The effect of display size and text splitting on reading lengthy text from screen

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Abstract

The present paper reports on an experimental investigation of reader performance and preferences with a screen-presented journal article. The effects of display size (20 lines and 60 lines) and sentence splitting on readers' manipulation, comprehension and subjective impressions are assessed. The results indicate that neither variable significantly affects comprehension but adjusted manipulation levels are significantly higher in the small window condition. Splitting sentences across screens also caused readers to return to the previous page to re-read text significantly more. Subjective data reveal a preference for larger screens and high awareness of text format. Implications for future work are discussed.

Introduction

Technological advances continue to make information presentation via computer screens more feasible and it is generally assumed that text will increasingly be accessed on screen as well as, or instead of, on paper (Wright and Lickorish, 1988). However, until recently concern focused mostly on the legibility of the screen image (Bauer et al., 1983; Gould et al., 1987) and research has indicated that particular factors of image quality are crucial determinants of legibility (see Dillon et al., 1988 for a detailed review). Important as this work is, it provides no insight into the higher cognitive issues involved in reading and manipulating computer-based text. Such issues grow in relevance as the advantages of electronic storage, transmission and presentation of text become apparent to industry, commerce and academia.

Specifically, little work has been done on the electronic presentation of lengthy texts where problems of navigation and location as well as manipulation of the document arise. With paper, readers have acquired a range of physical and cognitive skills for manipulating text and the relatively standard format of texts allows for easy transfer of these skills across the spectrum of paper documents. How electronic text may best be designed to facilitate similarly easy use remains an open question.

There has been some research on manipulation of electronic text, particularly on the relative merits of scrolling and paging. There is evidence to suggest that readers establish a visual memory for the location of items within a printed text based on their spatial location both on the page and within the document (Rothkopf, 1971; Lovelace and Southall, 1983). This memory is supported by the fixed relationship between an item and its position on a given page. A scrolling facility is therefore liable to weaken these relationships and offers the reader only the relative positional cues that an item has with its immediate neighbours. However, on the basis of a literature review, Mills and Weldon (1985) report that there is no real difference between scrolling and paging though Schwartz et al. (1983) found that novices tend to prefer paging (probably based on its close adherence to the book metaphor).

Scrolling has also been investigated in conjunction with direction (vertical or horizontal—Sekey and Tietz, 1982), rate (self-paced or machine-paced—Kolers et al., 1981) and display size (Duchnicky and Kolers, 1983). With reference to direction and rate, all seem to agree that ideally, lengthy texts should be presented vertically and at the readers choice

of rate. Even so, Kolers et al. (op. cit.) report that forcing readers to increase their rates by 10-20% does not lead to loss of comprehension and actually appears to increase efficiency of eye-movements as measured by rate and length of fixation.

Display size, however, is less clear-cut. Duchnicky and Kolers (1983) investigated the effect of display size on reading constantly scrolling text and reported that there is little to be gained by increasing display size to more than 4 lines either in terms of reading speed or comprehension. Elkerton and Williges (1984) investigated 1,7,13, and 19-line displays and reported that there were few speed or accuracy advantages between the displays of 7 or more lines. Similarly, Neal and Darnell (1984) report that there is little advantage in full page over partial page displays for text-editing tasks.

These results seem to suggest that there is some critical point in display size, probably around 5 lines, above which improvements are slight. Intuitively this seems implausible. Few readers of paper texts would accept presentations of this format. Our experiences with paper suggest that text should be displayed in larger units than this. Furthermore, loss of context is all too likely to occur with lengthy texts and the ability to browse and skim backward and forward is much easier with 30 or so lines of text than with 5 line displays. Of the experiments cited, only the Duchnicky and Kolers study was concerned with reading for comprehension and their passages were never longer than 300 words. Thus the findings on window size bear little relevance to reading of lengthy texts.

A related issue to display size and scrolling/paging is the splitting of paragraphs mid-sentence across successive screens. In this case, which is more likely to occur in small displays, the reader must manipulate the document in order to complete the sentence. This is not a major issue for paper texts such as books or journals because the reader is usually presented with two pages at a time and access to previous pages is normally easy. On screen however, access rates are not so fast and the break between screens of text is likely to be more critical.

Research into reading has clearly demonstrated the complexity of the cognitive processing that occurs. The reader does not simply scan and recognise every letter in order to extract the meaning of words and then sentences. Comprehension requires inference and deduction, and the skilled reader achieves much of his smoothness by predicting probable word sequences (Chapman and Hoffman, 1977). The basic units of comprehension in reading that have been proposed are propositions (Kintsch, 1974),

sentences (Just and Carpenter, 1980) and paragraphs (Mandler and Johnson, 1977). Splitting sentences across screens is likely to disrupt the process of comprehension by placing an extra burden on the limited capacity of working memory to hold the sense of the current conceptual unit while the screen is filled. Furthermore, the fact that between 10-20% of eye movements in reading are regressions to earlier fixated words and that significant eye movement pauses occur at sentence ends would suggest that sentence splitting is also likely to disrupt the reading process and thereby hinder comprehension.

To date, such issues have received scant attention from researchers. Yet they are likely to have pronounced effects on the acceptance and usability of electronic text. The present experiment therefore seeks to determine the importance of such display characteristics in reading lengthy texts from screen. The study requires subjects to read a journal article on screen where display size and sentence splitting are manipulated. The aim is to identify the effect of these variables on comprehension, reading behaviour and subjective impressions of the task.

Method

Subjects

Of the thirty-two subjects who participated in the experiment, 21 were male and 11 were female. Their ages ranged from 22 to 45, with a mean age of 29. The only criterion for participation was that the subject had completed at least 2 years, full-time, undergraduate study and were thus reasonably familiar with academic texts. Subjects were paid £5 for participation and all reported good or corrected vision.

Equipment & Materials

Hardware

Text was displayed on a high resolution, black on white, A3, Etap 'Atris' screen driven by a Hewlett-Packard VECTRA microcomputer.

Software

The experimental interface was specially written and was designed to imitate the basic manipulation available to readers of printed texts. It facilitated movement through the

document by paging forwards or backwards, jumping to particular page numbers or to the beginning and end of the text. The commands and their actions are described in Table 1.

Command	Action
N	Next 'page'
P	Previous 'page'
B	Goto the Beginning
E	Goto the End
No. <enter>	Goto specified page
Q	Quit the program

Table 1. Keystroke commands and their actions

These commands were permanently displayed at the foot of the screen. Each screen also permanently displayed the article title, the current 'page', the total number of 'pages' and the last seen 'page'. A typical screen is presented in Figure 1.

Insert Figure 1 here

Data logging routines in the display software captured subjects' input and its time of occurrence and this was used for later analysis of performance.

Text

The text employed for this experiment was titled "Geography, war and peace" (O'Loughlin and van der Wusten, 1986), a 3500 word theoretical analysis of international conflict. It was chosen so as to be equally unfamiliar to all subjects in terms of content while conforming to the general style and difficulty of an academic paper.

Questionnaire

A post-task questionnaire was designed to elicit information on matters such as ease of use of the interface, additional facilities that might prove helpful, difficulties subjects had and the extent to which subjects noticed the format characteristics of the text.

Task

The task required the user to read the text for understanding rather than detail. No time constraints were imposed and they were free to manipulate the text and re-read it in full or in part as often as they required. When satisfied that they had read the text sufficiently, the subjects were required to summarise its main points. Finally, they completed a questionnaire.

Design

A four-condition, independent subjects design was employed with the size of screen (small and large) and the text style (split sentence and non-split sentence) as independent variables manipulated to produce the following set of conditions:

Condition 1: 60 lines - non-split text;

Condition 2: 60 lines - split text;

Condition 3: 20 lines - non-split text;

Condition 4: 20 lines - split text;

In the non-split sentences conditions (1 & 3) only multiples of complete paragraphs were displayed on the screen while in the split conditions (2 & 4), there was no consideration of the paragraph unit with the result that all but one of the screens split the text mid-sentence.

Dependent variables were the comprehension measures, command usage and questionnaire responses.

Procedure

Subjects were run independently in a quiet experimental laboratory on the university campus. They were allowed to adjust the seat and monitor to suit themselves. The experimenter loaded a practice text and explained the commands to the subject who was then allowed to practise until satisfied that they understood the workings of the system sufficiently to proceed.

The experimental text was loaded and the subject informed that they should read the text for understanding rather than specific detail and that there were no time pressures or reading sequence constraints imposed. When the subjects completed this part of the trial to their satisfaction the system was switched off and they were requested to write a summary of the article. This, it was explained, should include the author's main points rather than specific details. Once more there was no time constraint on this activity and when it was completed to the subjects' satisfaction they were presented with the questionnaire.

Results

Comprehension measures

Comprehension scores were deduced by scoring the subjects' summaries according to a procedure based on the work of Kintsch and van Dijk (1978). This involves an iterative propositional analysis of the original text to produce a hierarchy of ideas or core concepts. The first level analysis reduces the original text to its basic propositions, these are analysed in turn to produce a second level abstraction and the procedure continues accordingly until a top level is arrived at where a global 'gist' of the text is described. Summaries are scored according to the presence of particular ideas, usually from the second or third level of the hierarchy (the lowest level being too specific and the higher levels being too general).

The advantage of this technique is that it produces a measure of comprehension that does not rely on simple memory for detail as could be the case if subjects were presented with questions. It also allows subjects to express everything they remember about the text and puts little pressure on them to "perform" or answer correctly though summaries composed of unstructured detail will not score highly. Therefore it is likely to produce a better measure of comprehension than a method based on question and answer sets.

Acceptance of Kintsch and van Dijk's theory of discourse is not a prerequisite for using the technique.

The original text was analysed and a hierarchy of propositions developed. Examination of a random sample of summaries indicated that for the present text, a second level analysis was most appropriate and all summaries were scored according to their inclusion of propositional units from that level (maximum score=60). Figure 2 presents the mean comprehension scores per condition.

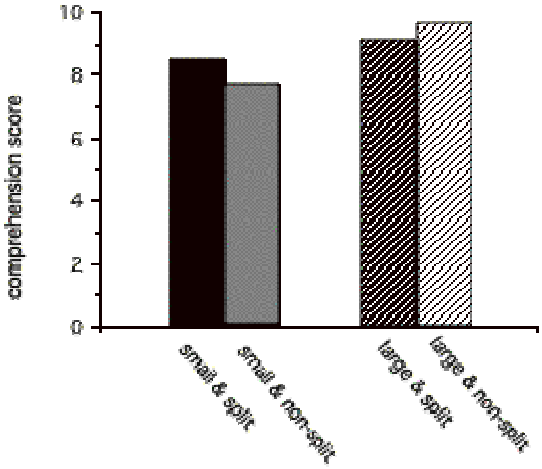

Fig 2. Mean comprehension scores per condition

While there is a slight trend in favour of larger screens, a 2x2 ANOVA revealed no significant effect for screen size ($F_{1,28}$=0.46, NS) or sentence splitting ($F_{1,28}$=0.01, NS), and there was no interaction effect ($F_{1,28}$=0.13, NS). Therefore it seems that screen size and sentence splitting have no significant effect on reader comprehension for this type of electronic text and task.

Reading Times

Time taken to read the text was computed for each subject. A 2x2 ANOVA revealed no significant effect for screen size ($F_{1,28}$=2.97, NS) or sentence splitting ($F_{1,28}$=0.20, NS) and there was no interaction effect ($F_{1,28}$=1.12, NS). These results are not too surprising

given the absence of a time constraint and the instruction to concentrate effort on comprehension of the text.

Reading time x comprehension

In order to investigate a possible relationship between time spent reading the text and subsequent comprehension level a Spearman's Rank Correlation Coefficient was calculated. This revealed a low overall correlation (rho=0.21, p>.2) and no significant correlations within conditions. In other words level of comprehension was not related to length of reading in this instance.

Performance measures

Obviously, users of a small screen will need to display more pages than users of a large screen in order to read similar amounts of text. Thus, gross indices of command usage offer little insight into any possible manipulation effects. In order to obtain a better impression of text manipulation only changes in direction of viewing and jumps in the same direction of 2 pages or more were examined. Each change of direction or jump of at least 2 pages counted as one manipulation. In other words if a subject read serially through the text from start to finish, their manipulation score would be zero regardless of display size. However, in order to avoid contamination with possible split sentence effects i.e., changes in direction resulting from single backward page movements to re-read text, independent previous page commands were not counted but were analysed separately. Figure 3 presents the mean adjusted manipulation scores per condition.

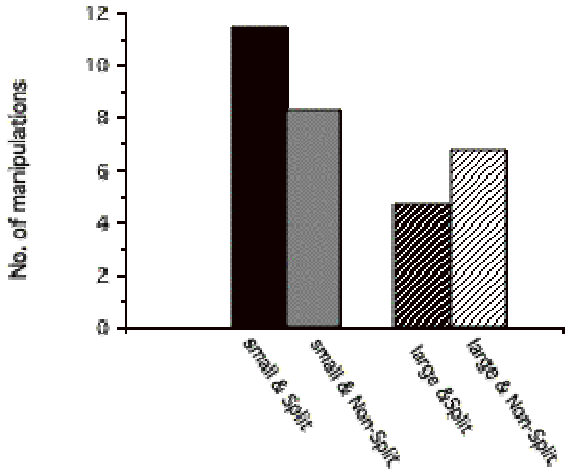

Fig.3. Mean manipulation scores per condition

The results were subjected to a 2x2 ANOVA which revealed a significant effect for screen size ($F_{1,28}=6.33$, $p<.05$), but not for sentence splitting ($F_{1,28}=0.90$, NS) and no interaction effect ($F_{1,28}=2.56$, NS). Given the coding of manipulation that was employed, the screen size effect does not result merely from the extra keypresses required to view the same information in the small screen conditions. It seems that subjects reading from the small screen jump about and alter their direction of reading the text significantly more than subjects reading from the large one.

Effect of Split Sentences

Use of the Previous Page command was analysed in order to investigate the effect of sentence splitting on performance. However it was not possible to compare gross usage rates of the command across conditions as this would have confounded use of the command to manipulate backwards generally with use aimed at re-reading the start of the sentence or paragraph that had been split. Thus the use of this command was coded according to its most likely use. As screen-fill rates were approximately 3 and 9 seconds for the small and large screens respectively it was possible to identify cases where the command had been issued and the resulting screen not even fully displayed. Similarly, where multiple repeated use occurred it was considered that these were more likely to reflect occasions when the subject was re-tracing the argument or attempting to locate a particular piece of text rather than re-read the split sentence, and accordingly, these were overlooked. Therefore, only combinations of Previous Page - Next Page, where the former command displayed the screen for longer than the screen-fill time, were interpreted as indices of the effect of sentence splitting on performance.

It was hypothesised that sentence splitting would increase the occurrence of this command sequence and examination of the data between individual conditions confirmed this. The mean usage level for condition 4 (small, split) was 3.88 (s.d.=2.47), over twice that for condition 3 (small, non-split) which was 1.75 (s.d.=1.75). A one-tailed t-test indicated a difference at the 5% level ($t=1.98$, $df=14$, $p<.05$). The mean usage levels for conditions 1 (large, non-split) and 2 (large, split) were 0.1, (s.d.=0.93) and 1.50 (s.d.=2.33) respectively. Though the mean levels were in the hypothesised direction this difference was not significant.

Combining the conditions according to the split/non-split distinction indicated that usage levels were twice as common in the "split" conditions. Mean combined level for conditions 2 and 4 (split sentence conditions) was 2.69 (s.d.=2.63) and for conditions 1 and 3 (non-split sentence conditions) the mean level was 1.38 (s.d.=1.41). A one-tailed t-test between these conditions was also significant ($t=1.76$, $df=30$, $p < .05$).

These results seem to indicate that splitting sentences across screens is likely to result in increased use of the previous page command as the reader turns back to recapture the sense of the text portion being read.

Questionnaire

The questionnaire contained a variety of items aimed at eliciting subjects' views on issues such as the range of facilities offered, improvements they would like, problems they encountered and whether or not they noticed certain experimental manipulations.

None of the available commands was rated as difficult to use. On a scale of 1 (difficult) to 5 (easy) all of the commands' median ratings were 5, with only one subject rating one command (No.<enter>) as difficult. The Next Page and Previous Page commands were rated as most useful (median ratings 5 and 4 respectively on a scale of 1 to 5, where 5 implies very useful). The End and the No.<enter> command were rated as least useful (median ratings of 3 in both cases). There were no significant rating differences observed between conditions.

Subjects were asked to rate the on-screen information on a scale of 1 (not helpful) to 5 (very helpful). The median ratings were 3 for Title, 4 for Page X of Y and 2 for Last Seen Page Number. There were no significant differences observed in the ratings between conditions. Thus, only the information about current position in the text was seen as particularly useful by the current sample.

The text that the subjects read was formatted such that paragraphs were indented and there was no right justification. The questionnaire asked subjects to state whether the text had certain formatting features. The results are summarised in table 2 below. The correct response is marked (•).

Did the text you just read have:	Yes	No
right justification?	11	21 •
blank lines between paragraphs?	7	25 •
sub-headings in capitals?	9	23 •
paragraphs indented?*	20 •	11

* one subject did not respond to this item of the questionnaire.

Table 2. Responses to items on text format

In all, 12 subjects correctly answered all items, nine made 1 error, 5 made two errors and 6 subjects made three errors. Several of the questionnaires contained comments to the effect that they were not sure of the answers to some of these items. Thus in order to obtain some indication of the significance of these distributions a one-way Chi-square analysis was carried out , though it should be noted that this procedure assumes a random distribution of responses which might not be the case with these items. This revealed that the distribution of responses to the items on blank lines ($X^2=10.125$, $df=1$, $p<.01$) and sub-headings ($X^2=6.125$, $df=1$, $p<.05$) were significant. The other two items approached significance ($p<.09$ in both cases). Therefore it seems as if subjects were generally aware of the formatting features of the text they read.

The splitting of sentences was the only text format manipulated between conditions. Subjects were asked whether or not the text they had read was split across pages. The responses were as follows (again, the correct response is marked •):

Did the text you read have only complete paragraphs on a page?

	Yes	No
Condition 1 (large screen - non-split)	5 •	3
Condition 2 (large screen - split text)	0	8 •
Condition 3 (small screen - non-split) 4 •	4	
Condition 4 (small screen - split text)	0	8 •

Table 3. Subjects' awareness of the text as complete or split paragraphs

What these results indicate is that all those who read split text seemed to be aware of it (Chi square: $X2 = 8$, $df=1$, $p<.01$). Those who read only whole paragraphs showed a chance distribution of responses (Chi square: $X2 = 0.25$, $df=1$, $p>.90$).

All subjects were provided with the opportunity to state what improvements could be made to the interface. While a wide range of suggestions were made there was some consistency in their responses. Table 4 presents the results.

Suggestion	No. of subjects
Alter page size	8
Scrolling facility	6
Dictionary	5
Highlighting facility	5
Alter text format	4
Contents page	3
Search facility	3
No suggestion	8

Table 4. Subjects' suggestions for improving sentence presentation.

The relative frequency of occurrence of the request for a scroll facility suggests that this may be a more acceptable way of interfacing text manipulation for some users. Interestingly, 5 of the 6 subjects who requested scrolling were in the small window/split sentence condition. Similarly, of those who wanted to alter the page size, 6 were in the small window conditions and wanted larger windows. The desire for a dictionary may reflect the nature of the text employed which was a theoretical analysis of a domain unfamiliar to the subjects.

Various other improvements were suggested by individuals e.g. colour, more information on the article, a clock, a word count etc. which reflect more idiosyncratic preferences.

Discussion

The results of this experiment demonstrate that screen size and splitting of sentences across screens are not simple issues for which clear guidelines may be drawn. While no significant effect for either variable on comprehension was observed it would be wrong to conclude from this that any 'reasonable' screen size is suitable for presenting electronic text or that sentence splitting is not detrimental to readers' performance.

Trends in the data indicate that levels of comprehension are noticeably higher in the large window condition for both split and non-split text. Similarly, reading from the large screen led to significantly lower adjusted manipulation levels. Of those subjects who expressed a wish to alter the screen size, three quarters of them were in the small screen condition and wanted to increase it. Thus, screen size does affect how readers interact with a text.

The same can be said for splitting sentences across screens. It caused readers to return to the previous page twice as often as readers of the non-split text, irrespective of page size. The fact that all readers of the split text reported noticing this fact would indicate that, if nothing else, sentence splitting has a nuisance value that would affect regular users. Therefore the recommendation that should be made on the basis of this work is that when presenting journal length electronic text to readers of this type, non-split text on a large screen is a better format.

Several points are worth raising with respect to these findings. Firstly, though no significant effect for display characteristics on reader comprehension were observed in this study, it must be emphasised that the measure of comprehension employed is

ecologically valid but not very sensitive. As mentioned earlier, it was selected as the best among a limited range of alternatives. Other researchers have favoured post-task questions (e.g., Duchnicky and Kolers, 1983) but it was felt by the present authors that these placed too much reliance on recall of detail. Multiple choice questions may have been employed but these suffer from similar limitations and require correction for guesswork on the part of subjects. Measuring comprehension is a problem for researchers in all areas where knowledge and learning are dependent variables. In the case of text comprehension any measure will reflect numerous factors other than text format, such as verbal reasoning ability and motivation of subjects. However, it is still felt that the Kintsch and van Dijk method is the most appropriate. A supplement to this, e.g., asking readers to rate their own level of comprehension might be a useful addition (though hardly an alternative) to the technique.

Secondly, the absence of a time constraint on reading the article in this study may have affected the comprehension scores. If one accepts that text comprehension is a process by which the reader builds a mental model of the author's message, then text format is likely to have an influence insofar as it affects the subjects' eye movements and physical manipulations of the text. Where the time available to read a text is unlimited, such influences are likely to have little effect on comprehension. Conversely, where time is limited, by increasing the cognitive demands on the reader to manipulate and re-scan text thus reducing processing capacity available for message comprehension, text format is likely to affect comprehension. This is a testable hypothesis that only future work can address, but it suggests further caution in drawing conclusions from the present study.

Thirdly, it must be reiterated that the "small" screen was a 20 line display which is close to the typical PC size and therefore cannot be described as genuinely small. Earlier research has concentrated on screen sizes of much less and comparatively, a 20 line screen would appear "large" (though still somewhat smaller than typical paper formats). All of the subjects in the present study had some experience of reading text from PCs and it is unlikely therefore that they would have considered the presentation as small. The "large" display was comparatively very large, approximately the size of A4 paper, and two subjects exposed to these conditions expressed a desire to reduce it. As mentioned earlier, the literature on window size is somewhat contradictory and highly task dependent but it seems likely that there is an upper limit on what constitutes a good screen size and larger is not always better.

Fourthly, the manner in which manipulation was measured in this experiment ensured that simple measures of paging, which would have been proportionally related to screen size, were not taken as indices. Rather, jumps and changes in reading direction were employed. This raises the question of why readers in the small screen conditions manipulated the text significantly more. The most plausible explanation is that these readers needed to jump about more in order to obtain navigational information such as headings, sub-headings, graphs etc.. However, the text employed had only 3 section headings and no graphics. Therefore readers in the large screen conditions would have manifest similar rates of manipulation (as it was coded in this study) if subjects were only jumping about to headings.

An alternative explanation is that when reading, all subjects like to check back and re-read earlier sections or to trace an argument backward and forward. In this case, readers in the small screen condition would have to jump almost 3 pages to cover the same amount of text as readers of the large screen had on one page. The page display record for readers in the large screen condition might therefore present an inaccurate image of methodical serial reading, whereas in reality several backward or forward jumps were being made. While this conjecture matches the observations and evidence from readers of paper articles (Thomas and Augstein, 1972) it is difficult to draw a firm conclusion one way or the other without data on within-page reading strategies for the large screen (i.e., eye movement records).

It is possible that the nine seconds refill rate for the large screen may have been too great a deterrent to manipulation of this nature. However the lack of direct comments (it may have been implied in the request for scrolling) from subjects about this when asked to suggest improvements would seem to indicate that it is not as simple as that. Obviously further work is required.

A fifth point of interest is the level of awareness all readers manifested of the text format. Without explicit instructions to observe such features, it was expected that subjects would only answer these items at chance levels of accuracy. However, the majority of subjects correctly described all features of the text format and the statistically significant identification rates for split text, blank lines and sub-heading lettering would suggest that readers notice more detail about the text than was perhaps expected. This is particularly the case where the formatting is poor, perhaps suggesting that good design is transparent.

Finally, the role of task cannot be overlooked. These results refer only to detailed reading of a lengthy academic article. It should not be assumed that these findings are transferable to other task domains with other types of text. Even with similar texts, it is clear that readers employ several strategies for extracting information depending on their goals (Dillon et al. 1989) and the optimum display size for such tasks may be very different from that required for detailed reading.

Conclusion

Optimum display size remains an issue that requires further empirical attention. The 60 line screen employed in this experiment received some criticism and may prove to be too large for tasks of this nature, though its approximation to A4 size would suggest an empirical comparison with paper is required. Readers seem to think that a 20 line screen is too small for reading lengthy texts and although no significant decrement in comprehension levels was observed, the need to consider the role of time constraints has been raised. Small screens also lead to greater manipulation though no single cause of this has been identified.

Splitting text across screens does not seem to affect comprehension levels but readers take significant notice of its presence for us to hypothesise that, at least, it would be a nuisance to regular users. The fact that it causes readers to turn back twice as often to the previous page regardless of screen size lends credence to this view.

Further work could look at other display sizes and other text types. The reading strategy for this type of material may differ for other texts and thus the display characteristics may produce different effects. Furthermore, reading strategies may change over time particularly with increased exposure to screen presented text and longitudinal studies of reader interaction with this medium are vital in order to gain an impression of the likely long-term effects of the display on performance. From a methodological point of view, the analysis and measurement of comprehension is likely to remain an issue but this must not prevent researchers from examining it as best they can.

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