The effects of three different computer texts on readers’ recall: based on working memory capacity

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Abstract

This study investigated the effects of three different computer texts on readers’ recall based on individuals’ different working memory capacities. In addition, the intermediate effects of the total reading time were taken into account. The findings indicated that the structure and presentation of text influence how well information is remembered. Those who read the linear, traditional text produced better recall scores than those who read the hypertexts. In particular, when the total time spent on reading was controlled, the difference between the two hypertexts disappeared. Furthermore, the participants with different working memory capacities appeared to exhibit different results in that those who were low in working memory produced the best results with the traditional text while the difference was not significant among the different conditions for those who were high in working memory.

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1. Introduction

Unlike paper-based materials, modern information technologies enable the adaptation of communication to the needs of individuals. Such technologies are capable of modifying the format of a text’s order and detail in ways that enhance users’ learning experiences, individually. At the center of these new technologies are various forms of hypertext and hypermedia. Hypertext is a computer-mediated text in which highlighted words or titles enable readers to interactively determine the order and
level of detail by serving as links to other excerpts or documents of supporting information. Traditional text, on the other hand, refers to a text unchangeably formatted from a certain beginning to a certain ending point, with no diversionary links to other excerpts or documents.

Today, hypertext is widely used, but little systematic research has investigated how much better or worse information is learned from hypertext formats than with traditional text or how to design hypertext to enhance human learning experiences. Hypertext users are no longer constrained to traditional formats that give readers a specific order to follow for the presentation of information. The hypertext technologies provide readers the ability to control the order in which information is presented and to form their own cohesion and sequence of information. It was hypothesized that a reader, in a hypertext environment, takes an active role in finding information and encountering different types of information (Bourne, 1990; Dee-Lucas & Larkin, 1995). However, there is considerable disagreement as to whether hypertext is beneficial for all individuals’ cognitive learning processes (Dee-Lucas & Larkin, 1995; Gordon, Gustavel, Moore, & Hankey, 1988; Hammond, 1989; Hammond & Alinson, 1989; Jonassen & Wang, 1990; Schroeder, 1994; Spiro & Jehng, 1990). Two of the most frequently cited problems are disorientation and cognitive overload created by the nonlinear nature of hypertext (Heller, 1990; Jonassen & Wang, 1990; Schroeder, 1994; Spiro & Jehng, 1990). It was suspected that the choices and multiple potential paths taken through hypertext might overload readers’ cognitive capacities, in turn creating cognitive disorientation. Concerning this, it is logical to test whether or not hypertext actually impairs information processing. In this study, two different types of hypertext were examined in comparison with a linear, traditional text. It was hypothesized that individuals who read the hypertexts would produce poorer recall scores than those who read the linear, traditional text.

In addition, individuals’ different working memory capacities were suspected to interact with the effects of the different computer texts. Some computer text formats or styles are suspected to be processed more easily by readers, depending on their different working memory capacities (Budd, Whitney, & Turley, 1995; Dee-Lucas & Larkin, 1995; Lorch, 1989; Schroeder, 1994). Working memory is the mind’s temporary memory storage used for initial processing of incoming information (Baddeley, 1986). It is known as one of the key elements of learning or acquiring knowledge. It is well documented that different individuals have different working memory capacities (Baddeley, 1986; Baddeley, Logie, Nimmo-Smith, & Brereton, 1985; Budd et al., 1995).

In this study, three types of text formats (the traditional text, the structured hypertext, and the networked hypertext) were investigated. Traditional text refers to linear information presentation in a way that no hyperlink was presented while the others, hypertexts, contained hyperlinks connecting pages of text in a manner that formulates two distinct ways of organizing textual content. The structured hypertext was defined as a text format where links organized pages of text in a hierarchical order. On the other hand, the networked hypertext was defined as a text format that contained links without any structural consideration. In other words, wherever a term existed in the text for which an elaborating excerpt existed, a link was
presented. Therefore, it was suspected that the text format without any consideration of a content structure (the networked hypertext) would require more cognitive capacity than the structured hypertext.

Investigating the advantages and disadvantages of different hypertext formats in relation to relevant individual characteristics is an important step in exploring the new computer-based learning environment. It may help uncover the effects of hypertext and help to create more effective computer-mediated text based on an individual reader’s needs. This study explores a relationship between limited working memory capacity and different computer text formats. The purpose of this study was to explore how text formats affect a reader’s recall based on his or her working memory capacity. A post-test only experiment with the three variations of computer text formats was used to test these relationships. The central focus of the research was an individual’s limited working memory capacity and computer text formats.

2. Literature review

2.1. Hypertext and cognition

One of the challenges for instructional designers is how best to present information (Schroeder, 1994) for students’ learning. Most studies have been done with traditional text, such as books, but more recent studies started addressing the acquisition of knowledge in terms of hypertext.

Traditional text presents a continuous linear flow of information. When readers read a text, they are required to build a mental representation of the content in their own minds. With traditional text, readers read from top to bottom so that text processing is continuous. On the other hand, hypertext seems to interrupt continuous text processing where readers move back and forth between the text units. Dee-Lucas and Larkin (1995) speculate two possible effects of this discontinuity. First, “Interruptions in text study could interfere with the development of an integrated representation of the text as a whole” (p. 435). Each time when readers select a new piece of information, they have to build a connection with and incorporate prior information. It would be difficult for readers to identify the main idea of an overall text. Second, “Interrupted text study may increase the depth of processing of content within each unit by focusing attention on the individual unit” (p. 435).

To remember factual information successfully, retrieval must be in response to some sort of cue (Farr, 1987). Dee-Lucas and Larkin (1995) argued that unit titles in hypertext would be better remembered than corresponding headings and subheadings from traditional text. The way in which the text is partitioned into units is assumed to be highly salient to the reader in hypertext because this information guides them to their next choice.

On the other hand, others argued that hypertext may actually hinder information processing by causing disorientation and an additional cognitive burden of comprehending information as a whole while selecting links and remembering what links they click (Heller, 1990; Jonassen & Wang, 1990; Schroeder, 1994; Spiro & Jehng,
Schroeder further argued that hypertext requires specific navigational skills which demand more cognitive resources from readers than traditional text.

Hypertext readers must integrate specific content to the text as a whole. Maintaining coherence among information appears to be a potential problem in using hypertext (Marshall & Iris, 1989). Dee-Lucas and Larkin (1995) speculated that readers process the text units as segmented information rather than as interrelated information. Thus, readers with hypertext may have difficulty identifying the main points from the text as a whole, compared with readers using traditional text. Some attempted to address this issue by providing extra instructional aids such as different types of navigation tools. However, whether these supplementary aids are useful for all readers’ learning is in question. For example, Phillips, Watson-Paelis, Cook, Ming, and Tiancheng (1992) found those individuals provided with the most minimal navigational tools achieved the highest recall. They speculated that it might be because the participants were less reliant on aids which led to put their own cognitive efforts to process the information. Dee-Lucas and Larkin also found that the minimally structured overviews that allow students to construct their own organization of the information produced the best learning results.

However, these two assumptions, not incompatible with one another, must rest equally with a well-documented fact about human cognition: Individuals have limited working memory capacities.

2.2. Limited working memory capacity

According to Ericsson and Kintsch (1995), “to perform any cognitive tasks, an individual must maintain access to large amounts of information, needs contextual information to integrate information in the current sentence coherently with information in the text previously read, and maintain the results of intermediate steps in memory” (p. 211).

One crucial concept in the information-processing literature is working memory, a system responsible for the temporary storage and processing of information (Baddeley, 1986). Working memory plays a critical role in integrating information during reading. Several models show a dual role of working memory: First, it grasps recent information from a text and connects it to related information in long-term memory. Second, it temporarily maintains main information for constructing an overall understanding of the passage (Baddeley, 1986; Kintsch & Van Dijk, 1978; Lee-Sammons & Whitney, 1991).

It is well documented that individuals have different capacities for working memory and these individual differences predict readers’ level of text integration ability. For example, Yuill, Oakhill, and Parkin’s study (1989) showed that readers with low working memory span have poorer text integration abilities than readers with high working memory span. It was suspected that it is because individuals with low working memory capacity are less able to maintain necessary information in an active state (Lee-Sammons & Whitney, 1991).

On the other hand, some data suggest that it may be because individuals with high working memory capacity are better able to maintain multiple, tentative interpretations
and use text elements to test those interpretations (Baddeley et al., 1985; Lee-Sammons & Whitney, 1991). For example, Lee-Sammons and Whitney examined the effect of working memory capacity and readers’ perspectives on comprehension of a narrative text. In their study, participants were told to read the story from different perspectives (e.g. either from the perspective of a potential home buyer or a potential burglar) and to think about the relevance of each sentence from that perspective. It was found that the participants remembered more information relevant to the new perspective than information relevant to the original encoding perspective. However, the results were different based on their working memory capacities. For low- and medium-span readers, shifting perspectives resulted in less recall of new information than if the perspective was held constant while high-span readers remembered information independent from shifting perspective. Moreover, low-span readers were poorer at remembering information not relevant to the original encoding perspective while high-span readers remembered similar amounts of perspective-relevant and irrelevant information. They concluded that the degree to which participants used the perspective to guide their comprehension varied with working memory span. In sum, the working memory capacity is not only important in selecting learning strategies, but also in maintaining and operating strategies for retrieval from long-term memory (Baddeley, 1986).

2.3. Working memory capacity and text format

Individual differences in working memory capacity are related to differences in what kind of how much information is retained when one is reading texts (Baddeley, 1986; Budd et al., 1995, Lee-Sammon & Whitney, 1995).

According to Budd et al. (1995), in order to establish relationships between closed clauses or sentences, readers have to maintain the information most recently processed from the text in working memory. Thus, working memory facilitates the comprehension of text by building coherence at a local and global level. In this aspect, if texts are coherent at a more global level, readers will require less working memory capacity to process new information.

Reading is much easier if there is a clear concept stated at the beginning of the passage because readers need only adopt and test it against the remainder of the passage. Otherwise, readers have to construct one while they are reading. Furthermore, readers are required to modify it when they confront new information inconsistent with their initial interpretation (Kieras, 1981). These activities require more working memory to process information. Budd et al. (1995) found that when materials were easy, the performance differences of readers with different working memory spans were small or insignificant. However, these differences got larger when materials were difficult to understand. Lower span participants performed more poorly on a detailed question in the topic-absent (where there is no heading) condition. These data imply that certain text or passage formats can help or hinder readers remember more detailed information from a text. Therefore, individuals’ working memory capacities should be considered when designing effective hypertext learning materials.
A well-designed computer text requires less working memory by the way in which the text is presented (Budd et al., 1995; Dee-Lucas & Larkin, 1995; Schroeder, 1994). Unfortunately, few computer materials have been designed in consideration with individual different capacities. Individuals’ different working memory capacities are expected to interact with hypertext formats. It is important to address the problems or the benefits of new hypertext systems that can be adapted to meet readers’ limited abilities.

Hypertext is normally used in an integrated way with other visual or auditory aids such as video, audio, and graphics. For this reason, it is hard to consider hyper-link systems themselves as hypertext applied in practice. However, the way hyper-link systems affect an individual’s cognitive information processing should be studied on a micro level.

To design effective hypertext based on individuals’ needs, this research focused on individuals’ different working memory capacities. Investigating the dynamics of text formats and individuals’ different working memory capacities may help to address the nature of the information processing by determining the text formats that work best for each individual. It will allow us not only to identify how hypertext effects interact with individuals’ working memory capacity, but also to better distinguish what is the best hypertext design for its readers’ educational purposes.

Based on this literature review, the following four hypotheses were examined in this study.

2.4. Research hypotheses

**H1.** The participants reading from hypertext documents will have lower recall scores than those reading identical information from traditional linear-text documents.

**H1** is based on Jonassen and Wang (1990)’s suggestion that hypertext may actually hinder readers’ learning because hypertext systems can overload cognitive processing capabilities. It is logical to test whether or not hypertext actually impairs information processing by measuring how much information is remembered by the participants who read hypertext documents, in comparison with the participants who read traditional linear text documents.

**H2.** The participants reading from the structured hypertext will have higher recall scores than those reading identical information from the networked hypertext.

**H2** is based on the assumption that if hypertext systems cause disorientation (Heller, 1990; Jonassen & Wang, 1990; Schroeder, 1994; Spiro & Jehng, 1990), then information presented in a way, which helps a reader to acquire the general structure of an article, might prevent a reader's disorientation.

**H3.** The participants with high working memory span will have higher recall scores than those with low working memory span, regardless of the text format.

**H3** is based on working memory literature which shows that individuals have different working memory capacities (Baddeley, 1986). It is known that these capacities
play a critical role in cognitive tasks, such as recall. For example, Lee-Sammons and Whitney (1991) found that high working memory participants remembered more information than low working memory participants.

**H4.** The detrimental effect of hypertext in participants’ recall scores will be greater for the participants with low working memory span than those with high working memory span.

An interaction is anticipated. H4 is based on the logical assumption that it will be even harder for lower working memory span participants to process information in hypertext than for high working memory span participants, if hypertext actually hinders participants’ recall and comprehension in general.

### 3. Method

The experimental design was a post-test only model with three variations of computer text formats. The manipulation involved reading an article in one of the three formats: traditional text, structured hypertext, and networked hypertext. After participants finished reading, the participants were asked to take the factual recall tests followed by the reading span tests with demographic questions.1

In the experiment, each participant was randomly assigned to one of three groups, corresponding to the three text formats. The participants’ working memory span was measured by the reading span tests, classifying participants into three different categories; High Working Memory Span, Medium Working Memory Span, and Low Working Memory Span.

#### 3.1. Materials

After seven initial articles were tested, a topic was selected based on the level of interest and gender neutrality in the article. The article selected was, “The battle against segregation in America”,2 being determined the most interesting for both males and females.

The development of the recall test for this article involved the following procedure: 22 multiple-choice questions were written for a factual recall test with approximately six questions for each paragraph of the article. Sixteen graduate students (in Journalism and Communication) participated in the pretest to determine which items to use. \(t\)-Tests for the participants’ interest level and item difficulty scores were computed. Sixteen multiple-choice questions were adopted and six questions were dropped from the recall test.3

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1 In this study, the reading span tests were given after the stimulus because it was considered that the stimulus manipulation did not affect the results of the reading span test results.

2 Topic 4: “The battle against segregation in America” from How to prepare for the GRE, p. 521.

3 This is based upon the result of an analysis. Items with Item Discrimination scores greater than 0.50 were kept. Also, \(t\)-tests for males vs. females and item difficulty scores were computed.
3.2. Design and procedure

Participants were randomly assigned to one of the three conditions: traditional-text, structured hypertext, or networked hypertext (Fig. 1).

The researcher explained the test procedures at the beginning of the study and participants were told to read the text completely and not to go back to the readings after they began the recall test. Computers were preloaded with a letter from the researcher explaining the study and a link, which randomly led participants to one of three different conditions. The computer program, presenting the article, recorded how much time each participant spent on each screen of the article as well as which links he/she clicked. The experiment was conducted in a computer lab.

In condition 1, the article was presented in traditional text format with a link titled, “turn to the next page”, to simulate the pages in a paper-based book. The participants were to read the article in traditional text format, from top to bottom. After the participants finished reading, they clicked on the button “Finished”. After clicking on this button, participants were automatically taken to the working memory tests, followed by the recall tests, and ending with the demographic questions. A “Back” button was available enabling the reader to return to the previous page while reading.

In condition 2, the article was presented in a structured-hypertext format. The structured-hypertext consisted of each sub-topic on a different screen, linking hierarchically by highlighted, underlined key terms in the text. The reader began reading at the top level and was able to click on links for several levels of sub-topical information. As in condition 1, a “Back” button was available enabling the reader to return to the higher levels in the hierarchy.

Fig. 1. Three different conditions.
In condition 3, the article was presented in a networked-hypertext format. The text was presented with each excerpt on its own screen. The user was able to navigate between excerpts by clicking on highlighted, underlined terms, serving as links. No structure, such as hierarchical, was used between links. Instead, wherever a term existed in the article for which an elaborating excerpt existed, a link was presented. This created a Web-like, user navigated architecture of links where looping was possible. As in conditions 1 and 2, a “Back” button was available for the reader to return to previous screens, as would be found in a Web-browser or Windows Help file.

After participants finished reading, each participant was given three reading span tests and the recall test. Fourteen questions were given to participants regarding demographic information, computer usage and familiarity, affinity for history, attitude toward computers and the degree of interest in and experience with hypertext. Each participant took from 30 to 45 min for the whole process.

3.3. Data analysis

The purpose of the analysis was to find out whether presentation of the same information in different text formats affected participants’ recall scores and if these scores varied by the participants’ working memory capacities. In addition, data were collected to describe participants’ race, age, computer ownership and use, Internet access, World Wide Web sites viewing time, and familiarity with hypertext. ANOVA and an Independent-Samples t-test were used to test for the effect of the different text formats and working memory span.

3.4. Recognition data

Of the 16 recall measuring questions, the minimum number correct was 3 and the maximum correct was 15 with a mean of 8.4 and a standard deviation of 2.9.4

3.5. Working memory

In the past, the studies for measuring working memory span were mostly done with a test of storage capacities for unfamiliar and unrelated information such as five or six unrelated digits or words. However, this type of test was criticized for not being able to indicate the capacity of working memory available during reading. Daneman and Carpenter (1980) designed a task to measure the capacity of working memory during reading. They presented participants with a series of unrelated sentences that they needed to comprehend to answer following text questions. At the end of the presentation, participants were asked to remember as many of the last words of the sentences as possible. The number of words a subject correctly remembered became the participants’ reading span.

In this study, the reading span test, similar to Daneman and Carpenter’s, was given three times. Each test used a black computer screen with unrelated sentences centered in large yellow type. The sentences were presented for approximately 4 s

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4 The reliability of these 16 items was tested. The Cronbach α score was 0.61.
each, followed by prompts for the participant to remember and enter the last word of each sentence. Each test began in this manner with one sentence, then two, three, four, and five sentences. Each series of sentence displays and questions were followed by a question about content to assure the participant read the complete sentence. The results of the first test (first sentence) were discarded due to exceptionally low scores. The mean scores of the second and third tests, however, were used to categorize participants’ working memory span into the three groups of low, medium, and high (Table 1).

3.6. Participants

Ninety-six undergraduates were tested. Twenty-two sessions were held. Participants were compensated with extra credit in their college courses. Of the 96 participants, 68%, \( n = 65 \), of participants were white, 19%, \( n = 18 \), were Hispanic American, 4%, \( n = 4 \), were Asian or Pacific Islander, 2%, \( n = 2 \), were African American. Ninety-two per cent of the participants were between 19 and 22 years old. Sixty-six per cent were female, \( n = 63 \), and 34% were male, \( n = 33 \).

3.7. Computer use and familiarity

Seventy-seven per cent of the participants owned a computer and 99%, \( n = 94 \), said they were able to use computers either at home or at work/school or both while one participant responded “I don’t use computers at all.” Also, 98% of participants have access to the Internet. Fifty per cent, \( n = 48 \), of the participants answered that the average time they spend on the Internet per day was less than 30 min, 24%, \( n = 23 \), more than 30 min to 1 h, and 18%, \( n = 17 \), between 1 h and above while 8%, \( n = 8 \), of the participants said they did not look at the Internet at all. The participants also were asked to rate their ease of reading from a computer screen: 66%, \( n = 60 \), of the participants were fairly comfortable with reading text from a computer screen while 21%, \( n = 21 \), answered “uncomfortable” or “very uncomfortable”. In terms of familiarity with the term “hypertext”, 36%, \( n = 35 \), of the participants said they were “familiar” while 54%, \( n = 52 \), answered “unfamiliar”. A question about their highest level of hypertext knowledge was asked. Table 2 shows the proportion of participants who selected each level. Only about 14% said they could create hypertext documents.

<table>
<thead>
<tr>
<th>Valid</th>
<th>Frequency</th>
<th>Per cent</th>
<th>Valid per cent</th>
<th>Cumulative per cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>20</td>
<td>20.8</td>
<td>20.8</td>
<td>20.8</td>
</tr>
<tr>
<td>Medium</td>
<td>60</td>
<td>62.5</td>
<td>62.5</td>
<td>83.3</td>
</tr>
<tr>
<td>High</td>
<td>16</td>
<td>16.7</td>
<td>16.7</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>96</td>
<td>100.0</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>
4. Results

4.1. The effects of text formats: condition

H1 suggested that participants reading from the hypertext documents would have lower recall scores than those reading identical information from traditional linear-text, on computer screens.

ANOVA was used to test whether computer text formats, which represent traditional text, structured hypertext, and networked hypertext, affected the number of correct answers on the recall test. Text format had a significant effect on recall scores, \( F(2, 91)=3.6, P<0.05 \). Further analysis (LSD) revealed that there was a significant difference between the recall scores of the traditional text and the structured hypertext. The average recall score for the traditional text was 9.39 (S.D.=2.68, \( n=31 \)) while the recall score for the structured hypertext was 7.67 (S.D.=2.88, \( n=33 \); Fig. 2). The difference between the traditional text and the networked hypertext (\( M=8.89, \) S.D.=2.64, \( n=27 \)) was not significant with \( P=0.08 \). In sum, the recall score for the traditional text was higher than the recall score for the structured hypertext; i.e. those reading from traditional text had higher recall scores than those reading identical information from the structured hypertext documents.

However, it was suspected that this difference might have been mediated by the total reading time since it was found that the participants’ total recall scores were highly correlated with the participants’ total reading time, \( r^2=0.47, P<0.001 \). Therefore, the participants’ total reading time was tested as a covariate in GLM. As suspected, the participants’ total reading time was significant, \( F(1, 91)=14.1, P<0.01 \), and the condition effect still remained significant, \( F(2, 91)=5.2, P<0.05 \). However, the difference was shown between the traditional text and the others. The adjusted mean score for the traditional text was 10.03 (S.E. =0.56) while the mean of the structured hypertext was 8.45 (S.E. =0.62). One interesting finding was that the near significant difference between the structured hypertext and the networked hypertext disappeared after treating the total time variable as a covariate. The adjusted mean score of the networked hypertext came out to be 8.47 (S.E. =0.49).

H2 suggested that the participants reading from the structured hypertext would have higher recall scores than those reading identical information from the networked hypertext. Independent-Samples \( t \)-test showed that there is a significant dif-

Table 2
Level of hypertext use

<table>
<thead>
<tr>
<th>“What is your highest level of hypertext knowledge?”</th>
<th>% Of answering “Yes”</th>
</tr>
</thead>
<tbody>
<tr>
<td>I can create advanced hypertext documents</td>
<td>2</td>
</tr>
<tr>
<td>I can create basic hypertext documents</td>
<td>12</td>
</tr>
<tr>
<td>I know how to use hypertext, but I cannot create hypertext documents</td>
<td>20</td>
</tr>
<tr>
<td>I have heard the term hypertext, but I don’t know how to use it</td>
<td>7</td>
</tr>
<tr>
<td>I don’t know of hypertext at all</td>
<td>58</td>
</tr>
<tr>
<td>Total</td>
<td>100 (( N=96 ))</td>
</tr>
</tbody>
</table>
ference between recall scores of the structured hypertext condition and networked hypertext condition, \( t(57) = -1.8, P < 0.05 \). However, the result did not support this hypothesis and indicated the opposite direction in that the recall scores for the networked hypertext condition, \( M = 8.9, \text{S.D.} = 2.6 \), were higher than the recall scores for the structured hypertext condition, \( M = 7.6, \text{S.D.} = 2.9 \). However, when the total reading time was considered in the equation, this difference disappeared.

4.2. The effect of working memory capacity

H3 proposed that the participants with high working memory span would have higher recall scores than those with low working memory span.

An ANOVA model was used to test whether the participants’ reading span affected the number of correct answers on the recall test. The results did support this hypothesis and indicated that higher working memory participants had higher recall scores than the lower working memory participants, \( F(2, 91) = 4.6, P < 0.01 \) (Fig. 3). The mean of the high working memory participants’ scores was 10.39 (S.D. = 2.94, \( n = 16 \)) while the mean of other participants’ scores were 7.8 (S.D. = 3.16, \( n = 20 \)) for the low working memory participants and 8.1 (S.D. = 2.58, \( n = 60 \)) for the medium working memory participants.

H4 suggested that the effect of hypertext would be greater for the participants with low working memory span than those with high working memory span in participants’ recall scores.

This hypothesis was not supported, \( F(4, 91) = 1.18, P = 0.33 \) even though the anticipated direction was shown based on Independent-Samples \( t \)-tests. It was
shown that for the low working memory span participants, there was a near significant difference between the traditional text and the networked hypertext (Fig. 4): Those who read the article in the traditional text condition had higher scores than the participants who read either in the structured text condition or in the networked hypertext condition, $t(11) = 1.4, P = 0.09$, as anticipated. On the other hand, there was no significant difference among the participants who were in the different conditions. However, these results are inconclusive due to the small sample sizes in certain categories and call for further investigation.

5. Discussion

The findings of this study reveal that the structure and presentation of text influence how well information is recalled. Recognition seems to be affected by the structure in which the information was presented and the participants’ different working memory capacities. The participants who read the structured hypertext had much lower recall scores than the participants who read the traditional text or the networked hypertext. However, this difference disappeared when the participants’ reading time was considered. The findings showed that the participants who read the traditional text exhibited higher recall scores than those who read the other types of computer text. In sum, it was shown that the different types of hypertext systems seem to influence how much time an individual reads a given article and in turn influence how much information can be remembered. In this study, even though the
results are somewhat inconclusive, an anticipated direction was detected in that, for
the participants with the low working memory span, reading the article in the tra-
ditional text format produced the best recall scores while the recall scores of those
with the high working memory span did not vary by the conditions, as expected.

This study had several limitations that should be considered for interpretations of
the research and suggestions for future studies. One limitation of this study was the
sample size. Since working memory span was divided into three groups (low, med-
ium, and high) and compared in three different conditions, there were not enough
participants to compare in certain categories. Further research is required with more
participants for more accurate results.

Another limitation is related to the reliability of the recall test. The Cronbach’s \( \alpha \)
score was 0.61, which is relatively low. The refinement of the recall test should be
taken into consideration for future studies for developing a more reliable measure-
ment. In addition, the level of cognitive processing should be taken into consideration
in designing effective texts. In this study, simple recall was tested. However, effective
learning constitutes more than just being able to remember or recognize what was
read. The effects of computer texts may vary depending on what learning tasks are
being measured. Further investigations should be applied to deeper level cognitive
processing such as synthesis or problem solving tasks.
Furthermore, the findings should be interpreted in proper context as they apply to the real world. The manipulation of text formats is not necessarily as it would be found in the field in that the networked hypertext was supposed to simulate what was most commonly found in both computer application help systems and Web pages. The links within these three documents lead directly to other excerpts of the same document as where those on the Internet, for example, might lead to entirely unrelated content. However, since this study is focused on applications for learning, it was presumed that content should be focused for instructional purposes.

Hypertext comes in many different formats—different levels of details and different purposes. While hypertext can simply be pop-up fields with definitions or explanations, it can be as complex as a non-directed path through many documents. Therefore, a simplistic generalization should not be made based on these isolated findings. Careful investigations to unweave the complex relationships between different computer text formats and human cognition should continue.

Second, the study setting, as anticipated in an experimental study, should be carefully re-addressed. For the purpose of this study, the participants were located in a computer lab and asked to try to explore all the links before they clicked the finished button. It was not intended to simulate a naturalistic setting such as casually surfing the Internet. It was focused on instructional settings where certain learning purposes would be intentionally presented such as in a lab instructional setting. However, the purposes of reading can vary: reading can be for pleasure or finding information. Some materials may be better read in a linear fashion when gaining an understanding of the text as a whole is concerned, as this study indicated. However, the results should be applied carefully depending on practical situations. For example, when one is looking for the answer to a specific question/problem, hypertext may be more appropriate for finding information quickly.

The findings of this study can be utilized in practical settings. One example is designing effective learning materials for instructional purposes in a manner such that linear information presentation is given to those with low working memory capacities, as this will better accommodate them than the other two computer text formats investigated here. The findings of this study also reveal that the structure and presentation of text influence how well information is recalled at the first glance. However, the total time of reading was shown as an important mediating variable. It appears that the different hypertext formats influence how much information is read (a total reading time) and in turn affect how much information is remembered. This indirect causal relationship between the hypertext formats and the recall scores should be investigated in further detail. It might provide important aspects of designing effective hypertexts.

The study results indicate that hypertext systems may cause disorientation in the learning process and hinder factual recall. Many scholars have suggested that hypertext systems can overload cognitive processing capabilities and encourage over-simplification of the information read. However, this premature conclusion is dangerous and further careful research is required to determine whether or not reading from hypertext actually has detrimental effects on learning.
Previous literature usually asserts the positive role of hypertext in learning, based on the assumption that hypertext provides selective attention or reader control. Many educators believe that selective attention determines which information is processed or ignored (Plude, 1992); therefore, it accelerates information processing. It is worth examining “selective attention”, in terms of hypertext use, more closely to evaluate its implications for the future, regarding factual overall recall and recall of information of interest to participants.

The purpose of the study was to explore the effects of hypertext in relation with individuals’ limited working memory capacities. Considering individuals’ working memory differences that exist in learning materials in a hypertext learning environment, the findings in this research may give clues for further research. However, because the study contains several limitations, more careful examination of the working memory effect on readers’ recall is highly required.

Also, these different approaches to learning in a hypertext environment might be subject to differential responses based on working memory capacity and learning styles, and motivational factors. Isolated and simplistic conclusions from the studies of individual differences, which assert that high working memory people are simply physiologically or biologically superior, hinder the possibilities of narrowing the present gap. For this reason, a careful examination of individuals’ working memory capacity and computer text learning patterns will help researchers understand the complex relationships among individuals’ abilities, needs, and experiences as well as the nature of learning in hypertext environments.

References


