Reading Revisited: Evaluating the Usability of Digital Display Surfaces for Active Reading Tasks

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Abstract

A number of studies have shown that paper holds several advantages over computers for reading tasks. However, these studies were carried out several years ago, and since that time computerized reading technology has advanced in many areas. We revisit the issue of reading in the workplace, comparing paper use to state-of-the-art hardware and software. In particular, we studied how knowledge workers perform reading tasks in four conditions: (1) using paper, (2) using a dual-monitor desktop system, (3) using a pen-enabled horizontal display surface, and (4) using multiple tablet computers. We discuss our findings, noting the strengths and shortcomings of each configuration. Based on these findings, we propose design guidelines for hybrid horizontal + vertical systems that support active reading tasks.

1. Introduction

Contrary to expectations, the proliferation of the personal computer has not eliminated the use of paper for office work [20]. One common use of paper in office settings is printing digital documents for *active reading* (*i.e.*, annotating a document while reading for increased understanding and later reference).

In their 1997 study [13], O'Hara and Sellen observed knowledge workers perform an active reading task in which participants read and summarized a scientific magazine article. They found several ways that paper outshined a computer for performing this task, and provided three design recommendations for computer systems based on their observations: (1) "Recognize that annotation can be an integral part of reading and build support for these processes." (2) "The need to support quicker, more effortless navigation techniques." (3) "The need to support more flexibility and control in spatial layout."

Ten years have passed since this seminal study, and many of O'Hara and Sellens' suggestions have been incorporated into modern personal computers. For example, word processing software typically includes several mechanisms for annotating documents, such as the "comment" and "highlighter" tools in Microsoft Office Word. Tablet PCs and other similar products support annotation through the use of a stylus, and free-form ink written with a stylus can be added to documents using several software tools. Users also have more flexibility in laying out documents on-screen, since display resolution has increased dramatically, and it is increasingly common for users to have more than one display connected to their computer [5].

We conducted a study, closely modeled on O'Hara and Sellens' original methodology, to examine whether the affordances of modern computing hardware and software have succeeded in improving the usability of digital documents for active reading tasks. In our study, we observed participants performing active reading tasks in four conditions (see Figure 1): using paper, using a traditional computer with vertical displays, using a stylus-enabled horizontal surface, and using multiple tablet computers.

We contribute detailed findings on the usability of vertical, horizontal, and tablet computing systems for active reading. Additionally, we contribute design guidelines for hybrid horizontal + vertical systems that we believe will provide improved support for this common office task scenario. Before discussing our study and findings, however, we first present related work in the areas of computer-based active reading and horizontal computing research.

1.1 Related Work

1.1.1 Reading and Annotation

In addition to O'Hara and Sellens' study [13], there have been several other studies of digital reading and annotation. Adler *et al.* conducted a diary and interview study in 1998 [1], which allowed them to develop taxonomies of the different types of reading and writ-

Figure 1: In the Paper condition, participants had a printed article, blank paper and a variety of writing tools. In the Vertical condition, participants had two monitors, a keyboard, and a mouse. In the Horizontal condition, participants had two pen-enabled displays positioned horizontally on the desk, a stylus, a mouse, and a keyboard. In the Tablets condition, participants had three tablet computers and a stylus.

ing activities performed by people with varying occupations. They found a strong preference for paper, that reading was commonly performed in conjunction with writing, and that participants often switched between multiple documents during a single reading/writing task. Marshall and Ruotolo [10] studied the use of paper and digital versions of course by university students, and reported on when and why students chose to use different versions. Obendorf [12] compared the use of special software for annotating websites with typed text to the use of pencil and paper for annotating printouts of the same content, and found that paper was superior due to the flexibility it provided over the "Webnize Highlighter" tool. Hornbaek and Frokjaer [8] compared the use of normal, fisheye, and overview + detail representations of digital documents for a reading and summarization task, and found that fisheye views reduced task time while overview + detail views resulted in higher quality summaries. Studies of the ergonomics of reading from paper versus monitors have also been reported in the literature [3].

In addition to the aforementioned studies of reading and annotation practices, some researchers have developed novel systems intended to enhance the digital reading experience. Paper Augmented Digital Documents [6] attempt to preserve the affordances of both the paper and digital worlds for active reading tasks by using a special pen and paper to enable digital capture of annotations. The XLibris system [15] was a tablet computer designed specifically to support active reading; it used a stylus for ink annotations, allowed users to use their thumb to flip pages, and provided visual feedback about a document's length and the users' position within a document. PARC's eXperiments in the Future of Reading (XFR) project [7] produced several museum exhibits demonstrating futuristic reading interfaces; however, the designs were whimsical and provocative in nature, not suitable for everyday work.

1.1.2 Horizontal Computing

Advances in sensing and display hardware (such as DiamondTouch [2] or PlayAnywhere [25]) have resulted in an increased interest in novel computing form factors, particularly horizontal computing surfaces. These horizontal systems include both *table systems* (collaborative horizontal surfaces, such as [4][11][14][17][18]) and *desk systems* (single-user horizontal surfaces, such as [22][23][26]). Some, such as ConnecTables [21] or the UbiTable [18], involve several computing surfaces that operate together as a single system, while others involve only a single surface.

In their 2003 article on design guidelines for horizontal displays [16], Scott *et al*. state that the need to "elucidate which tasks are most suitable for tabletop" is still an area for future research. Researchers have been exploring the appropriateness of horizontal systems for a variety of domains, including visualization [4], photo management [17], gaming [14], and artistic expression [11]. A few systems offer affordances that are aimed toward office productivity tasks, such as the DigitalDesk's hybrid physical/virtual calculator [22] or the ability to use a fingertip to draw ink annotations on text, image, and html documents provided by UbiTable [18] and DiamondSpin [19]. The DeskJockey system [26] projects ambient content on a desk, but does not support input-based tasks such as active reading. Wigdor and Balakrishnan [24] performed a study showing the performance impacts of reading text at varying angles on a tabletop display; however, their study focused on reading short snippets (*e.g.*, words or phrases), while we are studying active reading tasks of a scope similar to typical office work practices. We were unable to find any studies of the use of a horizontal system to perform a realistic active reading task -- therefore this paper contributes valuable information regarding the suitability of horizontal computing systems for common tasks in this domain.

2. Methodology

To evaluate and compare the active reading experience using paper and three computer-based setups, we borrowed heavily from the methodology described in O'Hara and Sellens' 1997 paper [13], which allows us to make comparisons to their findings from ten years ago. Like [13], we used a text summarization task and set up the vertical condition to emulate a conventional situation. However, we chose to use a within-subjects design with all participants using all four setups (in a counter-balanced order) rather than between participants (as in [13]) so that we could gather participants' qualitative preferences among the four conditions. In this section, we describe our experimental methodology in detail.

We recruited twelve participants (half female) from within a large technology company. Participants had a variety of job roles (*e.g.*, administrative assistant, marketing, program manager, software developer), and ranged in age between 20 and 50 years. All participants had prior experience using a stylus to operate a Tablet PC, in order to reduce the training necessary for them to complete the two ink-enabled conditions (horizontal and tablets).

Before beginning the study, all participants completed a tutorial demonstrating how to use a stylus and specific features of our chosen word processing application (Microsoft Office Word 2007); this tutorial was done using the horizontal system's equipment, since it included both a stylus and a mouse and keyboard. The features covered in the tutorial were selected because they satisfied the design recommendations put forth by O'Hara and Sellens' original study – features for highlighting a document, inserting comments, adding ink annotations, repositioning and resizing windows, changing the number of pages visible at a time, and navigating within a document. Participants were able to refer to a printed copy of this tutorial throughout the remainder of the study.

Participants were then told that their manager had asked them to provide a one-paragraph summary of a four-page article from the New York Times science section. Participants were asked to think aloud while completing the task, and were given fifteen minutes in each condition (in order to enable completion of all four conditions within a reasonable time frame).

This reading-to-summarize task was familiar to our participants, and on our post study questionnaire all but one of them indicated that they performed similar tasks as part of their daily work. Participants offered examples of analogous tasks that were part of their jobs, such as reading and evaluating specification and legal documents, reading about new technologies and providing an overview to colleagues, and summarizing long emails to convey core ideas to others.

We used four different articles of similar length (between 974 and 1039 words) and complexity (as judged by pilot testing). The combination and presentation order of articles and conditions was counter-balanced, using a Latin Square design. In the paper condition, the article was printed single-sided; in all other conditions, the article was presented in Microsoft Word 2007.

Participants were also presented with two blank Word documents (piles of paper in the paper condition). The first was a "scratch" space, provided for optional note-taking, and the second was for composing the final summary. In all conditions, participants were informed that they could annotate the original article if they wished, and that they could modify any aspect of the setup (the position of paper, displays, input devices, windows, etc.) so as to be comfortable. All four setups used were situated on identical desks, measuring 48'' by 30''.

In the "paper" condition (see Figure 1), subjects were provided with three overlapping stacks of paper – the article on top, followed by the scratch paper and then the summary paper. There was also an array of writing implements (a pencil, red, blue, and black pens, and pink, orange, and yellow highlighters).

In the "vertical" condition (see Figure 2), participants were provided with a mouse, keyboard, and dual-monitor display. Each of the LCD displays measured 21'' diagonally and had a resolution of 1600 x 1200 pixels. We chose a dual-monitor configuration to represent status-quo computing setups since increased use of such setups is reported in the literature [5]. Additionally, on our post-study questionnaire, 75% of our participants reported having two or more displays connected to their office computer. The article, scratch, and summary documents were each open in separate windows of the word processing application. The windows were positioned overlapping by a small offset on the left-hand monitor. The article was on top, followed by the scratch and then the summary documents. Each window was zoomed so that the first page of the document was entirely visible

In the "horizontal" condition (see Figure 3), participants were provided a horizontal computing surface composed of two Wacom Cintiq 21UX[1] devices, operating as a dual-monitor system. Each Cintiq device consists of a stylus-sensitive, 21.3'' diagonal LCD screen with a resolution of 1600 x 1200 pixels. A stylus, wireless mouse, and wireless keyboard were initially located on the desk behind the displays. Additionally, touch strips on the device's bezels could be

[1] http://www.wacom.com/cintiq/

used to scroll within documents. The documents were configured on the left-hand Cintiq in a fashion identical to the vertical condition.

In the "tablets" condition (see Figure 4), participants were initially presented with three Motion Computing LE1600 slate tablets, each in the portrait orientation and having resolution 1024 x 768. Each tablet contained a single word processing document, maximized to use the entire display, and set to have the first page entirely visible. The tablets were laid on the desk with the article on the left, then the scratch document, then the blank summary. A single stylus, which could be used to operate all three tablets, was also on the desk.

The specific display technologies used in each condition were chosen to preserve ecological validity, utilizing high-end, commercially available hardware representing the status quo for each of the three digital form-factors.

Two observers took structured notes during the study, coding several behaviors inspired by [13] and by our own pilot studies. Participants were also videotaped. After participants had read the article and written their summary in one of the conditions, they completed a questionnaire about the experience. Participants also filled out a final questionnaire asking them to make comparisons among all four setups.

3. Results

After completing the study, participants ranked each of the four conditions based on the experience of reading the article, annotating the article, taking notes, and writing the summary (with a rank of 1 indicating the most preferred condition for each subtask, and a rank of 4 indicating the least preferred). Table 1 reports the median rankings for each subtask in each condition.

The ranking differences for each subtask were statistically significant[2]: Reading, χ^2 (3, N = 12) = 12.70, $p = .005$; Annotating, χ^2 (3, N = 12) = 12.10, $p = .007$; Note-taking, χ^2 (3, N = 12) = 12.13, $p = .007$; Writing, χ^2 (3, N = 12) = 22.36, $p < .001$. Pairwise tests reveal more detailed significance trends. For the reading subtask, the paper and tablets conditions were preferred to the vertical condition ($p < .015$). For the annotation subtask, the paper, tablets, and horizontal conditions were all preferred to the vertical ($p < .025$). For the note-taking subtask, paper was preferred to vertical ($p < .04$). For the writing subtask, the vertical condition was preferred to all of the others ($p < .02$), and the horizontal condition was preferred to both the paper and the tablets ($p < .03$).

[2] Because the data is not normally distributed, all of our analyses use non-parametric tests. We use the Friedman test to compare across the four conditions, and follow-up pairwise comparisons are done via Wilcoxon Signed Ranks tests. We use an alpha level of .05 for all statistical tests.

Table 1. Rankings of preferences for each condition by subtask (Median reported, scale 1-4 where 1 is the best possible ranking).

	Reading	Annotating	Notes	Writing
Paper	2	2	2	4
Vertical	4	4	4	1
Horizontal	3	3	3	2
Tablets	2	2	1.5	3

In O'Hara and Sellens' original study, they found that paper was superior to the computer for active reading; they explained these differences as due to challenges of computer tools in the areas of annotation, navigation, and spatial layout. Our preference data, however, indicate that computing tools now are comparable with, or superior to, paper in several respects. We explore the reasons for these preferences, examining annotation, navigation, and spatial layout issues, as well as issues relating to composition and ergonomics.

3.1 Annotations and Note-Taking

Ten years ago, O'Hara and Sellen found annotating on paper to be clearly superior to annotating using a traditional (*i.e.*, vertical) computer setup. The subjective ratings in Table 1 show that in our study, the vertical condition again fared poorly for annotation tasks; however, other computer form-factors (horizontal and tablets) provided an annotation experience comparable to paper. Participant comments highlight the positive experience of annotating in the tablets and horizontal conditions. For example, on the post-task questionnaire for the tablets condition, P7 commented, "The rest [reading, annotating, summarizing] feels like pen work, so I like that." Similarly, P2 commented, "Marking up the document was much more natural, as was taking notes." Referring to the horizontal condition, P2 said, "Annotating [is] fairly easy," while P11 commented, "Easy to annotate while reading." Participants did however, still experience challenges annotating in the digital conditions, such as insufficient margin space, and the overhead of entering a special inking mode in the word processor.

To evaluate any quantitative differences in how many and what type of annotations participants made in different conditions, we coded the annotations on the articles using the scheme introduced by Marshall and Brush [9]; annotations were counted and classified as *anchor-only* (*e.g.*, highlighted or underlined portions of the article's text), *content-only* (*e.g.*, a word or mark added to the page, but not explicitly connected to any portion of the article's text), or *compound* (*e.g.*, a word or mark added to the page with a line or other connection indicating a relationship to a portion of the article's text). Table 2 shows the annotation patterns for each condition, averaged across participants.

The stark difference between the vertical condition and the other three conditions supports the qualitative feedback. The total number of annotations applied to the articles differed significantly across conditions, χ^2 (3, N = 12) = 11.77, p = .008. Pairwise testing found that the total number of annotations applied in the paper and horizontal conditions was significantly higher than in the vertical condition (p < .03). Among the three conditions where participants annotated (paper, horizontal, tablets) there were no significant differences in the types of annotations (anchor, content, compound) that participants made.

One advantage the vertical condition did have over the others was the ease of using copy and paste as a method for taking notes and composing the summary. In the vertical condition, 75% of participants (8), used copy and paste while 16.7% of participants (2) used it in the horizontal condition and 25% of participants (3) attempted to copy and paste in the tablets condition although this functionality did not exist (due to using three separate tablets). P12's comments highlighted the importance of this feature, "A big part of 'active reading' for me is copying quotes and images from the source to the summary. This doesn't work on paper."

3.2 Navigation

Navigation between and within documents was another place that O'Hara and Sellen saw large differences between using paper and working digitally. In particular, they observed that using paper their participants could easily interweave navigation with reading using two-handed movements.

In our study we saw that the horizontal condition offered participants something more similar to their experience using paper for interleaving navigation with reading using two handed movements. Seven of the 16 participants (43.7%), used the touch strip on the bezel of the Cintiq displays with their non-dominant hand while pointing or using the stylus with their other hand. P10 commented: "It [touch strip] makes me feel like I'm multi-tasking and is an easy way to go through the document." In the tablets condition, 25% of participants (3) used one hand to mark a location in the article while using the other to write. This behavior was also common in the paper condition. These types of bimanual interactions, for example, using one hand to mark a place in the article while operating an input device with the other hand, were not seen in the vertical condition.

Table 2. Number of annotations applied to the original article in each condition (Mean reported).

	Anchor Only	Content Only	Compound	Total
Paper	19.8	1.6	1.5	22.9
Vertical	4.8	0.0	0.8	5.7
Horizontal	16.2	1.0	0.3	17.4
Tablets	15.2	0.4	0.5	16.1

3.3 Spatial Layout

O'Hara and Sellen observed many problems related to spatial layout in their vertical condition. Specifically, the limited viewing area afforded by the monitor meant participants in their study had to either shrink the documents or overlap windows, and spent time managing the position and size of windows.

We found that the multi-monitor setups we used in the digital conditions allowed participants to have several documents visible simultaneously, enabling glancing back and forth between documents to serve as a lightweight means of navigation similar to the paper condition. Several participants also viewed multiple pages within a document simultaneously. For example, in the tablets condition, 4 people (33.3%) set the article so two or more pages were visible, while 3 people (25%) viewed multiple pages at once in the horizontal condition. Watching our participants attempting to lay out multiple pages led us to conclude that there is still plenty of room for improvement to better support flexible and smooth arrangement of digital pages – for example, participants wanted but were unable to simultaneously view four pages laid out in a row, or to view non-consecutive pages of an article for side-by-side comparison.

Window management remained an issue for our participants and all participants spent time in the digital conditions tiling their windows so as to avoid overlap and avoid spanning monitors' bezels. Ironically, we may have moved from not having enough digital space in 1997 to having too much in 2007. In the horizontal condition, 4 participants (33.3%) explicitly mentioned the size of the Cintiq and being overwhelmed by it. For example, P1 commented "too much real estate - sprawled over multi-mons with no easy way to get back and forth." Five participants (41.7%) in the horizontal condition chose to use only one of the two available displays and 2 participants (16.7%) did this in the vertical condition (6 unique participants).

O'Hara and Sellen also observed that participants had problems integrating reading and writing in the vertical condition because only one window could accept input at a time. We similarly observed that digital systems' ability to have only one window in focus created confusion for our participants. An example of this occurred in the horizontal condition, and involved the use of the touch strips. Three of our participants assumed that the strip on the left of the display would scroll the leftmost document and the strip on the right of the display would scroll the rightmost document. They were confused to find that all the touch strips scrolled the single, focal document, regardless of its location. The former behavior, however, would have better supported bimanual interactions, such as scrolling through the article with one hand while writing the summary with the other.

3.4 Composition

When composing their summary, participants indicated a preference for text, rather than handwriting. In the horizontal condition, when participants had a choice of using the stylus to write their summary or the keyboard to type it, 75% (9) chose to type the summaries, despite the inconvenience of accessing the keyboard (6 participants pushed the display further away from them in order to make room for the keyboard, and 3 placed the keyboard on their laps). In the tablets condition, where no keyboard was available, 25% (3) of participants still created text summaries by using automatic handwriting-to-text conversion (a technique that we did not cover during the tutorial).

This preference for text reflects several factors. 33.3% of participants (4) mentioned that a handwritten summary seemed sloppy or unprofessional, and would not be considered acceptable by their colleagues. 41.7% (5) mentioned that their hand felt fatigued or cramped after writing the summary out on paper. 66.7% (8) also pointed out that they type more quickly than they write. Also, the ability to utilize special functionality, such as spell-checking, was considered desirable. Half of our participants (6) used spell-checking or thesaurus features, although doing so was never suggested by the experimenters.

3.5 Ergonomics

In all conditions, we told participants to feel free to adjust any aspect of their workspace in order to be more comfortable. Participants naturally repositioned the printed documents during the paper condition, and also in the tablets condition where every participant moved the tablets from their original position and 50% (6) tilted them off the surface of the desk (by holding them in the air, leaning on their lap, or propping them against other tablets). One participant even took the tablet over to a couch to sit and read. Four participants (33.3%) adjusted the positions of the monitors in the vertical condition by angling their center edges toward the back of the desk, creating a shallow "V" shape.

In contrast to the quick and somewhat effortless ergonomic adjustment in the paper, tablets, and vertical conditions, the horizontal condition required more thought and effort for 75% (9) of our participants. Two participants raised the height of the desk and worked from a standing position. Four participants propped books underneath the back edge of the displays so that they were tilted in drafting table style. Six pushed the displays backwards to make room for a keyboard and mouse, and four even rotated the Cintiq displays to be at a more paper-like writing angle.

On their questionnaires, 41.7% of participants (5) mentioned that they found the horizontal setup uncomfortable to use, although we did not explicitly ask about this. Comments included: "touch screens not at a good angle for use as a monitor" (P1), "bad angle for reading" (P3), "it made me nauseous to look at the screens" (P6), "you start to feel a little strained in the neck" (P10), and "not a comfortable working environment" (P12).

4. Discussion

At a high level, our results show that computing support for active reading tasks has made substantial progress since the mid-nineties. Our participants' preference rankings showed that the vertical and horizontal setups were preferred for the writing sub-task, that the horizontal and tablets setups performed on par with paper for the annotation sub-task, and that the tablets were on par with paper for the reading sub-task. While these results show that computing devices can be as good as, and even better than, paper for active reading, they also indicate areas for improvement. It's noteworthy that no single computing setup emerged as a clear choice for active-reading-based office work.

The vertical setup, which is the status quo in many modern offices, was a clear win for writing-intensive portions of the task. While annotation support for mouse-and-keyboard systems has clearly improved since O'Hara and Sellens' study, there is still further room for improvement, since nearly half the subjects did not avail themselves of annotation tools in this condition, and the available tools did not support content-only annotation styles. The vertical setup also did not support common bimanual actions, such as using one hand to "bookmark" interesting content while operating an input device with the other, perhaps because the vertical orientation would have made such pointing uncomfortable by requiring participants to hold their arms in an elevated position. While multi-monitor setups enabled glanceability, the user experience of laying out windows in a non-overlapping manner could be improved.

The horizontal setup was strong in its support for annotation, and in allowing users to bridge the worlds of handwriting and text. The orientation and hardware encouraged bimanual interactions, such as pointing-to-bookmark and scrolling while writing; further bimanual interactions could be supported by using multi-touch hardware. However, the displays' large size overwhelmed some users, with window management issues again degrading the experience. Additionally, the ergonomics of the horizontal setup were troublesome, requiring customization for the majority of users, and causing several to report physical discomfort (*e.g.*, muscle strain, nausea).

The tablets showed strong performance for reading and annotation. Users liked the freedom to rearrange the tablets, pick them up, and move them around in a manner analogous to paper. However, the lack of a keyboard and the inability to easily move information between different tablets was a drawback of this approach.

Because active reading tasks are commonplace for knowledge workers (for example, all but one of our participants reported performing such tasks as part of their job), it is important for hardware and software designers to consider how they can improve the utility of computing systems for this class of tasks. Based on the findings of our study, we recommend a hybrid approach for next-generation office computing systems that combines the best features of horizontal, vertical, and repositionable surfaces in order to capitalize on the affordances each offers for active reading. Such a system should:

Include both horizontal and vertical displays: With a hybrid system, digital documents could be easily moved between the horizontal and vertical spaces depending on whether they were the focus of annotation, reading, or composition.

Be configurable: Based on the challenges we saw as participants configured their environment in the horizontal condition, it is clear that any hybrid computing system must be highly configurable. For example, the angle of tilt of the horizontal display surface should be adjustable, and could also include tablet-sized removable components that could be lifted out and positioned for optimal comfort.

Support multiple input devices: Compared to ten years ago, current technology offers annotation options that performed on par with paper, but these are not typically part of office setups. In addition to stylus input for annotations, users' preference for text during composition makes a mouse and keyboard important – positioning these in a manner compatible with the horizontal surface may be challenging.

Allow bi-manual input and focus: Displays should support multi-point touch and stylus input to enable bimanual operations. In addition to the ability of hardware to receive multiple simultaneous inputs, software should support binding different parts of the input stream to different windows, in order to enable simultaneous bimanual interaction with two documents.

Improve software support for window navigation and management: Window management is known to be a challenge for multi-monitor environments [5], and hybrid systems will only increase users' difficulties, in this respect. Software is needed so that that users can quickly navigate among documents without being overwhelmed by the positioning choices created by a large display area. Automatic facilities for creating non-overlapping, non-bezel-spanning window layouts would enable users to focus on the documents, rather than on tweaking the documents' on-screen positions. Software should also be flexible in terms of within-document page layouts, allowing users to display more than two pages side-by-side in order to better take advantage of large displays. Also, restrictions allowing only consecutive pages to be shown side-by-side should be removed.

5. Conclusion

In this paper, we have presented quantitative and qualitative results from our study of active reading. Although digital systems have improved their support for active reading in the last ten years, there is still room for improvement. Our results reveal the strengths and weaknesses of status quo "vertical" systems, horizontal systems, and multi-surface tablet-based systems for this commonplace productivity task. Our findings on the suitability of each setup for annotation, navigation, spatial management, composition, and ergonomic comfort can inform the design of next-generation hardware and software for standard, horizontal, and tablet systems. Additionally, by synthesizing users' experiences with each system type, we proposed design recommendations for a hybrid system that would combine the strengths of vertical, horizontal, and reconfigurable surfaces. In future work, we plan to explore the potential of such a hybrid system for enhancing reading-based productivity tasks.

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