

Augmented Reading: Presenting Additional Information Without Penalty

Eric Bahna¹

Microsoft Corporation
One Microsoft Way
Redmond, WA 98052, USA
ebahna@microsoft.com

Robert J.K. Jacob

Department of Computer Science
Tufts University
Medford, MA 02155, USA
jacob@cs.tufts.edu

ABSTRACT

We present a new interaction technique for computer-based reading tasks. Our technique leverages users' peripheral vision as a channel for information transfer by using a video projector along with a computer monitor. In our experiment, users of our system acquired significantly more information than did users in the control group. The results indicate that our technique conveys extra information to users nearly "for free," without adversely affecting their comprehension or reading times.

Categories & Subject Descriptors

H.5.2 [Information Interfaces and Presentation]: User Interfaces – *Interaction styles*; H.5.2 [Information Interfaces and Presentation]: User Interfaces – *Evaluation/Methodology*

Keywords

Peripheral vision, eye tracking, reading, interaction technique evaluation, lightweight interaction, non-command interfaces, geographical information

INTRODUCTION

We demonstrate a novel, interactive display technique that leverages peripheral vision to communicate additional information to a user engaged in a reading task. We wish to convey the additional information through peripheral images without distracting the user from his or her primary focus of reading the text. In particular, our technique is created for leisure reading and reading to self-inform [8]. We base our design on lightweight, or non-command, user interaction [3, 7] because this approach allows us to present information to the user in a background or peripheral mode. Our design is motivated by a vision of nearly "free" ancillary information.

Consider a digital library about ancient Greece that includes a sentence such as, "Ictinus was the architect of the Parthenon." Environmental, geographical, or spatial information about places in the text, such as the Parthenon, would enhance the reader's understanding of such a text, particularly a modern reader who is less familiar with the

Parthenon than the author's contemporaries would have been. A conventional solution might provide a hypertext link in the text ("Ictinus was the architect of the Parthenon [click here for picture of Parthenon]") On a typical website, selecting the link would display the picture in the main browser window, replacing the text the user was reading; a "Back" button or other link would then take the user back to the text to continue reading. This method interrupts the reader's primary task, and is thus precisely the wrong approach. Our design suits situations in which the text is primary, and the environmental information is a relatively minor, ancillary piece of knowledge. We aim to keep the reader on his or her primary task (reading) while we simply provide some small amount of environmental information in the background. We do this with minimal distraction from the reading, without requiring any explicit action on the user's part, and without using up screen space that would normally be devoted to the text.

DESIGN

The motivation for our design comes from this scenario: Suppose a reader was enjoying a book while riding on a bus, which was driving through the same places mentioned in the text at the same time that they were mentioned. Even without looking up from the book, the reader would be able to get a rough sense of where he or she was at each point in the text – indoors, outdoors, urban, rural, daytime, nighttime – via peripheral vision through the bus windows. Similarly, our interaction technique aims to convey general awareness of the environment of the text.

In our design, we considered a college student studying a digital library. The user reads on a conventional display monitor, while the peripheral information is shown as a very large image on a wall just behind it. The peripheral image changes as the reader scrolls through the text in our system. We minimize distraction to the reader by gradually dissolving images from one to another.

Although the reader can look up at the wall at any time, our intention is that he or she need not ever look at it, but can

¹ The work reported in this paper was carried out during the first author's affiliation with the Department of Computer Science at Tufts University.

simply receive information through peripheral vision, just like the imaginary reader riding in the bus. The reader thus uses his or her foveal vision only for the reading task. Peripheral vision is little used in reading, so we view it as an extra available channel in this setting and we exploit it for communicating an approximate sense of place. We believe that this combination of foveal and peripheral vision makes a fuller use of the reader's available attentional resources, thereby conveying additional information. We tested this hypothesis in our experiment below.

Implementation

Our peripheral border display system was comprised of a Windows PC with a dual-head graphics card, a 15" LCD monitor, and a video projector. Our Java application displayed text on the LCD monitor and optionally displayed the corresponding images via the projector. The resultant projection covered an area of 62.5" by 96" on the wall behind the monitor. We also added a lightweight head-mounted ISCAN eye tracker and a Polhemus magnetic tracker. Figure 1 shows a photograph of the two displays as used during our experiment. A diagram of the system's layout is shown in Figure 2.

EXPERIMENT

We conducted an experiment to investigate the hypothesis that our system can provide a user with extra information related to the text while he or she is reading, without having a negative impact on the reading task. First, we measured the extent to which the system conveyed additional information. Second, we evaluated potential drawbacks, such as an adverse effect on reading time or comprehension of the content. Third, we determined more precisely how the extra information had been conveyed to the user. Additional details about this experiment, including a more thorough explanation of its design and a more detailed statistical analysis, can be found in our technical report [1].

Experimental Design

Our experiment utilized a completely randomized (between-subject) design with two conditions. In our study, the presence of the peripheral images was the independent variable. The projector displayed images in the experimental condition and a plain gray background in the control condition.

We decided against a within-subject design because that would require an additional set of content, introducing a new class of concerns over how similar the two sets of content were. For example, we would need to show that the texts were of similar difficulty and that the respective images were equally useful to their respective texts.

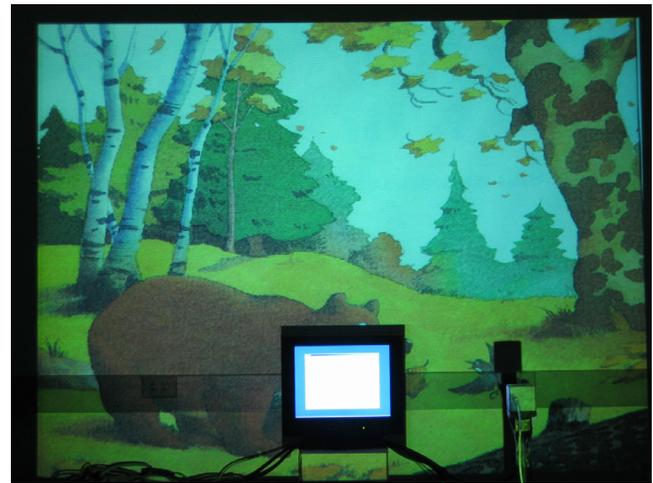


Figure 1: Peripheral Border Display System: The LCD monitor is shown as the light rectangle in the middle of the lower half of the picture. The Polhemus transmitter is shown to the right of the monitor.

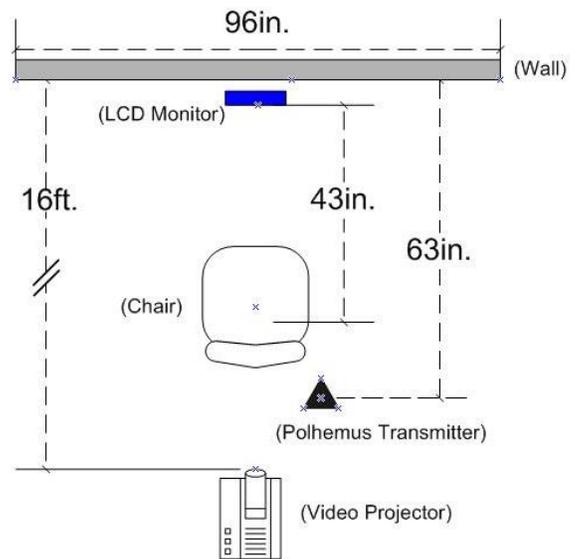


Figure 2: Diagram of Peripheral Border Display System (Overhead View)

Subjects

Eighteen subjects (13 males and 5 females) volunteered for the study. Nine subjects were assigned to each condition. All participants were college students from the Boston, Massachusetts, area, ages 21 to 26, and were not computer novices. There was no compensation for participation.

Experimental Stimuli

Our peripheral border display system works best with content that is primarily text and that includes some pictures or graphics that convey ancillary information. The content had to satisfy two additional criteria for our experiment. First, it had to take between 5 and 10 minutes to read and, second, our subjects should not have had prior knowledge of the content. Since we are not content creation experts, we

decided against composing our own text and images. Instead, we chose an illustrated children’s book [6] with an appropriate amount of text and a sufficient number of pictures as the content for the experiment.

Procedure

Subjects were asked to read a story while wearing an eye tracker. They were told that they would be timed during the reading task, that they would be asked questions afterwards, and that they could safely ignore the material that was projected onto the wall.

RESULTS

Subjects were given a written memory test that contained a total of 49 questions, which can be classified into 3 types: 26 text questions (whose answers were present only in the text), 10 reinforced questions (whose answers were present in both the text and the images), and 13 picture questions (whose answers were present only in the images).

Performance on the memory test is summarized in Table 1. As expected, we found that subjects in the experimental group correctly answered significantly more picture questions than did subjects in the control group. We employed a single-factor, two-level, independent-measures analysis of variance (ANOVA) to confirm significance. We followed-up with the median test, and it suggested that the two distributions were significantly different ($p = .024$) and did not share a common median. ANOVAs showed there was not a significant difference in performance on the text or the reinforced questions.

Questions	Experimental		Control		<i>p</i> -value
	M	SD	M	SD	
Picture	6.67	2.35	3.78	1.92	.011
Reinforced	6.22	1.30	6.22	1.92	1.000
Text	12.11	4.04	11.33	3.57	.671

Table 1: Number of Correctly Answered Memory Questions

There was no statistically significant difference in the reading times between the experimental and control groups: $F(1, 16) = 1.856, p = .192$. The observed mean and standard deviation was 364.11 seconds and 134.7 seconds, respectively, for the experimental group and 289.78 seconds and 93.0 seconds, for the control group.

After completing the memory test, subjects were asked questions about their experience, which they replied to using a 7-point Likert scale (1: strongly disagree ... 7: strongly agree). Subjects in the experimental condition reported significantly less fatigue and significantly greater enjoyment of the system as compared to the control group. There was not a significant difference between the groups with respect to enjoyment of the story, the helpfulness of the projector, and how distracted they felt by the projector.

Table 2 summarizes the eye tracker results. The Mann-Whitney U test showed a significant difference in both time

spent looking at the monitor and time spent looking at the projection. (There are two instances where we used the Mann-Whitney U Test in lieu of an ANOVA. We did so because the Hartley F-max test suggested that the assumption of homogeneity of variance may not be valid for the data in question.) An ANOVA showed no significant difference in the percentage of time that the two groups spent looking at a content-free area of the room (anywhere other than the monitor or the projection). From previous eye tracker studies, we expected that some subjects could not be properly calibrated with the eye tracker [11]. We were able to obtain eye tracking data for 14 of our 18 subjects (7 experimental and 7 control).

Line of Sight	Condition		<i>p</i> -value
	Experimental	Control	
LCD Monitor	95.7%	99.2%	< .05
Projection	4.1%	0.6%	< .05
Other	0.2%	0.3%	0.899

Table 2: Mean Percentages of Time Spent Looking at Various Locations

DISCUSSION

The results show that the peripheral images did indeed convey additional information “for free” (i.e. no significant affect on comprehension of the text or reading time).

Subjects’ performance on the picture questions indicates that the images do communicate additional information. The absolute difference between the means of the two groups is 2.89 questions, which is an improvement of over 22%. Subjects in the control group performed better than we had expected on the picture questions, probably due to successful guessing. Despite the control group’s unexpectedly good performance, both the ANOVA and the median test were significant. We also conclude that the peripheral images did not adversely affect comprehension of the text because there was not a significant difference in performance on the text or reinforced questions.

We would expect that if experimental subjects received the extra information through explicit examination of the images, then their reading times would be significantly different from those of the control group. However, there was not a significant difference in reading time between the groups, so we have shown that the extra information was received and retained without increasing task time.

The difference in time spent looking at the projection was very slight (only 3.5%), though statistically significant. We believe that a statistically genuine difference of such small magnitude is a low cost relative to the gain of additional information (22% improvement). The minimal effect of the eye data difference is reinforced by the fact that the reading times were not statistically different.

RELATED WORK

Peripheral vision has been leveraged by other researchers to provide more immersive virtual-reality (VR) worlds [10] and to support multitasking [5]. Our use of peripheral vision is different from the former in that we use a monitor and projector rather than a head-mounted display. The latter uses similar hardware to our system to facilitate multi-tasking, while our goal is to enhance a single reading task.

Baudisch et al. have combined a projector and LCD monitor to simulate a single, large, seamless display [2]. Our system uses a similar combination of hardware, but is different in that it uses the projector as a distinct display rather than merging it with the LCD monitor. Also, our technique employs a single, fixed focus area (the text on the monitor), rather than a dynamic one. We intended that users never need to switch their focus away from the monitor.

Tan et al. have used projected images to facilitate encoding and retrieval of primary content [12]. Although our use of projected images may incidentally reinforce information in the primary content, our main goal is to communicate entirely new information.

CONCLUSIONS AND FUTURE WORK

Our peripheral border display interaction technique showed how peripheral vision can be used as a basis to communicate additional information “for free” – without additional user effort and with no detectable adverse effect on reading time or comprehension. We used an eye tracker to examine in greater depth how our interaction technique conveyed the additional information. Our lightweight interaction used projected images to convey environmental information in a situation where reading the text ought to remain the primary focus of the user’s attention.

Several extensions of this system might provide even greater benefit to users. The experience can be made richer by showing the peripheral images on more spatially immersive displays [3, 8]. Our system could be extended to convey even more information through an aural channel by playing background sounds that change as the user reads through the text. We could also incorporate eye tracking to determine with greater precision where the user is reading [4, 12] in order to predict when to display each image.

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