Reading of Electronic Documents: The Usability of Linear, Fisheye, and Overview+Detail Interfaces

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ABSTRACT
Reading of electronic documents is becoming increasingly important as more information is disseminated electronically. We present an experiment that compares the usability of a linear, a fisheye, and an overview+detail interface for electronic documents. Using these interfaces, 20 subjects wrote essays and answered questions about scientific documents. Essays written using the overview+detail interface received higher grades, while subjects using the fisheye interface read documents faster. However, subjects used more time to answer questions with the overview+detail interface. All but one subject preferred the overview+detail interface. The most common interface in practical use, the linear interface, is found to be inferior to the fisheye and overview+detail interfaces regarding most aspects of usability. We recommend using overview+detail interfaces for electronic documents, while fisheye interfaces mainly should be considered for time-critical tasks.

Keywords
Reading activity, electronic documents, information visualization, user study, usability, information retrieval

INTRODUCTION
We investigate if interfaces using information visualization techniques can support reading of electronic documents. Although several interfaces for electronic documents using information visualization have been proposed, little is known about the usability of such interfaces. In an experiment, we compare 20 subjects' reading activity in a linear, a fisheye, and an overview+detail interface. We describe differences in usability between the three interfaces, describe different patterns of reading between interfaces, and illuminate some individual differences in reading. Based on these differences, we offer advice to designers of electronic documents regarding the usability of linear, fisheye, and overview+detail interfaces.

Our focus on reading of electronic documents has two motivations. First, electronic documents are increasingly being used in professional activities and are widely read on the World Wide Web, in online journals, and in electronic newspapers. Sellen & Harper [27], describing the use of paper and electronic documents among analysts at the International Monetary Fund, assess that 14% of the time analysts worked with documents, they used electronic documents only. Analysts used a combination of paper and electronic documents 35% of the time. A study of World Wide Web usage [7] found that users spend at least twice as much time using the information they find, compared to searching, browsing, or any other activity. Reading is the main activity in using information. A study of the usage of electronic journals [29] reports that 28% of a sample of 75 academics used such journals—mainly because of the accessibility of the journals and because the academics could read such journals at their desktop. Hence, improved support of reading represents an important challenge to interface designers with an impact on a range of activities and a large group of users.

Our second motivation stems from the belief that reading play a central role in information access and use. When users access a collection of electronic documents, they most often face a problem that they believe can be resolved by information in the collection [1,20]. Although gaining an overview of the collection and formulating queries are important activities, the problematic situation that motivated users to access the collection is ultimately resolved through interacting with the documents [1]. Users' interaction with documents are both physical—such as navigating to certain sections—and mental—such as trying to grasp the intention of the author with a particular sentence or to integrate the information in the document with their own ideas. Interacting with and reading documents are thus necessary for successfully resolving the users' problems. Much research has tried to improve users information access and use by better search engines, support for query construction, or collection overviews [8,28]. Here we take a complementary approach, focusing on the reading of individual electronic documents.

The remainder of this paper is structured as follows. First, we sketch related research on developing more usable electronic documents, focusing on the use of information visualization techniques. Then, we present an experiment comparing the usability of a linear, a fisheye, and an overview+detail interface used for reading scientific papers. Finally, we discuss limits and benefits of the overview+detail and fisheye interfaces, and draw some implications for design of information access systems and electronic documents.

RELATED RESEARCH

The problems users face when reading electronic documents are well described, as are ways to improve the readability and navigability of such documents (see [11,21,22,26] for overviews). Here we briefly review previous attempts to use information visualization techniques for presenting electronic documents.

One group of interfaces for electronic documents shows a graphical overview of the document separated from the detailed content of the document [4,6,13,16] (See [24] for a general discussion). Seesoft [13] maps source code into an overview by letting one line of code correspond to a thin row in the overview, color-coded to display useful information about the program. In the Thumbar [16], a graphical overview of World Wide Web pages is shown next to the display of the page itself. Concepts in the user's profile are highlighted both on the overview and on the web page. Byrd [6] extends scrollbars for an interface that presents electronic documents so that the distribution of query terms in the document is shown on the scrollbar using color-coding. This extension is believed to support navigation in a document and to aid users in gaining an overview of the distribution of query terms within the document. Boguraev et al. [4] present automatically generated summaries of electronic documents together with an overview of the entire document. The user can use the summaries to access the detailed content of the document. While we know of no empirical evaluations of graphical overview+detail interfaces for electronic documents, studies of text overviews for electronic documents and graphical overviews of hypertext suggest that overviews might be effective [9,10]. Note also the important Superbook studies [12], which showed that an expandable table of contents and a word lookup function improved performance by 25% over searching in a paper manual.

Several attempts have been made at distorting parts of the document [17,18,23,25]. The aim of the distortion is to show the entire document at once or to make the salient parts of the document visible. In the Document Lens interface [25], all pages in a document are shown laid out in rows. The user can zoom in on pages to make them readable using a rectangular focus, and pan making other pages come into focus. The pages not in focus are distorted to fit the area outside of the rectangular focus. Flip zooming [17] uses a similar layout of pages, but can show pages out of focus as a heading at readable size, rather than distorting them. The fisheye view [15] shows only those parts of a document that has a degree of interest above a certain threshold. The degree of interest for a part of the document is calculated from an a priori measure of importance, e.g. the part being a headline, as well as distance between the part and the current point of view. Kaugars [18] describe a system that presents electronic documents in four increasingly informative ways, one of which focus on the first couple of paragraphs that contain query terms. The rest of the document is distorted to fit the remaining part of the window. Páez et al. [23] present an interface for electronic documents, where the font size is bigger for the title, headings, and key sentences than for other parts of the document. Initially, the entire document is fitted on the screen. The user can then zoom in and read the interesting sections. Páez et al. did not find the zoomable interface for electronic document to be more effective than hypertext. In general, little is known about the usability of distorted electronic documents.

EXPERIMENT

In the experiment, we compared how subjects' reading activity was supported by a linear, a fisheye, and an overview+detail interface. Subjects answered questions about object oriented systems development and wrote essays that summarized and commented journal papers. We analyzed usability differences between the interfaces by grades given for the answers to the questions and the essays, by satisfaction and preference data, and by a log of the subjects' interactions with the interfaces.

Interfaces

Figure 1 shows screenshots of the three interfaces used in the experiment. In the linear interface, the document is shown as a linear sequence of text and pictures, similar to how documents are presented on paper and in most interfaces for electronic documents in practical use.

In the fisheye interface, certain parts of the document are considered more important than other parts; these parts are always readable. The remaining parts of the document are initially distorted below readable size, but can be expanded and made readable if the user clicks on them with the mouse. The aim of the fisheye interface is to reduce the time taken to navigate through a document and to support readers in employing an overview oriented reading style—first focusing on the important sections of the document, then expanding sections and reading the details. All sections can be expanded simultaneously, or returned to their initial state, by selecting a menu item in a pop-up menu.

Two measures are used to determine which sections to consider important. First, research in automatic summarization of documents suggests that sentences selected from the beginning and end of a document unit are among the best indicators of the content of that unit [5,19]. Hence, the first and last paragraph of a section is considered important and is initially readable; the other parts of the section are considered to be less important and are initially distorted. This scheme is recursively applied to subsections, so that when a section is expanded, only the first and last parts of subsections are readable. Second, empirical research has found that readers often attend to and find certain components of a document especially useful [3,11]. Therefore abstracts and section headings are always visible, and graphics and tables are diminished less than text. In the fisheye interface, the initial size of the documents used in the experiment was 25% of their size in the linear interface.

In the overview+detail interface, the document is shown as a linear sequence of text and pictures (the detail pane) together with a tightly coupled overview of the document (the overview pane). The position of the view of the document shown in the detail pane is indicated in the overview pane with a rectangular field-of-view. The field-of-view can be dragged to change which part of the document is shown in the detail pane. The user can also click on the overview, which changes which part of the document that is shown in the detail pane, effectively functioning as a scrollbar. The overview pane is a semantic zoom of the document, where section and subsection headings are shown at a fixed size. The remaining text and pictures in a section are zoomed to fit the space allocated to show that section, determined by the ratio between the length of that section in the detail pane, and the total length of the document. For the six documents used in the experiment, this ratio was on average 1:17. We believe that the semantic zoom and the stability of the overview pane is the main improvement over previous overview+detail interfaces for electronic documents.

For all three interfaces, the documents can be navigated using the mouse or the keyboard and have immediate feedback when scrolling. It is also possible to highlight words, which makes words in the document containing one or more of the words entered by the user appear red. Highlighted words are also shown in the overview pane and in sections in the fisheye interface that are diminished.

Design

The experiment employed a 2×3 within-subjects factorial design, with task and interface type as independent variables. The experiment consisted of three sessions, in each of which 20 subjects used one interface to solve a task of each type. Each session lasted approximately one hour and 45 minutes, for a total of 106 hours of experimental data. Tasks and interfaces were systematically varied and counterbalanced. We formed six groups based on all sequences of interfaces. The tasks for these six groups were found by randomly choosing latin squares such that the three interfaces and the three sessions have an approximately equal number of different tasks.

Subjects

The subjects in the experiment were students at the Department of Computing, University of Copenhagen (DIKU), who chose to participate in a course involving the experiment. The subjects had studied computer science for a mean time of 6.5 years. Of the 20 subjects, 15 were males and five females, with a mean age of 27. Sixteen subjects reported to use computers every day, four subjects several times a week. Fourteen subjects had self-reported familiarity with object oriented systems development from courses, 11 subjects had such familiarity from systems development projects.

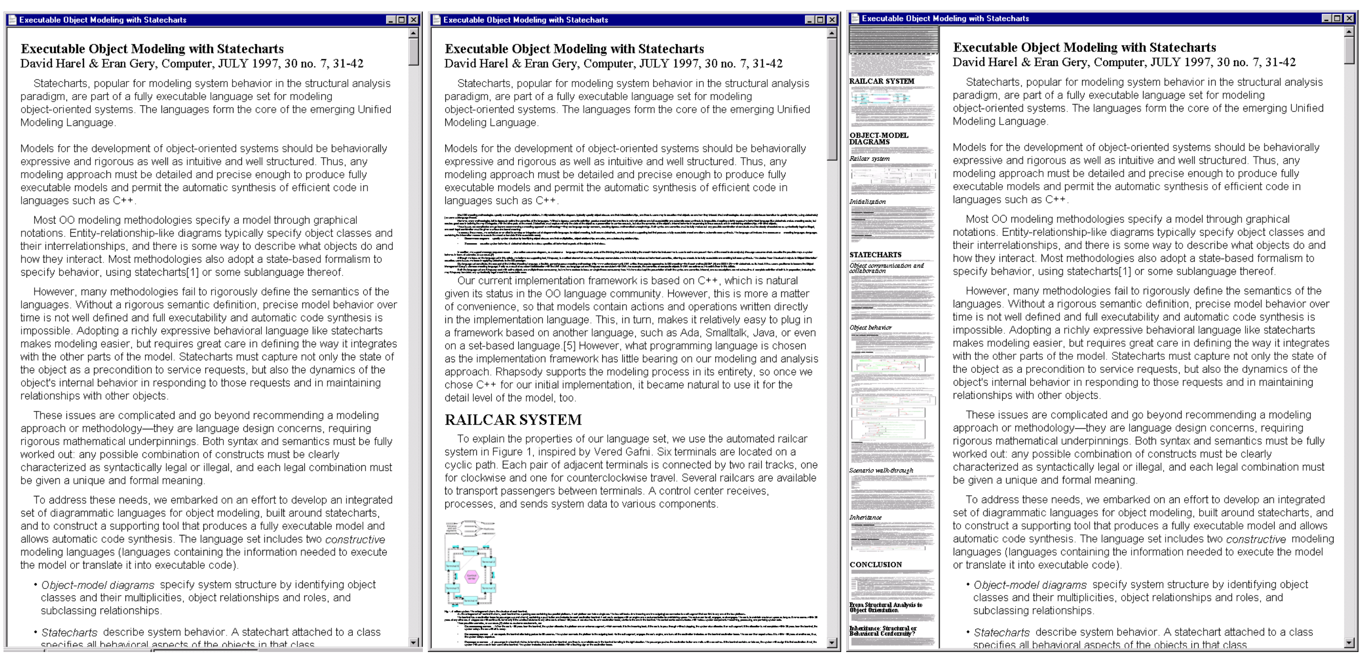

Figure 1—The linear (left), fisheye interface (middle), and overview+detail interface (right). The fisheye interface has certain parts of the document distorted below readable size. The distorted sections can be made readable by clicking on them with the mouse. The right part of the overview+detail interface is the detail pane, which is similar to the linear interface. The left part of the window is the overview pane, which shows the entire document zoomed to fit the window height. At the top of the overview pane is shown the field-of-view (dark gray area), which can be moved and dragged to change the content of the detail pane.

Tasks and Documents

The subjects were given two types of tasks: essay tasks and question-answering tasks. The essay tasks and the question-answering tasks correspond to two of what has been suggested as four typical reading tasks: reading-to-learn-to-do and reading-to-do [26]. In essay tasks, subjects read a document to learn the main content of that document. Afterwards and without access to the document, they wrote a one-page essay, stating the main theses and ideas of the document. Subjects were also requested to give approximately one page of comments about the document, which could serve as starting points for a classroom discussion. The subjects received the description of the tasks before beginning to read the document. After writing the essays, subjects were asked to answer six questions about the document just read. The subjects did not know these questions while reading the document; we therefore call these questions incidental-learning questions. Examples of incidental-learning questions include: "Which integrity problems can occur in what the author calls the simple business application architecture?" and "Which problems did the authors experience with respect to using object oriented databases?"

The second task type was question-answering tasks, where subjects answered six questions about a document, one question at a time. The six questions were varied as to 1) position in the document where the answer can be found (in the first or last part of the document); 2) how easily accessible the sentences or sections containing the answer are (whether they are near section beginnings, tables or figures); and 3) the usefulness of the words describing the question as terms for highlighting (whether or not the question contained terms that were located near the answer). Three examples of questions are: "What is, according to the paper, the biggest problem in relation to automatically transforming procedural code to object oriented code?", "What is the difference between structural and behavioral inheritance?", and "What is according to the author the difference between analysis and design?".

The documents used in the experiment were six IEEE journal papers, chosen from the top documents retrieved in response to a query on "user oriented systems development object oriented uml" in the Digital Library Initiative test bed at University of Illinois at Urbana-Champaign [2]. The paper versions of the documents were between 8 and 14 pages, contained on average four figures, and included one document with tables and one document with formulae. No subjects indicated that they previously had read any of the papers.

The descriptions of the tasks, the answers to tasks, the training material, and the satisfaction questionnaires were all in the native language of the subjects, Danish.

Dependent Measures

We measure the usability of the three interfaces by including measures of effectiveness, satisfaction, and efficiency, as recommended in [14]. Effectiveness of the interaction with the three interfaces is measured as the grade received for the answers to the tasks. The answers were graded blind by the first author, i.e., without any knowledge of which subject had made the answer or with which interface the answer had been made. We used a five point grading scale, ranging from zero—a missing or completely wrong answer—to four—an outstanding and well-substantiated answer. Table 1 shows an explanation of the grades. For the question-answering tasks, grades were given according to how many aspects of the question the answered covered. A classification of main ideas in the documents and important aspects of questions were developed to assist grading. For the incidental-learning questions, we counted the number of correct answers, resulting in a score from 0 to 6. Subjects in the experiment graded three randomly chosen sets of answers to the experimental tasks, as well as their own answers. They used the same scale for grading as the author. We wanted to use their grading as a subjective perception of the quality of the answers to the tasks.

Satisfaction was measured in three ways. After using each interface, subjects answered twelve questions about the perceived usability of the interface and their experience with solving the tasks. After having used all three interfaces, subjects indicated which they preferred. Subjects also wrote comments about the interfaces after using each of them, and described why the preferred using one of the interfaces.

The subjects' interactions with the three interfaces were logged. The main efficiency measure, time usage, is derived from the data logged. No time limit was imposed on the tasks. However, subjects were made aware of how much time they had used when reading one paper for more than one hour, or when they took more than 30 minutes to answer one of the six questions about a document.

Procedure

The experiment took place in a room without external disturbances, where two subjects participated at a time. Upon

Grade	Meaning
0	Completely wrong or missing answer.
1	Poor or imprecise answer. The answer is incomplete, describing only one aspect of the question, or is only partially correct.
2	Average answer. The answer describes relevant aspects of the questions and is in reasonable agreement with the document. For essays tasks, the comments raise some relevant problems in the paper and are substantiated.
3	Good answer. The answer describes many relevant aspects of the document and is in complete agreement with the document. For essay tasks, the comments raise relevant questions and are well substantiated.
4	Outstanding and completely adequate answer. The answer describes all relevant aspects of the question, includes additional relevant information, and is clearly written. For the essay tasks, the comments raise important questions in a thorough and substantiated way.

Table 1—The grading scale used for grading the experimental tasks.

arriving, the subjects were told about the purpose of the experiment. Next, subjects filled out a questionnaire about age, sex, their use of computers, the use of computers to read scientific documents, and their familiarity with the object oriented systems development. Then, subjects were trained in using the three interfaces until they felt confident in operating these. Training was supported by a two-page description of the specifics of operating the interfaces. The subjects also completed three training tasks, which introduced the subjects to the interfaces, and the question-answering and essay tasks. The mean time used to complete the training tasks was 35 minutes. After training, the subjects completed the first session of the experiment. Subjects returned the next day to the lab and completed the remaining two sessions.

The subjects received the tasks on sheets of paper, on which they also wrote the answers for the question-answering tasks. When subjects finished reading documents they were writing essays about, they received paper and pencil for writing the essay. The subjects were not allowed to write notes while reading the documents they wrote essays about.

Approximately four days after participating in the experiment, subjects received the documents used in the experiment, four sets of answers to the experimental tasks, including their own, and instructions on how to grade the answers. Subjects did not receive information on who had made the answers or the interface used for making the answer.

Data Analyses

Of the 20*3 possible solutions to the essay tasks, one subject did not complete a task, and one task was dropped because of a time usage three interquartile ranges above the 75-quartile, leaving 58 observations. For the question-answering tasks, out of 360 (20*3*6) possible answers, one subject failed to complete the task, leaving 354 answers. One subject's grading of one answer in a question-answering task was not done. We analyzed the data by ANOVAs with interface type, task, session, and subject as independent variables. Essay tasks and question-answering tasks were analyzed separately. All post-hoc tests were done using a Bonferroni test at a 5% significance level.

RESULTS

The results are divided into questions of how effectively subjects read documents, the subjects' satisfaction, and the subjects' efficiency. We also describe some differences in how documents are read in the three interfaces.

Effectiveness—Grades and Incidental Learning

The effectiveness measures are summarized in Table 2. Using the author's grading of the 58 essay tasks, we find a significant influence of interface on the grade obtained, $F[2,32]=4.16$, $p<.05$. A Bonferroni post-hoc test shows a significant difference at the 5% level between the overview+detail and the two other interfaces, suggesting that essays written after reading documents with the overview+detail interface receive higher grades. We find no significant difference between interfaces using the subjects' own grading of the essay tasks, $F[2,33]=.473$, $p>.6$.

The number of correctly answered incidental-learning questions is significantly different between the three interfaces, $F[2,32]=6.804$, $p<.005$. A post-hoc test shows that subjects using the fisheye presentation answered significantly fewer incidental-learning questions than subjects using the linear and overview+detail interface. Subjects using the fisheye interface answered on average 0.78 and 1.16 fewer questions than subjects using the linear and overview+detail interface, respectively.

For the question-answering tasks, no influence from interface was found on subjects' grading, $F[2,312]=.121$, $p>.88$, or on the author's grading, $F[2,313]=.179$, $p>.83$.

Satisfaction

Nineteen of the subjects prefer using the overview+detail interface; one subject prefers the linear interface. In their motivation for preferring the overview+detail interface, 10 subjects mention the overview of the documents structure and titles as an important reason; six subjects mention that the overview+detail interface support easy navigation.

Table 3 shows the subjects' answers to the questionnaires filled out after using each of the interfaces. We compared the answers using paired t-tests with a Bonferroni-adjustment of $0.05/12*3\approx.0013$. The overview+detail interface is preferred to the two other interfaces overall, as well on the dimensions terrible-wonderful, and frustrating-pleasant. Subjects score the fisheye interface significantly lower on the dimension confusing-clear than the overview+detail interface. Subjects also score the overview+detail interface higher compared to the linear interface on the question whether the documents were easy or hard to overview. Note, that this question is not as leading in Danish as in the English translation given here.

Interface	Essay tasks (N=58)			Question-answering tasks (N=354)	
	Author's grading	Subjects' grading	No. correct incidental-learning questions	Author's grading	Subjects' grading
Linear	2.00 (.86) -	2.35 (.75)	4.20 (1.24) +	1.99 (.94)	2.63 (.93)
Fisheye	1.95 (.78) -	2.32 (.67)	3.42 (1.22) -	2.04(1.04)	2.68 (.91)
Overview+Detail	2.47 (.84) +	2.53 (.61)	4.58 (1.22) +	2.08 (1.03)	2.66 (.95)

Table 2—Effectiveness of the three interfaces. The table shows the first authors grading of the experimental tasks, the subjects own grading, and the number of correct answers to incidental learning questions. Standard deviation is given in parentheses. A plus indicate a significant difference at a 5% significance level to the interfaces marked with minus.

We find no difference for the questions intended to investigate whether the subjects' perception of their tasks differed between interfaces.

Efficiency

Table 4 summarizes the time usage for the part of the essay tasks where subjects read the document, and for reading and writing the answers for the question-answering tasks.

We find a significant difference in time used for the essay tasks, $F[2,32]=4.92$, $p<.014$. A post-hoc test shows that the fisheye interface is significantly faster than the linear and the overview+detail interface; subjects complete essay tasks 16% faster.

For the question-answering tasks, we find a significant difference in time usage between interfaces, $F[2,313]=4.235$, $p<.015$. A post hoc test confirms that tasks solved with the overview+detail interface took approximately 20% longer than tasks solved with the linear interface. No difference is found between the linear and the fisheye interface.

Interface	Essay tasks (N=58)	Question-answering tasks (N=354)
Linear	44.4 (11.9) **-**	5.9 (3.5) **+**
Fisheye	37.4 (12.4) **+**	6.6 (4.3)
Overview+Detail	44.5 (12.2) **-**	7.1 (4.1) **-**

Table 4—Mean time usage in minutes for essay and each of the six questions in question-answering tasks, standard deviation is given in parenthesis. A plus denotes a significant difference to the interfaces marked with a minus at a 5% significance level.

Reading Patterns

From the logged interaction data, we are able to identify three patterns in how subjects read documents before writing essays. First, we describe subjects' reading of documents in three phases: initial orientation, linear read-through, and review (see table 5). In the initial orientation phase, subjects navigate through the document, looking especially at the abstract, the introduction, and the conclusion. In the linear read-through phase, subjects read through the document, often with regressions and skips forward to unread parts of the document. In the reviewing phase, subjects seemed to be reviewing important parts of the document. Note how only 30% of the subjects spend time in the initial orientation phase, although the fisheye interface seems to invite this behavior compared to the other two interfaces. Fewer subjects seem to be reviewing documents using the overview+detail interface and to use a smaller proportion of the total reading time to do so.

Second, we find substantial individual differences in the time used and grade obtained, in how subjects read the documents, and in which input method they used. The fastest subject spent on average 24 minutes to read the three documents used for essay tasks; the slowest subject used 2.5 times more. Incidentally, both subjects' essays received an average grade of 1.67. Two subjects read all their documents from one end to the other; four subjects used only a brief review; four subjects had both an initial orientation phase

Satisfaction question	Linear (N=20)	Fisheye (N=20)	Overview+Detail (N=19)
Overall reaction to the system:			
Very Poor - Very Good	3.60 (1.27) -	3.68 (1.25) -	5.35 (.88) +
How was the system to use:			
Terrible - Wonderful	3.55 (1.19) -	3.74 (1.05) -	5.15 (.67) +
Hard – Easy	5.85 (1.35)	5.68 (1.29)	6.20 (.83)
Frustrating – Pleasant	3.57 (1.33) -	3.63 (1.42) -	5.55 (.83) +
Boring – Fun	3.25 (.91)	3.63 (.83)	4.57 (.94)
Confusing – Clear	5.38 (1.61)	4.58 (1.54) -	6.15 (.93) +
How do you perceived the tasks just solved:			
Very Challenging - Very Easy	4.53 (1.16)	4.79 (1.08)	4.68 (1.08)
Were your answers to the tasks:			
Very poor - Very good	4.20 (.95)	3.63 (1.12)	4.33 (.77)
How much did you learn from reading the papers:			
Learned nothing - Learning a lot	4.40 (1.23)	3.95 (1.58)	4.07 (1.13)
Were the papers just read:			
Hard to understand - Easy to understand	4.60 (1.23)	4.13 (1.33)	4.65 (1.18)
Hard to overview - Easy to overview	3.35 (1.73) -	4.05 (1.34)	5.25 (1.26) +
Was information in the two papers just read:			
Hard to locate -Easy to locate	3.95 (1.47)	4.18 (1.24)	4.65 (1.38)

Table 3—Mean scores for the 12 satisfaction questions for each interface. The first column in the table shows the question asked to the subjects (in italics), and the two extreme values showed on the seven-point differential scale that the subjects marked their answer on. Low scores were given to the negative concept of the differential scale. The next three columns show the mean scores for the three interfaces, with standard deviation given in parenthesis. A plus denotes a significant difference to the interfaces marked with a minus, using a Bonferroni adjustment of .0013.

Interface	Initial orientation	Linear read-through	Review
Linear (N=20)	4 (7 min)	20 (37 min)	13 (10 min)
Fisheye (N=19)	9 (11 min)	19 (26 min)	16 (7 min)
Overview+Detail (N=19)	4 (7 min)	19 (39 min)	10 (8 min)

Table 5—Reading phases for essay tasks. The table shows the frequency of the initial orientation, the linear read-through, and the review phase for the three interfaces. In parentheses is shown the average duration of the phase for subjects where we identified the phase. We have only counted phases that last more than 1/20 of the total reading time.

and a review phase in all of their essay tasks; and ten subjects read the documents in a more complex way. Four subjects solved all their tasks using the keyboard for input, and three subjects used only the mouse.

Third, the preferred mode of interaction for the three interfaces differs. For essay tasks, 11 subjects used mainly the arrow keys and page up/down to navigate through the document in the linear interface; three subjects used mainly the scrollbars. In the fisheye interface, subjects equally used the scrollbar and the keyboard to navigate in the document. In the overview+detail interface users are equally likely to use the scrollbar and the keyboard. However, 25% of the times subjects scroll through a document they used the overview pane as a scrollbar. While this difference superficially seems to be a natural choice of input method given the need to expand fisheye sections and the availability of a clickable overview pane, we think it might suggest differences in the way documents are read. The keyboard only allows linear navigation, while the scrollbar also allows jumping around the document.

DISCUSSION

The overview+detail interface supports reading electronic documents better than the linear and fisheye interface. The subjects' answers to essay tasks are graded higher when the overview+detail interface is used. Subjects also strongly prefer the overview+detail interface to the two other interfaces, pointing out that it supports navigation and helps to gain an overview of the structure of the document. The overview pane seems to support these activities, which pose well-known problems to readers of linear presentations of documents [22]. We think our data should encourage designers of electronic documents to use overview+detail interfaces to improve reading effectiveness and users' satisfaction.

It is puzzling that subjects use significantly more time for the question-answering tasks in the overview+detail interface compared with the other interfaces. It has been suggested that overviews impede performance for certain tasks [10,30]. We speculate that the overview pane in some situations attracts the subjects' attention, either distracting them or supporting useful associations. For the question-answering tasks, the overview pane might primarily be distracting, causing subjects to further explore the document, even when they have already found a reasonable answer to the question.

In the fisheye interface, subjects efficiently read documents for writing essays. Subjects spend less time in the linear read-through phase compared to the other interfaces. The fisheye interface seems to support subjects in efficiently grasping the main ideas using an overview oriented reading style. The subjects' satisfaction with the fisheye interface suggests that they in general do not like to depend on an algorithm that determines which sections to distort. The relatively low score for the essay tasks and the low incidental learning scores indicate that designers should be cautious in using fisheye interfaces for tasks that require a document to be fully understood. We interpret these findings to suggest that the fisheye interface is mostly useful for tasks that are time critical, for example relevance judgments.

Our study has at least five limitations, which could make the topic of further research to support reading of electronic documents with information visualization techniques. We have only considered two types of motivations for reading documents (reading-to-learn-to-do and reading-to-do); reading to judge the relevance of a document is another important activity that would be useful to support. Second, we need to consider how reading document types different from scientific documents might be supported. Third, our exploration of how reading of electronic documents might be supported should be replicated and extended for real-life reading tasks. Fourth, we think further exploration of effective semantic zooming for electronic documents is an important area for further research. While our results suggest that subjects like to be able to read the headlines of sections on the overview pane and to recognize figures and tables, it is not clear if subjects benefit from the large areas of non-readable text on the overview. Finally, we want to examine closer the individual differences in preferred reading and interaction patterns.

CONCLUSION

In an experiment, we compared the usability of three interfaces for electronic documents based on information visualization techniques. We also investigated the reading patterns of 20 subjects using these interfaces. We find that subjects prefer the overview+detail interface and with this interface write essays that receive a higher grade. Subjects complete essays faster with the fisheye interface, but seem to gain a less complete understanding of the documents read. Subjects take longer time using the overview+detail interface for answering questions, suggesting that the overview might distract them or lead to unnecessary exploration of the document. We also found different reading patterns between the interfaces. The most common interface in practical use, the linear interface, is found to be inferior to the fisheye and overview+detail interfaces regarding most aspects of usability.

Since reading of electronic documents plays a crucial role in information access and use, our results suggest that these activities might be supported through a focus on reading and interaction with electronic documents. We recommend designers of electronic documents to use overview+detail interfaces for electronic documents. Fisheye interfaces will mostly be useful for time-critical tasks when gaining a more complete understanding of the document is less important. Further research should explore individual differences in reading patterns and investigate how different reading tasks might be supported.

ACKNOWLEDGEMENTS

We thank Ben Bederson, Peter Naur, Catherine Plaisant, and Ben Shneiderman for helpful comments on a draft of this paper. We also benefited from discussions of our work at the HCIL at University of Maryland and with our colleagues at DIKU Jens Arnspang, Knud Henriksen, Kristoffer Jensen, Jørgen Sand, and Jon Sporring. We acknowledge the Digital Library Initiative at University of Illinois at Urbana-Champaign for lending us the documents used in the study. Finally, we thank the CHI reviewers for constructive comments.

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