Methods for Manipulating **Electronic Documents** in Relation to Information Retrieval

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This study
is part of
preliminary work
aiming to find out
which graphic elements
help users navigate
in electronic information space.

The study explores
alternative methods
that can be used
to manipulate the content
of web pages,
looking at their effects
on finding
specific material
and acquiring
an understanding
of the content.

Four versions of an extract from a Human Computer Interaction (HCI) textbook were created:

a scrolling document

a document with links

a paging document

a document with frames

A series of tasks was carried out by two different groups of readers. Readers within each group were divided between the four versions of the document, with each reader reading only one version. Readers were asked to find information; read a text; answer a question; write a synopsis. Measures were taken of speed to locate information, comprehension of an issue and comprehension and memory of the text read.

The results indicated that the paging document and document with links enabled readers to find information more quickly. There were no differences among versions in the time taken to read the text, but second semester students read faster than seventh semester.

The methods of manipulating electronic documents offer advantages and disadvantages depending on the purpose of the text and the readers' tasks. It seems that if readers wish to find information quickly from an electronic document, the method of manipulating the document should be different from that applied to a large document which needs to be remembered.

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INTRODUCTION

Electronic documents have become an indispensable tool for almost all facets of everyday life. Readers of electronic documents can perform a variety of activities using the computer: read, search for information, buy, subscribe, communicate, answer questions, place orders, etc. Regardless of their tasks, readers have to search, read and make decisions.

Up to now, there exists little information on how readers are supported by the design of electronic documents. Web designers are guided by intuitive notions without knowing which elements can support readers and which other elements interfere with their interaction with computers.

The development of "theories of scope" or frameworks that can predict how some design features can work in specific circumstances would support design decisions for better documents (Wright, 1998). This study attempts to find out how methods of manipulation affect readers' performance in searching for information in hypertext.

READERS' PROBLEMS WHEN INTERACTING WITH ELECTRONIC DOCUMENTS

Navigation has been one of the problems in readers' interaction with electronic documents. The main concern is how readers adjust to technology when they are looking for information. Some of these adjustments are described below.

1) Readers have to learn a new language and new methods of manipulation and interaction with electronic documents:

> Readers have to learn the basic vocabulary to perform any task, such as 'download, browse, bookmark, link,' etc., and have to learn a new graphic language of icons displayed on the screen (Honeywell, 2000; Goonetilleke, 2001). Some readers may also have to learn these new terms in a foreign language as they have no meaning in their own language.

> Readers have to learn basic technical manipulations to navigate, such as the use of back-forward buttons, horizontal and vertical scroll, paging, links or frames, download time, history list, etc. (Schwarz, Beldie and Pastoor, 1983; Dyson and Kipping, 1997; van Nimwegen, Pouw and van Oostendorp, 1999).

2) Readers are presented with new ways of displaying information:

> Readers find a variety of images, text, links, buttons, sound, elements in motion; they face a new medium and new appearance not known in print.

> Readers have difficulty in recognizing the type of document they are accessing, in terms of size, form, contents, depth, interactivity, etc. The layout of most documents does not give any feedback as to whether readers are accessing the information they are looking for or not (Dillon and Gushrowski, 2000; Beghtol, 2001; Kwasnik, Crowston, Nilan and Roussinov, 2001; Toms, 2001).

3) Readers have to learn a new concept of movement in electronic space:

> Readers are afraid of getting lost, of not knowing where they are located, where they have been and where they are aiming for. They might be afraid of taking the wrong route and losing their present position or not finding their way back (Edwards and Hardman, 1989; Nielsen, 1990; Kim and Hirtle, 1995; Dillon and Vaughan, 1997; Allinson and Hammond, 1999; Otter and Johnson, 2000; Ahuja and Webster, 2001).

> Readers want to navigate fast and perform their task in the shortest possible time.

4) Readers have to cope with different cognitive demands from electronic documents:

> Readers have to understand the different structure of information in electronic documents, which consists of nodes of information connected in a non-linear pattern. Readers have to decide which path to take from the broad range of possibilities offered (On links: DeRose, 1989; Campbell and Maglio, 1999; Pajares, 2000. On structure: van Nimwegen et al, 1999; Gullikson et al, 1999).

> Readers are afraid of losing the 'thread of investigation' because they can be easily distracted in their search for information ending in an unexpected topic (Conklin, 1987; Kim and Hirtle, 1995).

> Readers could be overwhelmed by the amount of information presented when they find thousands of possible links that contain information in a search machine; they do not know which site to access. There is always the uncertainty that their information might exist in the links not accessed (Wurman, 1989; Nielsen, 1990; Boiarski, 1997).

These are some of the situations that readers have to face when learning to access electronic documents. In this study, we will focus on the method of manipulation, which is one of the basic interactions of readers with this technology.

METHODS OF MANIPULATING DOCUMENTS

One of the first challenges for users of electronic documents is how to manipulate the pages on the screen. Two basic methods have been addressed: scrolling and paging. There have been few studies regarding these issues that can shed some light on how readers perform with each method of manipulation. Two other methods will also be presented in this study: frames and links.

Scrolling and paging

Scrolling can be defined as the vertical or horizontal movement of the page on screen. This movement can be done through the use of a scroll-bar which slides up and down, right and left and helps the reader to go through the text.

'With scrolling, pages are visibly connected in a linear order. One can scroll to the next page but a part of the other page will be still visible, at least at the beginning, providing some temporary context. When the linearity is pronounced, or direct, this will lead to a clear insight into the structure' (van Nimwegen et al, 1999). Scrolling is more useful to present information that is lying close together (Schwarz et al, 1983). (The term scroll also refers to the way the ancient papyrus scrolls were used.)

Software designers have included some features to help readers scroll a page such as the arrows on the right border, and the square or bar that slides down and indicates the depth of the page being consulted. In word processors this square can also indicate the page number and the topic within the document. However, a disadvantage of the scrolling system is that it does not provide enough 'tangible data about the location of information shown on the screen. Each time the scroll tools are used they disrupt the spatial layout, making it difficult for writers to build a 2D representation of the set of information' (Piolat, Roussey and Thunin, 1997).

The paging manipulation tries to emulate turning the pages of a book. The reader will click on a specific mark on the page and a new page appears, completely changing the screen. This 'does not pronounce the linearity very well' and makes it difficult to know at which level of depth the reader is (van Nimwegen et al, 1999). Schwarz et al (1983) suggest that paging is better to connect information that is less related or lying apart. On the other hand, Piolat et al (1997) believe this change of screen helps readers feel like they are in the same document, just changing pages of a book.

There have been studies regarding these two methods of manipulation with contrasting outcomes. The first studies presented here are supportive of the paging manipulation over the scrolling mode. One of the first studies was done by Schwarz et al (1983) who applied a test to inexperienced users to find out in which 'mode of operation' the participants performed better in a word reading

task, line searching and sorting words. Even though the results do not show any statistically significant time differences, they state in their discussion 'in no case did scrolling prove to be superior to paging.' Moreover, paging was clearly preferred for the reading of a continuous text. Scrolling can therefore be considered as the less suitable mode of operation for the tasks they tested.

Another study that supports paging over scrolling was done by Dyson and Kipping (1997). Their test explored ease of reading different formats, either one column with long lines of text or three columns of text. Participants had to read three documents, two in a single-column, scrolled and paged, and one in three-columns and paged. The results showed no differences in reading rate between one-column with scrolling movement and three-columns paged format. They found that participants had different reading styles, whether long scrolling movements and/or repeated very small movements. 'The differences in reading rates that were identified show that paging is faster than scrolling' (Dyson and Kipping, 1997).

Piolat et al (1997) found that paging is better than scrolling in a text-reading and text-revising task. They describe their test as looking for 'screen dynamics' that is the way a text is presented on a computer screen and how users can reach various passages in the text. Their first experiment was to find out the participants' reading performance depending on the text presentation using scrolling or page-by-page.[1] Participants had to perform various tasks such as reading, sentence locating and summarizing. The results of this study show better performance of paging over scrolling. Piolat et al reported that readers using the paging version had a better grasp of content because of its similar presentation to a printed book and because readers could develop a better 'sense of text.'

[1] It is important to note that their page-by-page mode is different from the definition previously stated. They are referring to a page-by-page tool that only word processors have which allows a reader/writer to go from one page to the previous or next page.

On the other hand, van Nimwegen et al (1999) have found support for scrolling over paging by studying the influences of structure and reading-manipulation. They also studied three aspects of usability (efficiency, ease of learning and user-satisfaction) in five different electronic documents. The texts were organized in two different structures which were purely hierarchical or hierarchical structure

with partial linearity, and two methods of manipulation. A fifth structure combined the hierarchical structure with linearity, with scrolling within sections and paging between sections. The participants had to complete 24 search tasks on a city guide of Utrecht. They had to find the information as fast and as accurately as possible. Van Nimwegen et al found that scrolling is more usable than paging. 'Scrolling leads to a better insight into the structure than paging, which produces better performance'. They concluded that purely hierarchical structure and scrolling as reading-manipulation are the best use. Spool (1998) in his article on-line strongly supports scrolling or longer pages over paging or short pages. Longer pages make readers scroll down to see 'what lies below each screen...having greater success when the content is on a single page.' Unfortunately he does not give any further information on his research that would give additional insight into the problem.

As these results show, there is no clear guidance as to whether paging or scrolling methods of manipulation help readers perform their tasks. Another two methods of manipulation that are discussed are that of frames and use of links, since they are included in the study presented here.

Links

Links are the connections of nodes of information contained in a hypertext document, such as a web page. A 'node is a sort of stimulus material that can be activated and presented to a user' (Seyer, 1991). Links show readers the departure point to an explicit object when they are activated (Nielsen, 1990), they are mere indicators that another related content can be accessed. By choosing and responding to links, readers interact with the hypertext system. 'If a word or a picture is highlighted, the reader has to understand that it points to a relevant development of the text' (Nielsen, 1990).

'Links do not interrupt the flow of meaning: on the contrary, they enliven it' (Pajares, 2000). Pajares regards hypertext as a dialogue between the document and the reader. The author builds the hypertext to say something and expects the

reader to answer actively, interpreting and deciding upon which link to access. In her study on poetry displayed on screen, words have an extended meaning by the links that can be accessed; she states that not only structure and meaning can be perceived from hypertext but also a lower level that can be called lyrical. When readers follow the links they build their own interpretations or 'implicatures' enriching their experience with electronic documents. Pajares also suggests another kind of treatment of links if the document is regarded as informational. She suggests providing descriptive links, avoiding ambiguity and hence less interpretations, giving the readers a clear direction where the links are taking them, providing navigational aids, such as maps or buttons and creating indexes to show the overall structure (Pajares, 2000).[2]

[2] For an additional classification of links see DeRose (1989).

Links have been studied as a key element in navigation, especially because their incorrect use can make readers get lost in hypertext systems. Otter and Johnson (2000) developed a way of measuring how people become lost and suggest that 'some types of links have greater impact on lostness than others.' They presented a list, which summarizes the causes of lostness that readers reported in a questionnaire. The causes presented here are only those related to links:

> poorly or ambiguously labelled links
> confusing number of links or options
> continuing train of thought along many links
> location of the links on the page
> pictures that are non-obvious links
> getting distracted by attractive looking links
> more than one link to same destination
> links not following a logical order

Links are a unique characteristic of electronic documents. They are indicated in different ways, such as underlined words, arrows transforming into a pointing hand indicating a sensitive area, images or text changing color or shape when

the cursor steps on them, flashing elements, etc. The use of links and the way to indicate them might suggest that conventions are beginning to emerge.

Frames

There have been a number of discussions on the inconvenience of using frames, since they were first introduced. A summary of these positive and negative points are presented here. All these opinions come from authors who publish their views on the world wide web, (Nielsen, 1996; Merholz, 1998; Roselli, 1999; IS/Web Communications, 2001) and most of them do not present any data to support their findings. However, these opinions are shared by most specialists consulted and seem to come from their own experiences.[3]

[3] These opinions deal specifically with web sites as electronic documents.

The use of frames on a web page implies the division of the page into separate web pages next to each other. The frames are contained within a frameset, which defines the position and dimension of each frame; they might have a border, a scroll bar, different color or any sign to let the reader know that there are other active spaces that can be clicked on. One or two of the frames have fixed text that usually corresponds to the table of contents or the navigation bar; the other frames change their contents depending on the link that the reader accesses.

The readers get an overall view of the information placed on the screen that facilitates their navigation; with frames, readers have to take a sequence of actions to go through the document. Nielsen (1996) mentions that the concept of frames is against the idea of 'the page' as a unit, as Berners-Lee conceived it.

The advantages of using frames are:

> Content and navigation can be separated from each other. The divisions of the page provide separate areas for different materials as well as a separate space for navigation.

> Contents can be organized in alphabetical order for quick access to information. Readers can jump quickly by choosing the letter of the alphabet displayed in the frame.

> Information within a frame is always present, avoiding multiplication of texts.

> Frames allow the placing of commentaries at the same time as fixed information is presented.

> They are recommended for complex web sites that have intranet and several depths of information because frames can provide an always-present navigational menu. Intranets have a captive audience that can be trained in their use of the web site.

> Used properly, frames can add structure and ease of use to the site.

The disadvantages of using frames are:

NAVIGATION WISE:

> Frames add unnecessary complexity to design and navigation.

> Some browsers do not support the use of frames. Even some new browsers made the decision not to support frames.

> The back button can be broken because of the way frames are used.

> Scrolling navigation bars in the middle of the page can be confusing.

> Readers might feel confused when they want to access a site and only a frameset appears.

> Frames can increase load time. In some browsers, they override user preferences for image-loading, thus increasing actual load time.

PRINTING USE:

> Readers do not always get the print they expect. They will usually get the frame they are selecting and not the whole page as it is viewed on screen.

USE OF SPACE:

> Frames remove space from the screen that can be used by the contents.

COPYRIGHT ISSUES:

> There have been situations where one site's content appears in another site's frame.

BOOKMARKING:

> It is not possible to bookmark a page within a frameset. Browsers only mark the initial frameset, which can cause readers to access pages with no contents. The URL does not change as a user navigates through the site.

SEARCH ENGINES:

> There are several search engines that do not index framesets because the home page is only a frame with little content. Therefore many sites cannot be accessed this way. However, there are ways to avoid these problems.

MAINTENANCE:

> It is difficult to update sites with frames because it requires keeping track of the files.

READERS' OPINION:

> Several authors report negative opinions from readers who dislike the use of frames.

Merholz (1998) distinguishes two types of web sites, those related to information and those to application. Information sites are those that offer thorough information to be read. Application sites are those where readers are interacting with the

web, such as performing tasks and making interactions. Merholz suggests the use of frames for application sites because they are not affected by bookmarking, are controlled by the server, the elements do not have to be scrolled and they appear all at the same time.

An analysis of fifty web sites by the authors (González de Cosío and Dyson, in press) found similar results that agree with Merholz's distinction of web sites. The analysis found that there are different kinds of texts, depending on the sites profile. Those sites that need rapid transactions such as getting a ticket, consulting data from the bank, buying a product, etc. need specific and brief text. On the other hand, there are sites that offer a lot of information in their internal pages, such as descriptions, cultural information, texts on art, archaeology, results of research, etc. These sites are consulted for deeper and thorough reading.

There have been few studies done on the use of frames. A recent study that is closely related to the one presented in this paper, and looks at the performance and preference of framed and non-framed documents was done in Wichita State University (Bernard, Hull and Drake, 2001). Participants were presented with four versions of a document; each document had a different 'linking arrangement':

> Links embedded in the document

> Links at the upper left of the document

> A top frame with links

> Links within a vertical frame on the left of the document

Participants had to search for specific information and find answers to ten questions. Each answer should be found within five minutes to be considered correct. The authors did not find significant differences in search performance, accuracy, search time and search efficiency or preference among the four conditions. In a further study, Bernard and Hull (2002) compared the top-left links version with the vertical frame version in terms of preference. They asked participants questions on ease of navigation and ease of finding information and found significant differences that favored the frame condition.

This study attempts to identify which methods of manipulation allow readers to perform faster and more accurately when searching for information. A series of tests were prepared to find how scrolling, linking, paging or using frames were used to manipulate an electronic document.

This test measured:

> time to find specific information:
a definition, a list, a figure

> time to read a text

> accuracy and correctness in answering a question

> how much was remembered of the text
through formulating a synopsis

Readers

The tests were applied to two different groups of readers; the first group were forty second-semester Psychology and Design students; the second group were forty-one seventh-semester students from a variety of disciplines from the Universidad de las Américas-Puebla in Mexico. Within each group, readers were assigned one of four versions of the document. Different levels of English were distributed evenly between versions. Most students stayed throughout the test, but some of them had to leave before finishing the six tasks.[4]

Topic

The selected topic for the test was 'Perception and Representation' from J. Preece's book *Human Computer Interaction*[5] This chapter is suited to the test because it is a well structured text organized into sections, exercises, comments, questions and key points of the text; it is well supported by visual representations, such as photographs, schemas and tables that explain and exemplify various definitions.

[4] We thank professors Julio Penagos and Jorge Galicia for their support in performing the test with their students. Professor Penagos also helped with suggetsions and comments.

[5] Preece, J. 1994 *Human Computer Interaction*. The Open University: Addision and Wesley, 75–97.

Versions of electronic documents for the test

The test consisted of four versions of the text presented as a web site document. The content was kept exactly the same as the printed text. There were slight differences, just to adjust the content to the method of manipulation. The major differences among versions relied on the reader's manipulation of the document.

> Version 1: scrolling

The whole text was contained in one page, thus emphasizing a linear sequence of reading. The document had to be consulted through scrolling up and down; readers could know the length of the document. No links were contained in the text (*figure 1*).

> Version 2: linking

The document was contained in one page, but offered a table of contents with links to each topic and a back-button, on each section, to the beginning of the text; the readers could know the length of the document and navigate through links or use vertical scrolling. The title of the visited sections changed color (*see figure 2*).

> Version 3: paging

The text had a table of contents and links to each topic; every topic was placed on a separate page and had a back-button to the table of contents. Readers did not have an overall idea of the length of the document unless they linked to each section. The title of the visited sections changed color (*see figure 3*).

> Version 4: frames

The text had a table of contents (using a frame) to link to other sections of the document. It was always present in the document and independent from the rest of the text. The reading space was reduced by the table of contents and readers could not have an overall idea of the length of the document unless they navigated into each section. The title of the visited section changed color (*see figure 4*).

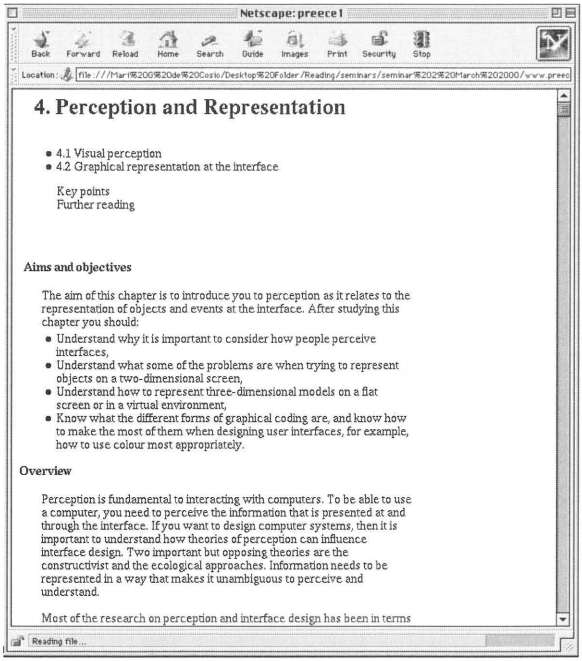

FIGURE 1
The first version is the scrolling layout. The students had to read the document by scrolling vertically. No links were contained in the text and no table of contents. The beginning of the document is shown in this image.

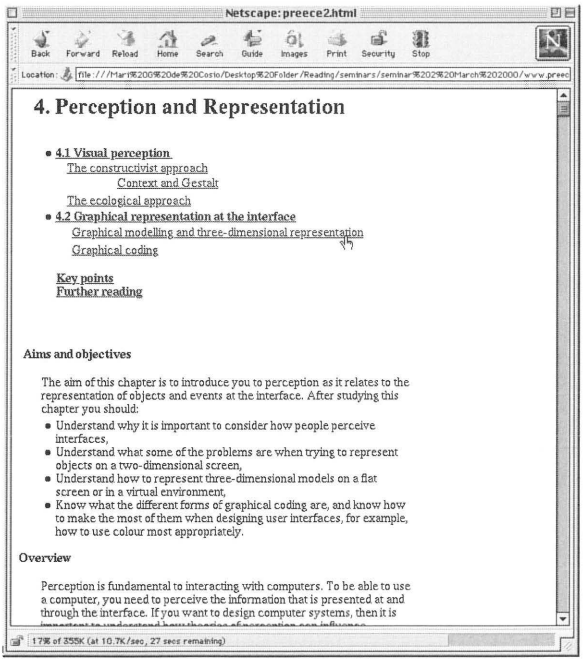

FIGURE 2
The second version is the linking document. The students could check the table of contents at the beginning of the text and link to the desired position. Everything was contained in the same web page, so the readers could also scroll up and down or use the 'back' button within the document. The table of contents is shown in this image.

FIGURE 3
The third version is the paging document. Each topic is contained in a single page. The students could go to each topic by linking from the table of contents. A 'back' button was provided to go to the previous topic accessed. A specific topic of the document is shown here.

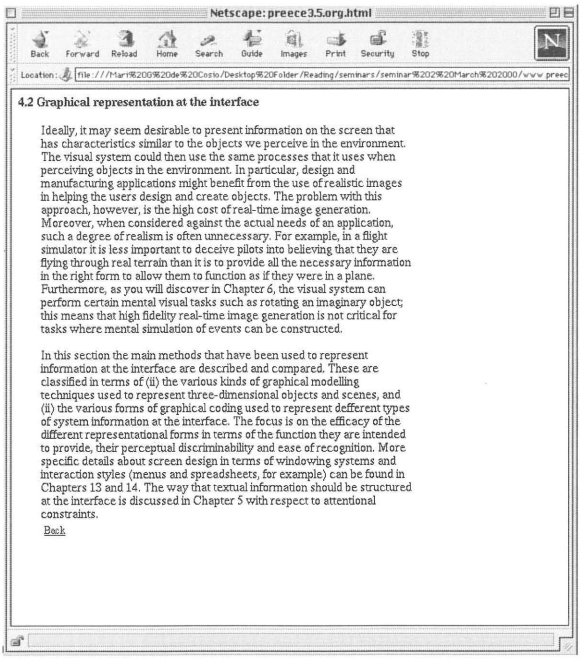

FIGURE 4
The fourth version is the frame document. The table of contents is presented in a frame. The students could always see the topics and navigate through the text without having a clear idea of the length of the text. The frame with the table of contents and one of the topics is shown in this image.

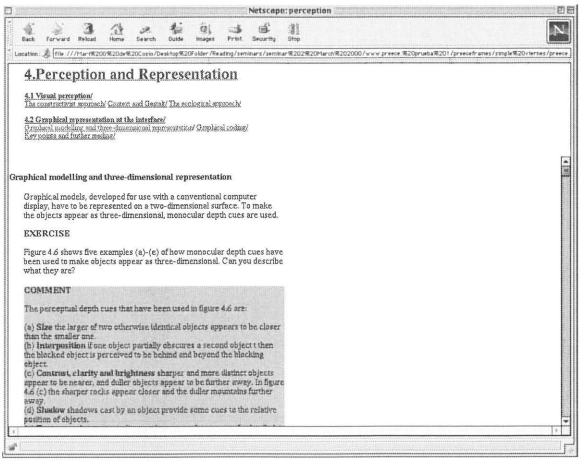

FIGURE 5
View of the classroom where the test was done. Each computer had the same characteristics on screen in terms of fonts and size of window.

Each version had advantages or disadvantages: either complete or sectioned information, slow or quick reference through links to specific subjects. In other words, participants read sections that varied in length, (but overall length of text was the same), had more or less control over the document or controlled their reading in a linear or non-linear way.

Physical setting

The test was developed in a special classroom that has a space for lecturing and a separate space for 24 Imac computers distributed in a line. The computers were divided into four groups; every six computers had a different version of the document (*figure 5*).

The tests

The students received the instructions on three separate pieces of paper: the first instruction (tasks 1–3) was given at the beginning of the test, so the results would not interfere with the next step that asked them to read the whole text (task 4). The participants specified the time it took them to perform each task by checking the clock on their computer. When the participants

had finished task 4, they answered the question (task 5) on their instruction paper and received the last instruction which was performed in the classroom, with pen and paper, and without any access to the electronic document (task 6).

Readers were asked to do the following tasks:

> Find Information. Participants had to find different kinds of information whether specific text, a list or an image. The different tasks were:

Task 1: find a definition
Task 2: find a list of text
Task 3: find a figure

> Read a text

Task 4: read the text on 'Perception and Representation'

> Answer a question

Task 5: answer a question related to the text read

> Write a synopsis

Task 6: make a synopsis or scheme of the text just read

RESULTS AND DISCUSSION

The first three tasks measured speed to locate different presentations of information, the fourth task measured time to read the text, the fifth task measured comprehension of an issue and the sixth task measured comprehension and memory.

> FINDING INFORMATION

This was measured by the time the students took to locate the text, the figure and the list; the time was recorded by the students on the instruction paper. Figure 6 shows the means for each version (tasks 1–3 combined) for each group of students. A comparison of the two groups of students across the four versions found only one main effect of version, ($F(3,73) = 3.91$, $p<0.025$) and no interaction. Linking and paging are faster than scrolling and frames.

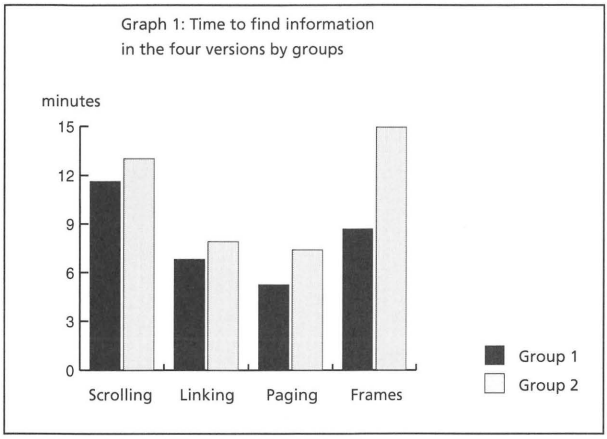

FIGURE 6
Finding information was faster when using paging and linking versions of the document in tasks 1–3.

It is interesting to observe contrasting results to those found by Bernard et al (2001). In their study, they did not find any difference in search performance between frames and non-frame versions, whereas in this study there is a clear difference among the methods of manipulation.

> READING THE TEXT

There were no significant differences between the four versions in time to read the text. However, there was a difference between the two groups ($F(1,70) = 6.53$, $p<0.025$). In this task, the second semester students read significantly faster than the seventh semester students (*figure 7*) . It seems to be that seventh semester students were more motivated and interested in the topic than the younger students.

> ANSWERING A QUESTION

Complete and accurate answers were coded as 'correct'; incomplete answers and wrong answers were coded as 'incorrect.' The data is shown in Table 1. The

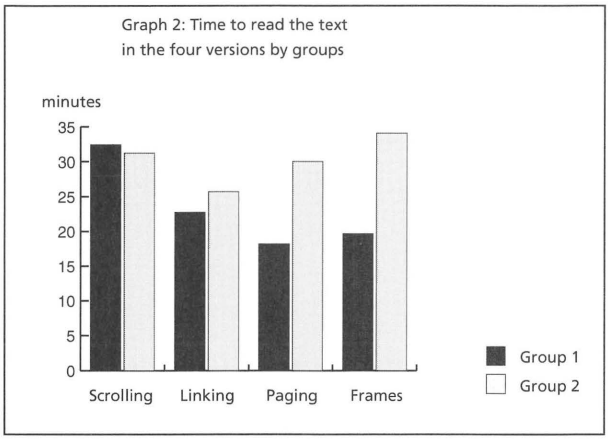

FIGURE 7
Younger students read the text faster in the paging version, whereas older students were faster in the linking version in task 4.

frequencies of incorrect answers were compared with correct answers. There were no differences among versions ($X^2 = 4.88$, 3 df, $p > 0.05$). Although there were more incorrect answers compared to correct in the scrolling version, whereas the reverse was true in the three other conditions, the differences are too small to be reliable.

> Writing a synopsis

There were no differences among versions when developing a synopsis ($X^2 = 1.61$, 3 df, $p > 0.05$). The data is shown in Table 2. Few students remembered the complete structure of the text, perhaps because it was rather long. However a repeated part of the structure was well remembered by most students; they could remember the text related to the answer of a question (task 5). This information supports the idea that active participation of students with the subject matter helps learning and memory.

CONCLUSIONS

Paging and linking are the two versions of documents that better supported readers in this test, in looking for information in the shortest time. This implies that quick scanning through a document might be easier in these two versions. These results agree with the outcomes of Dyson and Kipping (1997), Piolat et al (1997) and Schwarz et al (1983) studies which found superior performance for paging over scrolling. However, the integration of linking and frames version in this study as new variables shows that not only paging but also linking type of documents could better support readers.

It is worth mentioning that students did not have any distraction within the text while reading; there were no links to additional information nor linking images that they could explore. The students' concentration had to be dedicated to their document. This situation differs from readers' usual search for information on the web: distractions of text, color, images and links to other documents can interfere with their performance.

Task 5

	CORRECT	INCORRECT
SCROLLING	6	11
LINKING	13	6
PAGING	12	8
FRAMES	7	7

TABLE 1
Correct and incorrect answers in task 5

Task 6

	CORRECT	INCORRECT
SCROLLING	7	9
LINKING	6	13
PAGING	7	13
FRAMES	9	9

TABLE 2
Correct and incorrect answers in task 6

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