Visual Interference with a Transparent Head Mounted Display

Robert S. Laramee
Department of Computer Science
University of New Hampshire
Durham, NH, 03824 USA
rlaramee@cisunix.unh.edu

Colin Ware
Data Visualization Research Lab.
Center for Coastal and Ocean Mapping
University of New Hampshire
Durham, NH, 03824 USA
colinw@cisunix.unh.edu

ABSTRACT
Potential perceptual problems that may occur with monocular wearable displays are binocular rivalry and visual interference. We report the results from an experiment with a monocular wearable showing that text becomes increasingly difficult to read as the background becomes more complex. Indeed subjects adopted strategies to avoid the visually complex backgrounds and thereby minimize the interference.

Keywords
Wearable computing, Head mounted displays, visual interference, binocular rivalry.

INTRODUCTION
There is a broad-based movement towards small portable, or *wearable* computing devices. Small head mounted displays (HMDs) are being developed to support a number of applications ranging from augmented reality to aircraft inspection [2,4,5]. In this way, the user can potentially have a high resolution display available without having to carry a bulky monitor. A number of configurations are possible. The display can be opaque and worn over one eye, as was the case for an early model called the Private Eye™, the display can be transparent and worn over one eye, or the display can be transparent and worn over both eyes. Having completely opaque displays over both eyes is not generally useful except for immersion virtual reality applications. Of these configurations, the one eyed, transparent display appears to be preferred [2].

PERCEPTUAL ISSUES
There are a number of potential perceptual problems with transparent displays viewed with one eye. Here is a partial list.

Binocular Rivalry
One of the classic results of research into human attention is that we can selectively attend to input to either ear. However, this is not the case for the eyes. When dissimilar images are presented to the two eyes the brain reacts by going into an unstable state where parts of each image may appear and disappear, sometimes for several seconds. What is worse for the usability of monocular displays is that this process is not under the conscious control of the viewer. However, strong patterns will tend to be dominant over weak ones. This means that a high contrast text display presented to one eye will be competing with whatever information is presented in the other eye [1]. In general moving patterns will also tend to capture information better than static patterns.

Visual Interference
When two patterns are presented, one transparently overlaying another, there will be interference between the two. In general the more similar the patterns, in color, in texture, in motion (etc.) the greater the interference[3].

Depth of Focus
HMDs are constructed with lenses or mirrors so that a virtual screen appears at a fixed distance from the user. This distance is typically set at one or two meters. However, the real world imagery viewed through a HMD can be at the same or a different focal distance. Less interference can be expected if the HMD imagery and the external imagery are at different focal distances.

EXPERIMENTAL EVALUATION
All three of the above factors apply to the use of transparent monocular head mounted displays. To investigate we designed a task that involved selection of an item from a table viewed using a monocular transparent display.

HMD
Our HMD was a modified i-glasses™ display with 450x266 display. We converted this to a monoscopic display by removing the left eyepiece. We also rearranged the optics for the right eye as shown in Figure 1. A beam-splitter to blends external imagery with display imagery. This produced a virtual image of a computer display at approximately 1.0 meters combined with real world imagery that was optically unaltered except for having reduced luminance.

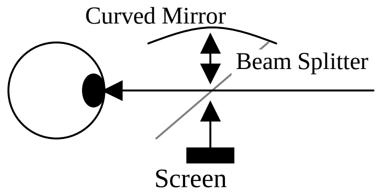

Figure 1. Real world imagery was combined with display imagery as shown.

Task

The task was to answer questions having the form "What is the price of lettuce?" presented at the top of the display screen. The answer was obtained by scanning a table as illustrated in Figure 2. Questions were randomly ordered from a set of 50 such that all table cells had an equal probability of containing the correct answer. Following a training session each subject answered 20 questions in each of the 6 experimental conditions. Subjects were tested for eye dominance and were paid $10 for participation.

Question #0: HOW MUCH DOES BUTTER COST?

ITEM NAME	AISLE	PRICE ($)	DISCOUNT
BEER	4	$3.99	NO SALE
SUGAR	10	$0.99	% 20 OFF
RELISH	13	$4.99	% 10 OFF
TEA	12	$3.99	NO SALE
ORANGES	3	$2.99	% 20 OFF
ORANGE JUICE	2	$3.99	% 10 OFF
DISHWASHER	5	$1.99	NO SALE
FROOT LOOPS	7	$5.99	NO SALE
PEARS	7	$2.99	% 10 OFF
GRAPES	10	$1.99	NO SALE
POTATO CHIPS	9	$0.99	% 20 OFF
BUTTER	9	$2.99	NO SALE
HAMBURGERS	8	$3.99	NO SALE
CHICKEN FINGERS	12	$2.99	% 20 OFF

Figure 2. Task screen: subjects were required to answer the question by selecting the appropriate table cell using the mouse.

Backgrounds

In order evaluate background complexity we used three backgrounds. One was a plain white wall, another was a bookshelf and the third was a 30" television showing a movie (with the sound off). All three backgrounds were displayed at two different distances. The first was approximately 1 meter so that the display and the background would simultaneously be in focus. The second was approximately at 2 meters making the background about 1 diopter out of focus when the participant focused on the display.

RESULTS

The results are summarized in Figure 3. This shows mean times to answer each question averaged across all subjects. The moving background conditions resulted in response times that were 37% longer compared to the uniform background ($p < 0.01$). However, in the bookshelf condition only the far condition showed a significant difference from a uniform background. This result is inconsistent with our prediction that the out of focus display would be less interfering. A possible explanation may be based on the anecdotal reports of some of the participants. They said that they searched for a relatively uniform area of the bookshelf as a background This strategy was not possible with the far condition because no sufficiently large uniform areas were available. In addition some participants reported not being able to see the application when the movie background was bright. One participant reported feeling rather ill after the study while another subject reported an eye twitch (only during practice).

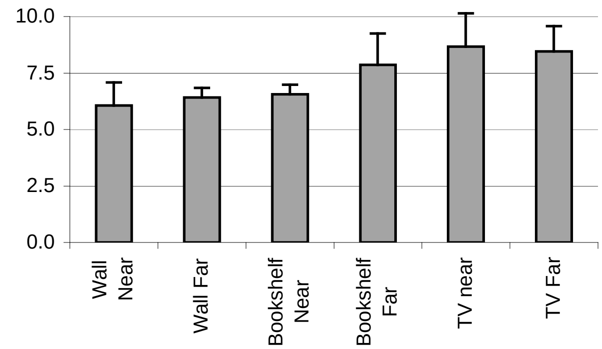

Figure 3. Mean time for table task under 6 viewing conditions. Vertical bars represent two standard errors.

CONCLUSION

Our results confirm our prediction that a transparent HMD would suffer from significant usability problems when viewed against anything other than a uniform background. This places severe restrictions on the use of such displays. For example, this kind of display would probably be unsuitable for use in any kind of crowded environment or where maintenance of visual attention is critical. It would also be unsuitable for use by someone in a moving vehicle. Nevertheless when hands-free operation and maximum portability are essential, HMDs may be the most viable option.

REFERENCES

[1] Alais, D. and Blake, R. (1999) Grouping visual features during binocular rivalry. Vision Research, 39, 4341-4353.

[2] Feiner, S., Macintyre, B., Hollere, T., and Webster, A touring machine: prototyping 3D mobile augmented reality systems for exploring the urban environment. Proc. ISWC'97. 13-14.

[3] Harrison, B.L. and Vincente, K.J. (1996) An experimental evaluation of transparent menu usage. ACM CHI'96 Proceedings, 391-398.

[4] Ockerman, J.J. and Pritchett, A.R. (1998) Preliminary Investigation of Wearable Computers for Task Guidance in Aircraft Inspection. Proceedings ISWC'98.33-40.

[5] Starner, T., Mann, S., Rhodes, J., Levine, J., Healey, D., and Picard, R. Augmented Reality through Wearable Computing, Presence, 6 (4) 386-398.