participants' adoption of a simplified annotating strategy. Participants explained that making annotations on paper was easier to integrate with the act of reading; in contrast, making annotations on electronic media sometimes interrupted a person's reading process. Accordingly, participants tended to use

annotation in such a way as to minimize disturbances to reading flow. For example, one participant noted the following:

> *P15 (general comments on electronic media): it is kind of easier actually to just stick with one and the other. While if I am thinking too much, this needs to be underlined or highlighted, then I am becoming more involved with the tool than I am with the text. So in this case, I am not actively involved with the text, I am actively involved with the software.*

With regard to the increased use of paper notes while utilizing electronic media, qualitative findings revealed that participants changed their annotating strategy due to the difficulty of annotating while reading with electronic media. In other words, even though participants were likely to rely on other types of annotations while using the paper medium, that same individual was more likely to annotate with a paper note with electronic media due to difficulty with electronic media, as noted in the following statement.

> *P1 (comments on computer condition): I made this [paper note]. This is the only way I can do it on computer.*

In addition, for those cases when participants used the same annotating strategies across all media, findings showed that maintaining the same annotating strategies for the electronic media required participants to change their reading processes. For example, an individual who annotates while reading a paper document is more likely to read an entire electronic document through and then go back to annotate parts that are of interest or importance, as noted in the following statement.

> *P13 (general comments on electronic media): on electronic medium, I would read through [the] whole article first, and then I start to highlight the important parts. But when I do it on the paper, I highlight passages as I went because it didn't slow me down reading the whole paper.*

(2) Generation-specific Reading Practices on Annotation Strategies

As the quantitative results show, Generation X used note significantly more than the Baby Boomers, while the Baby Boomers used symbol significantly more than Generation X. In discussing the underlying reasons for selecting a particular annotation strategy, participants expressed tendencies that could be related to generation-specific experiences. For example, the Baby Boomers reported that even though they had used a computer for more than 20 years, the computer was introduced after they were 30+ years of age. Thus, this group's earliest annotating experiences were associated with the paper medium. In addition, when Baby Boomers were younger (formative period), it was far less common to purchase a new book. Instead, this cohort was more likely to use local library resources or share books with friends or family. Accordingly, participants from this group tended to annotate as little as possible using symbol.

In contrast, participants in Generation X reported that they used computers during their formative year and still actively used a computer for reading and writing in work-related and personal tasks. Consequently, many participants from this group (Generation X) indicated that they were more adept at elaborating their thoughts when they could write note on the computer using a keyboard. Compare the following statements, the first from a Baby Boomer and the second from a Generation Xer:

> *P19 (Baby Boomer): I think, for me, first that [paper]'s what I used more; someone in my age group, paper has been used for a long time as opposed to electronic devices. Secondly, for me, I like using my hand, I am not just drawing straight underlines, I like to be able to circle, as part of just thinking process, even if maybe I go back, it doesn't mark itself, it may not mean anything for the summary, but it's part of the process of reading. It's not natural to do that. It's not my hand. Working with a device, so there's a third player, it's not direct. Being able to write, circle, draw an arrow, I think, that's sort of visual learning. It's more in practice than manipulating the device.*
>
> *P20 (Generation X): I want them underlined and I want to put a lot of comments [notes] next to them [underlined part], how it is related. I didn't know, why I need to do that*

more with the computer than with the other ones [paper, iPad]. I think this is because it's fast. It's fast to type. I felt more comfortable writing my ideas on computer and my ideas formed a lot quicker when I was writing [making notes on computer].

4.3. Movement

Movement is defined as the way participants interact with the text to satisfy their information needs, as shown in Table 10. While reading the articles, readers would routinely go back and review in order to combine related information. In addition, the figures and tables in the article made a reader halt their reading and connect that concise information with the text-based information. In this study, two types of movement were coded and analyzed: Networking and Jumping based on references.

4.3.1. Quantitative Results

(1) Networking

H_a: Participants' use of networking will differ between reading media.
H_a: Participants' use of networking will differ between generations.

Networking refers to when users re-read or review the documents with the goal of developing relationships in the text, as shown in Table 10. For example, when participants went back or forward to a certain page in order to combine related information, this was identified as a networking strategy.

The interaction effect of GENERATION x READING MEDIUM on participants' use of networking was not statistically significant. The READING MEDIUM effect was statistically significant (Friedman one-way ANOVA: $X^2_{(2)}$ =10.74, df=2, p=0.0047), whereas the GENERATION effect was not statistically significant. Additional paired comparisons showed that participants' use of networking also differed between the paper and computer conditions (p<0.0001), between the paper and iPad conditions (p<0.0001), and between the computer and

iPad conditions (p<0.0001). As shown in Figure 11, participants' use of networking was highest for the paper condition, following by the iPad and computer conditions.

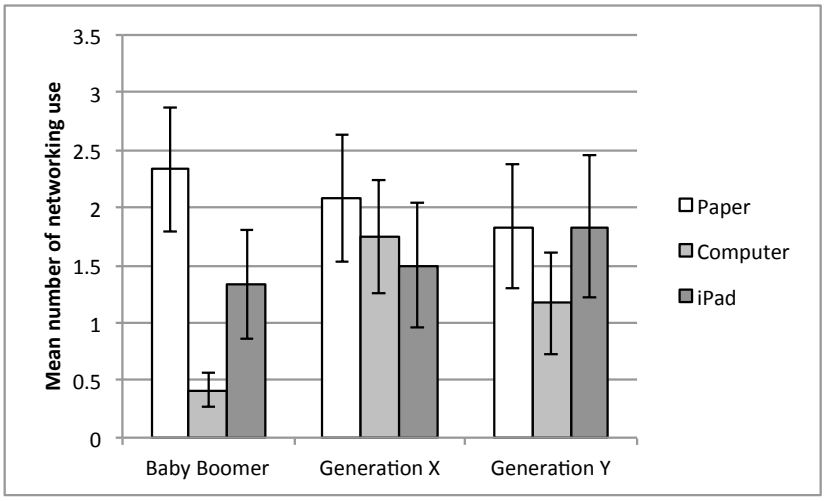


Figure 11. Mean number of networking use by media conditions and generation groups (error bars: 95.00% confidence interval)

(2) Jumping Based on References

H_a: Participants' jumping based on reference will differ between reading media.

H_a: Participants' jumping based on reference will differ between generations.

Jumping based on references refers to when users locate specific information based on references in the text, as shown in Table 10. For example, when participants moved directly from one part of the text to another because of references in the text, this was identified as a jumping based on references strategy.

The interaction effect of GENERATION x READING MEDIUM was not statistically significant. The GENERATION effect was not significant and the READING MEDIUM effect was also not significant.

4.3.2. Qualitative Results

As quantitative results confirmed, participants' use of movement strategies decreased with the use of electronic media (computer condition, iPad condition). Subsequent qualitative analyses were conducted to identify the underlying reasons for this trend. It was revealed that when participants were reading using electronic media, it was more difficult for them to effectively incorporate related information, including connecting related information and ignoring unrelated information.

In particular, participants reported two types of difficulty with electronic media: (a) finding suitable spots to stop their reading, and (b) remembering specific spots of interest to return to. Consequently, movement activities, such as networking or jumping to or from a reference point, decreased with electronic media. In other words, participants' reading processes tended to be linear in comparison to the analogous paper condition. For example, participants reported the following:

> *P17 (comments on the iPad condition): I read sequentially, [for example] this content is really irritating. If it is a paper, you can skip over them. But here [iPad], you don't know what's coming up afterwards, and then, you have to search through and search back. So I just keep reading through.*

> *P11 (comments on the computer condition): When I was reading the paper, it's really easy to find the stopping point I could come back to. But [on the computer], I didn't really find that. So I was having a hard time finding a good stopping point. So I just read all the text and went back so I didn't lose my place and have to scroll all around and keep finding it. I just keep going from the top to the bottom and scroll through.*

Figure 12 graphically depicts P09's reading processes over the duration of the task for all three media conditions. The stages are indicated at the bottom of the figure (i.e., reading stage and summarization stage). The horizontal axis shows time from the beginning to end of the task. The vertical axis shows page number. As can be seen, when reading from paper, this individual went

back to a previous page or moved ahead to a future page to incorporate related information during the reading process; in contrast, this participant tended to read linearly using both the computer and the iPad. Therefore, these observations showed how the difficulty with electronic media affected one's reading processes.

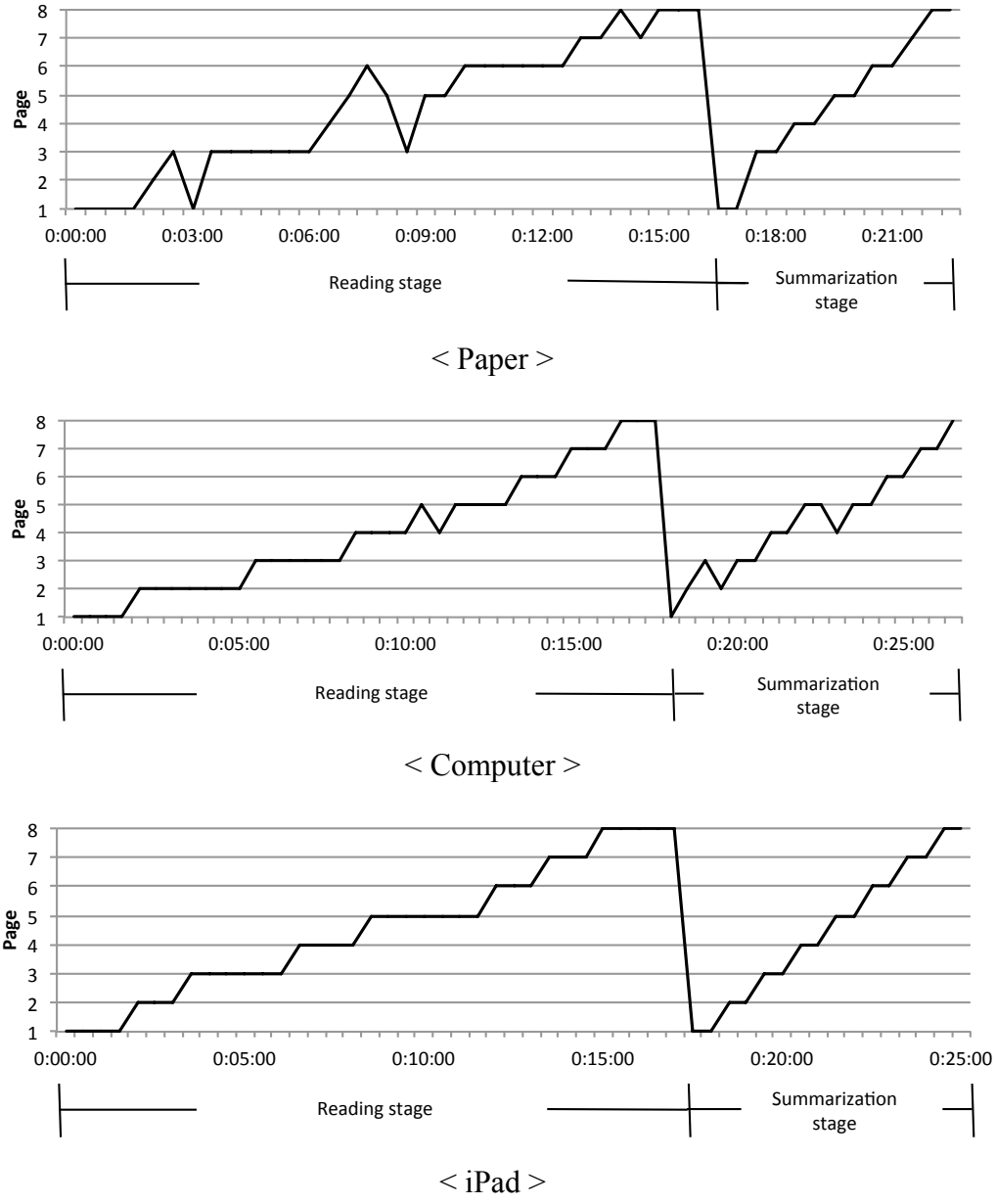
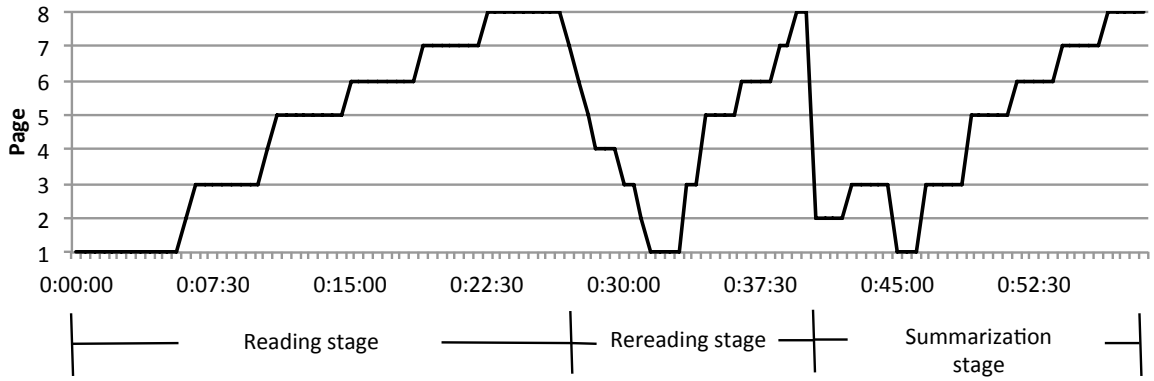


Figure 12. Participant (p09)'s reading processes over the duration of the task

In addition, this study revealed that the difficulty of incorporating related information when reading from an electronic medium could lead to a change in one's actual reading processes. As documented in Figure 13, some participants tended to skip related information until they had finished reading the entire document, and then returned to reread any skipped parts. Therefore, compared to Figure 12, there are three stages at the bottom of the Figure 13: reading stage, rereading stage and summarization stage. Among 36 participants, half of them (18 participants) showed these three stages when using electronic media.



<iPad>

Figure 13. Participant (p17)'s reading processes over the duration of the task

When reading from paper, participants naturally spread out the article pages and/or reorganized pages using fingering and laying out two pages together. However, when reading from the electronic media, they found it more difficult to incorporate related information since connecting information on electronic media requires scrolling up and down (computer) or moving up and down (iPad). Moreover, even within a single electronic "page," participants reported difficulty in efficiently acquiring information due to the requirement of scrolling up and down. Accordingly most participants stated their preference for a full screen view in order to minimize scrolling motions, even though they were able to adjust the size of the text. The following two quotes illustrate these findings:

P21 (comments on paper condition): [Participant laid out several pages together and looked at them.] This is what I like about having printed pages, I can look at the big

picture of the whole article, but I can also look at the little headings and sections, I can do it simultaneously.

P10 (comments on computer condition): The font was small. I should make them larger. But I was afraid that sometimes I lose my place when I get distracted. I knew I could make them larger, but I just want to see the full document on the screen as I am reading it. I would prefer to be able to know the contents on the page and how much I have left before I go to the next page without having to scroll up and down.

4.4. Monitoring

Monitoring refers to the process that readers use to keep track of their reading progress, as shown in Table 10. In this study, two kinds of monitoring strategies were coded and analyzed: a micro-monitoring strategy and a macro-monitoring strategy. As mentioned in 3.6.2, a dichotomous response was used for monitoring strategies due to the difficulties in discerning the number of behaviors (frequencies).

4.4.1. Quantitative Results

(1) Micro-monitoring

H_a: The proportion of participants using micro-monitoring will differ between reading media.

H_a: The proportion of participants using micro-monitoring will differ between generations.

Micro-monitoring refers to when users narrow their focus in order to extract information effectively, as shown in Table 10. For example, when participants pointed or followed a sentence using their hand, pen, mouse cursor, or stylus, this was identified as a micro-monitoring strategy.

Here, the READING MEDIUM effect was significant (Cochran Q test, $Q(2) = 13.3684$, $p=0.0013$), while the GENERATION effect was not significant. Additional paired comparisons showed that the proportion of people who used micro-monitoring was different between the paper and computer conditions ($p=0.0016$), between the paper and iPad conditions ($p=0.0578$), and between the computer and iPad conditions ($p=0.0348$). As shown in Figure 14, the

proportion of people who used micro-monitoring was highest for the paper condition, followed by the iPad and computer conditions.

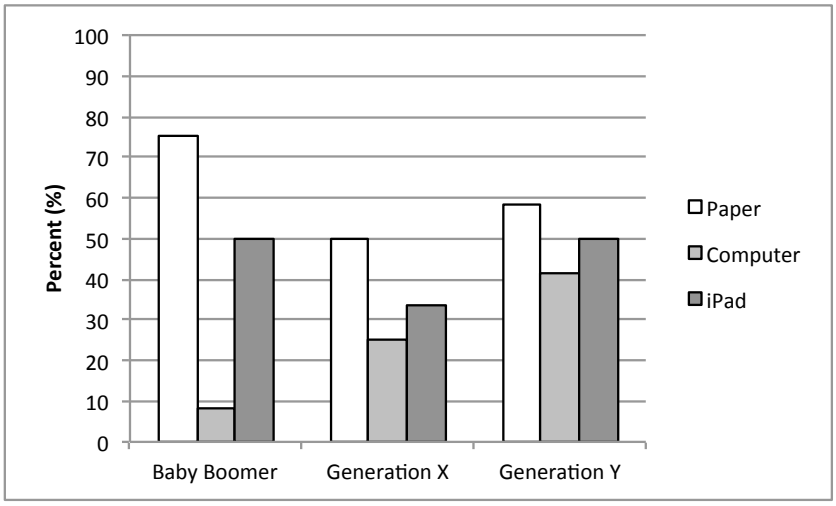


Figure 14. The proportion (%) of participants who used micro-monitoring for media conditions and different generation groups

(2) Macro-monitoring

H_a: The proportion of participants using macro-monitoring will differ between reading media.

H_a: The proportion of participants using macro-monitoring will differ between generations.

Macro-monitoring refers to when users broaden their focus beyond the present page in order to determine their current progress, as shown in Table 10. For example, when participants quickly skimmed the remaining pages by counting them or using the navigation panel on the electronic media, this was identified as a macro-monitoring strategy.

For the proportion of people who used macro-monitoring, there was no significant effect of either READING MEDIUM or GENERATION.

4.4.2. Qualitative Results

Although the quantitative results showed only differences in the proportion of people who used micro-monitoring across all three media, further qualitative analysis identified different levels of difficulty for both types of monitoring (micro- and macro-monitoring). In terms of micro-

monitoring, participants reported that they naturally used their finger or a pencil to follow the part that they were reading from paper and that such behaviors were more beneficial when the content was complex. However, when reading from electronic media, although the demand for micro-monitoring was higher, it was difficult to use this strategy. In particular, it was revealed that participants had particular difficulty under the computer condition, since they could utilize similar micro-monitoring behaviors as those used with paper with the iPad condition. Consider the following comments, for example:

> *P17 (comments on computer condition): I didn't use the mouse to follow sentences, because it will distract me if it is on there. It's not following something with your finger. I can control my finger much better than controlling the cursor.*

> *P15 (comments on computer condition): I found when reading on the screen, it is harder to keep my eye focused than reading on the paper. So the cursor helps to keep your eye where it needs to be. I go through each word using the cursor.*

Although the quantitative results did not reveal any significant differences in the proportion of people who used macro-monitoring, the qualitative results showed that macro-monitoring on electronic media required more effort from readers. Participants specifically mentioned that macro-monitoring on paper was much more natural and could be done using multiple senses (e.g., visual, auditory, and tactile senses). However, macro-monitoring with electronic media was compelling since it tended to stop a reader's flow of reading by diverting their visual attention to check a page number or by gauging the remaining portion to be read through the position of the scroll bar.

> *P24 (comments on paper condition): I could feel, you know, how many pages I had left every time I'm turning the page.*

> *P03 (comments on computer condition): I was pretty aware that I was half-way through because I was checking the bar occasionally in the side. I knew how big the bar is, and*

you can kind of estimate how more pages you have to go. But, I wasn't 100 percent sure about how much longer I need to read.

4.5. Overall Results

This section summarizes both the quantitative results and the qualitative results.

4.5.1. Overall Quantitative Results

Among eight total reading strategies examined, the following two showed the interaction effect of GENERATION x READING MEDIUM: symbol and paper note. The following three showed the READING MEDIUM effect: note, networking and micro-monitoring. The note strategy was the only one that showed the GENERATION effect.

Overall, participants' use of reading strategies was higher for the paper condition in comparison to either the computer or iPad conditions. When plotting each generation group's use of the four types of annotations separately (Figure 15), the Generation X group and Generation Y group were inclined to use both highlighting and note, while Baby Boomers tended to use both highlighting and symbol.

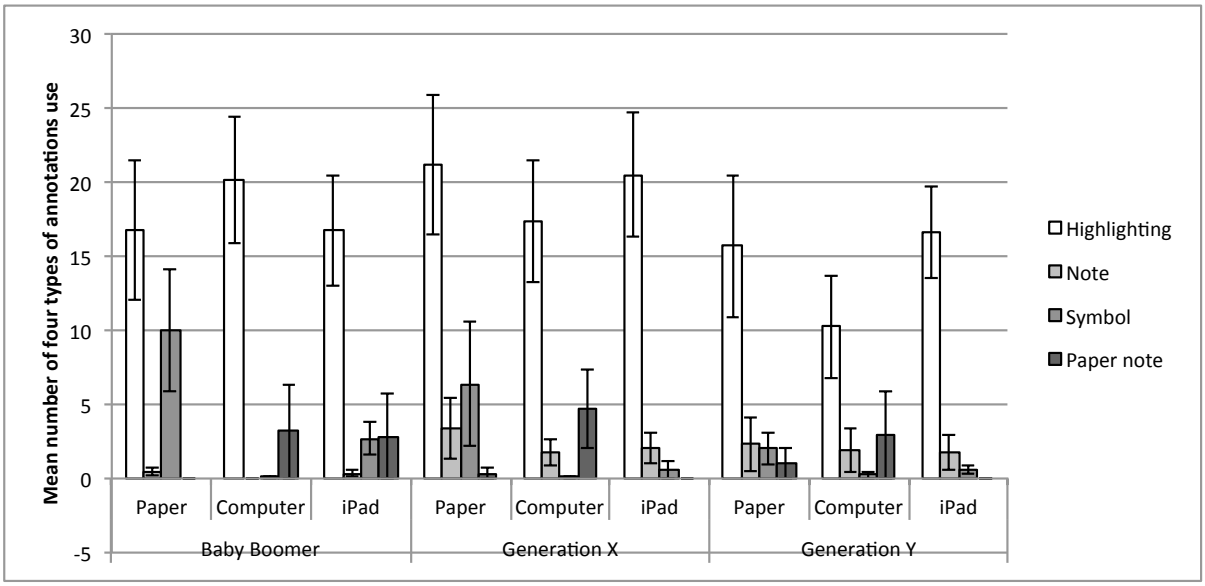


Figure 15. Mean number of four types of annotations use by media conditions and generation groups (error bars: 95.00% confidence interval)

4.5.2. Overall Qualitative Results

Overall, the qualitative findings supported the quantitative findings. Specifically, qualitative findings showed that readers' use of reading strategies were influenced by the use of different reading media. For all three generations, paper was the preferred reading medium for effective use of reading strategy. Participants reported that reading from electronic media tended to interfere with their use of reading strategies, forcing them to change their strategy.

The qualitative findings also showed that readers' use of reading strategies differed between generations. Readers' use of reading strategies was related to their experience (generation-specific reading practices); when readers were unable to effectively use certain strategies, it influenced their preference. With regard to the two electronic media, even though Baby Boomers expected that they would have more difficulty with the iPad than with the computer, the Baby Boomers responded that they were able to use their reading strategies more with the iPad in comparison to the computer. In contrast, Generation X responded that they were able to use their reading strategies more effectively with the computer rather than the iPad; consequently, this group favored the computer over the iPad. The Generation Y group did not indicate a reading preference for either the computer or the iPad. Along with the use of reading strategies, various other aspects contributed to such reader's preference. For example, being able to control the physical position of the reading medium was important. Results revealed that Baby Boomers were more comfortable with the iPad medium (over the computer) since they could position it as they might a paper book or magazine. In contrast, Generation X group preferred the physical position associated with computer reading. Therefore, a participant's preference was impacted by the overall experience as well as by his or her generation-specific reading practices. For example, Baby Boomers commented on how the iPad enabled them to perform the reading task, as follows:

> *P15 (comments on iPad condition): I think, with practice, I will be using my hand the way I use the paper. When I become really coordinated at it. I could be just using my finger. I don't even need to be holding the pencil (stylus). That's even more direct.*

P27 (general comments on electronic media): It [computer condition] is looking up like this and this [iPad] is supposed to be looking down like this. Maybe that [the reason he/she preferred the iPad to the computer] is similar with my habit looking down formed with reading on paper. [Even though she has used the computer over than 20 years] I felt I have more maneuverability with the iPad…..It's different kinds of concentration on that [computer] and on this [iPad]. I felt myself really just more distracted with the computer. Maybe because of the keyboard or mouse… With this [iPad], this [stylus] is in my hand. I concentrated because I have a technology that lets me to do things. But on the computer there are distractions trying to manage the technology.

In contrast, the Generation X group described how the computer facilitated their reading task, as follows:

P14 (general comments on electronic media): I'm really used to the computer, so the scrolling comes naturally to me. But with the stylus, it was distracting…on the computer it's up like this. But on the iPad, it's a weird position.

P18 (general comments on electronic media): Sometimes paper is floppy. It requires so much more effort keeping charge of paper whereas on the computer, it's just right there. It's very rigid and images are there. I don't have to worry about flipping over or anything like that.

P13 (general comments on electronic media): Tools on the iPad were more distractions for me to use. That's why I didn't make a critique note on the iPad. Making a critique, you know, you're writing comments for yourself. So it takes time to do if there are distractions on the task. It's almost like you write it down. You have to focus on your task. I think the reason I am less likely to put the critique on that [iPad] is because if you do the task, you have to get your feeling what you're looking at to make the change. I don't get that as much on the iPad. I will be much less likely to put in like those comments on the iPad. I'm more likely to do that on computer and paper. I really like using the

computer. I can write a note. We can write this much [long note]. It doesn't cut off the paper. Versus on here [iPad], if you write a lot, it's a mess.

5. Discussion

This study was designed to investigate how reading strategies can be used to assess the effectiveness of reading media as reflecting both cognitive and cultural aspects. In order to do that, this study explored how the way in which people interact with a text (i.e., reading strategies) is affected by their choice of reading medium, as well as by their generation-specific reading practices.

Based on usage of reading strategies (Figure 7, 8, 9, 11 and 14), the main finding from this investigation is that paper was the most useful medium for supporting people's use of reading strategies. The second most effective medium in supporting people's use of reading strategies was the iPad; moreover, Baby Boomers used their reading strategies more readily with the iPad in comparison to the computer (but not over the paper medium). The computer condition-although the Generation X group used their reading strategies more with the computer than with the iPad—was found to be the medium that was least effective in supporting participants' use of reading strategies.

5.1. Reading Strategies as Explaining the Cognitive Aspect

The results showed how readers' use of reading strategies is affected by the use of different media. With respect to annotating strategies, the participants in this study simplified or even changed their annotation strategies when using electronic media. When participants were reading from paper, they were able to employ different types of annotation tactics with a single tool in a relatively simple way. However, when they were reading from electronic media, they had to change from one type of annotation tool to another. Changing annotation strategies with an electronic medium is accompanied by menu manipulations, which would interrupt mental processing of verbal information (phonological loop) and require additional processing of visuospatial information (visuospatial sketchpad) in working memory. Therefore, participants in

this study tended to stick with one type of annotation. Movement strategies (e.g., networking, jumping based on references) also showed similar findings. The use of movement strategies tends to be linear when using electronic media. People reading from a computer or an iPad showed a tendency to skip over or ignore related information rather than incorporate it during the reading process. In order to effectively incorporate related information during reading, readers need to remember specific points of interest to return in order to locate specific information; this requires considerable involvement with sub-components (visuospatial sketchpad and phonological loop) in working memory. Reading from electronic media appeared to require more processing resources and participants in this study tended to resist incorporating related information due to limited working memory capacity.

Moreover, the results showed that the difficulty in using certain reading strategies could induce readers to change their reading processes in order to successfully complete the given reading task. This finding implies that the operation of the central executive was altered according to task goals, situational factors, sub-components' functions and their capacity. This finding was exemplified by the fact that when using electronic media, some participants first read an article through in its entirety, and then revisited certain sections of it to make annotations (as opposed to annotating while reading). With regard to incorporating related information (movement strategies), some participants also skipped or ignored related information until they finished reading and then reread those parts. That is, participants performed extra operations in order to reduce the amount of mental effort.

5.2. Reading Strategies as Explaining the Cultural Aspect

The results showed that there were significant differences in the readers' use of reading strategies among the generations, and that participants reported generation-specific experiences during their formative period as the underlying reasons for their choice of reading strategy. As discussed in Chapter 2 (Section 8), generation effect showed a discontinuous trend, while age effect showed a continuous trend. As exemplified in Figure 15, participants' use of reading strategies

did not continuously decrease or increase among the three generation groups according to age order, which reflects a generation effect.

In terms of annotation strategies, Baby Boomers tended to use symbol, while the Generation X group favored note—regardless of medium. Baby Boomers reported that paper was scarcer during their formative years and tended to be shared (e.g., through library usage), while the Generation X group described their active usage of computers and keyboard. This finding showed that such generation-specific usage of reading strategies is based on generation-specific reading practices and that such experiences play a role in knowing which particular strategies would be required and appropriate for successfully completing a given reading task. Baby Boomers and Generation X would have different mental models for their reading practices, which represent their knowledge of how they need to perform certain reading activities.

Generation-specific reading practices can be interpreted in terms of knowledge. In general, there are three types of knowledge: declarative knowledge, procedural knowledge and conditional knowledge. Declarative knowledge includes information about the task itself (e.g., goal and structure); procedural knowledge refers to information related to actually conducting a task; and conditional knowledge is about knowing when and why a certain action has been or will be applied (Garner, 1990; Lorch et al., 1993; Paris, Lipson, & Wixson, 1983). Therefore, generation-specific reading practices would correspond to a reader's shaped knowledge, coupled with their sociological environment (including technology experience) over time, which then contributes to that person's understanding of a task and how best to execute it.

In terms of monitoring strategies (micro-monitoring and macro-monitoring), Baby Boomers were the cohort that primarily exhibited the effects of generation-specific reading practices—and thus had the most difficulty using electronic media. The proportion of people who utilized monitoring strategies decreased when they read using electronic media. Participants had the most difficulty using monitoring strategies when reading from the computer. In contrast, they used similar monitoring strategies on an iPad as they did when reading from paper. Specifically, as shown in Figure 15, the proportion of people who used micro-monitoring dramatically decreased

in the case of the Baby Boomer group reading from a computer, while it only slightly decreased for the Generation X and Generation Y groups using the same medium. These results might imply that a generation group with technology experience during the formative period would have conditional knowledge that they could then apply appropriately to their reading practices according to the reading condition. In the case of the Generation X group, since they had experience with both paper and computer during their formative years, they were able to utilize strategies on both media. In contrast, since the Baby Boomers' experience with computers was after they had reached the age of 30, they had more difficulties with computers. As these results revealed, in order to engage in micro-monitoring while reading from paper, participants typically used their hands to follow sentences; conversely, when reading from a computer screen a person might slowly scroll the page to line up the sentence on the top of the screen or use a computer cursor to follow the sentence, which could not be replicated when using the paper version. Therefore, this study showed the possible existence of conditional knowledge that depends on different types of media, which supplements the results from existing studies (Lorch et al., 1993) describing the existence of conditional knowledge depending on reading circumstance (e.g., light reading versus exam preparation versus a reading-to-learn situation).

With regard to cognitive processing, crystallized intelligence in the model of working memory can also explain the fact that Baby Boomers were able to use their strategies more effectively with the iPad compared to the computer. As discussed in Chapter 2 (Sections 4 and 8), crystallized intelligence, which is based on experience and knowledge, increases with age. That is, Baby Boomers' crystallized intelligence, which was generated over time from reading from paper, would increase and could then be applied to reading from the iPad.

The concept of affordance (Gibson, 1977; Norman, 2002) played a critical role with regard to both the cognitive and cultural aspects of readers' use of reading strategies. Paper was still the most effective medium for supporting sensory affordance, physical affordance and cognitive affordance, which means that the inherent properties of paper help sensing, physically doing, and knowing about users' interactions. In particular, as the cultural aspect, generation-specific reading practices would be greatly related to cognitive affordance. Cognitive affordance refers to

the specific properties of a system that enable a person to know its proper operation. It is supported by sensory affordance and physical affordance, but it is also based on a users' experience, and cultural conventions (McGrenere & Ho, 2000; Turner & Turner, 2002). Different generation groups would have different mental models of reading practices as cultural schema. In their mental model, cognitive affordance as user experience and cultural convention would play an essential role in cognitive processing.

Overall, this study showed that readers' use of reading strategies differed depending on the medium and their generational experience. Reading strategies can reflect cognitive and cultural aspects of reading and reading strategies can be used as a process measure to assess the effectiveness of reading media.

The conceptual meaning of these findings was used to identify the importance of a person's culturally situated experience with an active reading task. As discussed in Chapter 2 (Section 9), the notion of culturally situated experience has been applied to explain individuals' behaviors, beliefs and actions (Dewey, 1938; Vygotsky, 1978; Kakar, 1981). Several studies have also explained how culture is situated in cognition and has a role in thinking and action (Oyserman, 2011; Semin, 2008). For this study, culturally situated experience is viewed as operationalizing the experience, which is established when a person performs active reading tasks using a certain medium during his or her formative period. This culturally situated experience remains embedded when the person later performs the same active reading tasks using different media, thereby influencing consequences such as behaviors, performance, and subjective responses. Figure 16 shows a conceptual model of a culturally situated experience.

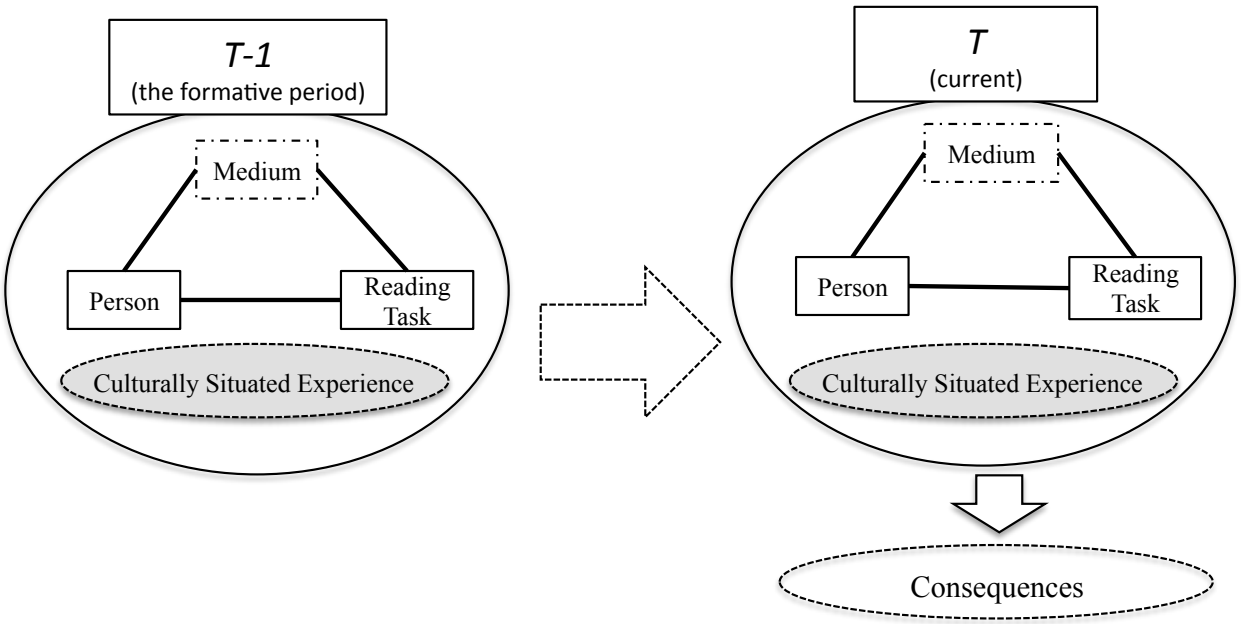


Figure 16. The conceptual model of a culturally situated experience

In general, this concept model of a culturally situated experience could be applied in different tasks or systems. User experience has been of significant importance in recent HCI studies. User experience is defined as all the aspects of how people use an interactive product/system (Alben, 1996). Aspects related to existing experiences that have been investigated including aesthetics, hedonics, and others (Hassenzahl, 2004; Tractinsky & Zmiri, 2006). In contrast, cultural aspects have been minimally investigated. When studies failed to uncover significant differences in associated technology, they tended to conclude that differences were linked to emotion, pleasure, and other factors that existing studies focused on as user experiences. However, this needs a complex contemplation about user, task, and artifact. As this study showed, cognitive and cultural aspects would be critical with regard to non-routine cognitive activities such as active reading, because cognitive aspects are key for those activities and a person's cognitive capabilities performing those activities tend to be established during the formative period. In order to explicate the culturally situated experience, an integrated approach is needed to consider to both cognitive and cultural aspects with regard to the use of a product/system. In this study, the use of reading strategies was investigated as the cognitive aspect, and different generational groups were included as the cultural aspect.

There are several limitations associated with this study. First, although this research revealed that in terms of cognitive and metacognitive reading strategy use, Baby Boomers favored the iPad and the Generation X group preferred the computer as a result of their generation-specific experiences, these results could not account for Generation Y's preferences. This may be because this group's (Generation Y) generation-specific experiences were not yet firmly established. It should be noted that this study viewed the formative period as occurring during the K-12 education years (before 18 years old) when reading strategies are typically taught and established. However, the formative period with respect to reading strategies has not yet been well defined; thus further studies are required to clarify the range of formative period for reading strategies. In fact, in terms of different types of interfaces, Docampo Rama et al. (2001) regarded the formative period as between 10 and 25, but Lim (2010) argued for extending a person's formative age up to the age of 30, rather than the mid 20s. Considering that the mean age of participants in the Generation Y group was 22.2, this factor could help explain these results. Second, the reading strategies investigated in this study corresponded to directly recognizable ones from behaviors and verbal protocols. Accordingly, the variables used limited the ability to explain more metacognitive strategies, which are sometimes difficult to capture.

Additional studies are needed to further explicate the extent to which reading strategies can explain reading differences in comparison to other existing measures. This study confirmed that readers utilized different reading strategies depending on the specific reading medium and their personal attributes (i.e., generation). In order to consider whether such differences are critical in performing reading tasks, they should be incorporated into future technology design. Moreover, researchers should consider reading strategy as a process measure, meaning that forthcoming studies should consider comparing readers' use of reading strategies and other existing measures such as outcome-based measures (e.g., performance, subjective response) and measures of cognitive load as a way of clarifying the relationship between reading strategies, reading medium, and generational influences.

CHAPTER 4. THE RELATIONSHIP BETWEEN READERS' USE OF READING STRATEGIES AND THEIR PERFORMANCES AND SUBJECTIVE RESPONSES

Abstract

Outcome measures such as reading speed and comprehension have traditionally been used to assess the efficacy of different reading media. However, contradictory results have been obtained and the underlying aspects influencing user performance and their subjective responses have not yet been clearly identified. As discussed in Chapter 3, although reading strategies can be used as a process measure to assess the effectiveness of reading media, the extent to which reading strategies can explain reading differences needs further investigation. Therefore, the purpose of this study was to examine the impact of the type of reading medium and the generation of the reader on their performances and subjective responses, as well as to investigate associations between readers' use of reading strategies, performance measures, and subjective responses. This study found significant differences on subjective responses between different types of reading media and generational groups. Results also confirmed relationships between readers' use of reading strategies, performance outcomes, and subjective responses. Such findings can explain how reading strategies can be used to assess the effectiveness of different reading media.

1. Introduction

Outcome measures such as reading speed and comprehension have long been used to assess the efficacy of different reading media. A large body of work using outcome measures has been reported, but there are many contradictions within their findings. Moreover, some studies have indicated no significant differences between electronic media and paper for outcome measures (Noyes & Garland, 2008), although people do show a preference for either reading from paper or reading from an electronic medium and resist changes in the workplace (Gladwell, 2002; Holzinger et al., 2011).

With regard to active reading activities, which have specific goals for reading and usually occur in an educational or workplace setting, knowing the extent to which newer advanced reading media are effective in terms of cognitive perspectives for diverse age groups is critical (Kol & Schcolnik, 2000). However, many studies that have investigated reading from paper versus reading from electronic media have been conducted from a technological viewpoint, focusing principally on technological specifications and functionalities to explain users' performance and subjective responses. In order to identify underlying differences with respect to reading from paper vs. reading from electronic media, the cognitive and cultural aspects of the use of these different media types must be considered (Eshet-Alkalai & Geri, 2007; Hornbæk & Frøkjær, 2003; Thayer et al., 2011). As yet, few studies have taken this approach and the relationship with users' performance and subjective responses have not been evaluated in any systematic way.

Reading strategies are regarded as crucial for readers' successful reading in terms of cognitive and cultural aspects. However, studies in the education field have tended to focus on evaluating and elucidating reading strategies for new learners (Afflerbach et al., 2008; Mokhtari & Reichard, 2002). Reading strategies are known to be affected by diverse factors, including the task type and the personal characteristics of the reader. The use of different reading media can also influence a reader's use of cognitive and metacognitive reading strategies. Reading strategies can also reflect the cultural aspects of the reader, since they represent cognitive capabilities acquired and developed during adolescence. As documented in the study described in Chapter 3, readers' use of reading strategies differed depending on the specific type of media and their generation (in this case, Baby Boomers, Generation X, or Generation Y).

The purpose of this study was to investigate the extent to which reading strategies can explain reading differences by investigating the associations with outcome-based measures of reading that are traditionally used in existing studies. Specifically, the impact of medium and generation on performances and subjective responses was examined, after which the associations between a reader's use of reading strategies, performance measures, and subjective responses were identified.

2. Methods

2.1. Overview of the Experiment

As described in Chapter 3, the experiment was conducted in a controlled laboratory setting. Thirty-six participants were recruited and performed a reading task with three types of media (paper, computer, and iPad) in an assigned sequence. Three generation groups (Baby Boomers, Generation X and Generation Y) of 12 participants each took part in this study. This phase of the research had two overarching goals: (1) to examine the impact of the type of reading medium and the generation of the reader on his or her performance and subjective responses, and (2) to investigate the relationship between readers' use of reading strategies and their performance and subjective response. Descriptions of the participants, medium conditions, reading task, and procedures are detailed in Chapter 3. A pre-experiment questionnaire (on computer experience and media usage) was employed and reading strategies were identified using protocol analysis, as noted in Chapter 3. Independent and dependent variables in this study are listed in Table 12.

Table 12. Independent and dependent variables

Variable	Component
Independent variables	• Reading medium (paper, computer, and iPad) • Generation (Baby Boomers, Generation X and Generation Y)
Dependent variables (Table 13)	• Performance: reading speed, overall comprehension • Subjective responses: usefulness, ease of use, satisfaction with the medium

2.2. Measures

A total of five measures, comprising two performance measures and three subjective responses, were obtained for each participant from each of the three sessions (paper, computer, and iPad), as shown in Table 13. Similar to a number of prior studies utilizing reading speed and overall comprehension as outcome measures (Dillon, 1992; Noyes & Garland, 2008), this research also employed these two measures to gauge reading efficacy.

Subjective measures were obtained using three constructs from the instrument developed by Davis (1989): usefulness, ease of use, and satisfaction. The items were reported on a 7-point Likert scale, anchored at the end points with strongly disagree (1) and strongly agree (7). These three constructs have been widely used to assess the quality of systems and products (Booth, 1989; Hornbæk, 2006; Kengeri et al., 1999; Pearrow, 2000), although usefulness is sometimes regarded as a higher construct consisting of both utility and usability (Bevan, 1995; Grudin, 1992).

To examine overall comprehension, one doctoral student from the School of Education at Virginia Tech was recruited to evaluate participants' written summarizations. The evaluation rubric consisted of three criteria: (1) organization, (2) elements of summaries, (3) grammar, usage, mechanics, and spelling. Each criterion was evaluated based on 4-point Likert scale, anchored at the end points with strongly disagree (1) and strongly agree (4).

Table 13. Outcome-based measures: performance and subjective response

Construct	Measure	Description
Performance	Reading Speed	Task completion time
	Overall comprehension	Summarization
Subjective Response	Usefulness	The extent to which an individual perceives that the given reading medium enhanced his or her reading performance
	Ease of use	The extent to which an individual believes that a given medium was free of effort
	Satisfaction with medium	The extent to which an individual was satisfied with a given medium

2.3. Data Analysis

A Shapiro-Wilk test was conducted to test for normality and all distributions were found to be non-normal. Accordingly, nonparametric data analyses, specifically Kruskal-Wallis and Friedman's analysis of variance, were conducted. To examine the interaction of generation and medium, an Aligned Rank Transform (ART) test was conducted (Sawilowsky, 1990; Wobbrock,

Findlater, Gergle, & Higgins, 2011). For the post-hoc paired comparison, a planned F-test was conducted. Effects were considered "significant" with an alpha level of 0.05.

To determine correlations between readers' use of reading strategies, performance outcomes, and subjective responses, a spearman rho was calculated for six reading strategies (highlighting, note, symbol, paper note, networking and jumping based on reference) and a rank-biserial correlation was calculated for two reading strategies (micro-monitoring and macro-monitoring).

3. Results

Before examining performance and subjective responses for the three different media, the order of media and document was tested. As a result, media order effects and document order effects were non-significant. Research questions for this study are as follows:

Research Question (RQ2): What is the impact of medium and generation on performance?

Research Question (RQ3): What is the impact of medium and generation on subjective response?

Research Question (RQ5): What is the relationship between readers' use of reading strategies and their performance, subjective response, and cognitive load?

3.1. Outcome Measures

(1) Reading Speed (Task Completion Time)

H_a: Participants' reading speed will differ between reading media.

H_a: Participants' reading speed will differ between generations.

The interaction effect of GENERATION x READING MEDIUM on reading speed was not statistically significant. The GENERATION effect was not significant and the READING MEDIUM effect was also not significant.

(2) Overall Comprehension

H_a: Participants' overall comprehension will differ between reading media.

H_a: Participants' overall comprehension will differ between generations.

The interaction effect of GENERATION x READING MEDIUM on overall comprehension was not statistically significant. The GENERATION effect on overall comprehension was approaching significance (Kruskal-Wallis test; $X^2_{(2)}$ =5.45, p=0.07) and the READING MEDIUM effect was also approaching significance (Friedman one-way ANOVA: $X^2_{(2)}$ =4.87, p=0.09). As shown in Figure 17, overall comprehension, which was based on the written summary, was higher when participants read from paper in comparison to either the computer or the iPad, with the Generation Y group demonstrating higher comprehension than other two generation groups across all three media.

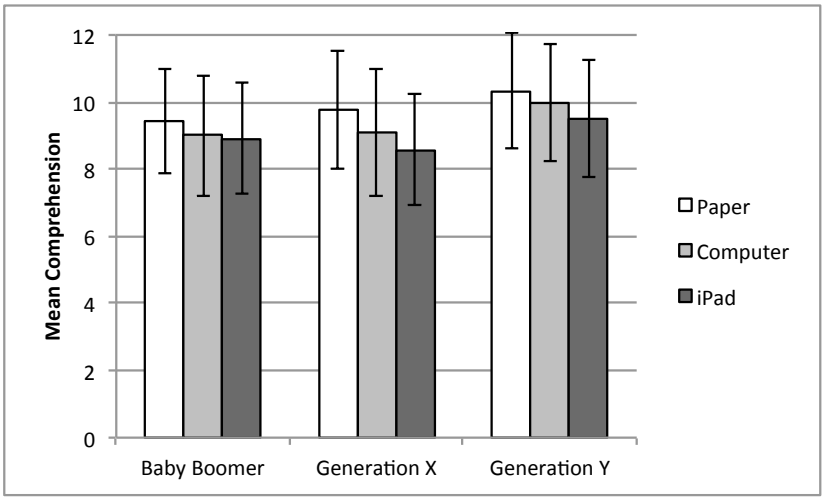


Figure 17. Effect of generation and reading medium on overall comprehension

3.2. Subjective Measures

(1) Satisfaction with the Medium

H_a: Participants' satisfaction with the medium will differ between reading media.

H_a: Participants' satisfaction with the medium will differ between generations.

The interaction effect of GENERATION x READING MEDIUM was not statistically significant, $F_{(4,\ 108)}$=1.79, p=0.14. There was a significant effect of READING MEDIUM (Friedman one-way ANOVA: $X^2_{(2)}$ =23.32, p<0.0001), while the GENERATION effect was approaching significance (Kruskal-Wallis test; $X^2_{(2)}$ =5.57, p=0.06). Additional post-hoc paired comparisons showed that readers' satisfaction with medium was significantly higher with the

paper condition than either the computer condition (p<0.0001) or the iPad condition (p<0.0001) (Figure 18).

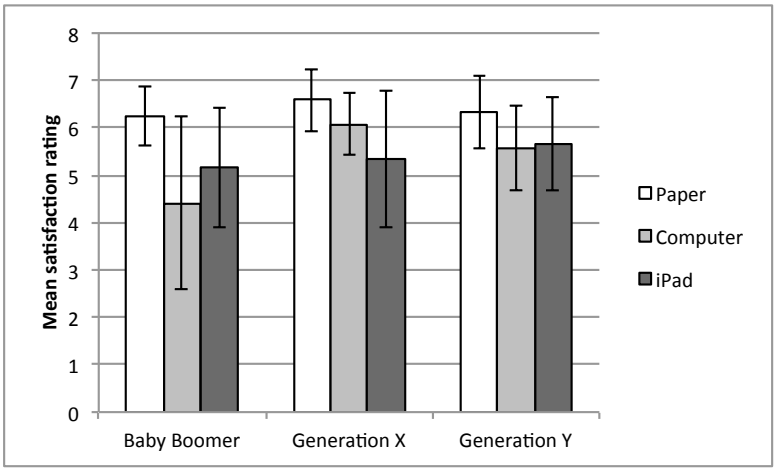


Figure 18. Mean satisfaction ratings for media conditions and different generation groups

(2) Usefulness

H_a: Participants' perceived usefulness will differ between reading media.
H_a: Participants' perceived usefulness will differ between generations.

The interaction effect of GENERATION x READING MEDIUM was not statistically significant, $F_{(4, 108)}$=1.65, p=0.17. The READING MEDIUM effect was statistically significant (Friedman one-way ANOVA: $X^2_{(2)}$ =20.05, p<0.0001), whereas the GENERATION effect was not significant. Additional post-hoc paired comparisons showed that usefulness ratings for the paper condition were significantly higher than for either the computer (p<0.0001) or iPad condition (p<0.0001) (Figure 19).

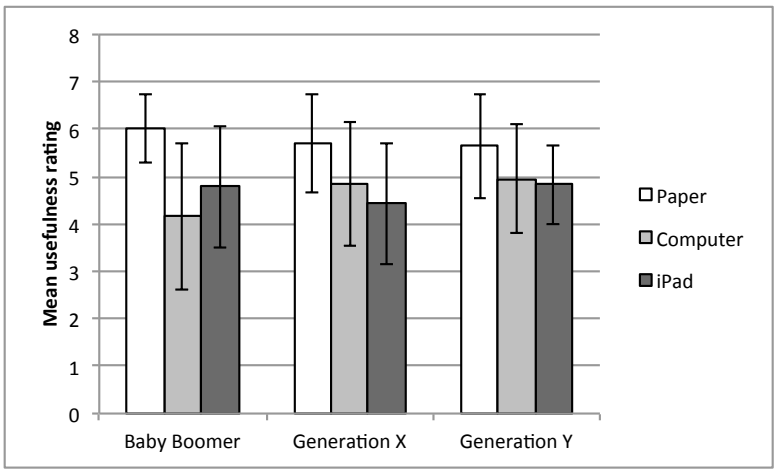


Figure 19. Mean usefulness ratings for media conditions and different generation groups

(3) Ease of Use

H_a: Participants' perceived ease of use will differ between reading media.

H_a: Participants' perceived ease of use will differ between generations.

The interaction effect of GENERATION x READING MEDIUM was statistically significant, $F_{(4, 108)}$=3.99, p=0.006. Additional paired comparisons on the interaction effect showed that the ease of use rating for the computer condition differed significantly between Baby Boomers and the Generation X group (p=0.02), with Generation Xers rating it higher than Baby Boomers. Specifically, the Generation X group reported ease of use ratings in the following order of preference: (1) paper, (2) computer and (3) iPad, while the Baby Boomers' ease of use ratings put paper first, followed by the iPad, and then the computer (Figure 20).

Additional paired comparisons on interaction effect showed that extrinsic cognitive load ratings between the computer and iPad conditions for the Generation X group were significant (p=0.01), while extrinsic load ratings between the computer and iPad conditions for the Baby Boomers were approaching significance (p=0.09). Specifically, the Baby Boomers gave higher ratings to the iPad than the computer, while for the Generation X group this ranking was reversed (Figure 22).

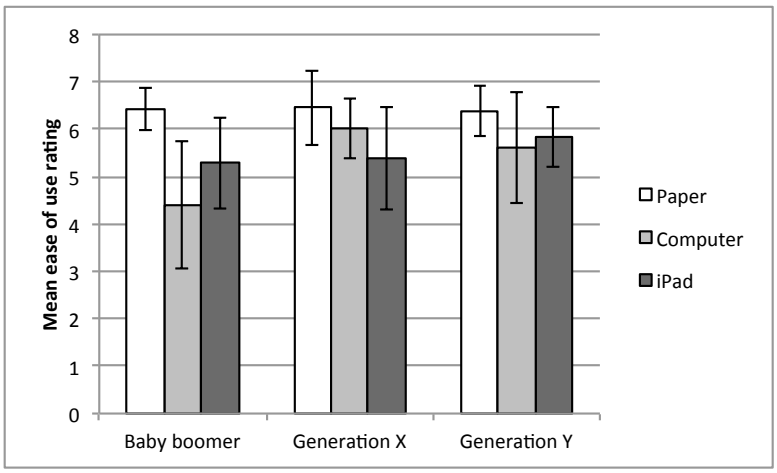


Figure 20. Mean ease of use ratings for media conditions and different generation groups

3.3. Correlations Between Readers' Use of Reading Strategies and Performance and Subjective Response

Among a total of eight reading strategies, six were significantly correlated with either performance or subjective responses (Table 14).

Specifically, the use of reading strategies had positive correlations with task completion time, which resulted in longer task completion time when using reading strategies. However, the use of reading strategies also had positive correlations with comprehension, which translates to better comprehension results when using reading strategies. That is, using reading strategies had negative correlations with time, but positive correlations with overall reading comprehension.

In terms of subjective responses, the use of reading strategies had positive correlations with all three subjective measures (usefulness, ease of use, and satisfaction with the medium). When readers were able to use their reading strategies, they perceived that the given medium enhanced their performance, increased ease of use, and they were more satisfied with the medium.

Table 14. Correlations between reading strategies and performance and subjective response

Reading Strategies	*Time*	*Comprehension*	*Usefulness*	*Ease of Use*	*Satisfaction*	*Overall*
Highlighting/Underlining						
Symbol			0.245 0.011*		0.251 0.009*	√
Note	0.216 0.025	0.322 0.001*	0.218 0.024*		0.195 0.043*	√
Paper Note						
Networking	0.237 0.014*			0.269 0.005*		√
Jumping based on references	0.250 0.009*					√
Micro monitoring			0.322 0.004*	0.257 0.022*	0.232 0.030*	√
Macro monitoring		0.336 0.030*	0.425 0.007*	0.411 0.009*		√

* Significant: an alpha level of 0.05
√: An association between reading strategy and cognitive load measures

4. Discussion

This study focused on (1) examining the impact of the type of reading medium and the generation of the reader on their performance and subjective response, and (2) identifying the relationships between readers' use of reading strategies (readers' behavior), performance outcomes, and subjective response.

4.1. The Impact of Medium and Generation on Performance and Subjective Response

As discussed in Chapter 3, readers' use of reading strategies differed depending on the specific reading medium and personal attributes (i.e., generation). In order to further explain the extent to which reading strategies can be used as process measures, and reading strategies can explain reading differences in comparison to other existing measures, the READING MEDIUM effect and GENERATION effect on both performance and subjective responses were assessed. Overall, while the READING MEDIUM effects on performance measures (i.e., reading speed and overall

comprehension) were not statistically significant, the effects of READING MEDIUM on all three subjective responses (i.e., usefulness, ease of use, and satisfaction with medium) were found to be significant. These results are consistent with previous studies that reported significant differences based on subjective responses, even though there were no differences for either reading from paper or reading from an electronic medium based on performance (Gladwell, 2002; Holzinger et al., 2011; Noyes & Garland, 2008).

Of the two performance measures, only overall comprehension showed trends for MEDIUM and GENERATION. This may be the result of a speed-accuracy tradeoff, since an emphasis was placed on comprehension rather than on speed. Specifically, the older generation had lower comprehension results compared to the younger generation, which reflects age-related differences. This finding is consistent with prior studies. For example, De Beni, Borella, and Carretti (2007) examined age-related differences in reading comprehension for two types of text (narrative and expository) and revealed age-related differences in working memory and meta-comprehension components for the expository text. Hence, for an active reading task with specific goals that requires analytic reading processes, the existence of age-related differences was confirmed. With regard to the READING MEDIUM effect, the comprehension results for all three of the generation groups were higher for the paper condition than for either of the electronic media conditions (Figure 17). Therefore, these results confirmed that despite advances in electronic media used for reading, better performance on a given reading task (reading and summarizing) is achieved with the paper medium.

In terms of subjective response, an effect for READING MEDIUM was identified with all three subjective responses (usefulness, ease of use, and satisfaction with medium). Paper was the preferred medium across all three generations from all three subjective responses. These results confirmed that paper is still considered the most useful, easy to use and satisfactory medium for active reading tasks. It must be noted that some existing studies have shown that electronic reading media could be as satisfactorily used as paper, but those studies' tasks were usually passive reading activities (Noyes et al., 2004). Therefore, when considering the types of reading

activities, the results of this study confirmed that electronic reading media still lag behind for active reading activities.

An interaction effect for GENERATION x READING MEDIUM was found for one of the subjective responses, ease of use. Specifically, the Generation X group ratings for ease of use were in the following order: (1) paper, (2) computer, and (3) iPad. The corresponding results for the Baby Boomers were as follows: (1) paper, (2) iPad, and (3) computer. Similar trends in the medium ratings were also found for usefulness and satisfaction. Although the Generation Y group also showed a slight preference for the iPad over the computer for all three measures, the difference was very small and they generally ranked the two almost equally. These results are interesting, as they indicate that the Generation X group appears to prefer reading from a computer over reading with an iPad, while Baby Boomers prefer the iPad over the computer. These findings are inconsistent with previous reports in the literature that users' technological experience and psycho-physiological factors will influence their preference for a reading medium (Noyes et al., 2004; Wastlund et al., 2005). It should be noted that the Baby Boomers who participated in this study had no previous experience with an iPad, while their experience with a computer extended over more than 20 years (M=20.25, SD=7.86). Therefore, results from this study should be interpreted as originating from generation-related experience as a cultural aspect of age, as discussed in Chapter 3.

As discussed in Chapter 3, this research stressed the importance of culturally situated experience—that this factor affected readers' use of reading strategies. This chapter also showed the impact of reading medium and generation on performance and subjective response; hence, it implies that culturally situated experience also influenced performance and subjective responses. Figure 21 shows a schematic framework for the effects of culturally situated experience on consequences.

4.2. The Relationship Between Readers' Use of Reading Strategies and Performance and Subjective Response

The impact of medium and generation on performance and subjective responses was confirmed, after which the association with other measures was investigated. Significant correlations between readers' use of reading strategies and both performance and subjective responses were identified. Specifically, all correlations showed positive associations. These results confirmed that participants who used reading strategies showed higher responses. Therefore, the findings of this study showed clear associations between readers' use of reading strategies and existing measures (performance and subjective responses). As discussed earlier, as technology advances, existing measures are limited in their ability to elucidate reading differences among media. In contrast, reading strategies can be successfully used to assess the effectiveness of reading media.

The findings discussed here should be further considered when designing reading media and determining appropriate media for targeted reading situations. When the medium supports a person's reading strategies, he or she will be more adept at performing tasks and will demonstrate a better subjective response. As described in this chapter and in Chapter 3, generation-specific usage of reading strategies was observed among participants in this study. Accordingly, it is recommended that both cognitive aspects and cultural aspects need to be taken into consideration when designing reading media.

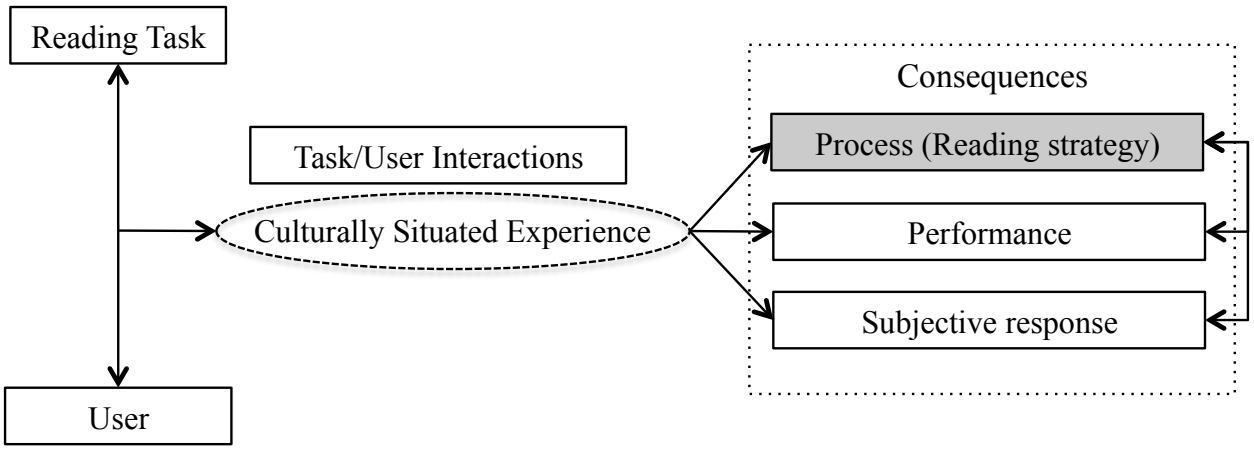


Figure 21. The effects of culturally situated experience on consequences

Despite the potential significance of the findings outlined herein, additional studies are needed to generalize these results. For example, this study utilized a single specific active reading task, namely "reading to learn" and a summarization task, in order to assess participants' reading strategies, performance and subjective responses. A subsequent study using different active reading tasks should be conducted to corroborate the findings of this study and to further our understanding of the role of readers' use of reading strategies in active reading.

CHAPTER 5. THE RELATIONSHIP BETWEEN READERS' USE OF READING STRATEGIES AND COGNITIVE LOAD

Abstract

Reading from electronic media has been regarded as requiring more cognitive resources than reading from paper. However, the specific aspects of reading media that influence cognitive load in terms of cognitive and metacognitive perspectives are not well understood and studies in this area are scarce. As discussed in Chapter 3, although reading strategies can be used as a process measure to assess the effectiveness of reading media, the extent to which reading strategies can explain reading differences in variables such as cognitive load merits further investigation. Consequently, a laboratory experiment was conducted to explore cognitive load during an active reading task using three different media (paper, computer, and iPad). This study examined the impact of the types of reading media and the generation of the reader on cognitive load and investigated the relationship between reader's use of reading strategies and cognitive load. Results showed significant differences on cognitive load depending on different types of reading media and individual attributes (generation). This study also identified an association between readers' use of reading strategies and cognitive load and further discussed how the effectiveness of different reading media can be assessed.

1. Introduction

The use of electronic reading media in both educational and workplace settings offers many benefits, particularly its convenience and rapid access to information anytime and anywhere. Despite these advantages, however, reading from electronic media has been regarded as requiring more in terms of cognitive resources than reading from paper. Indeed, several studies have found a higher load when people read from electronic media (Noyes & Garland, 2003; Garland & Noyes, 2004). Similarly, Noyes et al. reported a higher perceived cognitive workload for a computer-based task than a comparable paper-based task.

When people read from different types of media, it is not entirely clear which aspects of using those media influence which kinds of cognitive load, or how they do so. Existing studies have pointed to several factors, such as the low quality of electronic devices (Mayes, Sims, & Koonce, 2001), a lack of computer experience (Meyer & Poon, 1997), and the influence of psycho-physiological factors (Wästlund et al, 2005). However, electronic media introduced in recent years are greatly improved and are becoming more affordable for users. Therefore, the factors discussed in earlier studies have become less compelling for explaining perceived increased cognitive load when reading from electronic media.

Fundamental research addressing these cognitive aspects is somewhat scarce, in spite of concerns regarding cognitive resources. According to Autor et al. (2003), even though computer technologies have been found to be beneficial for routine cognitive tasks, it is often difficult to apply them to support complex cognitive tasks such as reading comprehension. Therefore, research that focuses on more task-specific cognitive and meta-cognitive perspectives will be imperative for further elucidating a reader's cognitive load when using different types of reading media.

Reading strategies have gathered interest in recent years, with evidence emerging of successful reading in terms of cognitive and metacognitive processes. Studies in the education field have focused on identifying reading strategies that learners use to improve achievement. Such reading strategies can vary depending on aspects such as a reader's personal traits, the type of reading task, and the type of reading media. As described in Chapter 3, the reading strategies that a person utilizes are likely to differ depending on the type of media and their individual attributes (i.e., generation).

The purpose of this study was to investigate the extent to which reading strategies can explain reading differences by investigating associations with cognitive load. Specifically, the cognitive load during an active reading task was investigated utilizing different types of cognitive load measures under three different media conditions (paper, computer, and iPad). The impact of

medium and generation on cognitive load was examined, and then the relationship between cognitive load and a reader's use of reading strategies was identified.

2. Cognitive Load and Working Memory

Cognitive load is defined as "the manner in which cognitive resources are focused and used during learning and problem solving" (Chandler & Sweller, 1991, p. 294). Cognitive load is determined by both the characteristics of the task (i.e., complexity, format, and type of medium), as well as by individual characteristics, which can include age, expertise level, and other factors (Paas et al., 2003). When addressing the concept of cognitive load, mental workload is often invoked. Mental workload includes the demands placed on a reader by the task and is used to explain processing capacity and limitations of working memory (Wickens & Hollands 2000). In contrast, cognitive load considers both working memory, which has a limited capacity, and long-term memory, which is unlimited in this respect—which is why cognitive load is generally used in association with tasks related to learning. Therefore, considering the tasks in this research phase ("reading to learn" and a summarization task), cognitive load represented a more appropriate way to assess the cognitive resources used during the task.

There are three components of cognitive load: intrinsic cognitive load, extrinsic cognitive load, and germane cognitive load. Intrinsic cognitive load refers to the inherent level of difficulty of the task being performed (e.g., instructional material), an extrinsic cognitive load is caused by external factors (e.g., the design of the instructional material), and the germane cognitive load, introduced by Sweller (1988), refers to the processing capacity used to construct schema in performing a task. According to Schnotz and Kürschner (2007), germane cognitive load is the "conscious application of learning strategies (i.e., strategies, which are not yet automated), the conscious search for patterns in the learning material in order to deliberately abstract cognitive schemata (i.e., mindful abstraction) and create semantic macro structures, restricting of problem presentations in order to solve a task more easily (i.e., by insight), meta-cognitive processes that monitor cognition and learning" (p. 496). Accordingly, the important concept of germane cognitive load, along with the extrinsic cognitive load, is expected to explain the reading

strategies people use to perform reading tasks, as well as how those reading strategies can be affected by the use of different media.

Cognitive load theory is based on human cognitive architecture and two important and related assumptions: the unlimited capacity of long-term memory and the limited capacity of working memory. In particular, working memory plays a critical role in explaining human information processing and cognitive load. Working memory is a temporary memory store and concurrently processes information. According to Baddeley (2003), the model of working memory consists of four components: the central executive, the visuospatial sketchpad, the phonological loop and the episodic buffer. Each of the components has limited capacity. The central executive is the primary component for managing tasks and controls the sub-components (visuospatial sketchpad, phonological loop, and episodic buffer). With regard to the three components of cognitive load, extrinsic load would be involved with the work of the sub-components, while germane load would be involved with the central executive's function, as well as with the work of the sub-components.

3. Methods

3.1. Overview of the Experiment

The experiment was conducted in a controlled laboratory setting. Thirty-six participants in three generations of 12 each (Baby Boomers, Generation X and Generation Y) were recruited. Participants were asked to perform reading task with three types of media (paper, computer, and iPad) in a predetermined sequence. Of particular interest for this study was to examine the impact of type of reading medium and the generation of reader on cognitive load and explore the relationships between readers' use of reading strategies and the resulting cognitive load. A description of the participants, media conditions, reading task and overall procedures were provided earlier, in Chapter 3. A pre-experiment questionnaire (computer experience, media usage) was administered and reading strategies identified using the protocol analysis described in Chapter 3. Independent and dependent variables are listed in Table 15.

Table 15. Independent and dependent variables

Variable	Component
Independent variables	• Reading medium (paper, computer, and iPad) • Generation (Baby Boomers, Generation X and Generation Y)
Dependent variables (Table 16)	• Physiological measures of cognitive load • Combined measures (mental efficiency) • Subjective measures of cognitive load

3.2. Cognitive Load Measures

Three types of cognitive load measures were obtained for each participant from each of the three sessions (paper, computer, and iPad), as shown in Table 16.

Table 16. Cognitive load measures

Type	**Measure**	**Description**
Physiological measure of cognitive load	Pupil radius	Task evoked pupillary response
Combined measure (Performance and mental effort)	Mental efficiency	$E = \frac{Z_{Performance} - Z_{Mental\ Effort}}{\sqrt{2}}$
Subjective measure of cognitive load	Overall Cognitive Load	Overall rating of task difficulty
	Intrinsic Cognitive Load	Load exposed by the task itself (e.g., material)
	Extrinsic Cognitive Load	Load beyond intrinsic cognitive load caused from external factors (e.g., instructional material)
	Germane Cognitive Load	Load that can be used to process construction and automation of schemas

(1) Physiological Measure of Cognitive Load

Task-evoked pupillary response (TEPR) was utilized as a physiological measure of cognitive load. Specifically, pupil radius was measured using the ASL (Applied Science Laboratories) mobile head-mounted eye tracker (Applied Science Laboratories, 2007) shown in Figure 22. The eye tracker recorded pupil radius at 30 Hz. In terms of physiological measures, pupil radius is assumed to increase as cognitive load increases (Van Gerven et al., 2004). Pupillary response measurements have the advantage of being objective and providing continuous information, and thus serve as an important impartial method for visualizing cognitive load patterns.

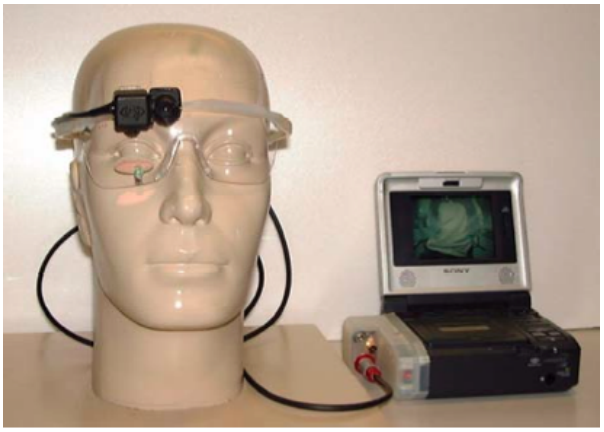


Figure 22. ASL MobileEye eye tracker

Three task-evoked pupillary responses are typically used: mean pupil dilation, peak dilation and latency to the peak (Beatty & Lucero-Wagoner, 2000). In this study, mean pupil radius was utilized.

(2) Mental Efficiency

"Mental efficiency" is a measure that combines an assessment of mental effort (overall cognitive load) with an assessment of performance in order to derive information on the relative efficiency of mental processes (Paas & van Merriënboer, 1993). This measure of mental efficiency is viewed as reliable and thus has been used in many existing studies (e.g., see Paas et al., 2003 for

a review) since it can help explain how people control their loads by adjusting their mental effort and performance. Individual measures of cognitive load such as performance and mental effort (overall cognitive load) are useful for assessing differences in cognitive load depending on different conditions. Nonetheless, research shows that interpreting levels of cognitive load would be made more meaningful by considering associated performance levels (and vice versa) (Paas et al., 2003). For example, readers using a given medium would be considered more efficient if their mental effort (cognitive load) were lower on the basis of their performance, or their performance were higher on the basis of their mental effort (cognitive load). Therefore, by combining the measures of mental effort and performance, one can ascertain signficant information about cognitive load that may not be reflected by one measure alone.

The measure of mental efficiency (Paas & van Merriënboer, 1993) is calculated as follows. The value of mental effort (overall cognitive load) and performance were first standardized. Subsequently, the efficiency score (E) was computed as the perpendicular distance between a z score for mental effort and a z score for performance, as follows:

$$E = \frac{Z_{Performance} - Z_{Mental\ Effort}}{\sqrt{2}}$$

Performance was measured by two outcome measures (reading speed and overall comprehension), as described in Chapter 3. Mental effort was obtained from one subjective measure: overall cognitive load. Two types of mental efficiency were then calculated: (1) mental efficency based on reading speed and mental effort, and (2) mental efficiency based on overall comprehension and mental effort.

(3) Subjective Measure of Cognitive Load

Subjective measures were obtained using four constructs: overall cognitive load, intrinsic cognitive load, extrinsic cognitive load and germane cognitive load. The questionnaire was modified from the instrument developed by Cierniak, Scheiter, & Gerjets (2009) in order to apply it to a reading task. The items were reported on a 7-point Likert scale, anchored at the end points with strongly disagree (1) and strongly agree (7).

In terms of assessing a subjective measure of cognitive load, the use of subjective measure is based on the assumption that individuals are able to examine their own cognitive processes and reliably report their own cognitive load experience. The subjective cognitive load measure (SCL), which is a unidimensional scale, has been widely used in existing studies (Paas et al., 2003). Several recent studies have used multidimensional subjective measures in order to assess the individual subclasses of cognitive load (Cierniak, Scheiter, & Gerjets, 2009; Gerjets et al., 2004; 2006). While the SCL is typically used in the field of cognitive load research, both measures were used in this study: unidimensional measure (overall cognitive load) and multidimensional measure (intrinsic cognitive load, extrinsic cognitive load and germane cognitive load).

3.3. Procedures

In order to gather data on their pupillary response, participants were asked to wear the ASL eye tracker to record their pupil radius during the task. First, participants donned the eyewear with a spectacle-mounted unit (SMU) and adjusted the tension of the headband to make it stable and comfortable (see Figure 21). Second, the researcher adjusted the combiner to capture the eye image and calibrated the point of gaze (POG). During calibration, the participant was asked to look at a series of dots at different locations. After the calibration, a baseline for pupil radius was recorded, and then participants proceeded to perform the given reading task.

In order to assess mental efficiency, the task completion time was recorded as a performance measure (reading speed) during the task and the final written summary was evaluated to provide a measure of overall comprehension by a doctoral student from Virginia Tech's School of Education, as described in Chapter 3. Subjective cognitive load was collected from the post-experimental questionnaire.

3.4. Data Analysis

3.4.1. Data Processing for Pupillary Response

For the data analysis of pupillary response, the analysis unit was first determined. In order to complete the "reading to learn" and written summary tasks, three types of task patterns were

observed (Figure 23). The largest groups of participants (83%) read the text and then summarized the content. A smaller percentage of participants (13%) read the text and composed a draft summary before creating the final version of the summary. The third and least common practice observed by participants (4%) was to read the entire text and then reread the same text prior to writing their summary (4%). Although some participants exhibited rereading and drafting behaviors, this percentage was less than 20% of the total. Therefore, the analyses of pupil data were conducted based on three stages: reading stage, summarization stage and overall stage (reading stage + summarization stage).

Pupillary response data was synchronized with the time line of the activities (baseline, reading stage, and summarization stage). In the time series data, pupil data that were not properly captured by the eye tracker (e.g., blinks) were discarded. Final pupil data for the reading stage and the summarization stage were calculated by subtracting baseline data from the pupil data. Mean pupil radius was calculated for the reading stage, the summarization stage and overall stage (reading stage + summarization stage).

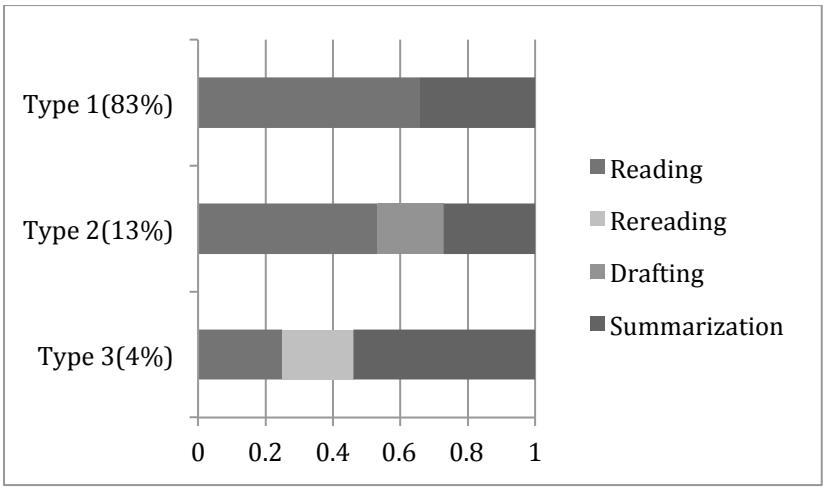


Figure 23. Task patterns on 'reading to learn' reading and summarization task

3.4.2. Quantitative Analysis

First, a Shapiro-Wilk test was conducted to test for normality for all cognitive load measures. All distributions were non-normal. Accordingly, nonparametric data analyses were conducted using

Kruskal-Wallis and Friedman's analysis of variance. To examine the interaction of Generation x Medium, an Aligned Rank Transform (ART) test was conducted (Sawilowsky, 1990; Wobbrock et al., 2011). For the post-hoc paired comparison, a planned F-test was conducted. Effects were considered significant with an alpha level of 0.05.

To determine correlations among cognitive load schemes, a bivariate correlation using a spearman rho was calculated. For correlations between readers' use of reading strategies and cognitive load measures, a spearman rho was calculated for six reading strategies (highlighting, note, symbol, paper note, networking and jumping based on reference) and a rank-biserial correlation was calculated for two reading strategies (micro-monitoring and macro-monitoring).

4. Results

Before examining the cognitive loads associated with the three different media, the order of media and document was tested. As expected, media order effects and document effects were non-significant. The research questions in this study are as follows:

Research question (RQ4): What is the impact of medium and generation on cognitive loads (cognitive load measures)?

Research question (RQ5): What is the relationship between readers' use of reading strategies and their performances, subjective responses, and cognitive loads?

4.1. Task-evoked Pupillary Response

(1) Pupillary Response (Reading Stage)

H_a: Participants' pupillary response on reading stage will differ between reading media.
H_a: Participants' pupillary response on reading stage will differ between generations.

The interaction effect of GENERATION x READING MEDIUM on mean pupil radius for the reading stage was not statistically significant, $F_{(4, 108)}$=1.85, p=0.13. The GENERATION effect was not significant and the READING MEDIUM effect was also not statistically significant.

(2) Pupillary Response (Summarization Stage)

H_a: Participants' pupillary response on summarization stage will differ between reading media.

H_a: Participants' pupillary response on summarization stage will differ between generations.

The interaction effect of GENERATION x READING MEDIUM on mean pupil radius for the summarization stage was not statistically significant, $F_{(4, 108)}$=0.84, p=0.50. The effect of the READING MEDIUM was significant (Friedman one-way ANOVA: $X^2_{(2)}$=18.1667, p=0.0001), but the GENERATION effect was approaching significance (Kruskal-Wallis test; $X^2_{(2)}$=5.2509, p=0.07). Additional paired comparisons showed that pupil radius under the computer condition were significantly higher than for either the paper condition (p=0.03) or the iPad condition (p<.0001) (Figure 24).

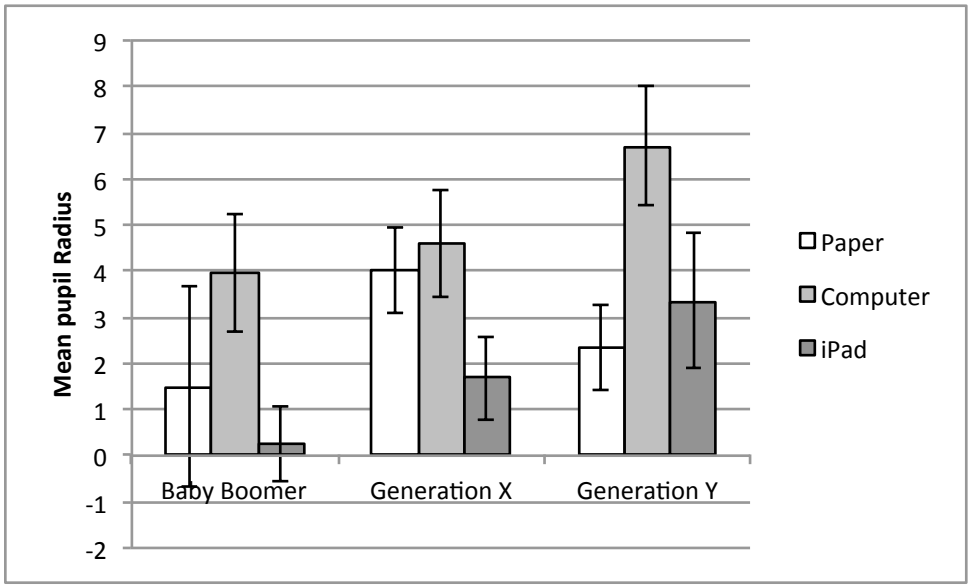


Figure 24. Task-evoked pupillary response (summarization stage) (error bars: 95.00% confidence interval)

(3) Pupillary Response (Overall Stage: Reading Stage and Summarization Stage)

H_a: Participants' pupillary response on overall stage will differ between reading media.

H_a: Participants' pupillary response on overall stage will differ between generations.

The interaction effect of GENERATION x READING MEDIUM was not statistically significant. The effect of the READING MEDIUM was significant (Friedman one-way ANOVA: $X^2_{(2)}$ =11.06, p=0.004), whereas the GENERATION effect was not significant. Additional paired comparisons showed that pupil radius for the computer condition were significantly higher than pupil radius for the iPad condition (p=0.008) (Figure 25).

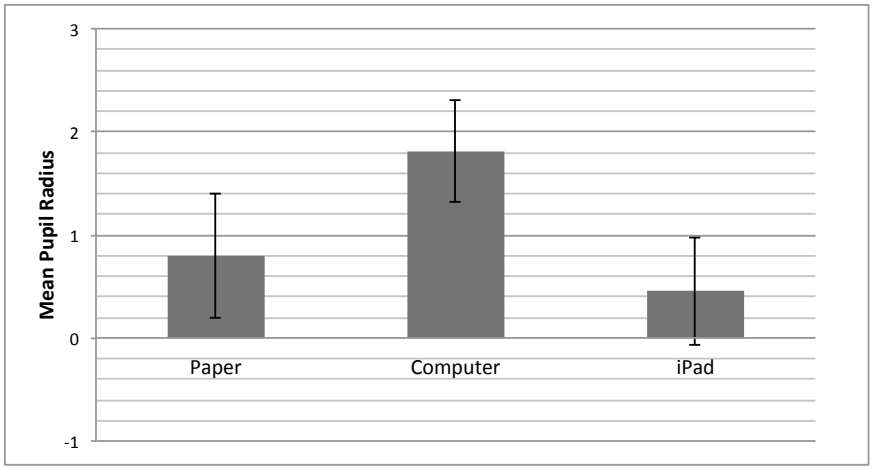


Figure 25. Effect of Medium on overall pupillary response (error bars: 95.00% confidence interval)

(4) Overall Results

In order to conduct an exploratory analysis of the pupil data, task-evoked pupillary response trends across time were plotted and compared. As shown in Figure 26 for Participant 12, pupil radius in the summarization stage increased with computer condition compared to both the paper and iPad conditions.

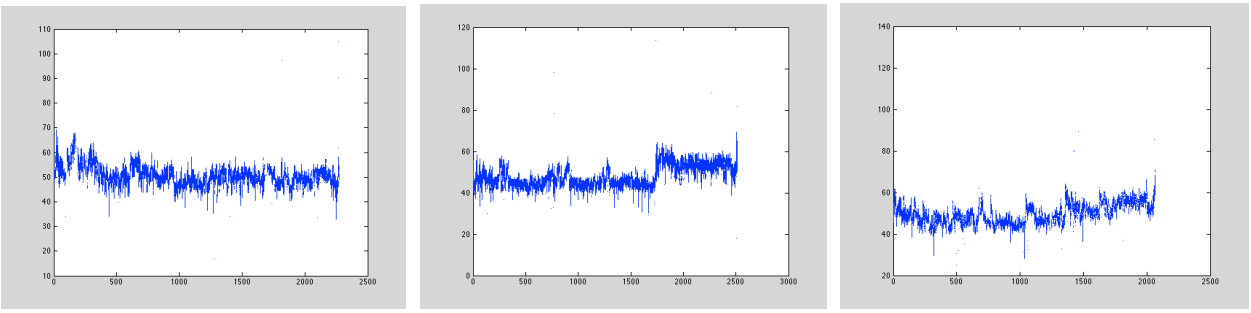


Figure 26. Task-evoked pupilary response on three media (participant 12)

4.2. Mental Efficiency

(1) Mental Efficiency Based on Reading Speed and Mental Effort

H_a: Participants' mental efficiency will differ between reading media.

H_a: Participants' mental efficiency will differ between generations.

The interaction effect of GENERATION x READING MEDIUM was not statistically significant, $F_{(4,\ 108)}$=1.31, p=0.28. The GENERATION effect was statistically significant (Kruskal-Wallis test; $X^2_{(2)}$ =7.42, p=0.02), but the READING MEDIUM effect was not significant. Additional paired comparisons showed that the Baby Boomer group exhibited lower mental efficiency compared to either the Generation X group *(p=0.02)* or the Generation Y group *(p=0.03)*.

(2) Mental Efficiency Based on Overall Comprehension and Mental Effort

H_a: Participants' mental efficiency will differ between reading media.

H_a: Participants' mental efficiency will differ between generations.

The interaction effect of GENERATION x READING MEDIUM was not statistically significant, $F_{(4,\ 108)}$=0.52, p=0.72. The GENERATION effect was statistically significant (Kruskal-Wallis test; $X^2_{(2)}$ =8.99, p=0.01), and the effect of the READING MEDIUM was also significant (Friedman one-way ANOVA: $X^2_{(2)}$ =8.36, df=2, p=0.02). Additional paired comparisons revealed that all three groups (Baby Boomers, Generation X and Generation Y) demonstrated greater mental efficiency when reading from paper than they did when reading from either the

computer (p=0.0001) or the iPad condition (p=0.0001). With regard to Generation effects, the mental efficiency of Baby Boomers was lower than the mental efficiency of the Generation Y group (p=0.003) (Figure 27).

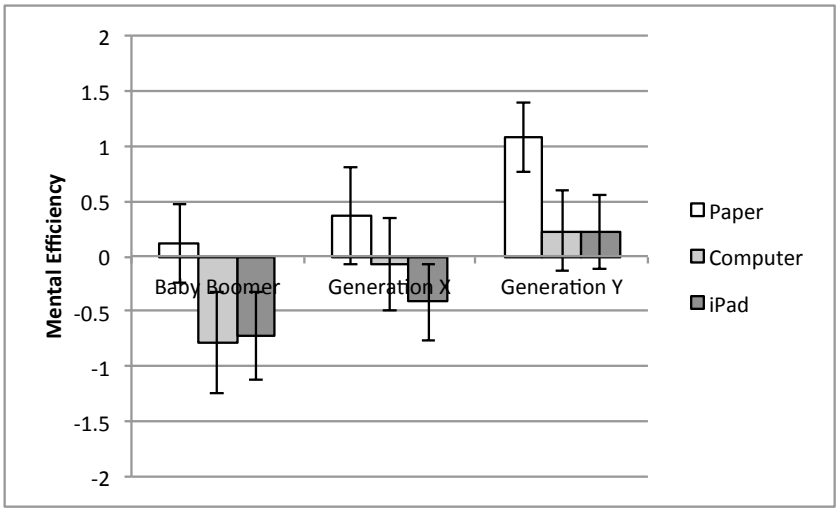


Figure 27. Mental efficiency for different media conditions and generation groups (error bars: 95.00% confidence interval)

4.3. Subjective Cognitive Load

(1) Overall Cognitive Load

H_a: Participants' overall cognitive load will differ between reading media.

H_a: Participants' overall cognitive load will differ between generations.

The interaction effect of GENERATION x READING MEDIUM was not statistically significant, $F_{(4,\ 108)}$=1.83, p=0.13. The effect of GENERATION was statistically significant (Kruskal-Wallis test; $X^2_{(2)}$ =9.91, p=0.007), and the effect of READING MEDIUM was also significant (Friedman one-way ANOVA: $X^2_{(2)}$ =11.73, p=0.002). Additional paired comparisons showed that participants' overall cognitive load ratings were lower when reading from paper compared to reading from the computer (p=0.005) or the iPad (p=0.001). In terms of the GENERATION effect, the overall cognitive load ratings were higher among the Baby Boomer group in comparison to the overall cognitive load ratings for both Generation X (p=0.02) and Generation Y (p=0.003) (Figure 28).

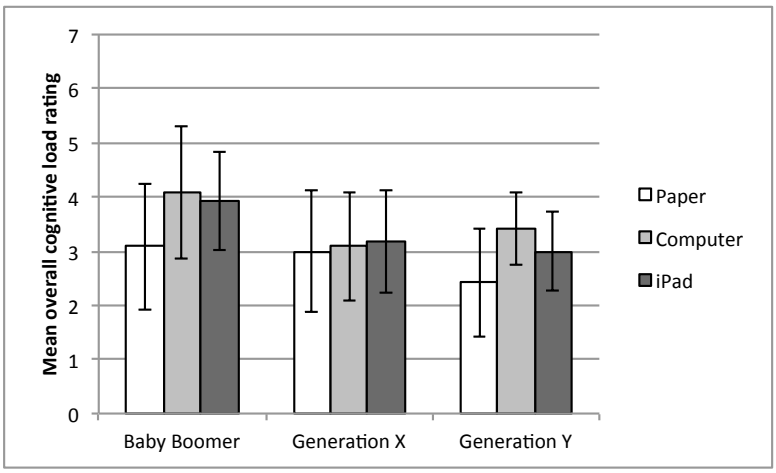


Figure 28. Mean overall load for different media conditions and generation groups

(2) Intrinsic Cognitive Load

H_a: Participants' intrinsic cognitive load will differ between reading media.

H_a: Participants' intrinsic cognitive load will differ between generations.

The interaction effect of GENERATION x READING MEDIUM was not statistically significant, $F_{(4,\ 108)}$=1.14, p=0.34. The effect of GENERATION was statistically significant (Kruskal-Wallis test; $X^2_{(2)}$ =9.28, p=0.01), while the READING MEDIUM effect was not statistically significant. Additional paired comparisons showed that the intrinsic cognitive load rating for the Baby Boomer group was higher than the intrinsic cognitive load rating for Generation Y (p=0.002) (Figure 29).

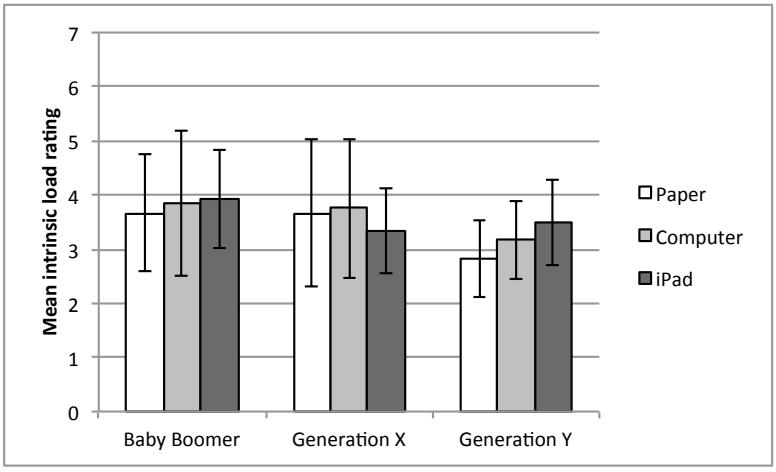


Figure 29. Mean intrinsic load for different media conditions and generation groups

(3) Extrinsic Cognitive Load

H_a: Participants' extrinsic cognitive load will differ between reading media.

H_a: Participants' extrinsic cognitive load will differ between generations.

The interaction effect of GENERATION x READING MEDIUM was approaching significance, $F_{(4, 108)}$=2.43, p=0.06. The effect of GENERATION was statistically significant (Kruskal-Wallis test; $X^2_{(2)}$ =9.81, p=0.01). The READING MEDIUM effect was also statistically significant (Friedman one-way ANOVA: $X^2_{(2)}$ =32.23, p<0.0001). Additional paired comparisons for the interaction effect showed that extrinsic cognitive load ratings between the computer and iPad conditions for the Baby Boomers were approaching significance (p=0.09), and extrinsic load ratings between the computer and iPad conditions for the Generation X group were significant (p=0.01). Specifically, the Baby Boomer group had higher ratings on the iPad than the computer, while the Generation X group had higher ratings on the computer than the iPad (Figure 30).

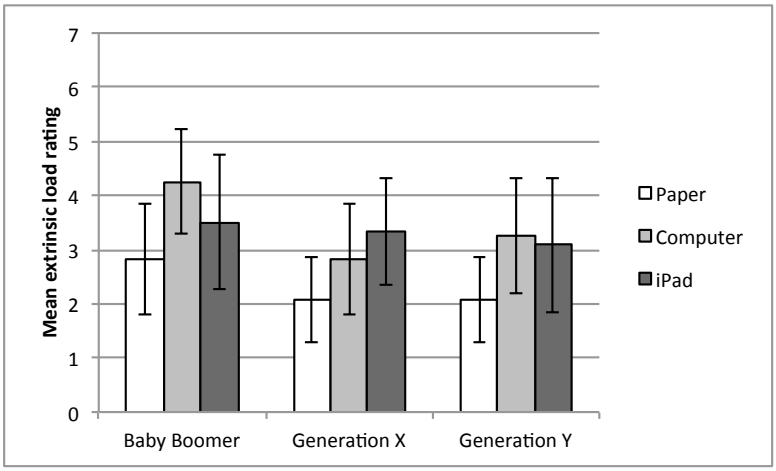


Figure 30. Mean extrinsic load for different media conditions and generation groups

(4) Germane Cognitive Load

H_a: Participants' germane cognitive load will differ between reading media.

H_a: Participants' germane cognitive load will differ between generations.

The interaction effect of GENERATION x READING MEDIUM interaction was not statistically significant, $F_{(4, 108)}$=1.89, p=0.12. The effect of READING MEDIUM was statistically significant (Friedman one-way ANOVA: $X^2_{(2)}$ =8.57, p=0.01), but the GENERATION effect was approaching significance (Kruskal-Wallis test; $X^2_{(2)}$=5.03, p=0.08). Additional paired comparisons showed that participants' germane cognitive load ratings were significantly higher when they read from paper than when they read from either the computer (p=0.004) or the iPad (p=0.03) (Figure 31).

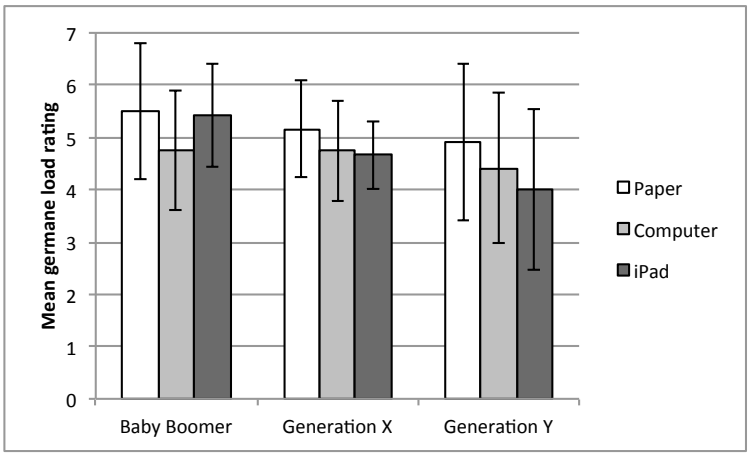


Figure 31. Mean germane load for different media conditions and generation groups

4.4. Correlations Among Cognitive Load Schemes

Table 17 shows correlations among cognitive load measures. There were significant positive relationships among each scheme: physiological cognitive load measures, mental efficiency measures, and subjective cognitive load measures. Mental efficiency measures had statistically significant correlations with subjective cognitive load measures. However, no correlations were found between the physiological cognitive load scheme and other schemes.

Correlations among cognitive load measures by generation group (Table 18, 19, and 20) were also calculated. Results showed that mental efficiency measures had statistically significant correlations with subjective cognitive load across the three generation groups. Physiological cognitive load also showed statistically significant correlations with other schemes with respect to the Generation Y and Baby Boomer groups.

Table 17. Correlations among cognitive load schemes

	Pupil (Reading)	*Pupil (Summary*	*Pupil (Overall)*	*Time_ overall*	*Compre_o verall*	*Overall Load*	*Intrinsic Load*	*Extrinsic Load*
Pupil (Summary)	**0.501 <.001***	1						
Pupil (Overall)	**0.884 <.001***	**0.736 <.001***	1					
Time_overall	0.016 0.871	-0.106 0.287	0.022 0.825	1				
Compre_overall	0.103 0.293	0.161 0.104	0.189 0.055	**0.514 <.001***	1			
Overall Load	-0.091 0.354	-0.098 0.320	-0.145 0.141	**-0.552 <.001***	**-0.765 <.001***	1		
Intrinsic Load	-0.160 0.101	-0.066 0.508	-0.170 0.084+	**-0.307 0.001***	**-0.433 <.001***	**0.504 <.001***	1	
Extrinsic Load	-0.060 0.542	-0.059 0.551	-0.134 0.176	**-0.307 -0.001***	**-0.489 <.001***	**0.646 <.001***	**0.381 <.001***	1
Germane Load	-0.001 0.993	-0.052 0.602	-0.051 0.609	0.068 0.485	0.073 0.456	-0.070 0.472	0.009 0.929	**-0.366 <.001***

* Significant: an alpha level of 0.05

Table 18. Correlations among cognitive load schemes (Generation Y)

	Pupil (Reading)	*Pupil (Summary*	*Pupil (Overall)*	*Time_ overall*	*Compre_o verall*	*Overall Load*	*Intrinsic Load*	*Extrinsic Load*
Pupil (Summary)	**0.485 0.003***	1						
Pupil (Overall)	**0.926 <.001***	**0.637 <.001***	1					
Time_overall	0.134 0.444	-0.272 0.114	0.062 0.724	1				
Compre_overall	**0.477 0.004***	0.133 0.447	**0.402 0.017***	**0.597 <.001***	1			
Overall Load	**-0.384 0.023***	-0.080 0.648	-0.307 0.073	**-0.417 0.011***	**-0.635 <.001***	1		
Intrinsic Load	-0.272 0.115	0.118 0.499	-0.197 0.258	**-0.343 0.040***	-0.325 0.053	**0.388 0.020***	1	
Extrinsic Load	-0.147 0.401	-0.035 0.843	-0.155 0.374	-0.034 -0.844	**-0.360 0.031***	**0.637 <.001***	0.322 0.055	1
Germane Load	0.230 0.185	0.159 0.363	0.218 0.209	0.072 0.679	0.327 0.052	-0.275 0.104	-0.244 0.152	**-0.603 <.001***

* Significant: an alpha level of 0.05

Table 19. Correlations among cognitive load schemes (Generation X)

	Pupil (Reading)	*Pupil (Summary*	*Pupil (Overall)*	*Time_ overall*	*Compre_o verall*	*Overall Load*	*Intrinsic Load*	*Extrinsic Load*
Pupil (Summary)	**0.525 0.001***	1						
Pupil (Overall)	**0.887 <.001***	**0.799 <.001***	1					
Time_overall	-0.118 0.499	-0.156 0.372	-0.160 0.360	1				
Compre_overall	-0.004 0.981	0.175 0.315	0.091 0.602	**0.494 0.002***	1			
Overall Load	-0.047 0.788	-0.091 0.602	-0.057 0.746	**-0.502 0.002***	**-0.759 <.001***	1		
Intrinsic Load	-0.169 0.333	-0.273 0.113	-0.221 0.202	-0.092 0.594	-0.297 0.079	**0.488 0.003***	1	
Extrinsic Load	-0.156 0.371	-0.127 0.466	-0.241 0.164	-0.307 0.069	**-0.526 <.001***	**0.579 <.001***	**0.357 0.033***	1
Germane Load	0.016 0.926	-0.047 0.789	-0.024 0.889	0.248 0.145	0.207 0.226	-0.174 0.311	-0.212 0.214	**-0.457 0.005***

* Significant: an alpha level of 0.05

Table 20. Correlations among cognitive load schemes (Baby Boomer)

	Pupil (Reading)	*Pupil (Summary*	*Pupil (Overall)*	*Time_ overall*	*Compre_o verall*	*Overall Load*	*Intrinsic Load*	*Extrinsic Load*
Pupil (Summary)	**0.428 0.012***	1						
Pupil (Overall)	**0.830* <.001**	**0.743 <.001***	1					
Time_overall	0.040 0.819	0.013 0.942	0.110 0.536	1				
Compre_overall	-0.143 0.407	0.063 0.723	0.005 0.976	0.005 <.976	1			
Overall Load	**0.379 0.023***	0.156 0.363	0.012 0.946	**-0.559 <.001***	**-0.839 <.001***	1		
Intrinsic Load	-0.110 0.524	0.140 0.431	-0.022 0.902	**-0.391 0.018***	**-0.434 0.008***	**0.501 0.002***	1	
Extrinsic Load	0.167 0.332	0.128 0.472	0.084 0.638	-0.313 0.063	**-0.474 0.004***	**0.632 <.001***	0.308 0.068	1
Germane Load	-0.308 0.068	-0.241 0.171	**-0.388 0.024***	0.050 0.775	-0.073 0.671	0.039 0.820	0.275 0.105	-0.313 0.063

* Significant: an alpha level of 0.05

4.5. Correlations Between Readers' Use of Reading Strategies and Cognitive Load Measures

Among the eight reading strategies, seven were significantly correlated with one or more of the cognitive measures (Table 21).

Specifically, the physiological measure of cognitive load had positive correlations only with networking strategy, which indicates higher cognitive load.

In terms of mental efficiency, the use of reading strategies showed positive correlations with two measures of mental efficiency, which indicates lower mental effort on the basis of performance, or higher performance on the basis of mental effort when using reading strategies.

With regard to three components of cognitive load (intrinsic cognitive load, extrinsic cognitive load, germane cognitive load), the use of reading strategy had correlation with each of them. Specifically, intrinsic cognitive load had negative correlation with only one reading strategy. Since intrinsic cognitive load is caused by the inherent level of task difficulty (in this study, the readability of the article), this result was negligible. Extrinsic cognitive load have positive correlation with paper note strategy, which indicates increased load when using paper note strategy. As shown in Chapter 3, paper note strategy was used when participants experienced difficulties using reading media and were unable to use their preferred reading strategy. The existence of a positive correlation between paper note strategy and extrinsic cognitive load also indicates a participant's difficulty with the reading media. Also important to note is that the use of reading strategies had positive correlations with germane cognitive load except note strategy, which means increased germane cognitive load (i.e., greater capacity to process schema construction) when using reading strategies. The paper note strategy had negative correlations with germane cognitive load, which represents a consistent trend with extrinsic cognitive load outcomes.

Table 21. Correlations between reading strategies and cognitive load measures

Reading Strategies	*Pupil (Reading)*	*Pupil (Summary)*	*Pupil (Overall)*	*Time_overall*	*Compre_overall*	*Overall Load*	*Intrinsic Load*	*Extrinsic Load*	*Germane Load*	*Overall*
Highlighting									0.312 0.001*	√
Symbol				0.297 0.002*	0.215 0.025*	-0.240 0.012*	-0.240 0.012*			√
Note				0.313 0.001*	0.363 0.0001*	-0.245 0.011*				√
Paper note								0.198 0.040*	-0.235 0.014*	√
Networking		0.193 0.049*		0.241 0.012*					0.193 0.045	√
Jumping based on references										
Micro monitoring					0.245 0.030*				0.287 0.009*	√
Macro monitoring					0.431 0.006*	-0.339 0.025*				√

* Significant: an alpha level of 0.05
√: An association between reading strategy and cognitive load measures

5. Discussion

In this study using different types of cognitive load measures, the cognitive load during an active reading task using three different media (paper, computer, and iPad) was investigated. The results (1) confirmed significant differences with respect to cognitive load depending on reading medium and generation groups, and (2) identified relationships between a reader's use of reading strategies (readers' behaviors) and cognitive load measures.

5.1. The Impact of Medium and Generation on Cognitive Load

As discussed in Chapter 3, readers' use of reading strategies differed according to the specific reading medium and personal attributes (i.e., generation). In order to further explain the extent to which reading strategies can be used as process measures, and reading strategies can explain reading differences in comparison to other existing measures such as cognitive load, READING MEDIUM effect and GENERATION effect on cognitive load were examined.

Three types of cognitive load measures were used: physiological measure of cognitive load (task-evoked pupillary response), mental efficiency, and subjective measure of cognitive load. Effects due to READING MEDIUM were found for all three types of cognitive load measures. Consistent with the results of previous studies (Noyes et al., 2004; Noyes & Garland, 2003), the data revealed that among the three types of reading media (paper, computer, and iPad), reading from paper generated a lower cognitive load than either of the two electronic media.

In terms of physiological measure of cognitive load, task-evoked pupillary responses were analyzed based on three different stages: reading stage, summary stage, and overall stage (reading + summarization). A significant effect for READING MEDIUM and a trend for GENERATION effect were observed for the summary stage, but only a significant effect for READING MEDIUM for the overall stage. In other words, there were no discernible differences for reading stage regardless of the type of medium employed. However, participants did demonstrate different cognitive loads depending on the type of reading media during the summary stage, which represents the point at which readers are retrieving relevant information and synthesizing it in order to create a final outcome (summarization).

In particular, the pupil radius results when reading from the computer were significantly higher than for either paper or the iPad. This finding implies that participants experienced a higher cognitive load when reading from a computer. There are several possible explanations for this result. First, the reading position itself may have affected pupillary responses. Although the reading positions for both the paper and iPad conditions were identical, reading from a computer requires a different position that may or may not be comfortable for an individual. As discussed in Chapter 3, this factor could negatively influence a person's preference. Second, as shown in Table 14, no correlations were found between physiological cognitive load scheme and other cognitive load schemes. Quite apart from other cognitive load measures, such as subjective measure of cognitive load or mental efficiency, a reader's physical interactivity with the medium may have something to do with pupillary responses. For example, in order to locate specific information in an article, a person using an iPad needs only to swipe up or down on the screen; in contrast, a person reading from a paper document must exert more physical movement to

manipulate and organize the pages. This may explain why the iPad condition, which has a similar reading position and requires less physical interactivity in comparison to the paper condition, showed the lowest physiological cognitive load.

Two types of mental efficiency constructs were examined based on two outcome measures—reading speed and overall comprehension. Only the GENERATION effect was noted with respect to mental efficiency with reading speed; in contrast, both READING MEDIUM and GENERATION effects were found for mental efficiency with overall comprehension. Mental efficiency with overall comprehension showed the most significant results. This finding may be due to a speed-comprehension tradeoff, since participants were instructed to value comprehension over speed. Specifically, these results indicate that participants reading from paper were more efficient in comparison to when they read from either of the electronic media (computer or iPad); in short, paper was still the most efficient reading medium overall in our assays. In terms of GENERATION effect, the youngest generation group (Generation Y) demonstrated more efficiency than the oldest generation group (Baby Boomers).

In terms of the subjective cognitive load results, three types of cognitive loads were examined separately: intrinsic cognitive load, extrinsic cognitive load and germane cognitive load. For intrinsic cognitive load, only Generation effect was manifested, which reflects age-related differences regarding the load perception of the task itself. Both READING MEDIUM and GENERATION effects were found for the extrinsic load, while a significant effect of READING MEDIUM and a trend for GENERATION effect were identified for germane cognitive load. These results indicate that paper had a lower extrinsic cognitive load and a higher germane cognitive load in comparison to either of the electronic media. Additionally, the younger generations (Generation X and Y) reported lower extrinsic cognitive loads and higher germane cognitive loads than the Baby Boomers when performing the given reading task with the three different types of media. These results confirmed that paper represents a medium requiring a low manipulative load (extrinsic load), while at the same time facilitating an effective reading experience in schema construction and schema automation (germane load) for reading activities.

Even though there was no interaction effect identified for GENERATION x READING MEDIUM (except a trend for extrinsic cognitive load ratings), a trend was identified for extrinsic cognitive load and germane cognitive load. Specifically, the Generation X group had lower extrinsic cognitive load ratings and higher germane cognitive load ratings in the following order: (1) paper, (2) computer, and (3) iPad. The Baby Boomer group had lower extrinsic cognitive load ratings and higher germane cognitive load ratings in the following order: (1) paper, (2) iPad, and (3) computer. As with the results for subjective measures described in Chapter 4, the Generation X group exhibited lower cognitive loads when reading from a computer as opposed to reading from an iPad, the opposite of the findings for the Baby Boomers, who had lower cognitive loads with the iPad than the computer. Therefore, as discussed in Chapters 3 and 4, it was confirmed that the extent to which different generations can effectively use their reading strategies with a particular medium is a significant factor for regulating their cognitive load.

5.2. The Relationship Between Readers' Use of Reading Strategies and Cognitive Load

As discussed in Chapters 3 and 4, in order to use reading strategies as valid process measure, they should show correlations with existing measures such as cognitive load. Significant correlations between readers' use of reading strategies and each cognitive load measure were identified. As shown in Table 21, the use of reading strategies was negatively correlated with overall cognitive load, intrinsic cognitive load and extrinsic cognitive load, leading to a decreasing cognitive load. Additionally, the use of reading strategies was positively correlated with mental efficiency measures and germane cognitive load, corresponding to better efficiency in supporting effective reading. Therefore, these results confirmed an association between a reader's use of reading strategies and cognitive load measures and the importance of supporting a reader's use of reading strategies; consequently, reading strategies can be used to assess the effectiveness of reading media. Furthermore, this result also supports the importance of certain generation-specific usages of reading strategies based on generation-specific reading practices as a result of the Generation effect on the use of reading strategies reported in Chapter 3.

As discussed in Chapter 3 and 4, this research has shown the importance of culturally situated experience in a reader's use of reading strategies. This study (Chapter 5) confirmed the impact of reading medium and generation on cognitive load, hence, it also implies that culturally situated experience can influence cognitive load. Figure 32 shows a schematic framework for the effects of culturally situated experience on consequences.

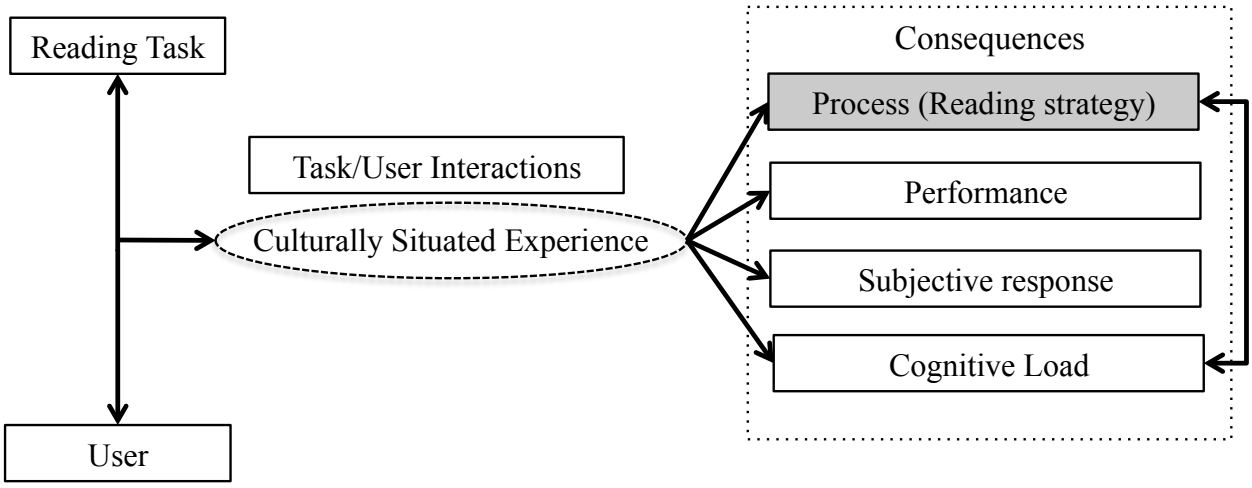


Figure 32. The effects of culturally situated experience on cognitive load

More specifically, Figure 33 shows how culturally situated experience influences cognitive load. Reading strategies as process measures are the ones that effectively reflect both cognitive aspect and cultural aspect—i.e., culturally situated experience. Therefore, as documented in Figure 32, culturally situated experience was assumed to signify readers' use of reading strategies in explaining cognitive processes and cognitive load theory. Difficulties with using different reading media would likely burden components in working memory (and its limited capacities). Processing visual information (visuospatial sketchpad) as well as verbal information (phonological loop) would be challenged, which can lead to extrinsic cognitive load in the CLT. Difficulties with the functioning of the sub-components and central executive would thus be significantly linked to a reader's use of reading strategies, resulting in further germane cognitive load.

This study is important in that it clarified which aspects of using electronic medium could impose cognitive load. As confirmed by reading strategy outcomes, culturally situated experience could reduce extrinsic cognitive load and impact one's capacity for germane cognitive load. It is difficult, however, to clearly define how readers' behaviors are connected with functions in working memory and specific load in CLT. Future neuroimaging techniques such as positron-emission tomography and functional magnetic resonance imaging may explain these interesting relations, but at present they are still somewhat intrusive and difficult to utilize.

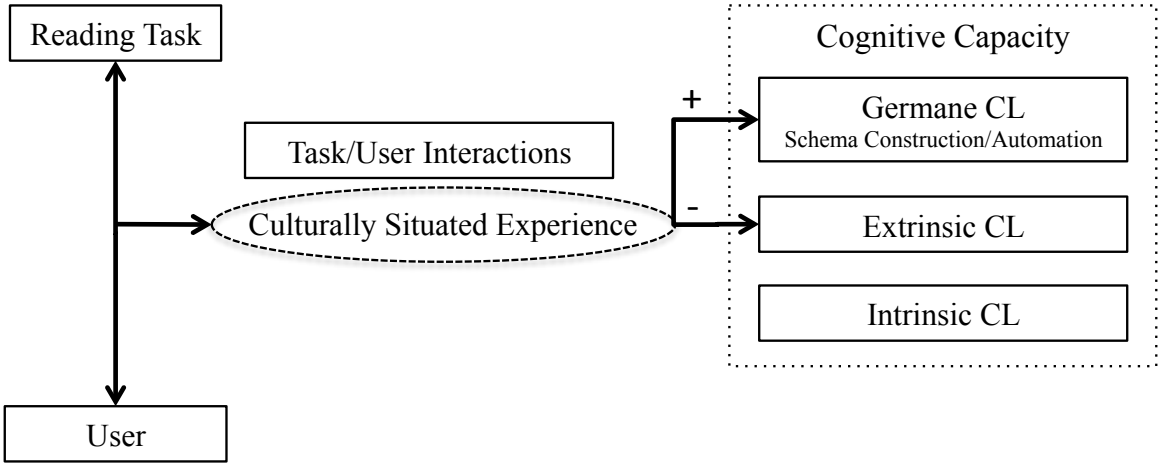


Figure 33. The effects of culturally situated experience on cognitive load

In summary, this study confirmed the association between reading strategies and cognitive load, wherein a reader's effective use of reading strategies is critical for their cognitive load results. Given this finding, designers should take this relationship into account in future designs for reading media to reduce the cognitive load of readers. Second, as revealed in this study and in the prior studies (Chapters 3 and 4), there is a definite generation-specific usage of reading strategies. These findings should thus be considered in determining appropriate reading media for certain situations (e.g., task-based, worker group-specific, or learner group-specific) in order to maximize the advantages of using a given reading technology.

In addition, from a methodological perspective it is important to note that this study delivered useful results by employing several different types of cognitive load measures. Previous studies (Mayes et al., 2001; Noyes et al., 2004) used mental workload rather than cognitive load for examining cognitive resources. Nonetheless, even though the concept of mental workload is useful for explaining processing capacity within a person's working memory, cognitive load that explains processing in both working memory and long-term memory is more suitable for the type of task used in this study. In addition, by utilizing three types of subjective cognitive load ratings (intrinsic cognitive load, extrinsic cognitive load, and germane cognitive load), this study was able to elucidate the differences for all three types of cognitive load in the context of different types of media and individual attributes (i.e., generation).

There are several limitations associated with this study. With regard to physiological cognitive load measures, the pupil radii of the younger participants in this study (Generation X and Generation Y) tended to be wider than the pupil radii of the Baby Boomers. This could be the result of naturally occurring physiological declines in pupil radius with age. As discussed by Van Gerven et al. (2004), older people's eyes tend to have smaller dilation capacity than younger people's eyes. This physiological fact makes direct comparisons of pupillary responses between younger people and older people problematic at best. Therefore, even though trends regarding Generation effect were observed for pupillary response (during the summarization stage), only the Reading Medium effect could be empirically confirmed by the results. In other words, despite the fact that pupillary response is generally regarded as a highly sensitive and valid measure for assessing cognitive load (Paas et al., 2003), generation-specific outcomes using this factor cannot be proven at this time. Thus, in order to examine Generation effects on physiological cognitive load, other measures should be considered.

Further studies are needed to confirm the findings discussed in this study. As detailed in Chapters 3 and 4, this study used a single reading task as a representative active reading task. Therefore, future studies using other active reading tasks should be conducted to certify a reader's use of reading strategies and generation-specific usage of reading strategies.

CHAPTER 6. OVERALL DISCUSSION AND LIMITATIONS

This chapter will discuss findings across three chapters (Chapter 3, Chapter 4, and Chapter 5).

(1) Age Effect Vs. Generation Effect

Regardless of age or generation, when people read, both biological and cultural influences are at work in the cognitive processing of reading activities. With regard to reading from different reading media, crystallized intelligence in working memory, which is based on experience and knowledge, would play a critical role as a cultural factor. As discussed in Chapter 2 (Section 4 and 8), crystallized intelligence increases with age and a reader will use it when he or she reads from any type of reading media. In the case of Baby Boomers—who in this study had no prior reading experience with the iPad, nonetheless used their crystallized intelligence honed from reading from paper and applied it to reading from the iPad.

As discussed in Chapter 2 (Section 8), age effect indicated a continuous trend while generation effect signified a discontinuous trend. As shown in readers' use of reading strategies (Figure 15), participants' use of reading strategies did not continuously decrease or increase among the three generation groups according to the order of age groups. Specifically, participants used symbol in the following generation order: (1) Baby Boomer, (2) Generation Y, and (3) Generation X. In contrast, participants used notes in the following generation order: (1) Generation X, (2) Generation Y, and (3) Baby Boomer. Therefore, the pattern of readers' use of reading strategies was discontinuous with generation groups.

As also discussed in Chapter 2 (Section 8), performance differences between younger and older adults can be justified as an age effect in cases when different generation groups use the same strategies (Baltes, Reese, & Lipsett, 1980). However, as shown in Chapter 3 (Section 4.5.1), Generation X group tended to use both highlighting and note, while Baby Boomers were inclined to use both highlighting and symbol. Differences among generations are difficult to link to age effect since the three generation groups used different set of strategies, and the use of reading

strategies had an association with both subjective responses (Table 14) and cognitive load (Table 21).

As shown in readers' use of reading strategies (Chapter 3), in their subjective responses (Chapter 4) and in cognitive load results (Chapter 5), Baby Boomers favored the iPad over the computer, while Generation X favored the computer over the iPad—and this preference would be unlikely to change as they aged. If such results were based solely on age effect, it could be assumed that members of Generation X would alter their preference in favor of the iPad when they got older. However, this extrapolation is not reasonable as showed by the underlying reasons (generation-specific reading practice) for their use of reading strategies, the subjective responses, and cognitive load results. Consequently, the results from this study showed the generation effect.

(2) Confounding Effects from Experience

This study confirmed the importance of reading experience during the formative period (before 18 years) rather than overall reading experience over a person's lifetime in reading media preferences. It should be noted that this study included a familiarization session during which participant were instructed about using the electronic media; they also performed trial tasks in order to minimize any confounding effects from experience.

In addition, as shown in Chapter 3, Baby Boomers' computer experience (M=20.25, SD=7.86) was higher than Generation X (M=18.67, SD=4.91) and Generation Y (M=11.75, SD=3.62). Additionally, none of the Baby Boomers had any prior experience reading with an iPad before taking part in this experiment. Nonetheless, the fact that Baby Boomers favored the iPad over the computer shows that their behaviors, preferences, and cognitive load were related to their reading experiences during their formative years rather than overall experience over their lifetime.

However, to further verify the importance of reading experience during one's formative period a time-lag study would be required. In other words, such a study would examines people's

behaviors, preference, and cognitive load at different points in time, which would be essential for clarifying whether differences are due to either generation or time.

(3) The Extent to Which the Results from This Research Can Be Applied to Other Reading Tasks and Explain Reading Differences Among People

As discussed in several studies (Oyserman, 2011; Smith-Jackson, 2011), culture is based on context, which implies that cognitive processes such as thinking and acting are context sensitive. This notion can explain the extent to which the results from this research can be applied to other reading tasks and explain reading difference among people.

As discussed in Chapter 2 (Section 7), it was expected that reading strategies would play a role in explaining active reading since it requires dynamic cognitive processes such as thinking, learning and decision-making. Accordingly, "reading to learn" (and the subsequent creation of a written summary) was used as an active reading task in this study. While the results from this study could be applied to other active reading tasks, further studies using other active reading tasks should be conducted to confirm the applicability of this study to other situations. In addition, as a conceptual finding, this study detailed the importance of culturally situated experience and envisions that such culturally situated experience would be critical with regard to non-routine cognitive activities. Again, in order to verify these associations, additional studies using diverse activities are required.

As discussed in Chapter 2 (Section 8), the reasons for selecting three generation groups and specific categorizations (age ranges) were based on Howe and Strauss (2009)'s generation cycle in American history and Oblinger (2004)'s view that different generations are a "product of their environment." For this study, every participant was a native English speaker and a resident of the U.S. Thus, these results would not be applicable to people in other countries since environmental influences and cultural traditions differ across countries.

(4) The Extent to Which the Results from This Research Can Explain Reading Differences on Different Types of Media

As shown in Chapter 3, in terms of the use of reading strategies, Baby Boomers favored the iPad over the computer, while Generation X preferred the computer over the iPad. Both generations reported hardware characteristics (physical position: Vertical vs. Horizontal) as well as software characteristics (interface: GUI vs. TUI) for their preference. In order to explain additional underlying reasons for reading media preferences, one would need to clarify which aspects play a role in readers' use of reading strategies. This research used three types of media: paper, computer and iPad. The computer is vertically situated with a GUI interface, while the iPad is horizontal with a TUI interface. However, the different combinations between hardware and software (i.e., vertical versus horizontal, or TUI versus GUI) were not specifically addressed in this study. Thus, further research is needed to clarify how software and hardware characteristics are coupled with each other in ways that could influence reading media preferences. Similarly, although the applications used in the computer and iPad are representative software for those media, their usability was not directly assessed. With respect to participants' behaviors, preferences, and cognitive load, there might be confounding effects due to the usability of the software. In other words, participants might have preferred the paper condition because of the poor usability of the software on the computer and iPad. Further studies are required to exclude any confounding effects from software usability. It would also help to clarify the impact of hardware characteristics and software characteristics on participants' behaviors, preferences, and cognitive load.

CHAPTER 7. RECOMMENDATIONS

As noted earlier, the current workforce is aging and includes diverse age groups. With the introduction of new technology, workers of all ages need to be able to effectively use whatever systems are in place. As shown in this study, with regard to an active reading task, reading strategies can be used as process measures to assess the effectiveness of reading media. This research also generated the following recommendations to be considered when designing or assigning reading media (e.g., the design of workstation or training system) in the workplace and educational settings.

(1) Use an Integrated Approach to Consider Both Cognitive and Cultural Aspects.

This research presents the importance of culturally situated experience for non-routine cognitive activities. In order to elucidate these experiences, an integrated approach is needed that takes into account both cognitive and cultural aspects in designing human-computer interactions for non-routine cognitive activities. Cognitive aspects have been studied for many years and they are still essential factors in explaining how the use of different technology impacts the way we act. Cultural aspects have not yet been widely considered; in particular, the established experience during the formative period should be considered. As shown in this research (Chapters 2 and 3), the mental model and affordance played a critical role in explaining how people understand and behave differently based on their experience and cultural conventions. Therefore, in modeling or designing human-computer interaction, this approach should be considered.

(2) Gather Information Not Only About Users' Current Context of Use, but Also About Users' Context of Use During the Formative Period.

As discussed in Chapter 3, participants' current cognitive and metacognitive processes are largely based on their experience during the formative period. For example, Baby Boomers showed a tendency to use symbol, and the underlying reasons for selecting this particular annotation strategy can be found in their experience during their formative period. Besides task-

related factors, other factors affecting users' perceptions may also be related to generation-related experience during the formative period. In this study, the physical position when reading a text was important for participants' preference and preferred physical position was based on users' experience during their formative period. Therefore, when designers or researchers specify users' context of use and requirements, it is necessary to gather information not only about users' current context of use but also about their context of use during the formative period.

(3) Do Not Make Any Assumptions About the Needs of Older Populations.

It should be noted that Baby Boomers' opinions of reading from the iPad changed after the experiment. As shown in Chapter 3 (Section 4.5.), Baby Boomers expected that they would have more difficulty with the iPad than with the computer, but in fact found the opposite to be the case. When conducting research with older populations, there is always the risk of judging their needs, capabilities and preferences based on the researcher's own perspectives. But as shown in this research, researchers and industrial designers may need to focus on generation effects rather than age effects in order to determine preferences among specific population/age groups. Therefore, designers or researchers must be cautious in forming prior assumptions when specifying users' needs, capabilities, and limitations.

(4) Create Design Solutions to Support or Facilitate Users' Cultural Practices.

As discussed in Chapter 2 (Section 5), different cultural groups (generation in this research) are likely to have their own cultural meta-schema containing a specific mental model. This study showed that different generation groups have different mental models for reading practices with regard to active reading activities (the given task in this study), and these different mental models affect people's behaviors, performance, subjective responses and cognitive load. Therefore, designers or researchers should create design solutions to support or facilitate users' cultural practices for active reading activities.

(5) Consider the Impact of One Change on Other Task Processes.

Many studies have focused on examining the differences among different reading media based on one specific function or strategy. As discussed in Chapter 3, even though participants used the same annotating strategies on different media, maintaining the same annotating strategies across the three different media resulted in participants having to change their reading processes. In addition, the difficulty of incorporating related information leads to changes in one's actual reading processes. Hence, when designers design or evaluate design solutions, they should consider to what extent a change in one function will affect other task processes.

(6) Recommendations Regarding Experimental Design and Evaluating Solutions:

- Within-subjects design should be considered in order to clarify how the different types of media influence users' behaviors, since users' reading behaviors often differ considerably.
- For dependent measures, cognitive processes such as reading strategies should be considered because such cognitive process explains the underlying reasons on participants' behaviors, preference, and cognitive load. In particular, the way users utilize diverse reading strategies to successfully complete a reading task should be considered rather than focusing on a single reading strategy.
- For dependent measures, researchers should not form conclusions based on one type of measure. In particular, performance measures in this study were limited to explaining differences in reading from different media; other measures such as subjective responses and cognitive load should be considered in confirming their findings.
- As dependent measures, researchers should be careful in using physiological cognitive load measures such as pupillary responses. As discussed in Chapter 5, pupillary response is highly affected by physical interactions and may not accurately reflect the true cognitive load experienced. Therefore, physiological cognitive load should be interpreted in conjunction with other types of cognitive loads (e.g., subjective cognitive load).

CHAPTER 8. CONCLUSION

1. Summary

The overall objective of this research was to develop and evaluate a new to test the effectiveness of reading media in terms of supporting design and evaluation. Specifically, this research examined how reading strategies can be used as a process measure. First, this study investigated readers' use of reading strategies based on different types of media and associated generational differences. A laboratory experiment was conducted in which three-generation groups (Baby Boomers, Generation X and Generation Y) were asked to perform an active reading task (work-related reading task) with three types of media (paper, computer, and iPad) in a predetermined sequence. Readers' use of reading strategies was collected from task observation and RTA (Retrospective Think Aloud) sessions. Quantitative analyses revealed significant differences in a reader's use of reading strategies depending on the medium and their individual attributes (i.e., generation). Detailed qualitative analyses were conducted to elucidate these findings.

Second, this research investigated the relationships between a reader's use of reading strategies and other measures: outcome-based measures (performance and subjective responses) and cognitive load measures. Reading speed and overall comprehension were employed as the performance measures, while subjective measures (subjective responses) were obtained using three constructs: usefulness, ease of use, and satisfaction. In terms of the cognitive load, three types of cognitive load were obtained: physiological cognitive load, mental efficiency, and subjective cognitive load. Quantitative analyses revealed that readers' use of reading strategies had clear associations with their performances, subjective responses, and cognitive loads.

2. Major Outcomes and Contributions

Overall, this research demonstrated how reading strategies could be used as process measures to assess the effectiveness of media for active reading activities. Active reading (the focus of this

research) is a non-routine cognitive activity that represents an essential activity in the workplace or classroom. Considering reading activities in those settings, two aspects should be considered: medium and person. The medium used in reading is changing with recent advances in technology. Accordingly, the person who relies almost exclusively on paper may wish to experiment with electronic reading media. Therefore, it is important to ensure that the use of electronic reading media supports reading activity as effectively as the traditional medium (i.e., paper) did.

However, studies have failed to uncover significant differences associated with reading from different media or have found conflicting results from different measures, although people are known to show a preference for either reading from paper or reading from an electronic medium and may resist changes in the workplace (Gladwell, 2002; Haper and Sellen, 1995; Holzinger et al., 2011; Potthast, 2008). This research focused on investigating the reading strategies that people use in terms of cognitive and metacognitive strategies and how the use of different media affect these strategies. In particular, different generation groups were considered since cognitive and metacognitive capabilities, like reading strategies, are established during the formative period.

This research showed that reading strategies can effectively reflect both cognitive and cultural aspects and can be used as a process measure to assess the effectiveness of electronic reading media. The act of reading is a cognitive process, but there are few reports of how the use of different reading media affects readers' cognitive and metacognitive reading processes. This research therefore focused on investigating the reading strategies that people of different generations use and how different media affect these strategies. Using both quantitative and qualitative data, the findings revealed that readers' use of reading strategies differed depending on the medium used and individual attributes (i.e., generation). Based on such findings, this research presented the importance of culturally situated experience, which is an established experience that a person inculcates using certain artifacts during his or her formative period. This culturally situated experience affects current usage of different artifacts for performing the

task—in this case the reading strategies that participants employed in reading with different media.

This research also showed the extent to which reading strategies can explain reading differences by investigating the associations between readers' use of reading strategies and other measures (performance, subjective response, and cognitive load) that are traditionally used in research in this area. Performance and subjective responses are often used to assess the efficacy of different reading media as outcome-based measures, but contradictory results have been reported and the underlying aspects that influence readers' performance and subjective responses have not yet been clearly identified. With respect to cognitive load, reading from electronic media is generally regarded as requiring more cognitive resources than reading from paper, but precisely which aspects of reading media influence cognitive load in terms of cognitive/metacognitive perspectives is not well understood. The results reported herein show that investigating reading strategies could effectively explain the reading differences associated with different media in terms of performance, subjective responses, and cognitive load.

It is expected that these results will contribute to the design of better electronic reading media for active reading activities (e.g., work-related reading activities). This research proved the importance of effectively supporting readers' use of a range of reading strategies. In order to improve the use of each strategy, various design implementations can be generated and their efficacy evaluated based on the methodology used in this research. With respect to generation-related effects, designers need to be aware of these issues and incorporate them when designing electronic reading media.

These results will also contribute to the determination of appropriate reading media for particular situations (e.g., task-based, worker group-specific, or learner group-specific) in order to successfully introduce and encourage users to utilize electronic reading media. This research has shown that readers' use of reading strategies is associated with performance, subjective responses, and cognitive load. Therefore, it is necessary to select suitable reading media that effectively support readers' use of reading strategies. In terms of the generation-related effect, it

is important to make use of suitable reading media that take into account user group characteristics.

In terms of the conceptual aspect of this research, this study presented the importance of culturally situated experience for non-routine cognitive activities. It also suggests the use of an integrated approach that takes into account both cognitive and cultural aspects in designing human-computer interaction for non-routine cognitive activities. Further studies are required to explore this notion, but this perspective can be applied to a variety of other application domains.

3. Future Work

Future studies should focus on generalizing the findings reported in this study. As discussed in Chapters 3, 4, and 5, this study used a single reading task to represent a wide variety of active reading tasks. Therefore, future studies using other active reading tasks should be conducted to verify readers' use of reading strategies and the generation-related effect.

As discussed in Chapter 3, this study included directly recognizable reading strategies from behaviors and verbal protocols. In order to explain a wider range of metacognitive strategies, future studies are needed to develop more comprehensive methods to evaluate the reading strategies that people utilize with different media.

In terms of cognitive load measures, as discussed in Chapter 5, the generation effect cannot be confirmed using only the physiological measure of cognitive load (i.e., pupillary responses) due to the physiological deterioration of the human eye with age. Future studies using other physiological measures must be devised in order to reveal a generation-related effect in terms of physiological cognitive load.

As discussed in Chapter 5, mental workload is often mentioned alongside cognitive load. Existing studies have frequently used the NASA-TLX (an assessment of perceived workload) to examine subjective cognitive load. Future studies using both assessments (subjective cognitive

load and workload) should be considered in order to further validate the use of the multidimensional subjective cognitive load measures used in this study.

This study has highlighted the importance of culturally situated experience and the use of an integrated approach that considers both cognitive and cultural aspects with respect to non-routine cognitive activities. In order to further support this notion, future studies of other cognitive activities and application domains should be conducted.

REFERENCES

Adler, A., Gujar, A., Harrison, B. L., O'Hara, K., & Sellen, A. (1998). A diary study of work-related reading: design implications for digital reading devices, *In Proceedings of CHI98*, 241–248.

Adler, M.J. and van Doren, C. (1972). *How to Read a Book*. Simon and Schuster, New York, NY.

Afflerbach, P., Pearson, P. D., & Paris, S. G. (2008). Clarifying differences between reading skills and reading strategies. *The Reading Teacher, 61(5),* 364–373.

Alben, L. (1996). Quality of experience: defining the criteria for effective interaction design. *Interactions, 3,* pp.11-15.

Alexander, P. A., & Jetton, T. L. (2000). Learning from text: A multidi- mensional and developmental perspective. In M. Kamil, P. Mosenthal, P. D. Pearson, & R. Barr (Eds.), *Handbook of reading research* (Vol. 3, pp. 285–310). Mahwah, NJ: Erlbaum.

Altun, A. (2000). Patterns in cognitive processes and strategies in hypertext reading: a case study of two experienced computer users. *Journal of educational multimedia and hypermedia, 9(1),* 35-55.

Anderson, R. C., & Pearson, P. D. (1984). A schema-theoretic view of basic processes in reading comprehension. In P. D. Pearson (Eds.), *Handbook of reading research* (255-291). New York: Longman.

Andre, T., Hartson, H. R., Belz, S. & McCreary, F. (2001). The user action framework: a reliable foundation for usability engineering support tools. *International Journal of Human-Computer Studies, 54(1),* 107-136.

Applied Science Laboratories, (2007) Applied Science Laboratories (2007). *MobileEye Operation Manual*. Applied Science Group Company, Bedford, MA, 1.32 edition.

Autor, D. H., Levy, F., and Murnane, R. J. (2003). The skill content of recent technological change: an empirical exploration. *Quarterly Journal of Economics, 118 (4)*. 1279-1333.

Baddeley, A. (2003). Working memory: looking back and looking forward. *Nature Reviews. Neuroscience, 4*, 829-839.

Baddeley, A. D., & Hitch, G. (1974). Working memory. In K. W. Spence and J. T. Spence (Eds.). *The Psychology of Learning and Motivation. Vol. 8* (pp. 67-89). New York: Academic Press.

Baltes, P. B., Reese, H., & Lipsett, L. (1980). Lifespan developmental psychology, *Annual Review of Psychology, 31,* 65-110.

Bartlett, F. C. (1932). *Remembering: an experimental and social study*. Cambridge University Press.

Beatty, J., & Lucero-Wagoner, B. (2000). The pupillary system. In J. T. Cacioppo, L. G. Tassinary, & G. G. Berntson (Eds.), *Handbook of psychophysiology* (pp. 14–162). Cambridge, UK: Cambridge University Press.

Becker, H. A. (2000). Discontinuous change and generational contracts. In S. Arber and C. Attias-Donfut (Eds.), *The myth of generational conflict*, 114–132. England: Routledge & Keegan Paul.

Belmore, S. M. (1985). Reading computer-presented text. *Bulletin of the Psychonomic Society, 23(1)*, 12–14.

Bevan, N. (1995). Measuring usability as quality of use. *Software Quality Journal, 4(2),* 115–130.

Booth, P. A. (1989). *An introduction to human-computer interaction*. London: Lawrence Erlbaum Associates.

Borgman, C. L. (1986). The user's mental models of an information retrieval system: an experiment on a prototype online catalog, *International Journal of Man-Machine Studies, 24(1)*, 47-64.

Brown, G. J. (2001). Beyond print: reading digitally. *Library Hi Tech, 19(4),* 390–399.

Brünken, R., Plass, J., & Leutner, D. (2003). Direct Measurement of Cognitive Load in Multimedia Learning. *Educational Psychologist, 38(1)*, 53-61.

Butcher, K. R., & Kintsch, W. (2003). Text comprehension and discourse processing. In F. Healy & R. W. Proctor (Eds.), *Handbook of psychology: Experimental psychology* (Vol. 4, pp. 575–595). New York: Wiley.

Bureau of Labor Statistics. (2012). *Labor force projections to 2020: a more slowly growing workforce,* January 2012 Monthly Labor Review.

Burtless, G., & Quinn, J. F. (2002). Is working longer the answer for for an aging workforce? *Boston college center for retirement research issue brief, 11*, 1-12.

Campbell, A.J., Marchetti, F.M., & Mewhort, D.J.K. (1981). Reading speed and text production: A note on right-justification techniques, *Ergonomics, 24*, 633-640.

Chandler, P., & Sweller, J. (1991). Cognitive load theory and the format of instruction. *Cognition and Instruction, 8,* 293–332.

Chen, N., Guimbretiere, F., Dixon, M., Lewis, C., & Agrawala, M. (2008). Navigation techniques for dual-display e-book readers (p. 1779). *Presented at the Proceeding of the twenty-sixth annual CHI conference*, New York, New York, USA: ACM Press.

Cierniak, G., Scheiter, K., & Gerjets, P. (2009). Explaining the split-attention effect: Is the reduction of extraneous cognitive load accompanied by an increase in germane cognitive load? *Computers in Human Behavior, 25(2),* 315–324.

Collins, A., & Gentner, D. (1987). How people construct mental models. Pages 243-268 in D. Holland and N. Quinn, editors. *Cultural models in language and thought*. Cambridge University Press, Cambridge, UK.

Cortada, J. W. (2008). Patterns and practices in how information technology spread around the world. *IEEE Annals of the History of Computing. 30(4)*, 4-25.

Cox, M. T. (2005). Metacognition in computation: A selected research review. *Artificial Intelligence, 169(2)*, 104–141.

Craik, K. J. W. (1943). *The nature of explanation*. Cambridge University Press, Cambridge, UK.

Czaja, S. J., & Sharit, J. (1993). Age differences in the performance of computer-based work. *Psychology and aging, 8(1)*, 59–67.

Czaja S. J. (1996). Aging and the acquisition of computer skills. In Rogers WA, Fisk AD, Walker N, editors. *Aging and Skilled Performance: Advances in theory and applications*. p 201 –220 Mahwah,NJ: Lawrence Erlbaum Associates.

Davis, F. D. (1989). Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. *MIS Quarterly, 13(3),* 319–340.

De Beni, R., Borella, E., & Carretti, B. (2007). Reading comprehension in aging: The role of working memory and metacomprehension. *Aging, Neuropsychology, and Cognition, 14,* 189 –212.

DeLong, D. W. (2004). *Lost knowledge: confronting the threat of an aging workforce*, Oxford University Press, New York.

Dewey, J. (1938). *Experience and education*. New York: Collier Books.

Dillon, A. (1990). The human factors of hypertext. *International Forum on information and documentation, 15(4)*, 32-36.

Dillon, A. (1992). Reading from paper versus screens: A critical review of the empirical literature. *Ergonomics, 35(10),* 1297–1326.

Dillon, A., & McKnight, C. (1990). Towards a classification of text types: a repertory grid approach. *International Journal of Man-Machine Studies, 33(6),* 623–636.

Docampo Rama, M., Ridder, H., & Bouma, H. (2001). Technology generation and age in using layered user interfaces. *Gerontechnology, 1(1),* 25–40.

Ericsson, K. A., & Simon, H. A. (1993). *Protocol analysis: Verbal Reports as Data.* Cambridge, MA: MIT Press.

Eshet-Alkalai, Y., & Geri, N. (2007). Does the medium affect the message? The influence of text representation format on critical thinking. *Human Systems Management. 26(4),* 269-279.

Flavell, J. H. (1976). Metacognitive aspects of problem solving. In L. B. Resnick (Eds.), *The nature of intelligence* (pp. 231-236). Hillsdale, NJ: Erlbaum.

Flavell, J. H. (1979). Metacognition and cognitive monitoring: a new area of cognitive-developmental inquiry. *American Psychologist, 34,* 906-911.

Flavell, J. H. (1987). Speculations about the nature and development of metacognition. In F. E. Weinert & R. H. Kluwe (Eds.), *Metacognition, Motivation and Understanding* (pp.21-29). Hillside, New Jersey: Lawrence Erlbaum Associates.

Fleiss, J. L., Levin, B., & Paik, M. C. (2003). The measurement of interrater agreement. In J. L. Fleiss, B. Levin, & M. C. Paik (Eds.), *Statistical methods for rates & proportions* (3rd ed., pp. 598-626). Hoboken, NJ: Wiley.

Garland, K. J. & Noyes, J. M. (2004). CRT monitors: Do they interfere with learning? *Behaviour & Information Technology, 23,* 43–52.

Garner, R. (1990). When Children and Adults Do Not Use Learning Strategies: Toward a Theory of Settings. *Review of Educational Research, 60(4),* 517–529.

Garner, R. (1994). Metacognition and executive control. In R. B. Ruddell, M. R. Ruddell, & H. Singer (Eds.), *Theoretical models and processes of reading* (pp.715-732). Newark, DE: International Reading Association.

Gaver, W. W. (1991). Technology affordances. *In Proceedings of the CHI Conference on Human Factors in Computing Systems*, ACM Press: New York, 79-84.

Gentner, D., & Gentner, D. R. (1983). Flowing waters or teeming crowds: mental models of electricity. Pages 99-130 in D. Gentner and A. Stevens, editors. *Mental models*. Lawrence Erlbaum, Hillsdale, New Jersey, USA.

Gerjets, P., Scheiter, K., & Catrambone, R. (2004). Designing Instructional Examples to Reduce Intrinsic Cognitive Load: Molar versus Modular Presentation of Solution Procedures. *Instructional Science, 32(1/2)*, 33–58.

Gerjets, P., Scheiter, K., & Catrambone, R. (2006). Can learning from molar and modular worked examples be enhanced by providing instructional explanations and prompting self-explanations? *Learning and Instruction, 16(2),* 104–121.

Gibson, J. J. (1977). The Theory of Affordances. In R. E. Shaw and J. Bransford (eds) *Perceiving, Acting, and Knowing*, Hillsdale, NJ: Lawrence Erlbaum Associates.

Gladwell, M. (2002). *The social life of paper*. The New Yorker, 78(5), 92–96.

Glenn, N. D. (1977). Cohort analyses. In E. M. Uslaner (Ed.), *Series: Quantitative applications in the social sciences*. Beverly Hills, California: SAGE Publications inc.

Goldman, S. R. & Saul, E. U. (1990). Flexibility in text processing: A strategy competition model. *Learning and individual differences, 2,* 181-219.

Goldman, S. R., Varma, S., & Cote, N. (1996). Extending capacity constrained construction integration: Towards "smarter" and flexible models of text comprehension. In B. K. Britton & A. C. Graesser (Eds.), *Models of text comprehension* (pp. 73-113). Hillsdale, NJ: Lawrence Erlbaum Associates.

Goodman, K. S. (1994). Reading, writing, and written texts: A transactional sociopsycholinguistic view. In R. B. Ruddell & M. R. Ruddell & H. Singer (Eds.), *Theoretical Models and Processes of Reading* (4th ed., pp. 1093-1130). Newark, Delaware: International Reading Association.

Gould, J. D., Alfaro, L., Finn, R., Haupt, B., & Minuto, A. (1987). Reading from CRT displays can be as fast as reading from paper. *Human Factors 29(5)*, 497-517.

Graesser, A. C. (2007). An introduction to strategic reading comprehension. In D. S. McNamara (Ed.), *Reading comprehension strategies: Theory, interventions, and technologies* (pp3-26). Mahwah, NJ: Lawrence Erlbaum Associates.

Graesser, A. C., Singer, M., & Trabasso, T. (1994). Constructing inferences during narrative text comprehension. *Psychological Review*, 101, 371-395.

Grudin, J. (1992). Utility and usability: research issues and development contexts. *Interacting with Computers. 4(2)*, 209-217.

Haas, C. (1989). Does the medium make a difference? two studies of writing with pen and paper and with computers. *Human-Computer Interaction. 4(2),* 149-169.

Haberlant, K. (1999). *Human memory*, Boston, Allyn & Bacon.

Halasz, F. G., & Moran, T. P. (1983). Mental models and problem solving in using a calculator. *In Proceedings of CHI'83 Human Factors in Computing Systems.* New York: ACM.

Harper, R. & Sellen, A. (1995). *Paper-supported collaborative work. Technical Report EPC-1995-109.* Cambridge, Rank Xerox Research Centre, 16 pp.

Hart, S. G., & Staveland, L. E. (1988). Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. In P. A. Hancock & N. Meshkati (Eds.), *Human Mental Workload* (pp. 139– 183). Amsterdam: Elsevier Science.

Hartson, H. R. (2003). Cognitive, physical, sensory, and functional affordances in interaction design. *Behaviour & Information Technology, 22(5),* 315–338.

Harvey, S., Goudvis, A., & Graves, D. H. (2000). *Strategies that work: Teaching comprehension to enhance understanding*. Portland, ME: Stenhouse Publishers.

Hassenzahl, M. (2004). The interplay of beauty, goodness and usability in interactive products. *Human Computer Interaction, 19,* pp.319-49.

Herath, C. (2010). *How do we Read Online: The Effect of the Internet on Reading Behaviour*. Victoria University of Wellington, Unpublished thesis.

Hofstede, G. (1997). *Cultures and organizations: Software of the mind.* London: McGraw Hill.

Holzinger, A., Baernthaler, M., Pammer, W., Katz, H., Bjelic-Radisic, V., & Ziefle, M. (2011). Investigating paper vs. screen in real-life hospital workflows: Performance contradicts perceived superiority of paper in the user experience. *International Journal of Human-Computer Studies, 69(9),* 563–570.

Hornbæk, K. (2006). Current practice in measuring usability: Challenges to usability studies and research. *International Journal of Human-Computer Studies, 64(2),* 79–102.

Hornbæk, K., & Frøkjær, E. (2003). Reading patterns and usability in visualizations of electronic documents. *ACM Transactions on Computer-Human Interaction (TOCHI),* 10(2), 119–149.

Howe, N., & Strauss, W. (2009). *Millennials Rising.* Vintage Books, New York.

ISO 13407 (1999). *Human-centred Design Processes for Interactive Systems*. International Organization for Standardization, Genève, Switzerland.

Jiménez, R. T., García, G. E., & Pearson, P. D. (1996). The reading strategies of bilingual Latina/o students who are successful English readers: Opportunities and obstacles. *Reading Research Quarterly, 31(1),* 90–112.

Kakar, S. (1981). *The inner world: A psycho-analytic study of childhood and society in India,* New Delhi: Oxford University Press.

Kalyuga, S. (2011). Cognitive Load Theory: How Many Types of Load Does It Really Need? - Springer. E*ducational Psychology Review. 23*, 1-19.

Kalyuga, S., Ayres, P., & Chandler, P. (2003). The Expertise Reversal Effect - Educational *Psychologist, 38(1),* 23-31.

Kalyuga, S., Chandler, P., & Sweller, J. (1998). Levels of Expertise and Instructional Design. Human Factors: *The Journal of the Human Factors and Ergonomics Society, 40(1),* 1–17.

Kengeri, R., Seals, C. D., Harley, H. D., Reddy, H. R., & Fox, E. A. (1999). Usability study of digital libraries: ACM, IEEE-CS, NCSTRL, NDLTD. *International Journal of Digital Library, 2,* 157-169.

Kintsch, W., & Van Dijk, T. A. (1978). Toward a model of text comprehension and production. *Psychological review, 85 (5),* 363-394

Kol, S., & Schcolnik, M. (1997). Reading from screen vs. reading from paper: A pilot study. *CAELL Journal, 8(1),* 10-14.

Kol, S., & Schcolnik, M. (2000). Enhancing screen reading strategies. *Calico journal, 18(1),* 67–80.

Kruk, R. S., & Muter, P. (1984). Reading of continuous text on video screens. *Human Factors, Factors, 26(3),* 339-345.

Lim, C. S. C. (2010). Designing inclusive ICT products for older users: taking into account the technology generation effect. *Journal of Engineering Design, 21(2),* 189–206.

Liu, Z. (2005). Reading behavior in the digital environment: Changes in reading behavior over the past ten years. *Journal of Documentation, 61(6),* 700–712.

Liu, Z., & Huang, X. (2007). Gender differences in the online reading environment. *Journal of Documentation. 64(4),* 616-626.

Lorch, R. F., Lorch, E. P., & Klusewitz, M. A. (1993). College students' conditional knowledge about reading. *Journal of Educational Psychology, 85(2),* 239-252.

Luff, P., & Heath, C. (1998). Mobility in Collaboration. *In Proceedings of the CSCW '98 Conference on Computer-Supported Cooperative Work.* ACM Press, New York, NY, 305–314.

MacFadyen, H. (2011). The reader's devices: The affordances of ebook readers. Dalhousie *Journal of Interdisciplinary Management. 7.* 1-15.

Mannheim, K. (1985). *Ideology and Utopia*. Mariner Books.

Marakas, G. M., Johnson, R. D., & Palmer, J. W. (2000). A theoretical model of differential social attributions toward computing technology: when the metaphor becomes the model. *International Journal of Human-Computer Studies, 52,* pp719-750.

Marshall, C. C., & Brush, A. J. B. (2004). Exploring the relationship between personal and public annotations, *Joint conference on digital libraries 2004,* 349–357.

Marshall, C. C., & Ruotolo, C. (2002). Reading-in-the-small: a study of reading on small form factor devices, *Joint conference on digital libraries 2002*, 56–64.

Mayes, D. K., Sims, V. K., & Koonce, J. M. (2001). Comprehension and workload differences for VDT and paper-based reading. *International Journal of Industrial Ergonomics, 28(6),* 367–378.

McGrenere, J., & Ho, W. (2000). Affordances: Clarifying and evolving a concept. *In Proceedings of Graphics Interface*. Canadian Human-Computer Communications Society: Toronto, 179-186.

Meyer, B. J. F., & Poon, L. W. (1997). Age differences in efficiency of reading comprehension from printed versus computer-displayed text. *Educational Gerontology, 23(8),* 789–807.

Miholic, V. (1994). An inventory to pique students' metacognitive awareness of reading strategies. *Journal of reading, 38*, 84-86.

Millis, K.K., Kim, H.J., Todaro, S. Magliano, J., Wiemer-Hastings, K., McNamara, D. (2004). Identifying reading strategies using latent semantic analysis: Comparing semantic benchmarks. *Behavior Research Methods, Instruments, & Computers, 36(2),* 213-221.

Mills, C. B., & Weldon, L. J. (1986). Reading text from computer screens. *ACM Computing Surveys, 19,* 329-358.

Mokhtari, K., & Sheorey, R. (1994). Reading habits of univer- sity ESL students at different levels of English proficiency and education. *Journal of Research in Reading, 17(1),* 46–61

Mokhtari, K., & Reichard, C. A. (2002). Assessing students' metacognitive awareness of reading strategies. *Journal of Educational Psychology, 94(2),* 249–259.

Morris, M. R., Brush, A. B., & Meyers, B. R. (2007). Reading revisited: Evaluating the usability of digital display surfaces for active reading tasks, *Microsoft research publication, IEEE, OCT 2007.* 79–86.

Mulder, L. (1992). Measurement and analysis methods of heart rate and respiration for use in applied environments. *Biological psychology, 34,* 205-236.

Murphy, P. K., Long, J. F., Holleran, T. A., & Esterly, E. (2003). Persuasion online or on paper: a new take on an old issue. *Learning and Instruction, 13(5),* 511–532.

Murray, T. (2003). Applying text comprehension and active reading principles to adaptive hyperbooks. *Cognitive Science, 15,* 501–508.

Muter, P., & Maurutto, P. (1991). Reading and skimming from computer screens and books: the paperless office revisited? *Behaviour & Information Technology, 10(4),* 257–266.

Muter, P., Latrémouille, S. A., & Treurniet, W. C. (1982). Extended reading of continuous text on television screens. *Human Factors, 24,* 510-508.

Nielsen, J. (1989). The matters that really matter for hypertext usability, *In Proceedings of the ACM Hypertext '89 conference*, 239–248.

Nisbett, R. E., & Wilson, T. D. (1977). Telling more than we can know: Verbal reports on mental processes. *Psychological review, 84*, 231-259.

Norman, D. A. (2002). *The Design of Everyday Things*. Basic Books (AZ).

Norman, D. A. (1983). Some observations on mental models. In D. Gentner & A. L. Stevens (Eds.), *Mental Models*, Hillsdale, NJ: Erlbaum.

Noyes, J. M., & Garland, K. J. (2003). VDT versus paper-based text: reply to Mayes, Sims and Koonce. *International Journal of Industrial Ergonomics, 31,* 411-423.

Noyes, J. M., & Garland, K. J. (2008). Computer- vs. paper-based tasks: Are they equivalent? *Ergonomics, 51(9),* 1352–1375.

Noyes, J., Garland, K., & Robbins, L. (2004). Paper-based versus computer-based assessment: is workload another test mode effect? British Journal of Educational Technology - Wiley Online Library. *British Journal of Educational Technology, 35,* 111-113.

Oblinger, D. G. (2004). The next generation of educational engagement. *Journal of interactive media in education,* 2004(1).

Oetjen, S., & Ziefle, M. (2007). The Effects of LCD Anisotropy on the Visual Performance of Users of Different Ages. *Human Factors, 49(4),* 619–627.

O'Hara, K. (1996). *Towards a typology of reading goals.* Technical Report EPC-1996-107, available http:// www.xrce.xerox.com/publis/cam-trs/pdf/1996/epc- 1996-108.pdf

O'Hara, K., & Sellen, A. (1997). A comparison of reading paper and on-line documents, *Proc. CHI 1997*, 335–342.

Oyserman, D. (2011). Culture as situated cognition: cultural mindsets, cultural fluency, and meaning making. *European Review of Social Psychology, 22(1),* 164-214.

Paas, F. G. (1992). Training strategies for attaining transfer of problem-solving skill in statistics: A cognitive-load approach. *Journal of Educational Psychology. 84,* 429-434.

Paas, F. G., & Merrienboer, J. J. G. (1994). Variability of worked examples and transfer of geometrical problem-solving skills : a cognitive-load approach. *Journal of Educational Psychology. 86*, 122-133.

Paas, F., Tuovinen, J. E., Tabbers, H., & Van Gerven, P. W. M. (2003). Cognitive load measurement as a means to advance cognitive load theory. *Educational psychologist, 38(1),* 63–71.

Paris, S. G., Lipson, M. Y., & Wixson, K. K. (1983). Becoming a strategic reader. *Contemporary educational psychology, 8,* 293-316.

Paris, S. G., Lipson, M. Y., & Wixon, K. K. (1994). Becoming a strategic reader. In R. B. Ruddell, M. R. Ruddell, & H. Singer (Eds.), *Theoretical models and processes of reading* (4th ed.). Newark, DE: International Reading Association.

Paris, S. G., Wasik, B. A., & Turner, J. C. (1991). The development of strategic readers. In M. L. Kamil & P. B. Mosenthal & P. D. Pearson & R. Barr (Eds.), *Handbook of Reading Research* (Vol. 2, pp. 609-640). White Plains, NY: Longman.

Pearrow, M. (2000). *Web site usability handbook.* Rockland, MA: Charles River Media.

Pereira-Laird, J. A., & Deane, F. P. (1997). Development and validation of a self-report measure of reading strategy use. *Reading Psychology, 18(3),* 185–235.

Potthast, J. (2008). Ethnography of a Paper Strip. Science, *Technology & Innovation Studies, 4(1).* 47-68.

Pressley, M., & Afflerbach, P. (1995). *Verbal Protocols of Reading: The Nature of Constructively Responsive Reading*. Hillsdale, NJ: Erlbaum.

Pressley, M. (2000). What should comprehension instruction be the in- struction of? In M. Kamil, P. Mosenthal, P. Pearson, & R. Barr (Eds.), *Handbook of reading research* (Vol. 3, pp. 545–561). Mahwah, NJ: Erlbaum.

Pugh, A. K. (1978). *Silent reading: an introduction to its study and teaching*. Heinemann Educational, London, UK.

Robson, J. I., & Crellin, J. M. (1989). The role of user's perceived control in interface design, employing verbal protocol analysis. *Applied Ergonomics, 20, 4*, pp.246-251.

Rotter, J. B. (1966). Generalized expectancies for internal versus external control of reinforcement. *Psychological Monographs, 80 (1),* 1-28.

Salthouse, T. A., Hambrick, D. Z., Lukas, K. E., & Dell, T. C. (1996). Determinants of adult age differences on synthetic work performance. *Journal of Experimental Psychology: Applied, 2(4),* 305-329.

Sackmann R. & Winkler O. (2013). Technology generations revisited: The internet generation. *Gerontechnology, 11(4),* 493-503.

Sawilowsky, S. S. (1990). Nonparametric Tests of Interaction in Experimental Design. *Review of Educational Research, 60(1)*, 91–126.

Schaie, K. W., Rosenthal, F., & Perlman, R. M. (1953). Differential Mental Deterioration of Factorially "Pure" Functions in Later Maturity. *Journal of Gerontology, 8(2).* 191-196.

Schilit, B.N., Price, M.N., Golovchinsky, G., Tanaka, K., & Marshall, C.C. (1999). The reading appliance revolution. Computer (USA), *Computer, 32(1),* 65-73.

Schlick, C., Ziefle, M., Park, M., & Luczak, H. (2008). Visual displays. In: Jacko, J., Sears, A. (Eds.), *The Human Computer Interaction Hand- book: Fundamentals, Evolving Technologies and Emerging Applications*. LEA, Mahwah, New Jersey, pp. 201–228.

Schmitt, M. C. (1990). A questionnaire to measure children's awareness of strategic reading processes. *The Reading Teacher, 43,* 454-461.

Schnotz, W., & Kürschner, C. (2007). A Reconsideration of Cognitive Load Theory. *Educational Psychology Review, 19(4),* 469–508.

Schumacher, G., & Waller, R. (1985). Testing design alternatives: a comparison of procedures. In T. Duffy and R. Waller (eds.) *Designing useable texts*, pp 377-403, Orlando, FL: Academic Press.

Sellen, A. J., & Harper, R. H. (2001). *The myth of the paperless office*. The MIT Press.

Semin, G. R. (2009). Language, culture, cognition: how do they intersect? In R. Wyer, C. Chiu, and Y. Hong (eds.) *Understanding culture: theory, research, and application*, (pp.259-270). New York, NY: Psychology Press.

Shimamura, A. P. (2000). Toward a cognitive neuroscience of metacognition. Consciousness and *Cognition, 9,* 313-323.

Smith-Jackson, T. L., Artis, S., Johnson, K., & Resnick, M. (2013). *Cultural Ergonomics*. CRC Press Llc.

Smith-Jackson, T, L., Iridiastadi, H. and Oh, C. G. (2011). Cultural ergonomics issues in consumer product design. In M. Soares (Ed.). In *Handbook of Human Factors and Ergonomics in Consumer Product Design: Methods and Techniques*. London, UK: Taylor and Francis, pp. 211-222.

Stine, E. A. L., Cheung, H., & Henderson, D. T. (1995). Adult age differences in the on-line processing of new concepts in discourse. *Aging and Cognition, 2,* 1–18.

Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive Science, 12(2)*, 257–285.

Sweller, J. (2005). Implications of cognitive load theory for multimedia learning. In R. E. Mayer (Ed.), T*he Cambridge handbook of multimedia learning* (pp. 19-30). New York: Cambridge University Press.

Sweller, J., Van Merrienboer, J. J. G., & Paas, F. G. W. C. (1998). Cognitive Architecture and Instructional Design - Springer. *Educational Psychology Review, 10(3),* 251–296.

The Economist. (2008). *Not dead, just resting: how discredited technologies can be unexpectedly resurrected*. Retrieved from http://www.economist.com/node/12381449?story_id=12381449

Thayer, A., Lee, C. P., Hwang, L. H., Sales, H., Sen, P., & Dalal, N. (2011). The imposition and superimposition of digital reading technology: the academic potential of e-readers, *Proc. of CHI 2011*, 2917–2926.

Thomas, H., 2006. Remembering the office of the future: the origins of word processing and office automation. I*EEE Annals of the History of Computing 28 (4),* 6–31.

Tomes, E. G. (2000). Understanding and facilitating the browsing of electronic text. *International Journal of Human-Computer Studies, 52(3),* 423–452.

Tractinsky, N. & Zmiri, D. (2006). Exploring attributes of skins as potential antecedents of emotion in HCI. In P. Fishwick (Ed.), *Aesthetic computing*, Cambridge: MIT Press.

Triandis, H. (1972). *The analysis of subjective culture.* New York: Wiley.

Turner, P., & Turner, S. (2002). An Affordance-based Framework for CVE Evaluation. In *People and Computers XVI-Memorable Yet Invisible* (pp. 89–103). London: Springer London.

U.S. Census Bureau. (2003). C*omputer and Internet use in the United States: 2003*. U.S. Census Bureau.

van den Broek, P., & Gustafson, M. (1999). Comprehension and memory for texts: three generations of reading research. In S. R. Goldman, A. C. Graesser, & P. van den Broek (Eds.). *Narrative comprehension, causality, and coherence* (pp. 15-34). Mahwah, NJ:Erlbaum.

van den Broek, P., Risden, K., Fletcher, C. R., & Thurlow, R. (1996). A "landscape" view of reading: Fluctuating patterns of activation and the construction of a stable memory representation. In B. K. Britton & A. C. Graesser (Eds.), *Models of understanding text* (pp.165-187). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

van Dijk, T. A., & Kintsch, W. (1983). *Strategies of discourse comprehension*. Academic Pr.

Van Gerven, P. W. M., Paas, F., Van Merrienboer, J. J. G., & Schmidt, H. G. (2004). Memory load and the cognitive pupillary response in aging. *Psychophysiology, 41(2),* 167–174.

Vygotsky, L. (1978). *Mind in society: The development of higher psychological processes.* Cambridge, MA: Harvard University Press.

Wallen, E. S. & Mulloy, K. B. (2006). Computer-based training for safety: comparing methods with older and younger workers. *Journal of Safety Research. 37(5).* 461-467.

Wästlund, E., Reinikka, H., Norlander, T., & Archer, T. (2005). Effects of VDT and paper presentation on consumption and production of information: Psychological and physiological factors. *Computers in Human Behavior, 21,* 377–394

Weymann A. & Sackmann R. (1994). Modernization and the Generational Structure. Technological Innovation and Technology-Generations in East and West Germany. In: Becker HA, Hermkens PL, editors. *Solidarity of Generations. Demographic, Economic and Social Change and its Consequences.* Amsterdam: Thesis; 1994; pp 721-743; www. soziologie.uni-halle.de/sackmann/docs/solidarity- of-generations.pdf; retrieved March 15, 2013

Wickens, C.D., & Hollands, J.G. (2000). *Engineering Psychology and Human Performance*, 3rd ed. Prentice Hall, Saddle River, NJ.

Wightman, D., Ginn, T., & Vertegaal, R. (2010). TouchMark: Flexible document navigation and bookmarking techniques for e-book readers, *In Proceedings of Graphics Interface.* 241–244.

Wilkinson, R. T., & Robinshaw, H. M. (1987). Proof-reading: VDU and paper text compared for speed, accuracy and fatigue. *Behaviour & Information Technology, 6(2),* 125–133.

Wobbrock, J. O., Findlater, L., Gergle, D., & Higgins, J. J. (2011). The aligned rank transform for nonparametric factorial analyses using only ANOVA procedures, *CHI 2011,* 143–146.

Ziefle, M. (2009). Visual ergonomic issues of LCD displays-an insight into working conditions and user characteristics. In: Schlick, C.M. (Ed.), *Methods and Tools of Industrial Engineering and Ergonomics for Engineering Design, Production, and Service – Traditions – Trends and Vision*. Springer, Berlin, Heidelberg.

APPENDICES

Appendix A. IRB Approval

VirginiaTech

Office of Research Compliance
Institutational Review Board
2000 Kraft Drive, Suite 2000 (0497)
Blacksburg, VA 24060
540/231-4606 Fax 540/231-0959
email irb@vt.edu
website http://www.irb.vt.edu

MEMORANDUM

DATE: June 18, 2012

TO: Tonya Smith-Jackson, Kyunghui Oh

FROM: Virginia Tech Institutional Review Board (FWA00000572, expires May 31, 2014)

PROTOCOL TITLE: Investigating Reading Strategies Practices Across Various Media

IRB NUMBER: **12-253**

Effective June 18, 2012, the Virginia Tech Institution Review Board (IRB) Chair, David M Moore, approved the Amendment request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report within 5 business days to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at:

http://www.irb.vt.edu/pages/responsibilities.htm

(Please review responsibilities before the commencement of your research.)

PROTOCOL INFORMATION:

Approved As:	**Expedited, under 45 CFR 46.110 category(ies) 6,7**
Protocol Approval Date:	**March 7, 2012**
Protocol Expiration Date:	**March 6, 2013**
Continuing Review Due Date*:	**February 20, 2013**

*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

FEDERALLY FUNDED RESEARCH REQUIREMENTS:

Per federal regulations, 45 CFR 46.103(f), the IRB is required to compare all federally funded grant proposals/work statements to the IRB protocol(s) which cover the human research activities included in the proposal / work statement before funds are released. Note that this requirement does not apply to Exempt and Interim IRB protocols, or grants for which VT is not the primary awardee.

The table on the following page indicates whether grant proposals are related to this IRB protocol, and which of the listed proposals, if any, have been compared to this IRB protocol, if required.

Appendix B. Informed Consent Form

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Informed Consent for Participants
in Research Project Involving Human Subjects

Title of Project: Investigation of Reading Strategies Across Various Media

Investigator(s): Kyunghui Oh and Dr. Smith-Jackson, Faculty Advisor

1. Purpose
The purpose of this study is to investigate how the use of different media impacts the act of reading.

2. Procedures
This Informed Consent document will be reviewed and signed by you. We will then ask you to complete a short questionnaire including demographic data and the use of media for reading activities.

Before the actual experiment, you will have a familiarization session. In this session, you will receive instructions about using electronic media, and you will be asked to perform trial tasks. Once you complete the trial tasks with all media and feel comfortable performing the actual tasks with different media, you will begin the actual experiment.

In the actual experiment, you will be asked to perform an active reading task with each of three media (i.e., paper, computer, and tablet). In each condition, we will conduct two sessions: task observation session and retrospective think aloud (RTA) session. First, the observation session will be administered. You will be asked to perform an active reading task while wearing an eye tracker. Upon completing the active reading tasks, the RTA session will be administered with video-playback of observed data. During the playback, you will be asked to verbalize your thoughts regarding the reading activity, especially with respect to the reading strategies you used. After the session, you will be asked to complete a post-experiment questionnaire regarding text familiarity and competence with a given medium.

Each condition will take about one (1) hour to complete. The entire experiment (three conditions) will take about three (3) hours to complete.

3. Risks
Participation in this study is not expected to place you at even minimal risk for harm. The tasks related to using media (i.e., paper, computer, and tablet) for reading are normal activities that are not considered to be stressful. However, if at any time you become uncomfortable, you will be allowed to leave the study with no penalty.

4. Benefits
Your participation in this project will be used to develop user requirements for electronic media for reading activities. The findings of this project will be applied to the creation of an interface that is more usable for reading activities. While this research may yield such benefits, no promise or guarantee of specific outcomes can be assured. You may contact the investigators listed at the end of the Consent Form to inquire about the results and conclusions of this research.

5. Extent of Anonymity and Confidentiality
The results of this study will be kept strictly confidential, and your identity will not be revealed. The information you provide will be associated with a participant number (not your name), which we will use to identify you during analyses and in any subsequent written reports describing the research.

6. Compensation
If you meet all of the inclusion criteria, you will be compensated at a rate of $10 per hour for your participation. (If you were recruited by the VT Psychology SONA system, you will receive 3 credits for participation, 1 credit per hour).

7. Freedom to Withdraw
You are free to withdraw from this study at any time without penalty and without having to state your reason for doing so; there will be no penalty or withholding of compensation for leaving the study.

8. Participant's Permission
I have read the Consent Form and conditions associated with this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent:

_____ Date_____
Subject signature
_____ Date _____
Witness (optional except for certain classes of subjects)

Should I have any questions about this research study, how it is to be conducted, my rights as a research subject, or whom to contact in the event of a research-related injury, I may contact:

Kyunghui Oh
Ph.D. Student
Department of Industrial and Systems Engineering
210 Durham Hall
Blacksburg, VA 24061
(540) 808-8638 / khoh@vt.edu

Dr. Tonya L. Smith-Jackson

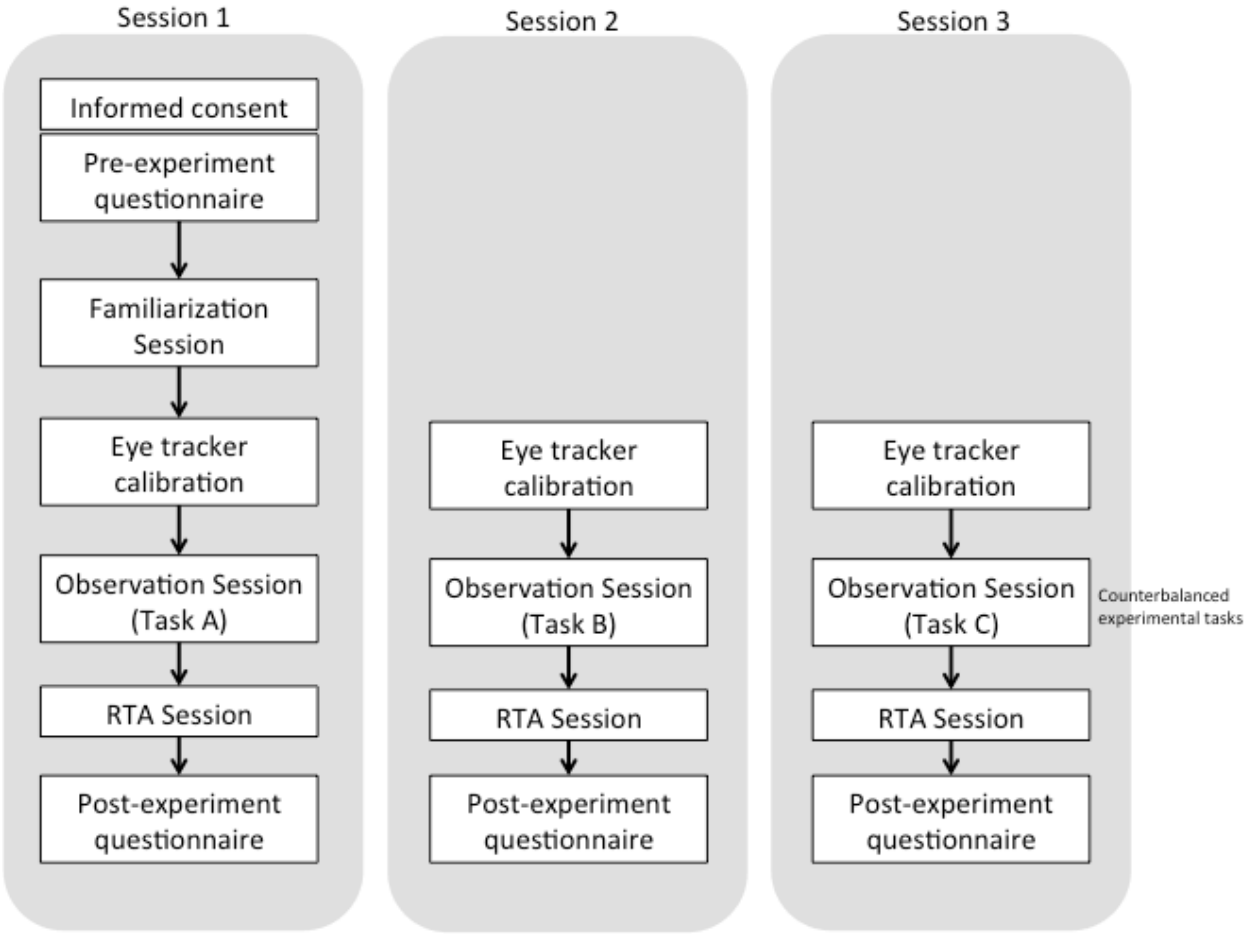
Professor
Department of Industrial and Systems Engineering
250 Durham Hall
Blacksburg, VA 24061
(540) 231-4119 / smithjack@vt.edu

In addition, if you have any questions regarding your rights as a participant in University Research, you may contact the following individual:

Dr. David Moore
Chair, Virginia Tech Institutional Review Board
For the Protection of Human Subjects
Office of Research Compliance
2000 Kraft Drive, Suite 2000 (0497)
Blacksburg, VA 24061
(540) 231-4991

Appendix C. Experimental Materials

1. Overview of the Experimental Procedures



2. Experimenter's Script

(1) Introduction

Thank you for participating in this experiment. My name is Kyunghui Oh. I am a graduate student in the ISE Department at Virginia Tech.

My dissertation research is intended to study how the use of different media impacts the act of reading with respect to active reading activities. The term "active reading" means that the reader consciously thinks about the ideas being read. Therefore, active reading usually combines reading with learning, critical thinking, and decision-making. Typical reading activities in your educational or workplace setting are considered active reading tasks. Therefore, please perform your experimental tasks as usually performed in your educational or workplace setting.

Before we proceed with this experiment, I need to make sure we have your informed consent to proceed with this experiment. Please take a few minutes to read this consent form. If you agree, please sign it at the bottom.

[Give participant informed consent form and wait for participant to respond]

Thanks for the consent form. I would also like to know some basic demographic information about you, so kindly complete the questionnaire I will give you.

[Give the pre-experiment questionnaire and wait for participant to enter his/her responses]

(2) Familiarization Session

Now, I am going to give you instructions about using the electronic media, and ask to perform trial tasks to familiarize yourself with the electronic media. Once you complete the tasks with all media and feel comfortable performing the actual tasks with different media, you will begin the actual experiment.

[Give instruction about using electronic media]

[Ask to do trial tasks]

Now, we will proceed to the actual experimental tasks. I am going to ask you to perform an active reading task with each of three media (i.e., paper, computer, and tablet). For each situation, you will have 30 minutes to complete the active reading task. We will be recording the time taken for each task, as well as reviewing your summarizations as a final outcome, so please try to complete the task as carefully as you can.

(3) Eye Tracker Calibration

Let's put on the eyetracking device and calibrate it.

[Put the eye tracker on their head]

[Do calibration steps]

[Start the recording]

(4) Task Observation Session

Here is the article you will be reading and summarizing. You can start now!

[Once the participant completes the task] Let us now remove the eye tracker.

[Stop the recording]

(5) Retrospective Think-Aloud Session

Now, we will review your reading process and conduct the retrospective think-aloud session.

[Replay video]

(6) Closure

Finally, I'd like to know your overall experience regarding this experiment, so I would appreciate it if you would complete the questionnaire I will give you.

[Give the post-experiment questionnaire and wait for participant to enter his/her responses]

Thank you very much for your participation and valuable information. Here is the compensation for your time. I need your signature here. Again, we very much appreciate your contribution to this study.

[Escort them out of room/building]

3. Pre-experiment Questionnaire

Participant ID: _____

(1) Demographic Information

- Age: _____ (Your birth year: _____)
- Gender: □ Male □ Female
- Occupation: _____
- First language: _____

(2) The Use of Media for Reading Activities

- Please select the media you use for work-related reading activities, and specify how frequently you are engaged in work-related reading activities with the specified medium?

	Never	Everyday	2-3 times per week	Once a week	1-3 times per month
Paper	□	□	□	□	□
Computer	□	□	□	□	□
Tablet computer	□	□	□	□	□
iPad	□	□	□	□	□
Kindle	□	□	□	□	□
Others (_____)	□	□	□	□	□

- Please select the media you use for casual reading activities, and specify how frequently you are engaged in casual reading activities with the specified medium?

	Never	Everyday	2-3 times per week	Once a week	1-3 times per month
Paper	□	□	□	□	□
Computer	□	□	□	□	□
Tablet computer	□	□	□	□	□
iPad	□	□	□	□	□
Kindle	□	□	□	□	□
Others (_____)	□	□	□	□	□

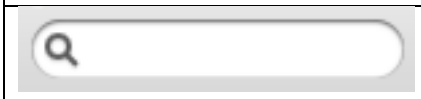
(3) The Use of Technology

Which of the following devices do you own and how many years have you used them?

	Check the box if you use the device	- How long have you used them? - Name of Model
Computer	□	- (_____) - (_____)
Tablet (e.g., tablet computer, iPad)	□	- (_____) - (_____)
Smartphone (including iPod touch)	□	- (_____) - (_____)
E-book reader (e.g., Kindle)	□	- (_____) - (_____)

4. Familiarization Session

- Computer: Preview application

Features	Descriptions
 button at the top-left of the window	Make the contents of the PDF bigger
 button at the top-left of the window	Make the contents of the PDF smaller
 button	Search by keyword
 button at the top of the window	View the content only
 button at the top of the window	View the content sheet
 button at the top of the window	View the content as thumbnails
 botton at the top of the window	View a PDF's table of contents in the sidebar
The gray disclosure triangle  next to the name of the chapter	View a list of subjects under a chapter in the sidebar
Click the name of the chapter or page in the sidebar	Jump to a specific chapter or page listed in the sidebar
Choose **Go to Page** from the **Go** menu, type a page number	Go to a specific page number
Choose **Add Bookmark** from the **Bookmarks** menu, type a name for your bookmark	Bookmark a page in a PDF
Choose the page from the **Bookmarks** menu	Open a bookmarked page
Annotation button	(Create/Modify/delete) notes, highlighting, links, arrows, or other annotations
	
Navigation using gestures	Zoom, flip pages (two finger scroll, three

	finger scroll)

- Trial tasks
    - View features:
        - View content only
        - View the content as thumbnails
    - Navigation
        - Zoom pages
        - Flip pages (two finger scroll, three finger scroll)
    - Annotation
        - Create/modify/delete a note
        - Create/modify/delete highlighting
        - Create/modify/delete underlining
        - Review created annotations
    - Searching by keyword
    - Bookmark
        - Make/delete bookmark
        - Review created bookmarks

- iPad: iAnnotate

Features	Descriptions
Navigation using gesture	- Zoom - Flip pages (single page mode) - Tab anywhere to hide the tab bar - A three-finger tap to enter full screen mode - Tab and hold on document to bring up tools - Tab and hold any area of text to bring up tools - Double tab to bring up your five most recently used tools - Tab the double arrows under the toolbar to show more toolbars
 Button at the navigation panel	View the content as thumbnails
 Button at the navigation panel	View a PDF's table of contents
 Button at the navigation panel	View annotation list
 Button at the navigation panel	Search by keyword
Annotation	(Create/modify/delete) - Drawing annotation: pencil annotation, straight-line annotation - Markup annotation: highlight, underline, strikeout - Note annotation - Sound clip annotation - Typewriter annotation
Bookmark	(Create/delete) bookmarks

- Trial tasks
    - View features:
        - View content only
        - View the content as thumbnails
    - Navigation
        - Zoom pages
        - Flip pages (depending on single page mode setting)
    - Annotation
        - Create/modify/delete a note
        - Create/modify/delete highlighting
        - Create/modify/delete underlining
        - Create/modify/delete strikeout
        - Create/modify/delete pencil annotation
        - Create/modify/delete straight-line annotation
        - Create/modify/delete sound clip annotation
        - Create/modify/delete typewriter annotation
        - Review created annotations
    - Searching by keyword
    - Bookmark
        - Make/delete bookmark
        - Review created bookmarks

5. Eye Tracker Calibration
Procedures

1. Ask participant to put on the eye tracker. Suggest that the participant adjust the tension of the headband so that the eye tracker is stable and comfortable.

2. Ask participant to look forward

(Researcher) research will adjust horizontal position of eye tracker. It should be aligned with the position of right eye

3. Ask participant to look forward

(Researcher) researcher will adjust the mirror on the eye tracker and position the image of the eye within the display window

4. (Spot calibration) ask participant to maintain a forward gaze

(Researcher) will adjust threshold to get three CR (85~95) and hit calibration button

5. (Pupil identification) ask participant to maintain a forward gaze

(Researcher) will adjust threshold to get clean public image (97.5~99)

6. (Scene calibration) ask participant to look in certain positions (6 positions)

(Researcher) researcher will adjust the differences between actual position and position recognized by the system.

7. (Researcher) Start recording and confirm that data is being saved correctly in the computer

6. Task Observation Session

Task Instruction (Students)

You are about to take an important mid-term exam. In addition to the material you have already been reviewing, your professor asks to review this article and summarize it as part of your grade (Within 500 words). In fact, your ability to understand and summarize the article will be critical for the success of this exam.

First, your professor asks to read a document to learn its main contents. Afterwards, you are required to make a summarization with access to the document. You will have 30 minutes to complete this task. Although we want you to complete the summary within the 30 minutes, it is important that you read and understand in order to write an accurate summary.

This type of task is one that you have likely been doing in your educational setting. Therefore, we are asking you to perform this task exactly as you would normally do in your educational setting. We will be recording the time it takes you to complete this task, as well as reviewing your summarization as a final outcome.

Task Instruction (Workers)

You and your supervisor are working late in order to prepare for an important meeting tomorrow. Your supervisor asks you to review this article and provide a written summary (Within 500 words). In fact, your ability to understand and summarize the article will be critical to the success of the meeting.

First, your supervisor asks to read a document to learn its main contents. Afterwards, you are required to make a summarization with access to the document. You will have 30 minutes to complete this task. Although we want you to complete the summary within the 30 minutes, it is important that you read and understand in order to write an accurate summary.

This type of task is one that you have likely been doing in your workplace setting. Therefore, we are asking you to perform this task exactly as you would normally do in your educational or workplace setting. We will be recording the time it takes you to complete this task, as well as reviewing your summarization as a final outcome.

7. RTA Session (Instruction & Questions)

Instruction

In this session, we are interested in what you are thinking about while you are reading the document and creating a summary. In order to do this, I am going to ask you to **THINK ALOUD** as you work on the given task. What I mean by "think aloud" is that I want you to tell me EVERYTHING you are thinking from the time you first start to read the document until you finish the summarization. Please do not plan out what you intent to say or explain to me what you are saying. Just act as if you are alone in the room speaking to yourself. It is most important that you keep talking. If you are silent for an extended period of time I will remind you to verbalize your thoughts. Do you understand what I want you to do?

Questions used during RTA session

(General Questions)

- Could you tell me what you were thinking and seeing?
- Could you tell me more about that?

(Examples of Probing Questions)

- Reading process (static continuous reading, scanning, skimming, repeated reading)

- Could you tell me about your reading process?
- Could you tell me what "certain process" means in your overall process of reading?
- Could you tell me why you were relying on that "certain reading process"?

- Reading process (Dynamic discontinuous reading: jumping, narrowing, broadening)

- Could you tell me about your reading process?
- Could you tell me what "certain process" means in your overall process of reading?
- Could you tell me why you were replying on that "certain reading process"?

- Could you tell me how you found specific locations of sentences or text?
- Could you tell me what makes you act the way you did?

• Reading behavioral activity (annotation, bookmarking)

- Could you tell me about your reading activity?
- Could you tell me what "certain activity" means in your process of reading?
- Could you tell me why you were relying on that "certain activity"?
- Could you tell me what makes you act the way you did?

• Overall reading (outlining, networking, reviewing)

- Could you tell me how you organize/monitor your overall reading process?
- Could you tell me how your reading process or reading activity is decided?
- Could you tell me what makes you act the way you did?
- Could you tell me how you are engaged in your reading task?
- Could you tell me the kinds of "reading processes or reading activities" that were important for you to accomplish the given active reading task?

8. Post-experiment Questionnaire

Participant ID: _____

Session: _____

(1) Satisfaction

▪ I was **satisfied with the given medium** to perform the given task (active reading).						
1 Strongly disagree	2 Disagree	3 Somewhat disagree	4 Undecided	5 Somewhat agree	6 Agree	7 Strongly agree
☐	☐	☐	☐	☐	☐	☐

(2) Perceived Usefulness

▪ Using the given medium improves my performance for this kind of task (Active reading) in my job.						
1 Strongly disagree	2 Disagree	3 Somewhat disagree	4 Undecided	5 Somewhat agree	6 Agree	7 Strongly agree
☐	☐	☐	☐	☐	☐	☐

▪ Using the given medium for this kind of task (active reading) in my job increases my productivity						
1 Strongly disagree	2 Disagree	3 Somewhat disagree	4 Undecided	5 Somewhat agree	6 Agree	7 Strongly agree
☐	☐	☐	☐	☐	☐	☐

▪ Using the given medium enhances my effectiveness for this kind of task (active reading) in my job.						
1 Strongly disagree	2 Disagree	3 Somewhat disagree	4 Undecided	5 Somewhat agree	6 Agree	7 Strongly agree
☐	☐	☐	☐	☐	☐	☐

▪ I find the given medium to be useful for this kind of task (active reading) in my job.						
1 Strongly disagree	2 Disagree	3 Somewhat disagree	4 Undecided	5 Somewhat agree	6 Agree	7 Strongly agree
☐	☐	☐	☐	☐	☐	☐

(3) Perceived Ease of Use

▪ My interaction with the given medium was clear and understandable						
1 Strongly disagree	2 Disagree	3 Somewhat disagree	4 Undecided	5 Somewhat agree	6 Agree	7 Strongly agree
☐	☐	☐	☐	☐	☐	☐

▪ Interacting with the system does not require a lot of mental effort						
1 Strongly disagree	2 Disagree	3 Somewhat disagree	4 Undecided	5 Somewhat agree	6 Agree	7 Strongly agree
☐	☐	☐	☐	☐	☐	☐

▪ I find the given medium to be easy to use						
1 Strongly disagree	2 Disagree	3 Somewhat disagree	4 Undecided	5 Somewhat agree	6 Agree	7 Strongly agree
☐	☐	☐	☐	☐	☐	☐

▪ I find it easy to get the system to do what I want to do						
1 Strongly disagree	2 Disagree	3 Somewhat disagree	4 Undecided	5 Somewhat agree	6 Agree	7 Strongly agree
☐	☐	☐	☐	☐	☐	☐

(4) Cognitive Load

- How easy or difficult was this task to perform?

1 Extremely easy	2 Very easy	3 Easy	4 Neither easy nor difficult	5 Difficult	6 Very difficult	7 Extremely difficult
☐	☐	☐	☐	☐	☐	☐

- How easy or difficult was the reading content for you?

1 Extremely easy	2 Very easy	3 Easy	4 Neither easy nor difficult	5 Difficult	6 Very difficult	7 Extremely difficult
☐	☐	☐	☐	☐	☐	☐

- How easy or difficult was it to perform the task with the given medium (e.g., paper, computer, tablet)?

1 Extremely easy	2 Very easy	3 Easy	4 Neither easy nor difficult	5 Difficult	6 Very difficult	7 Extremely difficult
☐	☐	☐	☐	☐	☐	☐

- How much were you engaged in a given reading task depending on the given medium used?

1 Not at all	2 A little bit	3 Somewhat	4 Moderately	5 Quite a bit	6 Very much so	7 Intensively so
☐	☐	☐	☐	☐	☐	☐

Appendix D. Data Coding Manual

(1) Coding Procedures

a. Data coding
   - Two individual coders will independently review the video and transcripts and code the data based on a priori code (a priori coding).
   - While you (coder) independently review and code the data, you can establish new category and sub-codes (emergent coding).

b. Reconciliation meeting
   : The researcher and two coders will have a reconciliation meeting to compare code and reconcile any differences that show up between coders' codes.

c. Reliability
   : The researcher will check the reliability of the coding. If the level of reliability is not acceptable, the researcher and coders will repeat the previous steps.

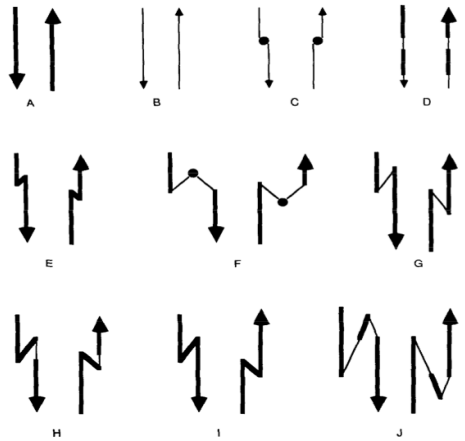
(2) List of a Prior code and Final Code

A priori code	Final code
• Reading (receptive reading, reflective reading) • Skimming • Scanning • Repeated reading • Jumping • Networking • Narrowing • Broadening • Annotation (anchor-only) • Annotation (content-only) • Annotation (compound) • Bookmarking • Outlining • Reviewing	• Highlighting • Note • Symbol • Paper note • Networking • Jumping based on reference • Micro-monitoring • Macro-monitoring

(3) A Priori Code

Code	Reference
Reading	O'Hara, 1996 Ohno, 2007 Pugh, 1975
- Definition: reading is the most detailed and slowest process. In this process, the user reads each sentence word by word.	
- Decision Rule • Eye tracker: the user's eye moves horizontally to follow each word: progressive eye movements from left to right. • Verbal report: the user reports his/her activity as reading each sentence word by word. (1) Receptive reading: receptive reading involves holding some portion of the already read text in working memory and allows integration of meaning with current being read text. (2) Reflective reading: reflective reading involves interruptions by moments of reflective thoughts about the content of the text.	
Scanning	O'Hara, 1996 Ohno, 2007 Pugh, 1975
- Definition: scanning is the fastest process to locate specific information. Specifically it refers to searching the text to see whether a particular piece of information is present or to locate a piece of information known to be in the text.	
- Decision Rule • Eye tracker: the user's eye jumps from one paragraph to the other paragraph quickly. The gaze alights discontinuously on a few words of each paragraph. • Verbal report: the user reports his/her activity as searching the text to locate a particular piece of information or to determine whether it is desired information.	
Skimming	O'Hara, 1996 Ohno, 2007 Pugh, 1975
- Definition: skimming is a rapid reading process that can be used for establishing a rough idea of the text. This is useful in instances where the readers needs to decide whether the text will be useful to read or to decide which parts to read.	
- Decision Rule • Eye tracker: the user does not have sufficient time to fixate on each word and just gazes at some part of each paragraph. • Verbal report: the user reports his/her activity as grasping a general sense of the content or to retain only the main points.	
Repeated reading	O'Hara, 1996
- Definition: repeated reading is a reading process in which the user read repeatedly the text.	
- Decision Rule • Eye tracker: the user repeatedly reads the text. • The user reports his/her activity as reading the text repeatedly	
Jumping	Marshall & Bly, 2005 Pugh, 1975
- Definition: jumping is a kind of skimming or scanning. Specifically, jumping is a discontinuous activity to locate a piece of information and more intellectual activity as potentially relevant information is evaluated.	
- Decision Rule • Eye tracker: the user will discontinuously scan or skim the text. Electronic media: using direct links from the table of contents, keyword searching. • Verbal report: the user reports his/her activity as locating a particular piece of information.	

Networking	O'Hara, 1996 Yoon et al., 2011 Tashman & Edwards, 2011 Wolfe & Neuwirth, 2001 Pugh, 1975
- Definition: networking allows the user to facilitate rereading and review of documents, and produce relationships in the texts (e.g., definition, temporal, causal, compare, contrast)	
- Decision Rule (1) Flipping: the user flips between two remote pages by using simple gestures (e.g., fingering) • Eye tracker, verbal reports (2) Retrieving annotations or bookmarks: Retrieving annotations or bookmarks involves tracking annotations or bookmarks people made. • Eye tracker, verbal reports (3) Responsive reading: the user engages deeply on reading process, focused on reflection and construction of knowledge. • Eye tracker, verbal reports	
Narrowing	Marshall & Bly, 2005 Pearson et al., 2010
- Definition: narrowing is the activity people use in order to narrow their focus to a particular portion of the page.	
- Decision Rule • Eye tracker: (paper) the user tends to fold his/her document down to one or two columns. (electronic media) he user tends to scale document up on electronic media. • Verbal report: the user reports his/her activity as focusing the attention.	
Broadening	Marshall & Bly, 2005
- Definition: broadening is the activity people use in order to broadened their focus beyond the page by manipulating the article itself. Specifically, the users monitor their progress of reading and look for a sign in order to recognize their current progress.	
- Decision Rule • Eye tracker: the user may scan ahead or skim the remaining text very quickly, or they may turn ahead a number of pages, checking how much is left to read. • Verbal report: the user reports his/her activity as broadening the attention. Especially, the user reports his/her activity as recognizing or monitoring their progress of reading.	
Annotation (anchor-only)	Marshall & Brush, 2004 Morris, 2007 O'Hara, 1996 Qayyum, 2008
- Definition: a deep processing of the material often accompanies a user's use of anchor-only annotation, as the reader needs to decide what is important to highlight or underline. This deeper processing can facilitate better understanding and recall.	
- Decision Rule • Eye tracker: the user makes underlining or highlighting.	
Annotation (content-only)	Marshall & Brush, 2004 Morris, 2007 O'Hara, 1996 Qayyum, 2008
- Definition: a deep processing of the material often accompanies a user's use of content-only annotation, as the readers need to decide what is important. This deeper processing can facilitate better understanding and recall.	
- Decision Rule • Eye tracker: the user makes marks (e.g., *)	
Annotation (compound)	Marshall & Brush, 2004 Morris, 2007 O'Hara, 1996 Qayyum, 2008
- Definition: a deep processing of the material often accompanies a user' use of compound annotation, as the readers need to decide what is important. This deeper processing can facilitate better understanding and recall. Specifically, compound annotation additionally allows the information in the text to be reworded and reorganized as well as integrated	

with other knowledge. This requires an understanding of the original piece of text and how the content and relationships presented in the text can be restructured to create a new, more goal-specific organization. - Decision Rule • Eye tracker: a word (e.g., note-taking) added to the page with a line or other marks indicating a relationship to a portion or the article's text.	
Bookmarking - Definition: Bookmarking enables user to bookmark a page in a causal manner and return to it quickly when required. - Decision Rule • Eye tracker: physical book mark, digital bookmarking function	Pearson et al., 2010 Yoon et al., 2011
Outlining - Definition: outlining allows the user to produce an alternative representation of the meaning of the text. Once these have been established, the article is read more carefully and facts extracted from the text are assigned to each subdivision. - Decision Rule • Eye tracker: the user will have initial skim activity before reading each sentence word by word. • Verbal report: the user reports his/her activity (skim activity) as outlining whole texts or identifying the main subdivisions of the text.	O'Hara, 1996 Hornbaek & Frokjer, 2003 Murray, 2003
Reviewing - Definition: reviewing is the activity people use to summarize or finalize whole contents in the article - Decision Rule • Eye tracker: after the user read through whole contents, the user repeatedly reads the text. • Verbal reports: the user reports his/her activity as summarizing or finalizing whole contents in the text.	Hornbaek & Frokjer, 2003 Murray, 2003
Local process of reading - Definition: local process of reading explains reading patterns (e.g., serial reading, non-serial reading) - Decision Rule (example) FIGURE 3 Schematic of ten local reading strategies. The thicker lines refer to sentences that are read, the thinner lines to sentences that are skimmed, and the • refer to single sentences that are read. Each strategy is schematized for when the reader's general direction is from the beginning to the end of the text and for when the reader's general direction is from the end to the beginning of the text.  	Goldman & Saul, 1990 Hillesund, 2010 Hornbaek & Frokjer, 2003

(4) Final Codes Used in This Study

Highlighting
- Definition: Highlighting refers to when users highlight or underline the text.
- Decision Rule • Eye tracker: The user makes underlining or highlighting.
Note
- Definition: Note refers to when users make a note in the margin of the paper or use the tool on the electronic media
- Decision Rule • Eye tracker: The user makes a note.
Symbol
- Definition: Symbol refers to when users make a symbol on the paper or use the tool on the electronic media (e.g., !, |, ?, {}, *, √)
- Decision Rule • Eye tracker: The user makes a symbol.
Paper note
- Definition: Paper note refers to when users make a note on a separate piece of paper.
- Decision Rule • Eye tracker: The user makes a note on a separate piece of paper
Networking
- Definition: Networking refers to when users re-read, review the documents and intend to make relationships in text.
- Decision Rule • Eye tracker: The user is going back to the previous page or looking at different parts in multiple pages. • Verbal reports: The user reports his/her activity as rereading the text and making relationships in text.
Jumping based on reference
- Definition: Jumping based on reference refers to when users locate specific information based on a reference in the text.
- Decision Rule • Eye tracker: The user is directly moving from one part to another part of the text (referenced part). • Verbal reports: The user reports his/her activity as locating a particular piece of information.
Macro-monitoring
- Definition: Macro monitoring refers to when users broaden their focus beyond the present page in order to determine their current progress.
- Decision Rule • Eye tracker: The user quickly skims the remaining pages by counting them or using the navigation panel on electronic media. • Verbal reports: The user reports his/her activity as recognizing or monitoring their progress of reading.
Micro-monitoring
- Definition: Micro monitoring refers to when users narrow their focus in order to extract information sufficiently
- Decision Rule • Eye tracker: The user is pointing/follwoing sentence using the hand or pen. The user is pointing/following

sentence using the cursor (computer)

- Verbal reports: The user reports his/her activity as narrow their focus to a particular portion of the page.