# Effects of Tiled High-Resolution Display on Basic Visualization and Navigation Tasks

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### ABSTRACT
Large high-resolution screens are becoming increasingly available and less expensive. This creates potential advantages for data visualization in that more dense data and fine details are viewable at once. Also, less navigation may be needed to see more data. However, little work has been done to determine the effectiveness of large high-resolution displays, especially for basic low-level data visualization and navigation tasks. This paper describes an exploratory study on the effects of a large tiled display with a resolution of 3840x3072 as compared to two smaller displays (1560x2048 and 1280x1024). We conclude that, with finely detailed data, higher resolution displays that use physical navigation significantly outperform smaller displays that use pan and zoom navigation. Qualitatively, we also conclude that use of the larger display is less stressful and creates a better sense of confidence than the smaller displays.

### Author Keywords
High-resolution display, information visualization.

### ACM Classification Keywords
H5.m. Information interfaces and presentation: Miscellaneous.

### INTRODUCTION
Large high-resolution displays, with greater numbers of pixels, have the potential to increase the quantity and granularity of displayed information. In this paper, we define *resolution* as the total number of pixels in the display. Related dimensions are the physical *size* of the display, and the pixel *density* of the display. Together, size and density define total resolution. While it is possible to increase resolution by using high-density display technologies (such as IBM's Big Bertha), here we focus on increasing resolution by tiling displays into larger sizes (e.g. Figure 1). This is distinct from large projected displays that increase size, but decrease density, with no net change to resolution.



Naively, one might expect that more pixels is always better, particularly in data visualization where the goal is to enable users to absorb large amounts of information quickly. However, it is not clearly evident if increased resolution would be beneficial, or to what extent. There is limited empirical evidence on interactive high-resolution visualization. One counter-argument is the fundamental perceptual and physical limitations of humans, such as the relatively small focal area of the human eye [6]. [2][4] show advantages of higher resolutions for standard high-level desktop applications tasks, using up to 3 tiled screens. Studies such as [5] show advantages of large size, but low resolution. [1] shows visualization advantages of a mixed density display that implements focus+context by combining a small and large size display, both at low resolution. This leads to open questions about the value of high resolution from a basic perceptual and navigation point of view.

**Figure 1: The nine-monitor tiled configuration. The total resolution is 3840x3072 (11,796,480 pixels).**

The fundamental issues are summarized in Table 1. The critical tradeoff revolves around data access. Low-resolution display offers a smaller view-port into the data space. Hence, it provides less simultaneously visible data items or less data detail, and requires more virtual navigation of the view-port to access remaining hidden data or detail. *Virtual navigation* involves changing the display by some interactive technique such as zoom and pan.

On the other hand, high-resolution display offers a larger view-port. Hence, more data and detail is displayed at once. However, because the resolution (and size) is larger, perhaps exceeding human perceptual limitations, more physical navigation may be required. *Physical navigation* is physical bodily movement that users must make to examine different portions of the display, such as head movement, changing body position, or sliding their chair. In general, based on a simple space-scale analysis [3], less virtual navigation is required to access all portions of the total data space.

| | **View** | **Navigation** |
|---|---|---|
| **Low Resolution** | Fewer data items visible or data items have less detail. | Increased virtual navigation, less physical navigation. |
| **High Resolution** | More data items visible or data items have more detail. | Decreased virtual navigation, more physical navigation. |

**Table 1: A summary of tradeoffs related to view and navigation issues for low or high resolution.**

What is the benefit of increased visible data of high-resolution displays? If there is a perceptual performance benefit, how much is it? What is the effect of the navigation tradeoffs associated with using such displays?

## EXPERIMENT DESIGN

The goal of this experiment is to explore the fundamental tradeoffs between low- and high-resolution displays for basic low-level visualization and navigation tasks. We were especially interested to see how people's behavior differed for low-resolution and high-resolution displays. These issues are studied in the context of large 2D spatial data spaces, containing small finely detailed data objects. These data spaces are modeled after common visualization applications such as GIS, satellite, or astronomical data images. Users must find various visual features within the large 2D space. 2D virtual navigation is based on simple zoom+pan interaction.

This 3x3x2 design experiment has 3 independent variables:

- Display resolution (total number of pixels):
    a. One monitor: 1,310,720 pixels
    b. Four monitors: 5,242,880 pixels
    c. Nine monitors: 11,796,480 pixels.
- Target size (with respect to the total 2D data image size): Large, Medium, and Small targets.
- Task type: Find target, and Compare targets.

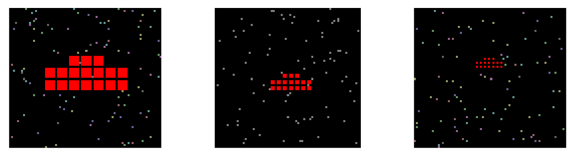
### Displays

The three display resolution conditions where constructed from tiled LCD monitors. Each LCD monitor has 17 inch diagonal with 1280x1024 resolution. Figure 1 shows the 3x3 9-monitor configuration, the condition with the highest resolution. The 4-monitor condition used a 2x2 tiled array. The 1-monitor configuration is a single LCD.

### Data and Targets

For purposes of control, we developed data images containing controlled visual stimuli that were fabricated solely for the purpose of this study. We did not intend to study a particular visualization technique or representation, but to study basic perception and navigation. Data images were high-resolution (3840x3072), containing small number of red dot stimuli in a sea of thousands of grey dots. The red stimuli were the targets of the user tasks.

Since the granularity or scale of the targets within the 2D data space is likely to affect user tasks at various display resolutions, we varied target size to measure the effect. An example target at the three different sizes used in the experiment is shown in Figure 2.



**A) Large B) Medium C) Small**

**Figure 2: 3 different sizes of an example target used in the comparison task.**

To clarify how size of the display relates to the size of a given target, we have provided table 2. The display size to target size ratio is simply the total pixel count for a given display divided by a given target size. For example, the size of the one monitor configuration compared to a large target is 3.2 (or 3200 times bigger) while the nine monitor configuration divided by a large target is 28.9 (28900 times bigger). Ratios have been divided by 1000 for convenience.

| **Ratio** | 1 Monitor | 4 Monitors | 9 Monitors |
|---|---|---|---|
| Small Target | 12.8 | 51.4 | 115.7 |
| Medium Target | 6.4 | 25.7 | 57.8 |
| Large Target | 3.2 | 12.8 | 28.9 |

**Table 2: Ratio of display size to target size in pixels (display size ÷ target size ÷ 1000).**

### Tasks

Two basic visualization tasks are examined: finding a single target, and identifying paired targets in a high-resolution image. The first task consisted of finding a red dot out of thousands of gray ones. The second task, a comparison task, consisted of finding red targets in an image and identifying identical pairs. The second task was more sophisticated than the first task in that the participants had to first find the red targets then compare all of the targets with each other to identify pairs that had identical shape. Figure 2 shows an example of one target shape used in the comparison task.

### Navigation

To accomplish the tasks, participants used the standard Microsoft image display software, called Picture and Fax

Viewer, which supports simple zoom and pan navigation. The 9-monitor configuration is large enough that zoom+pan is not needed to view the full image space. In the other conditions, zoom+pan are likely to be used out of necessity. Hence, this tests virtual navigation versus physical navigation. Participants were still able to zoom in or out and pan on the nine monitor configuration (although few participants actually did).

The dependent variable was performance time for each task. We measured how long it took to complete each task.

### Participants

All 36 participants were volunteers that were college students from a variety of majors. The participants were 36% female and 64% male. The ages of the participants ranged from 20 years old to 29 years old. All participants performed both types of tasks on all monitor configurations, but on only one particular target size. All participants were given a training session prior to actual testing.

## QUANTITATIVE RESULTS

Using traditional statistical methods, such as ANOVA and post-hoc contrasts such as the Tukey procedure, and with $\alpha = 0.05$, we found significance only for the small targets in the find task. In other words, we could not statistically say that any monitor configuration gave better performance time than any other when using the medium or large targets (Figure 4). However, using the small targets we found statistical significance between the one monitor and the nine monitor configurations. In other words, there appears to be a considerable trend indicating that the larger configurations produce a better performance than the smaller configurations when dealing with finer detail data.

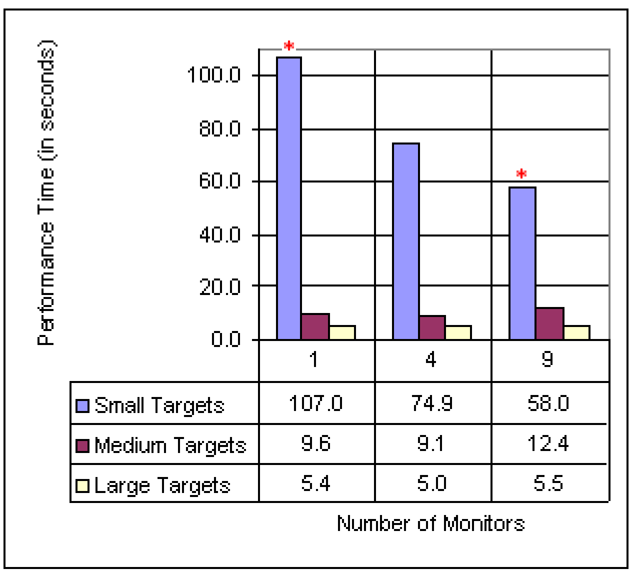



**Figure 4: Performance data for the find task. Statistical significance is indicated with a red asterisk.**

For the small targets in the compare task, we found that there was statistical significance between the four and nine monitor configurations (see figure 5). With the medium target size, the four and nine monitor configurations were better than the one monitor configuration. For the large target size, there was no statistical difference between any of the monitor configurations. In general, the smaller the target size for the compare task the larger the display needed to be to increase the performance time.

Our data suggests that nine monitors did not ever slow down participants, but rather drastically improved performance time with smaller targets. With the case of the large targets, the performance time of the nine monitor configuration was approximately the same as the one monitor configuration. On the other extreme, participant's performance time on the nine monitor configuration was less than half of the performance on the one monitor configuration. It also shows that the four monitor was never worse and was sometimes better than the one monitor configuration.

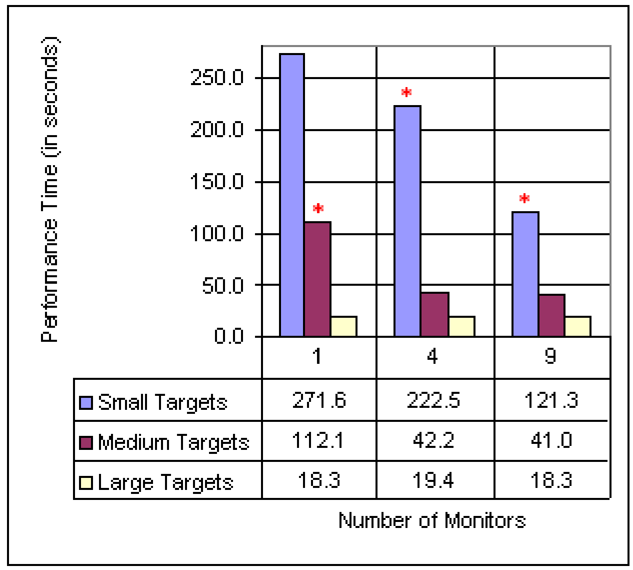



**Figure 5: Performance for the comparison task. Statistical significance is indicated with a red asterisk.**

## OBSERVATIONS

This section highlights the most common observations that were observed by several or all of the participants.

### *Higher resolution and physical navigation decreases repetition and increases confidence*

When participants used either the one or four monitor configurations, they would sometimes report the same pair of targets more than once. Approximately one-third of the participants accidentally reported a result more than once with the one monitor configuration. Approximately one-sixth of the participants did the same with the four monitor configuration. Reporting the same target pairs twice never occurred on the nine monitor configuration.

Our hypothesis is that because the image never moved with the nine monitor configuration the participants were able to remember the spatial position of targets better. If zooming or panning were used extensively then targets would "move" – the view point of the participant changed and the targets would change positions accordingly. The absence of repetitive reportings of the same pairs for the nine monitor configurations points to a lighter cognitive load.

Using the one or four monitor configurations participants would occasionally be unsure if they had found the second target to a pair or had simply found the same target twice. On the other hand, participants were able to be fully confident that they had not found the same shape twice with the nine monitor configuration, as they could literally put one finger on one target and another finger on the other target, clearly showing that the two targets were a pair.

### *Physical navigation preferred*

Although zooming was more popular than panning, participants preferred not to interact with the mouse at all. Several participants explained that they would rather squint at indistinct targets than actually zoom in. The participants wanted to evaluate the data as much as possible before touching the mouse. Participants tended to only zoom and pan when targets were too indistinct to see.

One possibility to explain this observation is that people do not like to lose context. By panning and zooming participants would lose context and get frustrated. Some participants exhibited a great deal of frustration in their body language and speech as they explained that they continuously felt lost and confused with the one and four monitor configurations. This was especially prevalent when using the small targets. At times the proctor had to calm the participant down before they would continue. The most frustrated individuals used exclusively pan and did not consider the idea of zooming. Another possible explanation why participants did not like to interact with the mouse is that they simply do not like to expend effort on interacting as they would rather move their bodies as in the real world.

### *Overview, even with physical navigation*

Participants preferred to be in a zoomed out mode. With the nine monitor configuration, participants preferred to step back from the monitors to get an overview picture first then step forward for more detail.

When dealing with the nine monitor configuration, participants preferred to look at one monitor at a time when stepping forward for detail. This strategy is similar to the strategy used with virtual navigation when panning. However, instead of getting lost in the display space, the bezels between the monitors acted as natural dividers to help orient the participants. A bezel is the plastic encasing that surrounds each tiled monitor.

Also, participants tended to walk, crouch, and have more overall physical movement. Although this aerobic computing was effective, people would also sit down and examine large areas of the screen from an adjustable chair.

## CONCLUSIONS

High-resolution displays can be a benefit in that they significantly improve performance time for basic visualization tasks in finely detailed data. We found that the high-resolution displays help people find and compare targets faster (up to twice as fast), feel less frustration, and have more of a sense of confidence about their responses.

We found that there is more physical navigation for high-resolution displays and more virtual navigation in low-resolution displays. Also, from our observations there appears to be a greater amount of frustration when dealing with pan+zoom as opposed to physical navigation. When participants used pan+zoom with the one and four monitors they would often become disoriented and agitated. The participants were more prone to believe that a target they were looking for did not exist when not immediately found.

## FUTURE WORK

We intend to continue analyzing the basic perceptual issues of large high-resolution displays. Several questions that need to be answered are: How do these results change as the data/pixel count scales up? How do the different navigation strategies, such as overview+detail, and focus+context, affect high resolution visualization? As resolution scales up, what are the physical navigation tradeoffs with large high resolution screens? How do our results differ when using a non-bezeled tiled display?

## ACKNOWLEDGMENTS

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