Evaluating User Disorientation: A Comparison of Hypertext and Continuous Zooming Interfaces

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Abstract

Hypertext systems have reached ubiquity in the World Wide Web (WWW). One of the most common side effects of hypertext use is disorientation and this problem is exacerbated in the WWW environment. Powerful workstations allow software engineers to create innovative interfaces that improve user performance while minimizing such side effects. One such innovation is continuous zooming, an interface mechanism that provides alternative control to scrolling and jumping. A series of studies were conducted to investigate how a continuous zooming interface affected user text comprehension performance in general and user disorientation. Results suggest that zooming in text is at least as good as hypertext jumping for comprehension tasks and that users are satisfied with zooming even with minimal practice.

Keywords

Direct manipulation, disorientation, graphical zooming interface, hypertext.

1 Introduction

A fundamental challenge for all professionals is processing an increasing volume of electronic documents. Hypertext allows users to move quickly among information objects but also causes the often-noted side effect of disorientation (e.g. Nielsen, 1995). Today's workstations support new software mechanisms beyond scrolling and jumping and software designers are creating innovative tools for users who must scan and read electronic documents. One class of mechanism receiving considerable interest allows users to continuously zoom and pan. Zooming and panning certainly provide alternative means for quickly extracting meaning from electronic documents. What is not certain, is how these new mechanisms influence overall human performance, especially the side effects of disorientation commonly associated with hypertext links. This study investigates how continuous zooming affects user comprehension and disorientation by comparing the results of reading electronic documents in three interfaces: Netscape, a hypertext interface; Pad++, a zooming graphical interface using a zoom only condition; and Pad++ using both zoom and jump conditions.

2 Background

Hypertext provides the user with the ability to read an electronic document in much the same way as the human mind works, by associating one idea with another through a series of links. The user

must decide which path to take through the document and thus becomes an active participant in the navigation process. Unfortunately, following many links, or nodes, often leaves the user with a sense of disorientation. Without tables of contents, page numbers, or indices the user can easily become entangled in a web of links and become "lost" (Balasubramanian, 1994). The interface needs to help the user to define a cognitive approach to retrieving information (Search, 1993).

Disorientation may occur when the interactive user interface fails to communicate to the user where he/she is in the physical space created by many links or when the user loses a sense of his/her original purpose in following a particular link (Mantei, 1982; Shneiderman, 1987; Foss, 1989; Gay and Mazur, 1991). More than a few dozen nodes or links create visual and spatial perception problems for the user and thus result in disorientation (Begeman and Conklin, 1988). To avoid this, the navigator must be able to conceptualize the space as a whole (Darken,1996).

Graphical user interfaces have contributed some solutions to the disorientation problems created by hypertext by putting the user in control of the interface through direct manipulation (Ziegler and Fahnrich, 1990). Direct manipulation most resembles human communication in that it is not restricted to words only, but uses gestures and signals (Booth, 1989). A variety of control or signalling devices such as the keyboard, mouse, joystick, and trackball allow the user to scroll and jump through text while the interface provides immediate feedback to user actions.

Pad++, a zooming graphical interface, adds the zoom feature using a three-button mouse (Bederson, 1994). The entire text can be reduced to fit on one screen and the user can enlarge or decrease the size of the font at will as well as move the text up and down (scroll) or side to side (pan). Appropriate input and output devices allow the user to bridge the gap between the goals of the user and the input actions as well as the gap between the system's feedback and the user's perception of attaining his/her goals (Hutchins, Hollan and Norman, 1986).

3 The Problem

Control mechanisms for digital information today are impoverished. Today's technology and design are limited to scroll and jump (paging is a special case of jump). Faster CPUs and improved display technology support new types of user control mechanisms such as pan and zoom. In particular, today's workstations support almost continuous zooming and panning that allow natural progressions of human perceptual processing rather than the discrete jumps currently supported by hypertext systems such as Netscape on the World Wide Web. Since one of the basic problems of hypertext is disorientation due to discrete jumps, continuous zooming and panning offer alternative control mechanisms that may minimize such disorientations. Zooming and panning solutions have been discussed as solutions in the abstract (e.g., Marchionini, 1995) but we are now in a position to begin testing the actual effects of such user control mechanisms.

Systems such as Spatial Management of Information (Donelson, 1978) and Pad++ (Bederson, 1994, 1996) provide continuous zooming and panning features for high-performance workstations and it is only a matter of time before such capabilities migrate to low-end workstations. Several theoretical and practical questions are offered by such developments.

What are the challenges and opportunities of zooming? What are the side effects of zooming? How does human performance change? What system performance changes are required? How to best integrate zooming and panning into design?

Researchers at the University of Maryland's Digital Library Research Group are particularly interested in how zooming and panning can be applied to text corpora. (Multimedia seems obvious, text is an essential knowledge representation form and will remain so for the foreseeable future).

4 Approach

We have chosen to investigate how continuous zooming mechanisms affect user disorientation. Our main approach is to conduct user tests with minimalist versions (blatant) of zooming and jumping mechanisms. In the second iteration of this work, user spatial abilities were considered as such abilities have been associated with computer-based performance in other studies (Vincente,1987; Egan, 1988; Butler, 1990; Salthouse, et. al, 1990; Norman, 1994).

5 Iteration 1: The first experiment

In our first study (Páez & Silva & Marchionini 1996) we explored the hypothesis that using a zooming graphical interface minimizes user disorientation when reading documents in an electronic environment.

We undertook an exploratory comparative study to address questions such as: *is the physical arrangement of the document important to understanding? Is it more or less disorienting to jump from screen to screen through a document, or have the entire document on one screen with all sections visually adjacent to one another? Can changing the computer interface minimize disorientation? Can it be more satisfying to the user?*

Thirty-six graduate students ranging in age from 22 to 42 were randomly assigned to read a hypertext document in either Pad++, a zooming graphical interface, or Mosaic, a jump-based interface. Questionnaires, observation, and taped interviews were used to compare and evaluate the use of the two interfaces with regard to learning time, performance and user satisfaction.

Disorientation

On the questionnaire used in that experiment, two questions were aimed at disorientation specifically. Both the zoom and jump groups were asked to rate their feelings about being lost and their ability to recover from feeling lost. Likert scales were used with '1' indicating that they never felt lost and they found it very easy to recover versus '5' indicating that they always felt lost and it was very difficult to recover. The zoom group had a mean of 2.444 (std. dev.=0.856) on the scale of 1 to 5 for feeling lost, while the jump group had a mean of 2.167 (std. dev.=1.098) for the same scale indicating the jump group felt lost less often. A t-test showed that these differences were not statistically reliable (t=.85, p= .40).

On the recover question, the zoom group had a mean of 1.611 (std. dev.=.778) as opposed to the jump group which had a mean of 2.000 (std. dev.=1.061). These results were not statistically reliably different (t=-1.23, p=.23) but suggest that the zoom group felt that it was easier to recover when they felt lost than did the jump group.

The most ambiguous results on disorientation came from the question on a comparison with the World Wide Web. Although there was no specific mention of the Web with respect to use of applications in the demographic section of the questionnaire, participants neither agreed nor disagreed with the statement, "I feel more disoriented using the World Wide Web than Pad++." The mean was 3.00 with a standard deviation of 1.534. The Web with its links to millions of documents is often the butt of complaints concerning disorientation, so this result was somewhat surprising. It was indicated that further research should target specific information about Web use/experience in order to make more accurate comparisons with Pad++.

Comprehension

Both groups of participants were asked to rate the effect jumping and zooming had on their ability to comprehend the article. They were somewhat ambivalent about each system's effect on comprehension, leaning toward the negative end of the scale. The jump group had a mean of 3.556 (std. dev.= 0.784) on a scale of 1 to 5 with '1' meaning that the system affected comprehension very satisfactorily. The zoom group had a mean of 3.294 (std. dev.=1.160). The t value was -.78 with a p of .44. In essence, the scores indicate that the zoom group rated their interface more satisfactory to comprehension. While the zoom and jump groups showed some ambivalence, still the zoom group score was closer to '1' than the jump group's score, '1' being most satisfactory. In addition, the zoom group felt very confident that the Pad++ system was conducive to finding information. They rated the system 2.167 on a scale of '1' to '5' with '1' meaning very confident.

They also were asked to answer five questions which dealt with content, their ability to locate and comprehend information. People in the jump group had an equal or higher percentage of correct answers across all five questions except for three tenths of a percent lower score on question five. In general, it could be concluded that the jump feature was more conducive to participants finding correct information than the zoom feature. The mean number correct in the zoom category was 4.333 (std. dev.= .767) and 4.647 in the jump category (std. dev.=.606). More people in the jump category answered all five questions correctly (71%) as opposed to those in the zoom category (50%).

Summary

Breaking a document down into main ideas and various levels of supporting information can reduce learning time. Also, the click and zoom maneuverability avoids the user having to learn special commands, another aid in reduction of learning time. Performance speed is improved by having the document in one physical space and by having the ability to recover quickly from error. The result of user action is immediately visible. Even in this limited study, user satisfaction was high with Pad++ for reading electronic documents.

Our questionnaire addressed these goals, but our quantitative data did not yield statistically reliable results. Although the zoom interface group felt that their comprehension was enhanced by the system, the jump group actually scored slightly higher on questions based on content and used less time than those in the zoom condition. Further study is needed to determine whether these trends are inherent in the mechanism or a novelty effect. Clearly, the problem of overshooting targets must be more fully investigated. This first exploration of the effects of continuous zooming interface mechanisms do suggest that continuous zooming is an intriguing and satisfying mechanism for users.

6 Iteration 2: Methodology

The current experiment compared three distinct interfaces developed for the first three chapters of the book "Sparks of Innovation in Human-Computer Interaction" edited by Ben Shneiderman, 1993. The chapters were marked up into five levels of granularity: title, main headings, subheadings, topic sentences and the remaining text. Font sizes varied across all levels so that the entire paper was visible on a single screen in the continuous zooming version. Figure 1 shows a portion of the screen containing all font sizes. The jump version was implemented using Netscape and the continuous zooming version was implemented using the beta 0.2.2 version of Pad++. The study was conducted in a laboratory at the College.

The three treatments in the experiment were:

- **Jumping:** Implemented in Netscape
- **Zooming:** Implemented in Pad++
- **Zooming/Jumping:** Implemented in Pad++

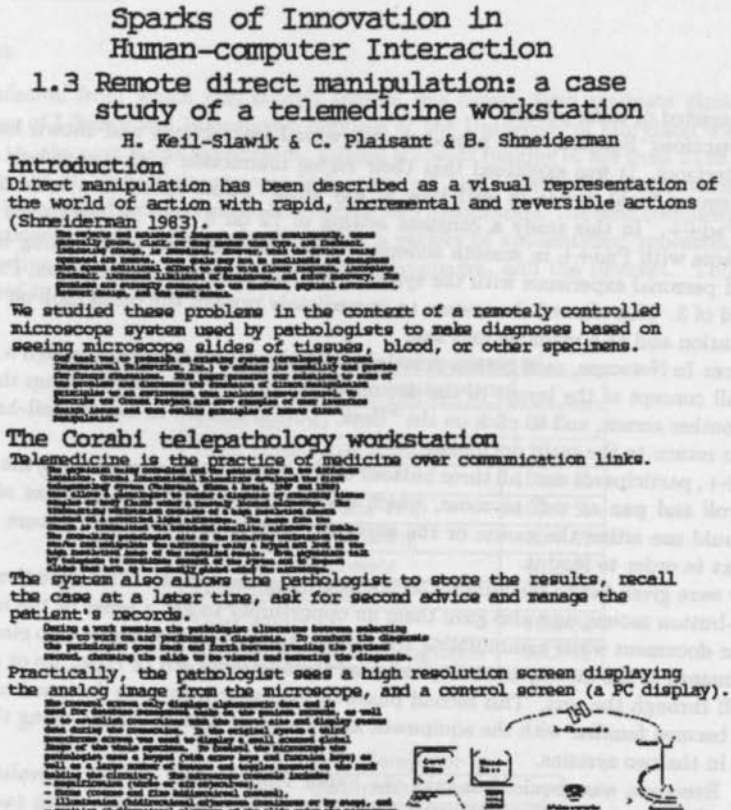

Figure 1: Portion of the screen containing all font sizes.

Questions

Our work was guided by four working questions:

1. Will users of the three interfaces have the same level of comprehension?
2. Will users of the three interfaces require the same time to perform tasks?
3. Will users of the three interfaces have the same level of disorientation?
4. Will users of the three interfaces have the same level of ability to recover when they feel disoriented?

(a) Paper Folding Test - Vz-2;
(b) 3 content questionnaires;
(c) 3 interface evaluations;

4. portable cassette recorder.

Procedures

Each session consisted of these phases:

1. Introduction: Subjects were provided with verbal instructions and shown how to manipulate the interfaces. It was explained that their verbal interaction with researchers would be audiotaped. Anyone could decide to withdraw at any time. Zoom speed is a user-controllable parameter in Pad++. In this study a constant setting of 12 on a 1 to 20 level scale was used for all participants with Pad++ in smooth zooming. This was based on pilot testing in the first experiment and personal experience with the system. For the jump-zooming session, Pad++ was set with a speed of 3. This allowed the system to immediately present the paragraph on the screen in a central location and at a readable font size.

2. Practice: In Netscape, each person practiced with the mouse to scroll through a document to get an overall concept of the layout of the document, to practice clicking to jump through the document to another screen, and to click on the "Back" button located in the top left-hand corner of the screen to return to the main document.

With Pad++, participants used all three buttons of the mouse to practice reading the document in order to scroll and pan as well as zoom, which allowed them to change the size of the text. Participants could use either the mouse or the keyboard to activate the zoom feature to enlarge parts of the text in order to read it.

Next, they were given five to ten minutes to practice using the system. This gave them practice with the three-button mouse, and also gave them an opportunity to get a sense of the hierarchical structure of the document while manipulating the text on the screen. For those who elected to use the keyboard instead of the mouse, arrow keys allowed them to move left or right, up or down, that is, pan or scroll through the text. This second phase of the experiment was designed to allow the participant to become familiar with the equipment and to reduce anxiety about using the jump or zoom features in the two systems.

3. Test: Everyone was required to take the Paper Folding Test - Vz-2 to evaluate spatial understanding. The maximum time permitted for this phase was six minutes, with two segments of three minutes each. Also, we required everyone to answer content questions based on reading each document. The questions were handed out one by one for each subject to answer them, after reading the entire article. Subjects were asked to point to the appropriate text on the screen in order to answer the questions and were permitted to refer to the article . Each participant was given unlimited time to accomplish this.

4. Evaluation: The subjects were also give a questionnaire designed to solicit demographic information as well as their comments on each system. The last phase consisted of a taped interview with each participant. They were encouraged to share their view of the system they had just used and make recommendations for future research. During the entire experiment, field notes were taken as participants were observed in their tasks, asked questions, or were interviewed. The researchers then listened to the tapes, expanded the field notes, and analyzed the results. Triangulation as a method of qualitative analysis was thereby assured through observation, questionnaires and field notes. Quantitative analysis was derived through the use of questionnaires.

The main independent variable was the type of interface: jump, zoom, and zoom/jump. A secondary independent variable was user spatial ability as measured by a standard spatial ability instrument.

The dependent variables used to address the research questions were:

1. **Performance on learning tasks.**
2. **User satisfaction.**

Subjects

The population from which this study's sample was drawn were graduate students enrolled in the College of Library and Information Services at the University of Maryland who were asked to volunteer to take part in the experiment. Fifteen students ranging in age from 23 to 60 participated. The mean age of all participants was 35.2 years; all had experience using a variety of computer types, including IBM PCs or clones, Macintosh, and mainframes. All used computers whether daily or a few times a week and were familiar with a variety of applications: processing, spreadsheets, games, on-line searching, e-mail, programming languages, and the Internet. This information is summarized in Tables 1 and 2.

Table 1: Subjects' background.

Subjects' background	
Mean age (23 - 60)	35.2
Used three types computers	20.0%
Used e-mail	100.0 %
Used World Wade Web	100.0 %
Used on-line searching	86.7 %
Used word processor	93.3 %
Used spreadsheet	73.3 %
Used games	60.0 %
Used programming languages	33.3 %

Table 2: Computer use.

Computer use	Percent
Every day	86.7
A few times a week	13.3
A few times a month	0.0
Rarely or never	0.0

Apparatus

Experimental material included:

1. **a Sun SparcStation 10 with a 21" color monitor;**
2. **consent form;**
3. **questionnaires:**

Administration

Two series of 45-minute experiments were conducted over a period of three weeks. The subjects signed a consent form and were asked to sit in front of a workstation after the workstation was set up. Weekly morning, afternoon and evening hours were made available. During the experiment, the researcher sat beside the subject and assisted him or her whenever there were difficulties. Each practice session and each test phase was timed.

7 Results and discussion

Our primary objective in this paper is to study the disorientation in electronic environments associated with each experimental condition. All subjects were tested on all treatments. Consequently, this section reflects both quantitative and qualitative measures. The following results were gathered from the subjects' responses to the questionnaires.

Learning

On the questionnaire used for the Pad++ group, we asked *how easy it was to learn to use the system with smooth zooming or jump zooming,* that is to become familiar with the three-button mouse and be able to manipulate it to use the zoom feature. Sixty percent of participants felt that it was very easy to learn to use Pad++ smooth zooming and 27% said it was difficult. Table 3 shows that on a Likert scale of 1 to 5, with '1' representing easiest, the mean score was 2.27 with a deviation of 1.58. Also, 67% of participants felt that it was very easy to learn to use Pad++ jump zooming and 13.% felt that it was difficult. The mean score was 2.13 with a deviation of 1.25. Observations made during the experiment indicated that almost all of the subjects had a difficult time in using the three-button mouse for the first few minutes.

This question did not affect the Netscape group because everyone had previously used that interface and were familiar with jumping and scrolling. Learning with regard to content is addressed below in the section of the results which discuss comprehension.

Table 3: Learning to use Pad ++.

Learning to use Pad++		
How easy learn to use Pad++	Mean	Std. Dev.
with smooth zooming (easy/difficult)	2.27	1.58
with jump zooming (easy/difficult)	2.13	1.25

Comprehension

All participants were asked to rate the effect of each condition (jump, zoom, and zoom/jump) on their ability to comprehend the electronic document they had read. On a scale of '1' to '5', the jump group had a mean of 3.13 (std. dev.=0.74) indicating the participants were ambivalent about whether or not Netscape would affect their comprehension. The zoom group in Pad++ had a mean of 1.93 (std. dev=1.28) and the zoom/jump group had a mean of 1.80 (std. dev=0.56) indicating that they felt very confident that the interface would help them with comprehension. Table 4 provides results from a One-way ANOVA using a Modified LSD (Bonferroni) test that illustrate that there is a statistically reliable difference shown.

It could be concluded that Netscape was less conducive to finding information than Pad++. The differences may have indeed been more dramatic if the Netscape participants had had an opportunity to jump to more than one level. Several people mentioned in their interviews that if there were more levels they would have had a more difficult time keeping track of the content of the document.

All participants were also asked to answer several content questions for each document including some true/false questions. Tables 5, 6, and 7 show that users who perceived the system as difficult answered fewer questions correctly and participants who perceived the system as conducive to learning answered more questions correctly. In the Netscape jump condition , the mean number of correct answers was 5.53 (Table 5). In the Pad++ zoom condition, the mean score for correct answers was 6.87 (Table 6), whereas the mean score in the Pad++ zoom/jump condition was 5.28 (Table 7). Although these results do not show statistically significant differences, they do reflect participants' confidence levels: subjects were more confident that zoom would help them find content than zoom/jump and scores were indeed higher for zoom than for zoom/jump. It must be kept in mind that a strict comparison of scores cannot be made since scores reflect three different electronic texts each with its own set of content questions.

Table 4: Comprehension/Capability to find information.

Comprehension/Capability to find information			
Rate of confidence find information	**Mean**	**Std. Dev.**	**(*)signif. diff.**
Pad++ jump smooth	1.80	.56	*
Pad++ smooth zooming	1.93	1.28	*
Netscape jump	3.13	.74	
One-way ANOVA			p.0003

Table 5: Content questions for Netscape JUMPING summary

JUMPING individual and total number correct summary (1=correct)										
Subject-Id	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Tot-cor.**	**Time (m.)**
A1	1	1	1	1	0	0	0	1	5	13.37
A2	1	1	1	1	1	1	1	0	7	8.02
A3	1	1	1	1	0	1	1	1	7	17.01
A4	1	0	0	1	0	1	0	1	4	12.37
A5	1	1	1	1	0	1	1	1	7	28.00
A6	1	1	1	1	1	1	1	1	8	10.46
A7	1	1	1	1	0	1	1	1	7	10.33
A8	1	1	1	1	0	1	0	1	6	15.36
A9	1	1	1	1	1	0	0	1	6	8.42
A10	0	1	0	1	0	1	0	1	4	14.23
A11	0	1	1	0	0	0	0	1	5	7.48
A12	0	0	0	1	0	1	0	0	2	5.50
A13	1	1	1	1	0	0	0	1	5	6.23
A14	0	0	1	1	0	1	0	1	4	4.48
A15	0	1	1	0	1	1	1	1	6	16.29
Total/Mean	10	12	12	13	4	11	6	13	5.53	11.84

Table 6: Content questions for Pad++ ZOOMING summary

ZOOMING individual and total number correct summary (1=correct)										
Subject-Id	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Tot-cor.**	**Time (m.)**
A1	1	1	1	1	1	1	1	1	8	7.82
A2	1	1	1	1	0	1	1	0	6	13.47
A3	1	1	1	1	1	0	0	1	6	8.15
A4	1	0	0	1	1	1	1	1	5	13.15
A5	1	1	1	1	1	1	1	0	7	5.36
A6	1	1	1	1	1	1	1	1	8	18.50
A7	1	0	1	0	1	1	1	1	6	35.00
A8	1	1	1	1	1	1	1	1	8	10.00
A9	1	1	1	1	0	1	1	1	7	7.48
A10	1	1	1	1	1	1	1	1	8	10.58
A11	1	1	1	1	1	1	1	0	7	9.24
A12	0	0	1	0	1	0	1	0	3	4.17
A13	1	1	1	1	1	1	1	1	8	6.06
A14	1	1	1	1	1	1	1	1	8	4.52
A15	1	1	1	0	0	1	1	1	6	14.31
Total/Mean	14	12	14	12	12	13	14	11	6.87	11.19

Table 7: Content questions for Pad++ ZOOMING/JUMPING summary

ZOOMING/JUMPING individual and tot. number correct summary (1=correct)											
Subject-Id	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	T-cor.(*)	Time (m.)
A1	1	1	1	1	0	1	0	0	0	1	6	9.34
A2	1	1	1	1	1	1	1	1	1	0	9	12.15
A3	1	1	1	1	1	1	0	0	1	1	8	6.11
A4	1	1	1	1	0	0	0	0	1	1	6	8.22
A5	1	1	1	0	0	1	1	0	1	1	7	4.32
A6	1	1	1	1	1	0	0	0	1	1	7	20.24
A7	1	1	1	1	1	1	1	1	1	1	10	15.00
A8	1	1	1	1	0	0	1	1	1	1	8	7.25
A9	1	1	1	0	0	0	1	1	1	1	7	9.11
A10	1	1	1	1	1	0	1	1	1	1	9	9.04
A11	1	0	0	0	1	0	0	0	1	0	3	15.35
A12	1	0	1	0	0	0	0	0	0	1	3	5.08
A13	1	1	1	0	0	0	0	0	0	0	3	15.01
A14	1	1	1	0	1	0	0	0	1	0	5	9.37
A15	1	1	1	1	0	1	1	0	1	1	8	6.49
Total/Mean	15	13	14	9	7	6	7	5	12	11	6.53	10.14

(*) Represents row data scores adjusted for purpose of comparison.

Spatial Visualization vs. Content

Table 8 shows the results of the Paper-folding Test (Ekstrom, Et. al. 1976), which measured spatial visualization, compared to the results of the comprehension scores. Tables 9 and 10 break out comprehension scores for users above and below the mean visualization scores. Participants who scored above the mean on the spatial visualization test, that is above 52.5%, also scored above the mean on the percentage of questions answered correctly in two of the three conditions.

The Netscape-Jump group had a mean of 6.0 correct answers with a standard deviation of 1.20 as opposed to the group who scored below the mean who averaged 5.0 correct answers with a standard deviation of 1.95. For the jump condition, a strong correlation was found between spatial visualization ability and comprehension performance (R=.58, p=.02).

Similar but weaker results were found in the Pad++-Zoom group: the group who scored above the mean on visualization, scored above the mean for correct answers (6.88 correct answers, std. dev.=0.83). The group who scored below the mean on visualization, scored below the mean on number of questions answered correctly: 6.86(std. dev.= 1.86). This condition did not yield a high correlation between visualization ability and comprehension performance, although it was in the positive direction (R=.22, p=.43).

In the Pad++-Zoom/Jump condition, those who scored above the mean on visualization had a mean score of 6.50 (std. dev.=2.62) while the group who scored below the mean on visualization had a mean score of 6.57(std. dev.= 2.07) on content questions. A strong correlation was found in visualization ability and comprehension performance (R=.43, p=.11). Thus, the expected positive relationship between visualization ability and comprehension performance was found in the jump condition which was familiar to users and the mixed condition to a lesser degree. The novel zoom condition apparently mitigated the predicted relationship between visualization ability and comprehension performance. Whether this is due to the limited practice subjects in this study had

or to some interface effect of zooming bears further investigation.

There were no strong relationships between visualization ability and time to answer comprehension questions for any of the three treatment conditions (jump R=.06, p=.83; zoom R=.19, p=.49; jump+zoom R=.16, p=.58). However, of the eight people (53%) who felt that Pad++ zoom would allow them to find content easily (they rated the system '2' on a Likert scale of '1' to '5'), 75% of them used less than the mean time to answer the content questions. By the same token, four participants (27%) rated Pad++ zoom '4' on the scale indicating they were not confident that they would be able to use the system well to find content. In the Pad++ zoom/jump condition, again 53% of the participants felt that they would be able to find content easily ('2' on a Likert scale of '1' to '5'). Of these eight people, 89% were able to complete the questionnaire and answer the content questions in less than the 10.14 minutes which was the mean time. The two participants who felt it was unlikely ('4' on the scale) that they would find content easily actually did take much longer than the mean time to answer the questions, needing 15 minutes each.

Table 8: Paper-folding Test - VZ-2.

Paper-folding Test - VZ-2 vs. Content questions				
Subject-Id	**Score Test-vz**	**Nets. Jump**	**Pad Zoom**	**Pad Zoom/Jump**
A1	27.0	5	8	5
A2	95.0	7	6	9
A3	74.0	7	6	8
A4	48.0	4	7	6
A5	59.0	7	7	7
A6	37.0	8	8	7
A7	64.0	7	6	10
A8	45.0	6	8	8
A9	69.0	6	7	7
A10	43.0	4	8	9
A11	60.0	5	7	3
A12	0.06	2	3	3
A13	54.0	5	8	3
A14	63.0	4	8	5
A15	50.0	6	6	8
Mean	52.5	5.53	6.87	6.53

User System Preference

Fourteen of the fifteen participants responded to the question concerning user system preference. When asked to compare the three interfaces as a medium in which to read electronic documents, 36% of the participants preferred Netscape, 29% preferred Pad++ with zoom, and 36% preferred Pad++ with zoom/jump. In other words, 72% of the participants preferred an interface that allowed them to quickly access a specific portion of the text and to have it at a readable font size. They preferred to "jump" to information rather than to have to scroll and zoom. This has design implications for all systems.

Table 9: Subjects over the mean in Paper-folding Test - VZ-2.

Spatial visualization vs. Contents				
Subject-Id	**Score Test-vz**	**Nets. Jump**	**Pad Zoom**	**Pad Zoom/Jump**
A2	95.0	7	6	9
A3	74.0	7	6	8
A5	59.0	7	7	7
A7	64.0	7	6	10
A9	69.0	6	7	7
A11	60.0	5	7	3
A13	54.0	5	8	3
A14	63.0	5	8	5
Mean	67.3	6.0	6.88	6.50
Std. Dev.	12.8	1.20	.83	2.62

Table 10: Subjects below the mean in Paper-folding Test - VZ-2.

Spatial visualization vs. Contents				
Subject-Id	**Score test-vz**	**Nets. Jump**	**Pad Zoom**	**Pad Zoom/Jump**
A1	27.0	5	8	5
A4	48.0	4	7	6
A6	37.0	8	8	7
A8	45.0	6	8	8
A10	43.0	4	8	9
A12	0.06	2	3	3
A15	50.0	6	6	8
Mean	35.7	5.0	6.86	6.57
Std. Dev.	17.5	1.95	1.86	2.07

Disorientation

All participants in all groups felt some disorientation. There were no significant differences among groups. On a Likert scale of '1' to '5' the Netscape group rated disorientation 2.20 (std. dev.=1.01); the Pad++ zoom group rated it 2.07 (std. dev.=.59); the Pad++ zoom/jump group rated it 2.33 (std. dev.=.90). These numbers do not change greatly if we look at participants either over the mean age of 35 or below it. Across the three groups the scores were 2.28, 2.14, and 3.0 respectively for those over 35. For those under 35, the scores were 2.13, 2.0, and 1.75. For the younger participants at least, there was a little less sense of disorientation in the Pad++ zoom/jump group, but again, no statically significant differences. A One-way ANOVA using a Modified LSD (Bonferroni) test for all three conditions showed no two groups were significantly different at the .05 level.

We also asked participants to rate how difficult it was to recover when they did feel some sense of disorientation. The Netscape group on a scale of '1' to '5' had a mean of 1.87 (std. dev.=1.19), while the Pad++ groups had means of 2.27 (std. dev.=1.16) and 2.07 (std. dev.=1.16) respectively. It would appear that the jump feature in Netscape and Pad++ jump provided some slight advantage to recover from feeling lost. However, ANOVA tests showed no statistically significant differences at the .05 level.

Conclusions

There are no conclusive answers to the four working questions for this investigation. With reference to the question concerning comprehension, users of the three interfaces exhibited almost the same level of comprehension. It still must be noted, however, that zoom and zoom-jump participants scored higher on comprehension. With respect to time, users of the three interfaces exhibited almost the same level of time necessary to answer the questions. Of course it must be kept in mind that some time was lost using the zoom condition since there was no mechanism present to adjust the zoom automatically. For example, ability to zoom was infinite often resulting in the participants zooming off the screen. Future development of the Pad++ system needs to address the issue of infinite zooming.

Our quantitative data did not yield statistically reliable results to the questions about disorientation and recovery from disorientation. Nevertheless, subjects performed equally well in all conditions with the Pad++ zoom condition favored slightly on comprehension performance and self reports of disorientation. It is also the authors' observation that participants exhibited less disorientation using the zoom interfaces.

In addition, we aimed to differentiate user performance across the jump and zoom conditions by assessing user visualization ability as a covariable. A strong positive correlation was found between visualization ability and task performance in the Netscape jump condition. It is likely that these results are due to the novelty of the Pad++ zoom interface and limited practice (10-15 minutes before conducting tasks) with the three-button mouse for zooming and panning. Nevertheless, subjects were highly favorable to the zooming condition and several observations and recommendations can be made.

8 Recommendations for additional investigation:

Zooming provides several advantages not addressed by this study. First, it allows users to get an overview of an entire document or information space. Several subjects in these studies commented on the ability to see an entire article on one screen and then move in and out of levels of detail easily. Second, zoom allows users to increase the size of fonts to comfortable reading levels, an ability important for users of different ages and eye conditions. Third, zooming provides an alternative to the scroll and jump mechanisms available in today's workstations and personal computers. The studies reported here illustrate that subjects did not perform worse with zooming than with more familiar mechanisms and were highly intrigued by the possibilities of using zooming. Taken together, these results suggest that software engineers consider integrating zooming mechanisms into interfaces as workstation technology continues to improve.

A number of issues arose in these studies that suggest future investigation. First, what are the effects of screen size? In these studies, a large, 21 inch color display was used and the effects of more typical small displays should be studied. Second, the zoom speed greatly affects user performance. A study of different zoom speed conditions will inform designers about what speeds to set as defaults. For text documents, the ratio between font sizes in different levels of textual detail requires investigation to determine default settings and control parameters for users. Finally, it is essential that automatic means of extracting textual summaries be developed if continuous zooming is to be fully implemented for text documents. This is a long-standing problem in information retrieval and natural language processing. Other questions will certainly be raised as designers gain more experience with zooming mechanisms. User studies are an integral part of the software design process to inform subsequent iterations, help discover design principles, and identify new goals for software design.

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