Attending to Large Dynamic Displays

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Abstract
Although studies have shown that physically large displays bring benefits in performance and user satisfaction, the expanded field-of-view (FOV) places considerably higher demands on our cognitive capacities. Understanding how we process information over a wide FOV is increasingly important to optimize interface design. So far, however, empirical investigations are scarce. We present an experimental paradigm and framework for research with large displays and we report a preliminary experiment that explores attentional performance over a wide FOV. The paradigm simulates aspects of tasks that are facilitated by large displays. Our data suggest that processing abilities in the center and periphery are similar only if distractors are not present. With distractors, peripheral processing is disrupted and performance is poorer than in the center. In general, both accuracy and speed decline if the user must process information simultaneously in both areas. We discuss the implications for interface design, and describe further work that we are planning within this framework.

Keywords
Attention, large display, dynamic display, wide field-of-view, central vision, peripheral vision

ACM Classification Keywords
H5.2. Information interfaces and presentation (e.g., HCI): User Interfaces---Ergonomics, Screen Design

Introduction

As graphics processing has become more powerful and as fabrication costs have continued to decline, the size of computer displays has increased substantially. In 2000, the most popular size of a computer monitor was 15 inches diagonally with an aspect ratio of 4:3. Today it is common to see displays of 24 inches, or even 30 inches, with an aspect ratio of 16:9. If we take 35 inches as a typical viewing distance from the user to the display [5], the horizontal visual angle subtended by a 24 inch widescreen monitor is about 33^o and for a 30 inch monitor it is about 41^o (figure 1). A 15 inch monitor with an aspect ratio of 4:3 subtends a horizontal visual angle of only 19^o. Hence much more of the viewing area of the larger monitors lies outside the area of central vision (usually taken to be about 5^o [10]). Objects can now be more than 20^o away from the central focus whereas, with yesterday's monitors, peripheral objects were less than 10^o distant.

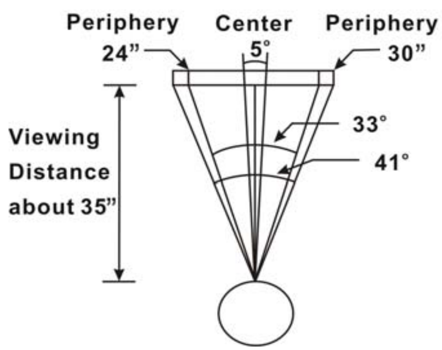

figure 1. Visual angles subtended by 24” and 30” widescreen monitors at a viewing distance of 35”.

The trend toward larger screen sizes creates novel opportunities but also presents new challenges for human-computer interaction (HCI) design and research. On the one hand, it has been shown [3,7,8] that physically large displays can improve user experience and performance but, on the negative side, usability problems and other difficulties were also noted in these pioneering studies. For example, tricky issues include: how to alert users when an application in the periphery requires interaction; how to best manage tasks on a large display with several active applications; how to reduce the workload during frequent task-switching; how to accommodate older users whose useful FOV has shrunk with age [2] and women whose FOV is generally narrower than that of men [4]. Fortunately, efforts are already underway to develop effective design guidelines and new approaches to meet these challenges [3,4,7,8].

To support this new research, an understanding of how human information processing can vary across a wide FOV is helpful. Unfortunately, empirical data regarding visual cognition in the periphery are relatively meager compared to our extensive knowledge of the properties of central vision, which has been amassed over many decades of research. Since there is good evidence that distinct mechanisms in the brain support cognition in these two visual areas [6], it is not possible to generalize what we know of visual cognition in the center to the peripheral region.

We have begun a program of research to study visual cognition in the center and periphery, and more particularly how the two processes interact. From the viewpoint of HCI, the important issues include (1) how users attend to and manipulate information presented across a wide FOV (distribution of cognitive resources) and (2) how processing in one area interferes with or facilitates processing in the other.

The real-time monitoring of stock prices is one practical application where a large display can be helpful. Effective monitoring of financial information usually requires the user to attend to multiple windows that contain numerical data that change frequently and dynamic visualizations (figure 2). Although monitoring is more convenient on a large display, users must attend to information presented in both the center and the periphery. Extracting useful information can be difficult because the windows are periodically refreshed and changes in the periphery may not be noticed, or not be noticed in time. Furthermore, only some of the changes will be of interest to the user—other dynamically changing data may have little or no importance. To make the task of monitoring even more challenging, much of the displayed information will share similar visual features (e.g. same size and color). Our experiment uses a well-known psychological task to mimic important aspects of this real life application.

figure 2. A typical multiple-window configuration, consisting of a primary central window plus several peripheral windows, in a stock price monitoring application on a large display.

Experiment

An enumeration task (figure 3) was used. Participants had to report the number of briefly presented targets (filled gray squares) in either the center or the periphery of the display. Enumeration is a well established technique for assessing attentional capacity [9], and the task also approximates some of the dynamic characteristics of the stock price monitoring application. On half of the trials in our experiment the targets were intermingled with distractors (unfilled circles); this simulates the situation where some information that is changing in a display is not important to the observer.

Method

The participants were 15 female undergraduates aged from 17 to 27 at University of Toronto. After briefly viewing targets with or without distractors, they had to report the number of targets by pressing the appropriate number key. In the single task condition, participants enumerated targets in the area (center or periphery) where the targets appeared. In the dual task condition, the participants had to enumerate targets in both areas simultaneously but were cued to report only the number of targets in either the center or the periphery. The cue appeared after the items had been presented with an equal probability (.5) of cueing the center or the periphery. The physical size of targets in the periphery was larger to compensate for the normal decrease in visual acuity toward the periphery [1]; a target in the center subtended 0.8^{o} within an invisible square area of 6^{o} and a target in the periphery subtended 1.6^{o} within an area of 50^{o}. Each single task consisted of 72 trials evenly distributed across the number of targets, which varied from one to six. Each dual task had 144 trials evenly distributed across the 36 treatment combinations (6 central target numbers X 6 peripheral target numbers). The percentage of errors made by participants and their response times (RT) were recorded.

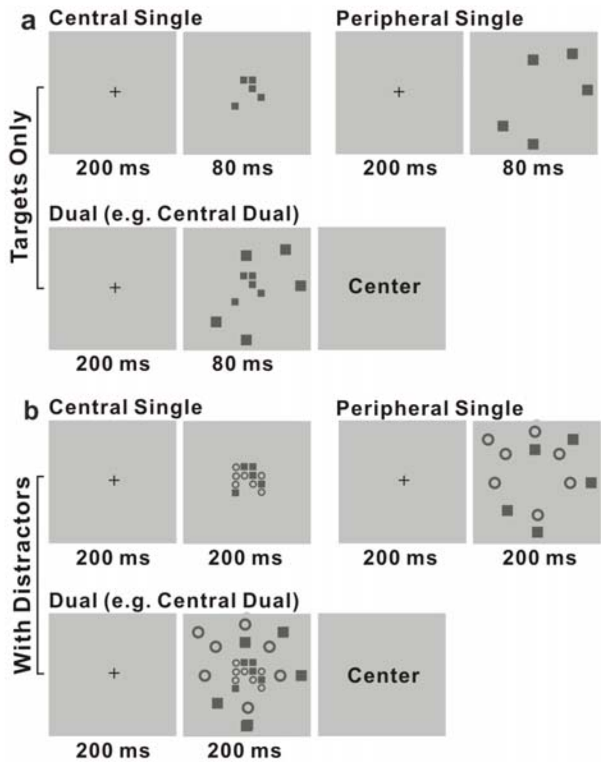

figure 3. Display sequences in the single task and the dual task conditions. **a.** Sequences for tasks with targets only (squares). **b.** Sequences for tasks with both targets and distractors (circles). In the single task condition, a fixation cross was first presented followed by the targets presented in either the center or the periphery. In the dual task condition, a cue ("CENTER" or "PERIPHERY") was presented after stimulus offset. Participants were instructed to respond both accurately and quickly.

Results

The percentage errors and RTs for each condition are shown in figure 4. In the targets-only condition, the performance in the periphery was almost as good as in the central area: no difference in Error, $F(1,14)=3.63$, $p=.08$; slightly slower in the periphery, $F(1,14)=30.23$, $p<.01$. In contrast, in the presence of distractors, performance in the periphery decreased significantly and became much poorer than in the center: higher percentage error, $F(1,14)=453.59$, $p<.01$; and slower in the periphery, $F(1,14)=52.76$, $p<.01$. Moreover, performance was generally poorer when information processing was required for both areas compared to only processing for one area: higher percentage error, $F(1,14)=118.86$, $p<.01$; and slower in dual task conditions, $F(1,14)=610.67$, $p<.01$.

General Discussion

From an applied perspective, our results suggest that 1) when windows are refreshed, updating should take place at different times—if the user is required to process several changes simultaneously, there will be a decline in both speed and accuracy; 2) in the periphery, refreshing information in two nonadjacent windows, particularly when the two are distant or non-relevant in content, should be avoided. Otherwise, the user is forced to process multiple information across a very wide visual field; 3) ideally, the window which has the focus should occupy the center of the display. If attention is focused on a window near the edge of the display, this will increase the visual angle associated with information presented in windows on the opposite side of the display. Automatic repositioning of the window which has the focus could benefit performance. This feature should be customizable since it may not be suitable in all situations.

We plan to extend this preliminary exploration using other experimental paradigms to assess attention, visual search, and executive function in tasks that approximate other common user activities where large displays are employed.

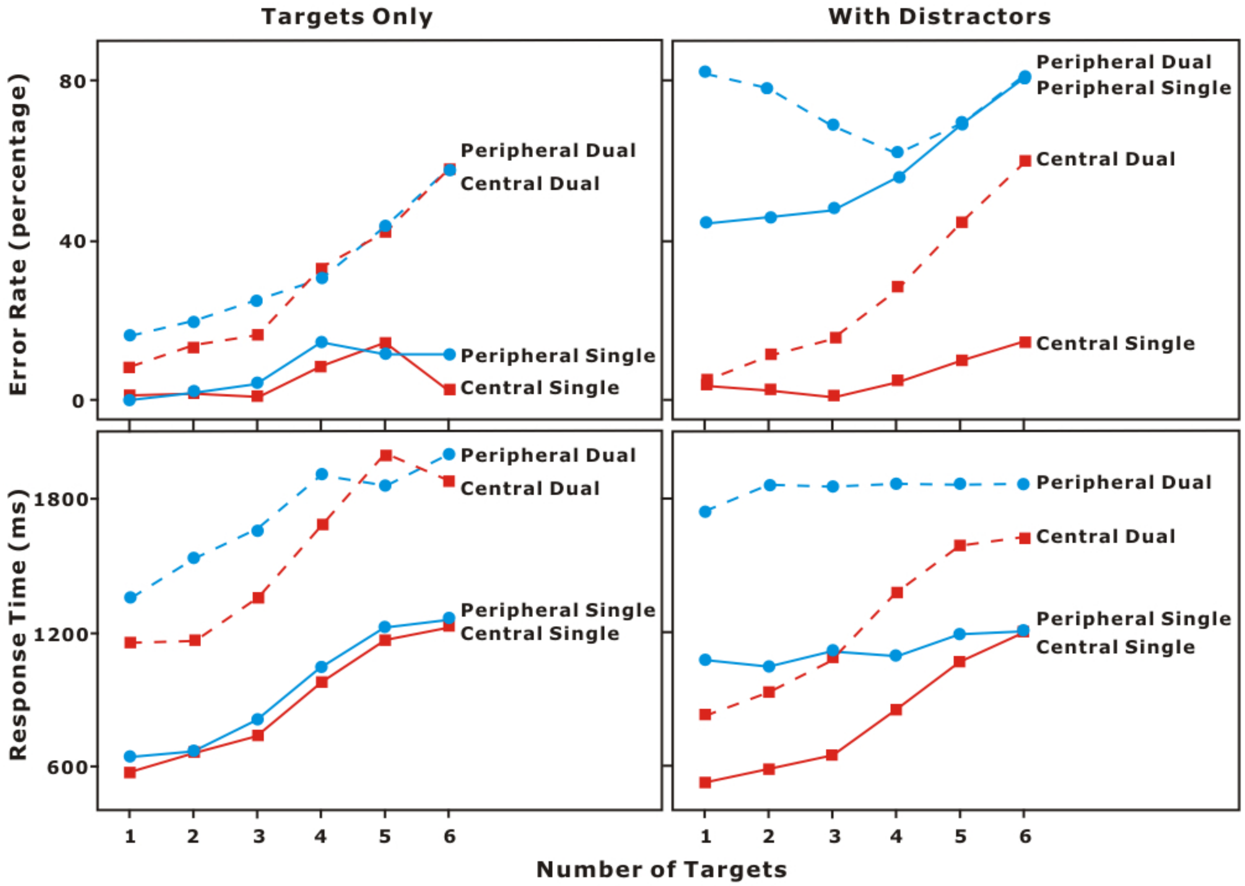

figure 4. Mean percentage errors (upper panels) and mean response times (lower panels) for each number of targets in the enumeration task with targets only (left panels) and with targets and distractors (right panels). Solid lines represent results from single tasks while the dash lines represent dual tasks. Data from the periphery are in blue and data from the center are in red.

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