Reading and Navigating of documents: digital versus paper.

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ABSTRACT
There is not one single variable that can completely explain why reading electronic text is not as favorable as reading on paper but several variables. This study focuses on a document (a history paper) in two different formats: printed and digital text. An experimental protocol was used to assess a reader's performance in terms of referencing and navigating through a document. This study considers the differences between the media i.e. paper versus electronic documents in terms of the process of navigation and reading. It is believed that particular locations of information(middle of the page, even odd pages) will allow the paper groups to have an advantage over the digital groups while other locations such as (odd even pages and bottom of pages) will allow the digital groups to have an advantage. It was found that there were no statistically significant results of reading digital documents versus reading on printed media.

Keywords
Reading, Electronic text, On-Line Reading, paper vs. digital

INTRODUCTION
With the increased used of computers in general, and the growth of the Internet the issue of reading documents in the electronic form is now being addressed. There is a range of issues associated with reading from a computer screen. Screen resolution, spatial representation, ease of use, non-tangibility, etc. Computers, document readers such as the E-book, and the Internet, are increasingly being used to read documents online. Yet, devices like printers and fax machines, and copiers still exist, and many people prefer to print a digital document, rather than read it online. Both print and electronic media deal with the written language, but there is a large difference in the way the textual elements are displayed.

There is little data available on how users actually read, understand, and navigate through the content. This leads to the question as to whether reading a digital document just as effective as reading a document on printed media. Results from experimental studies in the past have shown that multimedia technology is not as easily handled as printed media. Issues such as disorientation, lack of resolution, non-tangibility, and experience suggest barriers for users [7].

In the current stage of technological development, the presentation of text on computer screens has a negative impact on surface legibility [7]. With the use of greater contract, less information density, and bigger characters, this gap can be overcome. Screen legibility can also be improved through high definition screens [8].

This study seeks to address the issues associated with referencing information in digital documents on computer screens vs. in printed documents. Issues are addressed such as zoom, and having a high screen resolution so that legibility and readability of the document is not an issue [8]. A comparison of the speed to reference information in a paper document versus referencing a digital document is done to determine if navigating through a printed document has a particular advantage over digital document navigation, when search techniques are eliminated for the electronic text and users reading the paper media cannot use annotation.

PREVIOUS WORK
There has been a fair amount of research concerning the differences between reading on paper and digital documents but these have focused on differences like tangibility, storage, readability, speed, proof-reading accuracy, and comprehension of the document. Not a lot of concentration has gone into how a reader, in either medium, navigates through a document or manipulates it [12].

Many studies have shown differences in reading between digital and paper reading, though the differences varied among studies, and results are often inconsistent [2].

O'Hara states the perhaps the problem with most of the studies is the how the researchers approach the problem. Controlling to many of the variables may restrict too

much the task that would be too unlikely in the reading activities that most of us perform. [2]. O'Hara goes on to state, that if we are to pull out and significant results on the view of reading the design of the experimental method should be done with care, and it must use analytic methods which is will capture what is relevant [2].

O'Hara ET. Al set out to compare reading of digital documents against paper-based documents where subjects were split into two groups: paper-based or On-line based reading. O'Hara found that in either condition subjects spent a good amount of time moving through the document. That navigating through a paper document was anticipatory, where the turning of a page was of no distraction to the reader. The use of two hands to hold a place was also noticed. Navigation through a digital document was slower and often a one-handed activity [2].

While O'Hara study presents us with a clear set of differences between paper-based reading and On-Line reading, the attempt of this study seeks to be more specific.

The goal of this study is to determine if location of information in a document has an effect on the speed of navigation. A more empirical experiment was setup in this case, in conjunction with observation and welcomed comments from each subject. A factorial design was setup as to compare the results of four groups instead of just two groups as in O'Hara's design. In this case, there are two digital groups: multi-page view & single page view, and two paper-based groups: bound(stapled) and unbound(unstapled).

Experimental Design

One activity of reading is navigation. This can be done in many ways, and can serve many purposes, such as skimming through a document to find a specific piece of information, or skimming through to get an overview of a document if its already been read. Since navigation can be an important activity of reading, it became necessary to determine if paper has an advantage over digital depending on the location of the information. These could be, for example, if the information is at the beginning of a page, end of a page, between several pages of the document (odd/even or even/odd), or in the middle of a page (See Figure 1). It is expected that answers to questions that are located between several pages, will allow for subjects in the paper group to have better performance times. If the location of the question is at the bottom of an odd numbered page and the top of an even numbered page, then subjects in the digital groups will perform better since there is no flipping of a page to find the answer, and the information is presented to them on the several pages at one time. If the location of the information is in the middle or end of a page it is expected that there will be no significant difference between the groups.

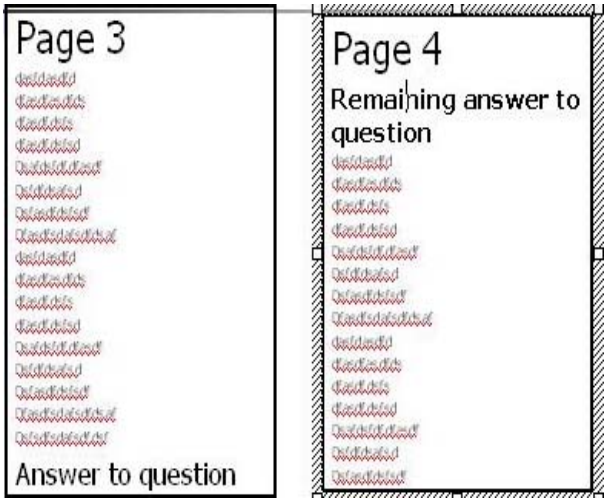

Figure 1A: Pages numbered 3 and 4 (odd/even bottom/top of page) highlight suggest location of answer. In this case digital views are thought to have advantage since page turning is not involved.

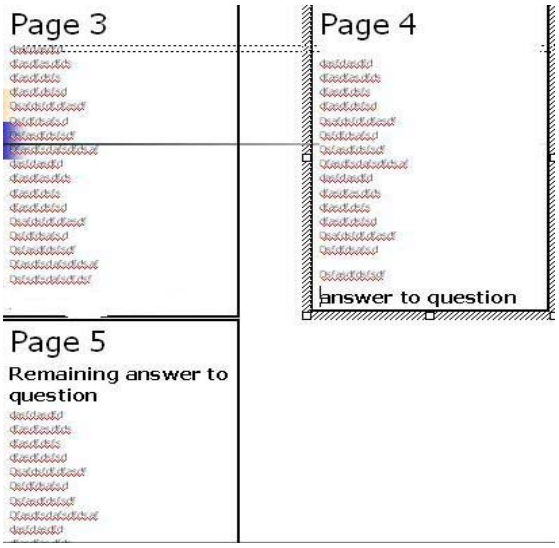

Figure 1B: Pages numbered 4 and 5(even/odd bottom/top of page). The paper group may have an advantage since the pages can be setup to have the information presented at the same time.

Figure 1C: Between Several Pages: Either group has no advantage

From the figures above, it is possible that digital layout of the document will have an advantage over paper. More specifically, if the location of the answer is between pages, then the subject will have more information available to them on the screen or it is between pages that are odd and even (i.e. bottom of page 1 and top of page 2).

Subjects in the paper groups may have an advantage over the digital groups if the location of the information was at the bottom of page 2 and top of page 3 since no page turning is involved, and the information on both pages is visible to the user (like in book format). In all of these cases, it was sought out that we find out if there is an advantage in navigation depending the location of the information.

The independent variable of the study was the format of the document (medium+layout) by which the document will be read by the subjects. The dependant variable is the time it takes the subject to reference the document and navigate through it to find the answer for each question in the questionnaire.

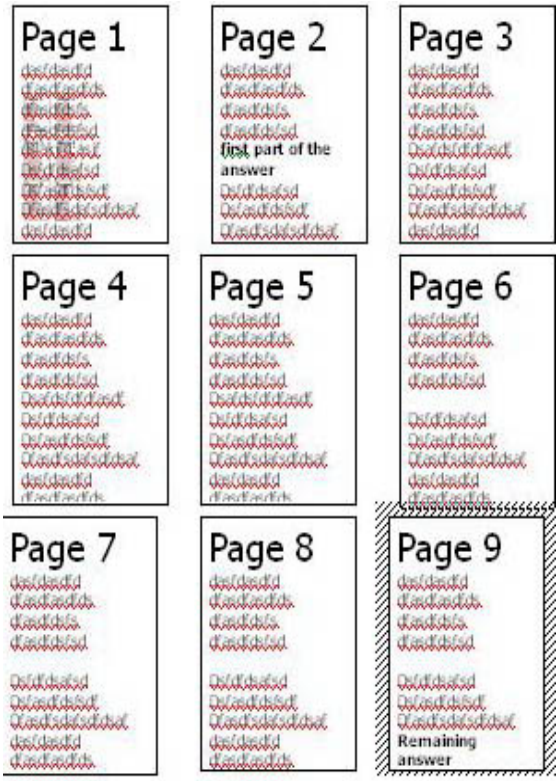

Figure 1D: Between Pages(even/odd middle/bottom) No advantage across groups

Subjects would be split into each of the 4 groups above. This is a factorial design, and a between subject study, therefore 10 subjects for each cell is necessary. In order, to get a good result set. So a minimum of 40 subjects would be needed. Figure 2 shows how the groups were split. It was chosen as to make a distinction to specific layouts available to users of documents. The comparison of paper and digital documents crossed with whether single views of information or multiple views of information were available.

	Paper	Digital
Bound	Stapled document	Single view
unbound	Unstapled document	Multi-view

Figure 2: Factorial experimental design

In all groups (paper & digital) subjects were to read the document. The document in all of the groups (paper & digital) was a 9 double-sided page Naval History paper, black on white printed-paper with two charts and in double column format.

The bound paper group, is given the document printed double-sided and stapled. The unbound paper group is given the same document (double-sided) only it is not stapled. The subjects in the unbound paper group are allowed to choose how they wish to spatially layout the document on the desk.

In the digital groups, the document with the same format was presented on a 21-inch computer screen with the resolution set at 1600X1200. The software application Adobe Acrobat 5.05 was used to display the document with the zoom set at 125%. The subjects were not allowed to search the document using the find or search tool provided by Acrobat, however they could scroll as they wished.

The one difference between the digital groups is subjects in the linear groups were only allowed to view a single page at a time and perhaps part of the next page. The subjects in the multi-view group can view parts of 4 pages at a time on the screen, instead of just one.

METHOD AND PROCEDURE

Eight volunteers from the Computer Science department were used as subjects. The subjects used the computer on a daily basis, and often printed out academic articles. Age, race, and gender of the subjects were of no importance to the study.

The subjects were randomly assigned to the bound paper group and the single-view digital group. So 4 subjects were tested in the bound paper group, and 4 subjects were tested in the digital single-view group. This was a between subject study, and no training was required for this. Each of the 8 subjects was asked to read the 9-page document, in which they were not timed. Once the subject was finished reading the document in either group then each subject was asked to fill out a questionnaire of 15 questions, which was presented to them on a tablet pc. The questionnaire was displayed using a tablet pc that sat on a book-reading stand next to the PC, on a large desk. (See Figure 3). Each subject was given an hour block of time to complete the task. Each subject was run separately.

Subjects paper group had only the tablet pc available to them to answer the questions, and the printed document. If the subjects were in the digital linear group then the subjects had the tablet pc available to them to answer the questions and the 21' inch computer screen which displayed the document. Figure 3 shows the experimental setup.

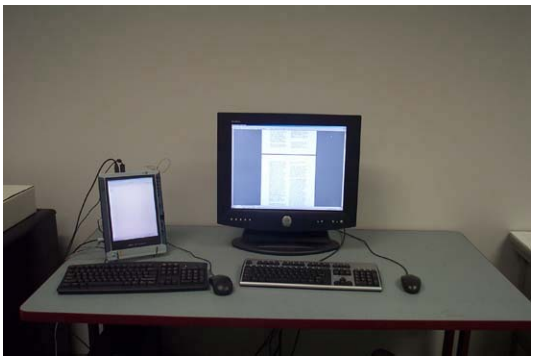

Figure 3: Experimental Setup

The questionnaire, which was located on the tabletPC, started out asking the subjects to enter in an ID, and then go the next page. Then a question was presented to them, once the subject understood the question, they could then proceed to the next page. The next page contained the stated question again, and a timer. When the subjects were ready to reference the document to find the answer to the question, the subjects pressed a button to start the timer. Once the answer was found within the document the subjects would type the answer in the provided textbox. Once finished answering the question, the subjects would click continue onto the next page, which contained the next question, this continued for each of the 15 questions.

It was important before navigating through the document that the subjects click the start button for the timer. When the subject starts typing, the time for that first keystroke details how long it took the subject to navigate through the document.

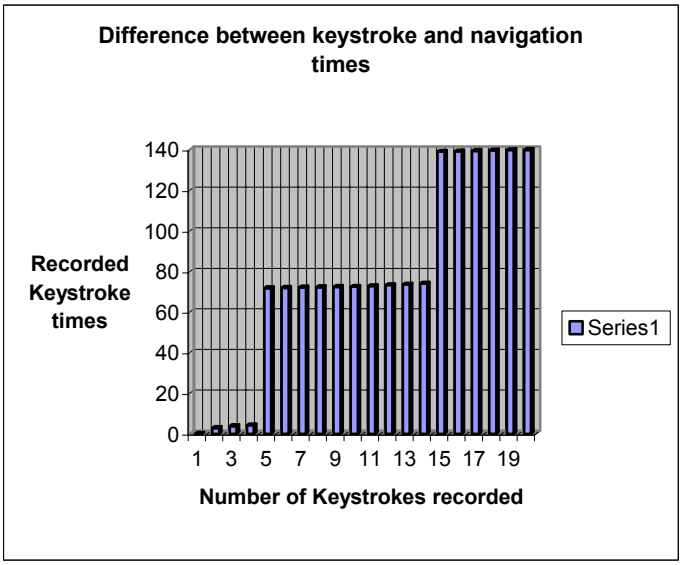

Figure 4: Sample Navigation/keystroke times

For example, a subject clicks the start timer, and then goes to reference the document. Before typing anything, the timer having started at zero, now has a time of 20 seconds that have gone by. When the subject begins typing the answer, the recorded keystroke time might be 20.36 sec signifying the first recorded time. This is what gets recorded. The time for the first key is recorded and every key thereafter. So if the subject types in the word "the", then the recorded times might be (20.36, 21.07, 21.40). The time for navigation, in this example would then be 20.36 seconds.

If the subject typed a part of the answer, and went back to referencing the document, the difference in keystroke times would reflect that. Figure 4 shows a sample from the result set which illustrates the difference between a navigation time and the recorded time between typing for each key hit. The huge jumps would signify navigation times.

For each question the subjects keystroke times were stored into a file with the subjects id attached to it. Each file contained the subject id, answers to the questions, and the times recorded for each keystroke related to the question.

It was determined that typing times between each keystroke was insignificant, but the difference between typing and navigation time is significant. It was determined by a series of tests that the time between each keystroke was anywhere from 0 seconds up to 2 seconds. Any amount of time greater than 2 seconds was determined to be a navigation time, or a quick back reference to the document once the subject found the answer to the question.

It was important not to measure how fast a subject read the document, question, or typed the answer to the question. So only navigation time is used for the result analysis. To make sure there was no delay in the recording of the keystroke times the script contained client-side code.

For each session, a non-intrusive observation was done in order to record how subjects navigated through the document, i.e. which questions took the longest to find the answer.

Once the subjects completed the questionnaire, they where asked to fill out a post-test questionnaire, and any comments they had were welcomed. The figure below shows how the script was looked to the subject.

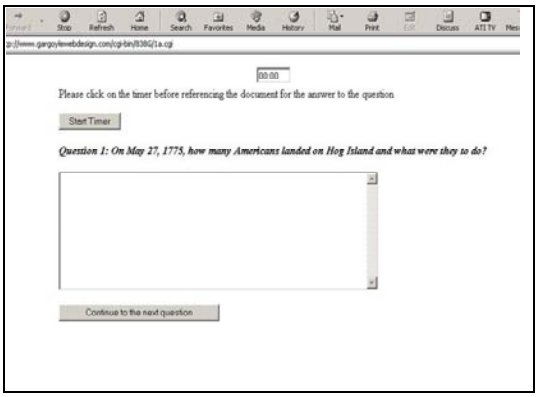

Figure 5: Screen shot of cgi–script used to record answer and keystrokes

DESIGN ISSUES

The naval history document was picked because subjects would less likely retain information as easily with one read through, since the document was extremely detailed and contain lots of names and dates to events. This will allow for the users to have reference the document to answer the questions on the questionnaire.

The number of pages was chosen to be a 9 page document double sided, since typically documents are double sided, and it was necessary to mimic as much of normal reading procedure as possible. 9 pages was picked because <9 page is most likely too trivial and anything greater than 9 pages, could limit the amount of physical layout available to subjects in the unbound paper group.

As far as layout goes, 5 pages are stapled or unstapled in the paper groups since it is double sided. The resolution of the screens becomes an issue when dealing with the non-linear digital group. 125% zoom was deemed good enough to maintain information on the screen and readability. With zoom set at 100% the readability was not too clear, with zoom set at 150% the amount of information available on the screen was far less**.** The 15 questions were chosen to give multiple coverage of the specific locations of answer to questions on the paper.

RESULTS AND DISCUSSION

Looking at the ttest values, none of them are under .05, or even under .1. Thus, there is no statistically significant difference between paper and digital on any task. This in and of itself is sort of intresting, since it expected that there would be an advantage of paper over digital depending on certain locations of information within a page, while digital would have an advantage in other cases..

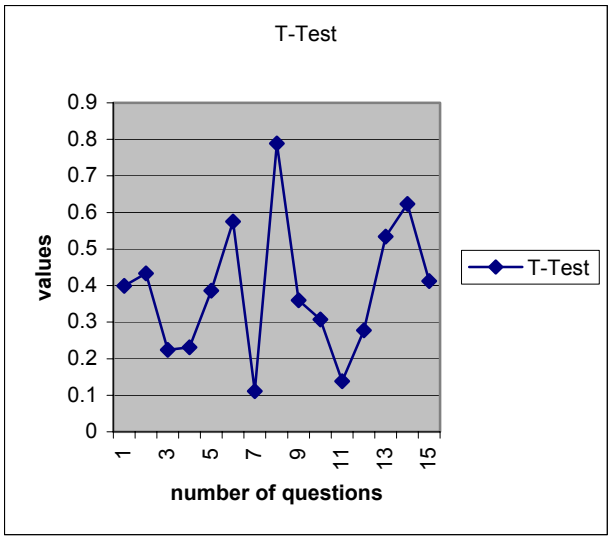

Figure 6: Two Tailed T-test

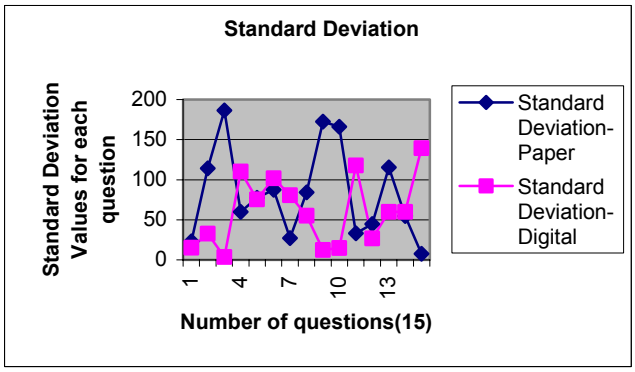

Figure 7: Standard Deviation of the two groups

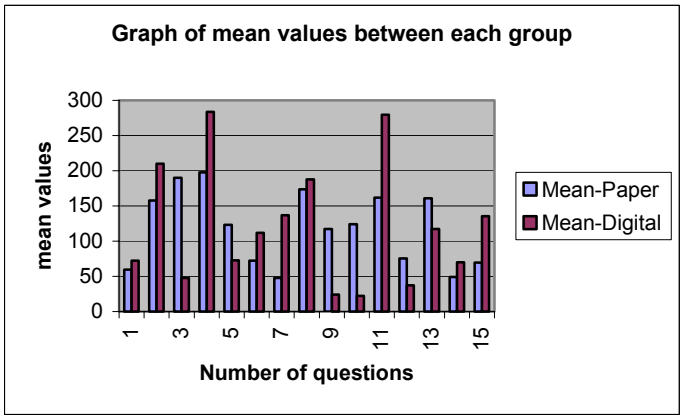

Figure 8: Mean Values of the two groups

Since there was no statistical significant difference, perhaps the reason for this was because so much time was spent referencing and searching the document, due to the fact that the subjects did not have a sense of where the content was located within the document. From the results, it is important to notice that there was a rather large standard deviation. Looking at the means for any questions and comparing against the calculated standard deviation, the standard deviation is sometimes larger that the mean. So the majority of the subjects fall within the large range between the mean and the standard deviation.

Since the standard deviation is so large, it is rather difficult to get statistically significant results. Why was the standard deviation so large?? Perhaps, it was because the choice of document was not best suited for the task. During observation, it was observed that subjects had to re-read through the document to find the answers often. In this case, reading time becomes a factor. Across the groups, it is not that one subject does better than another subject. Rather, on each question, a different subject was generally a lot faster or a lot slower than the other subjects. This most likely means that the large variance was not because of individual subjects performing uniformly slower of faster, but because of another factor that is unknown.

In general, subjects thought the task of reading the document and answering the questions was easy. A subject in the paper group commented on the fact that it was easy to navigate through the paper document because it was stapled, and it was easy to determine the beginning and end. A subject in the digital group was not pleased by the fact that the search (find) utility was not an option to be used. The subject thought it defeated the purpose of reading a digital document.

GENERAL DISCUSSION

Future Work

Since only a pilot study was run using eight subjects in two out of the four groups, a continuation of this study will need to be done to get a more conclusive result set. A larger population of greater than 40 subjects will be required to give a detailed result set.

As described earlier, one limitation of this work was the use of just one document: a print and digital version of a naval history document. In this study the document was extremely content-specific which made the document tedious to read. Perhaps a better choice in document will be considered next as to not bore the subjects. As this could limit comprehension therefore possibly affect the results. Further experiments comparing print and digital documents of a variety of documents are needed before general conclusions can be drawn.

Also, since a JavaScript was used in conjunction with a perl script to record navigation and keystroke times, in a

continuation of this study it would be better to use a java applet to record the keystrokes. Then just have the applet pull out the distinct navigation times instead of recording each keystroke. Since the current implementation, made reading the result sets slightly more difficult to read. Several scripts had to be written, whereas a local applet running on the machine would most likely be better.

It was noticed that during the study it could be likely that subjects would forget to click the "start timer" button before referencing the document. So, an enhancement to the code would need to make it so the subjects do not have to worry about clicking the timer.

Conclusions

In general, it was more difficult to read from the screen for a couple of reasons. First, when a subject reads from paper they to associate topics with the place on the page where they appear. Even though the outline of the page is visible on the screen, the article appears as more of a continuous large page rather than discrete pages.

Second, there is a visual nature to the amount of pages you have read in the paper based on how far you have flipped. A subject can pick up the packet of papers and immediately recognize how close they are to the end. To do that on the screen, one have to look at the page number and think about how far they had read when I saw a certain piece of information. That makes it more of a calculation than estimation.

The main contribution of this experiment is to add another set of results to the studies which currently exist. This experiment was more specific in it task setup and what it sought out to determine if there is an advantage of navigation depending on the location of the information in paper versus digital. Since there were no statistically significant results, a careful examination of the experimental design, and the choice of document will need to be addressed. A document that requires less reading and more navigation will be necessary for the task that is setup. The issue of the large standard deviation will need to be addressed.

There was a large difference between user times depending on the question. From observation it was noted that subjects remembered where things were within the document. However, each subject remembered different things, and this would have a distinct effect on the results. Hence the need for a bigger group of subjects is needed and a better choice of document.

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