Effects of Physical Display Size on GUI Designers' Perception and Implementation of Usability Guidelines

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Abstract. Recent advances in technology led to common use of large screen in daily use. Applications of large displays are categorized in three groups; private, semi-public and public applications. Private and semi-public displays allow visualization and manipulation of large amounts of data at once. The increase in display size leads to an increase in data amount, which in result causes users to adopt a complex way of use. These changes arise the need for research in usability, interaction and user performance aspects of large displays. This study evaluates the effect of physical display size and resolution on GUI designers' perception and implementation of usability guidelines. Results suggest that subjects perform better on large displays for visual search and comparison tasks such as checking alignment, visual format similarities, etc. Reading related evaluations, on the other hand, are not supported by the larger displays.

Keywords: large displays, physical screen size, user performance, usability.

1 Introduction

Over the last decades, we have witnessed the establishment of numerous HCI related standards. In today's technology where different types of systems and users are present, users' expectations have increased while consistency and usability in general have become significantly important. While display size have been studied and evaluated in terms of individual task performance, the effect of display size on formation of usable interface design should also be discussed since it is another factor that affects the user performance. This study addresses the relation between the physical screen size and interface designers' ability to implement and evaluate user interface (UI) standards. If a limit can be defined on the screen size which enables designers to create more usable interfaces, one may guarantee more successful products from usability point of view. In the user experiments, we focused on two basic tasks that users perform on computers almost every day: Reading&comprehension and visual search&comparison tasks.

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2 Background

The amount of data increases with the display size which, as a result, causes the users to adopt a complex way of use. However, too little is known on the differences between the users' behaviors and the physical and mental methods they adopt when they use such large displays and standard screen sizes. In studies [1, 2, 3, 4] on relation between display size and user performance, users have performed better on larger displays in spatial tasks, cognitive map formation and memory tasks. Bezerianos&Balakrishnan[7] and Huang&Mynatt [8] focused on determining the users' preference on screen size in their study and concluded that users prefer larger display sizes.

Independent from media, reading process involves not only resolution of information but also decoding the location of information in 2D space [5]. While reading on the computer screen, the reading process may be interrupted by navigational needs (such as paging, panning, etc). Field of view (FOV) should also be taken into consideration while evaluating screen size related factors. FOV plays a significant role on reading and comprehension ability. In [6], Kawashima suggests that the number of characters presented to user at once directly affects the comprehension performance of users. Virtual environment experiments shows there exists an upper limit on the FOV to ensure user success. Experiments with different FOV setups (10º, 20º, 40º, 80º and 120º) have shown users perform best when the FOV is 80º.

Visual search is another common task performed on computer screens. It involves focusing attention to different regions of view field and searching the focus area for a target object. Assuming the number of elements presented on the screen is constant, using larger displays will cause information spread over a larger area, which will cause more eye movements in pre-attentive phase and increased amount of data sent to brain. This will result in higher cognitive load and longer response times.

In the rest of this paper, reading&comprehension and visual search&comparison tasks will be used to evaluate the effect of physical display size on designers' performance on interface conformance tests.

3 User Experiment

In this study, we present the results of user experiments designed to reveal effects of display size and resolution factors on designers' ability to implement and evaluate user interfaces according to predefined design guidelines. During the experiments, designers were asked whether GUI forms that were given conformed to some predefined standard and the results were evaluated based on the response tie, correct response rate, mouse movement distance and participant behaviors.

User experiments had 3 different independent variables:

- Physical screen size
  - 17”
  - 22”
  - 40”
- Screen resolution
  - 800x600
  - 1024x768
  - 1280x1024
- Task Type:
  - Reading&Comprehension
  - Visual Search&Comparison

As physical screen size and resolution are varied, hypotheses in user experiments can be summarized as follows:

– ***H1:*** Participants will recall more information on larger displays.
– ***H2:*** Reading& comprehension will not be affected by physical screen size prvided that FOV will not be too high or too low. However, when the resolution is low, users’ reading performance will be lower on large displays.
– ***H3:*** On large displays, participants will perform spatial processing faster, and thus response times to related questions will be lower. However, correct responses will not change significantly.

3.1 Experiment Setup

In the experiments, 3 (three) different screens have been used. 1 17” Acer AL1716, 1 22” LG W2242S-PF LCD and 1 40” Alba LCD TV. On each display three different levels of resolution have been experimented.

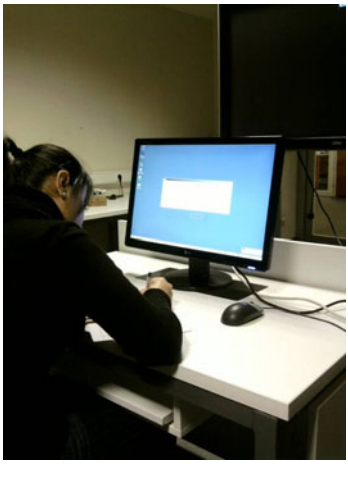

Fig. 1. Experiment setup

The experiment setup consisted of a display, an office table (except for the 40"), a mouse and a user chair. Since no keyboard input is required, no keyboard is placed on the experiment table for user comfort (Fig. 1).

During switching between screens, unused screens have been removed from the place, and the new screen has been placed at a marked distance from the user chair to preserve a constant FOV. In all experiments, displays were placed at proportional distances to preserve a FOV of approximately 50^{o}. Since previous studies have shown that user performance is higher between 45^{o}-60^{o}. While users' FOV was kept within this range, no method to fix FOV has been employed and users were left free to imitate a real working environment and to observe their responses to displays and resolutions.

3.2 Participants

10 participants (3 female, 7 male) have performed 3 experiments each to a total of 30 experiments. All the subjects have been chosen among graduate students who have worked on an interface design in the last 6 months. The participants consisted of 7 computer engineers, 2 software engineers and 1 electrical engineer.

3.3 Method

Each participant is first given a briefing on how the experiment will proceed. The procedure they should follow is explained in detail. Before the experiments, each participant has been informed that they will be given different-sized displays with different resolutions and that they will be requested to perform certain tasks on these display setups. They are asked to respond to these requests as quickly and correctly as possible with no given time constraints.

In each experiment, users are given a welcome screen with 5 design guidelines presented on it. Participants are given time to read and understand these guidelines and when they are ready they click a 'Start' button to start the experiment. In each question, a simple form is given and participants are asked whether the given form conforms to only one specific guideline given before. Each guideline involves either a reading&comprehension task or a visual search&comparison task. For example; users are asked to determine if there are any misspelled words in field labels, to determine whether all labels are aligned to same direction. Or to determine whether a given action button is present in the given user interface. On each screen, users are required to evaluate the given screen according to a single guideline only, and these guideline texts are given on each task screen so the users do not have to memorize them. Users are given two action buttons; if the interface conforms to the given guideline, the user clicks YES, otherwise user presses NO.

3.4 Collected Data

During the experiments participants and their screens have been recorded. Prior to experiments, participants have been informed that they are been recorded (Fig. 2).

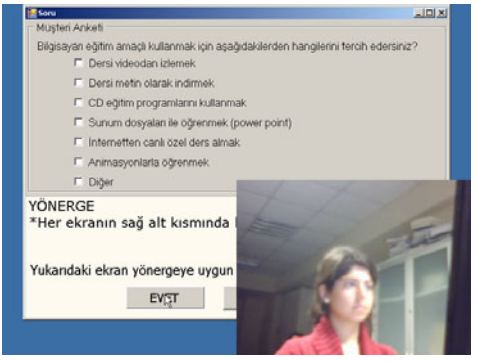

Fig. 2. User screen and camera capture

In addition to user recording, each participant's mouse movements, mouse total mouse displacement during the entire experiment, responses to questions and response times have also been recorded (Fig. 3).

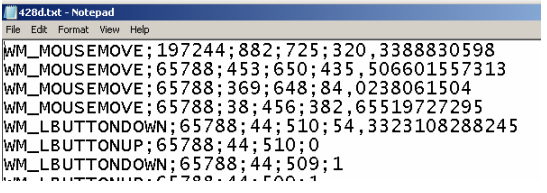

Fig. 3. Mouse movements record sample

Upon completion of computer-based experiment, participants are given a shot survey and they were asked to remember the guidelines they evaluated during the experiment. In addition, users scored and commented the experiment setup (display size and resolution) based on its convenience in daily work.

4 Results

Data collected during experiments have been analyzed according to task types, display sizes and resolution settings.

As expected, Figure 4 shows reading&comprehension response times do not significantly differ on 17" and 40" monitors. 22" monitor experiments resulted in decreased response times. This is a result that requires further analysis and reproducibility tests.

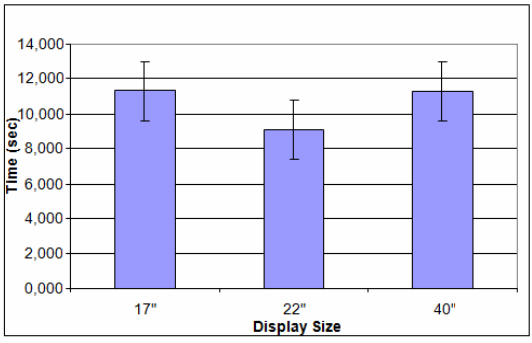

Fig. 4. Reading&Comprehension tasks average response times on different display sizes

On the other hand, Figure 5 shows that as display size increases, subjects became faster in cognitive processing and thus response times have reduced.

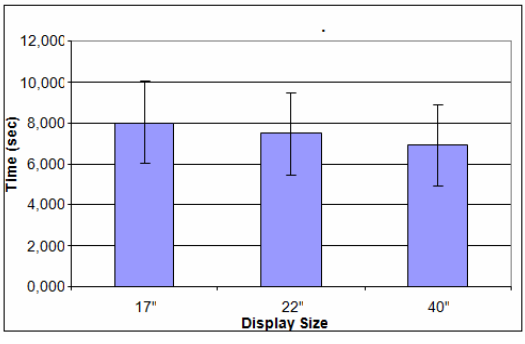

Fig. 5. Visual search&comparison average response times on different display sizes

In Figure 6, it is shown that different screen sizes and resolution levels had no significant effect on overall task success percentages.

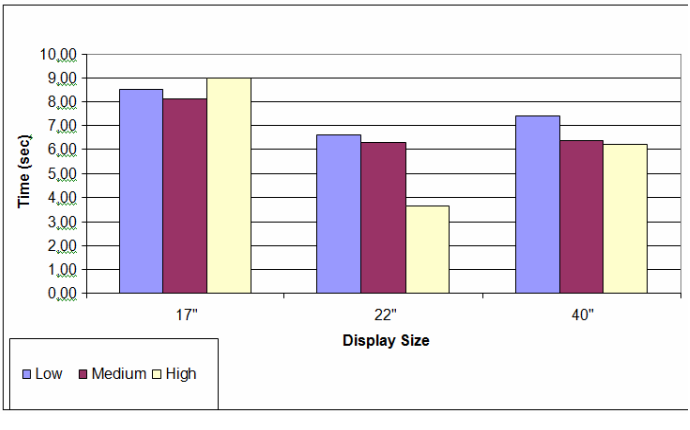

Fig. 6. Search&Comparison task response times on different display sizes and resolutions

With varying resolution levels, lower response times have been observed for search&comparison tasks with higher resolution settings on medium and large displays (Figure 7).

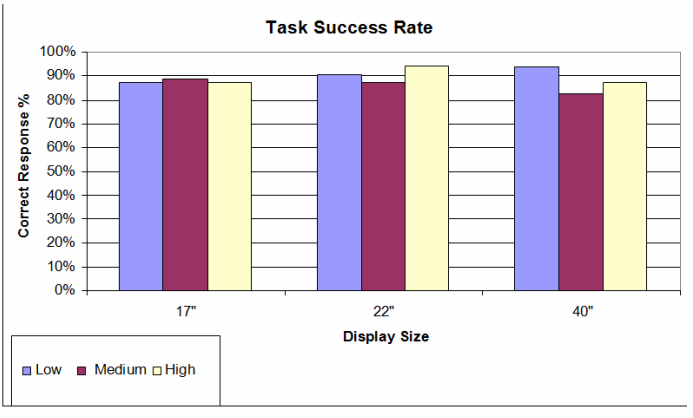

Fig. 7. Task success rates on different display sizes and resolutions

Since performance is both related to the correctness and the timing of the response, correct response per unit of time is used to evaluate the experiment results with a combined performance criteria. Simply, number of correct responses per unit of time is calculated as total correct responses divided by total response time. As can be seen from the Figure 8, resolution and display size has no direct effect on correct response per unit of time, with 22" high resolution, subject have shown the highest performance. However, according to subject surveys, this result may be related to the fact that most participants use 21"-22" monitors on a daily basis, so response times may benefit from subject familiarity.

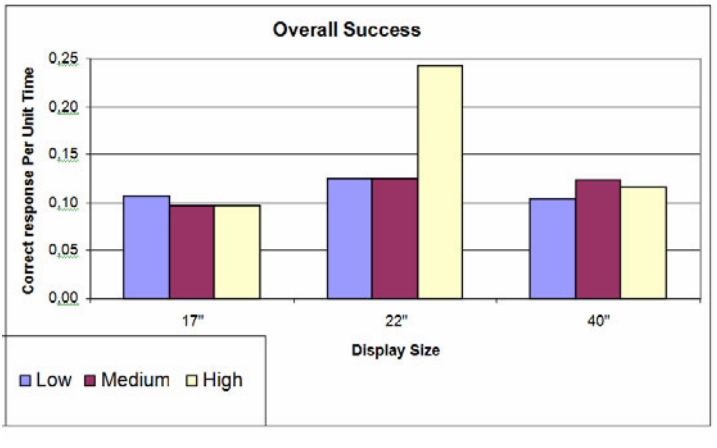

Fig. 8. Overall success rate on different display sizes and resolutions

4.1 Subject Comments and General Observations

Although subjects were not fixed to achieve constant field of view, in the experiment recordings no extreme movements to adjust sitting positions has been observed. This is important since large displays may be criticized for physical discomfort. While participants have not moved towards or away from the screen, they used mouse cursor as an aid to track their focus point. Although the experiments involved use of mouse for only clicking command buttons, subjects on large displays used mouse cursor for other purposes such as to check the alignment of GUI components and to follow text while they are reading.

After the experiments, participants were given a survey to score the experiment setup on a 0-4 scale where 4 is "strongly agree" and 0 is "strongly disagree". The results are given in Table 1 and Table 2.

Table 1. User preferences based on display size

Display Size	Would you use this display for daily work?	Would you use this display for interface design purposes (web/desktop interfaces)?
17"	4,00	3,67
22"	3,95	4,09
40"	2,10	2,40

Table 1 shows participants prefer 17" monitors for daily tasks, while 22" monitors are slightly more preferred for design purposes. 40" large display, on the other hand, has not been considered appropriate for either purpose. Similarly, in Table 2, medium and high resolution is more accepted by the users when compared to low resolution.

Table 2. User preferences based on resolution

Resolution	Would you use this resolution level for daily work?	Would you use this reslotion level for interface design purposes (web/desktop)?
800x600	3,00	3,06
1024x768	3,50	3,67
1280x1024	3,45	3,35

In these surveys, subjects have noted that 40" large display gives the feeling of watching a job done rather than actually doing it, so they have found it difficult to concentrate while working on a large display. Although this contradicts the idea of presence large displays claim to provide, these comments can be attributed to the nature of the given task –evaluating a GUI form- which can not benefit from presence.

5 Discussion

Users who have long preferred standard sized monitors, now prefer the largest displays they can afford and fit into their workspace. Under these circumstances, usability measures and interaction methods should be reevaluated. The fact that research have shown that screen size has direct effect on users performance brings up the problem of determining which screen size is more efficient on certain types of applications. In applications such as e-learning, information retrieval, crisis management and interface design, it may be possible to relate the screen size and user efficiency in order to match tasks with appropriate screen sizes.

While numerous studies have focused on 3D navigation and reading tasks on large displays, less has been done to observe the effects of physical display size on other frequently used skills. Goal behind this study is to observe reading&comprehension and 2D search&comparison processes under different display size and resolution settings. In some cases, results have confirmed the reporting of previous studies. Still, the experiments show that the amount of information subjects remember after testing on a large display is less when compared to subjects who tested on smaller displays. There are experiments that show users of large displays remember more information in 3D tasks. This indicates that cognitive processes involved with different tasks are affected by the screen size in different ways.

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