Effects of the Display Angle and Physical Size on Large Touch Displays in the Work Place

Craig Anslow
School of Engineering and Computer Science
Victoria University of Wellington
Wellington, New Zealand
craig@ecs.vuw.ac.nz

B.L. William Wong
Department of Computer Science
Middlesex University
London, UK
w.wong@mdx.ac.uk

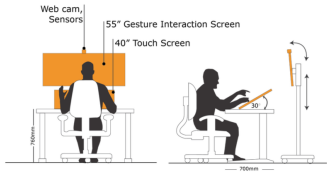
Permission to make digital or hard copies of part or all of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for third-party components of this work must be honored. For all other uses, contact the Owner/Author.
ISS'17, October 17–20, 2017, Brighton, United Kingdom.
©2017 Copyright is held by the owner/author(s).
ACM ISBN 978-1-4503-4691-7/17/10.
https://doi.org/10.1145/3132272.3135080

Abstract
Large display and touch screens are becoming ubiquitous within the work place including multiple display screens. There is limited evidence on what configurations and arrangements of the display screens are most effective for data analysis. We conducted two user studies to understand the effectiveness of the display angle, physical size, resolution, and touch precision for data analysis activities. Our results indicated that touch interaction for data analysis sitting at a workstation was most effective with medium sized screens at 27", high precision touch accuracy (not 4K resolution), and display angle titled at 30^0. The results from our studies can guide other researchers and developers who want to integrate large touch display screens into their work place environments.

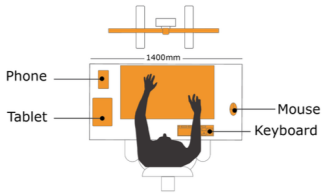
Author Keywords
Large high-resolution displays; touch display; work place

ACM Classification Keywords
H.5.2. [User Interfaces]: Graphical User Interfaces (GUI).

Introduction
The physical size, resolution, and combination of computer display screens has steadily increased over the years to support analytical work. There is limited evidence on what configurations and arrangements of displays are



(a) Two displays configured in X and Y positions.



(b) Birds eye view.

Figure 1: Analyst Workstation Design – consisting of two touch screens, phone, tablet, mouse, keyboard, and 3D sensor to support mid-air hand gestures on the Y display [2].

most effective for data analysis. Early work by Wellner produced a novel workstation to support general purpose work with the Digital Desk which was a tabletop computer, but did not cater for analyst work [8]. Guenther et al. propose using multi-touch interfaces to support cyber security analysis but do not describe the physical configuration of their system [4]. Lischke et al. [6] conducted a study to understand screen arrangements and interaction areas for large display work places, but did not explore or implement any applications. Andrews et al. [1] proposed combining a number of screens together to form a large display wall for an analyst. Both Lischke et al. [6] and Andrews et al. [1] did not consider augmenting their vertical display screen setups with horizontal display screens.

In this paper we explored the effectiveness of large touch displays for analytical work. We conducted two user studies to understand the effectiveness of the display angle, physical size, resolution, and touch precision for data analysis activities. Our results indicated that touch interaction for data analysis sitting at a workstation was most effective with medium sized screens (27"), high precision touch accuracy, not 4K resolution, and display angle titled at 30^0. The results from our studies can guide other researchers and developers who want to integrate large touch display screens into their work place environments to support analytical work.

Police Analyst Workstation Design

Police analysts work to solve crimes which is very time consuming and requires tremendous amounts of data analysis. Current tools lack the ability to effectively explore and visualize data to make informed decisions. We aim to support visual analytics for sense making in criminal intelligence analysis.

Our goal is to design and build novel interfaces that support police analysts to explore information across multiple surfaces using multi-touch gestures for input. We have designed a workstation for police analysts to interact more effectively with criminal intelligence data (Figure 1) [2]. Figure 1(a) shows the individual workspace which consists of a desk, 2 screens, keyboard, mouse, phone and tablet. The 1st display (X) is 40", multi-touch, and located on a table in a 30^0 (adjustable) angle. The 2nd display (Y) is 55" that is primarily designed for 3D mid-air hand gestures [3], but may support multi-touch interaction. The display is located on a stand that allows the height and angle to be adjusted as well as moving the screens together for collaboration purposes. Figure 1(b) shows a birds eye view of the workstation with peripheral devices for cross device interaction. To understand what design decisions for the *X Display* are most effective we propose the following research questions regarding the effect of the display angle, physical size, and resolution.

RQ1: What *angle* of the touch display is most effective for interaction?

RQ2: What *physical size* of the touch display is most effective for interaction?

RQ3: What *resolution* size of the touch display is most effective for interaction?

User Study

We wanted to understand how the physical size and angle of the touch screen (X Display) impacted interaction tasks for data analysis. Under these arrangements and to answer our research questions we conducted two independent studies to compare user cognition, behaviour, and subjective responses using two different types of interactive displays (multi-touch enabled) namely horizontal and titled displays.

(a) 27", 30^0, 2560x1440p.

(b) 32", 30^0, 3840x2160p.

(c) 40", 30^0, 3840x2160p.

Figure 2: Analyst Workstation setup configurations ranging in different form factors for physical size, angle, and resolution.

Study 1 was designed to understand what angle of the X display was most effective for interacting with data visualizations. We recruited five participants (3M, 2F). Three participants were computer science graduate students, one a postdoctoral researcher, and the other a lecturer. The average age was 35 years. The height of the participants ranged from 5 feet 6" to 5 feet 8", while one participant was much shorter at 5 feet 1". To get a better understanding about participants' touch experience we asked some questions to this regard. Only one of the participants used a tablet for work purposes which was the lecturer who used an iPad. None of the participants had used touch screens larger than 23". Besides mobile phones one participant stated that they use a touch screen on a daily basis while another stated monthly basis, and the rest never.

Study 2 was designed to understand what physical size, resolution, and touch technology was most effective for interacting with data visualizations. Study 1 helped inform the design of Study 2 by the identification of what angle of the X display was most effective for data analysis interaction tasks. We recruited 12 different participants (10M, 2F) for the second study to mitigate any learning bias. All participants were computer science graduate students. The average age was 32 years. The height of the participants ranged from 5 feet 5" to 6 feet, while two participants were much shorter at 5 feet 2". Two of the participants used a tablet for work purposes and were developing applications. Seven of the participants have used touch screens larger than 23". Five participants never use touch screens, four monthly, and three daily. Some of the comments about the use of touch screens was related to using them for purchasing items at shops.

To realize our analyst workstation conceptual design we implemented three variations of the workstation (Figure 2). Figure 2(a) shows the *27 inch setup* where there were two Asus 2560x1440 pixel screens, with capacitive touch technology. Figure 2(b) shows the *32 inch setup* where there were two Philips 3840x2160 pixel screens, with optical PQ Labs touch frames. Figure 2(c) shows the *40 inch setup* where there were two Samsung 3840x2160 pixel screens, with optical PQ Labs touch frames.

For each study all participants completed a pre-survey, training with the interfaces, a set of uniform tasks, and a post-survey. The training involved exploring the setups on similar kinds of applications participants would use for the tasks. The studies were performed according to a within subjects design. All participants interacted with the displays under all angle and physical size conditions. We counter balanced the order in which setup the participants started the study with to remove any learning bias. In total each study took up to 60 minutes to complete including introduction and survey time.

For Study 1 the participants performed the tasks on *four* different setups (physical size followed by angle of X display): 27" 0^0, 27" 30^0, 40" 0^0, and 40" 30^0. For Study 1 the participants performed the following touch interaction tasks to support representative data analysis activities:

- T1.1 **Drag items:** drag images around on the screen.
- T1.2 **Move and group items:** move and group objects on a screen with Bumptop[1].
- T1.3 **Maps:** use GoogleEarth[2] to navigate to specific a location.

[1] https://bumptop.github.io/
[2] https://www.google.com/earth/

For Study 2 the participants performed the tasks on *three* different setups (physical size followed by angle of X display): 27" 30^0, 32" 30^0, and 40" 30^0. For Study 2 participants performed the following touch interaction tasks to support representative data analysis activities:

- T2.1 **Maps:** use Google Maps to navigate to a location.
- T2.2 **Move and group items:** explore moving objects around a screen with Bumptop.
- T2.3 **Touch cursor:** touch the screen and see how many touch points are detected.
- T2.4 **Drag items:** drag crime profile images around the screen.
- T2.5 **Order items in a list:** order items in crime locations and types of crimes.
- T2.6 **Move image items:** move people from one crime group profile to another.
- T2.7 **Edit list:** add a crime type and location items to a list.
- T2.8 **Move text items:** move crime items between lists.
- T2.9 **Chart zoom:** zoom and pan on axes in a chart.
- T2.10 **Selection gesture:** select nodes in a graph using a lasso gesture.

We video recorded participants' to capture how they interacted and collected their thoughts when they were thinking aloud. The pre-study survey collected demographic data and participants' experience with touch interfaces. The post-study survey collected perceived effectiveness of the different display screen setups ranging from Very Ineffective to Very Effective, and we also included a NASA TLX survey[3] to understand the mental workload. Follow up interviews were performed to understand how each of the participants interacted during the studies regarding any observed interesting behaviour.

[3] https://humansystems.arc.nasa.gov/groups/tlx/

Results

We present the results from each of the two studies independently. Study 1 considered the angle of the X display while Study 2 built upon Study 1 results and considered the physical display screen size and resolution.

Study 1 – 0^0 vs. 30^0 Display Angle

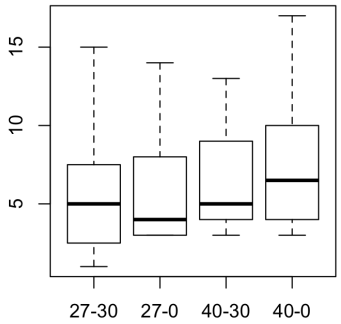
The aim of study 1 was to identify which display screen setup the participants preferred with respect to the angle of the X display. The two options were 0^0 or 30^0, and 27" or 40" physical size. Figure 4(a) shows the perceived effectiveness rated by each of the participants for completing all of the tasks with the different setups (27" and 40"). The results show that the 27" 30^0 (expressed as 27-30) setup was preferred followed by 40-30. The least preferred options was when the X display was at 0^0. For the 27-0 setup it was like having a very large iPad and not so effective when tying to interact with two hands. For the 40-0 setup this was partly due to the ability to reach to the far edge of the screen and corners, and it was particularly troublesome for the shorter participants:

"40 -0 was too big to move the contents around on the screen" – PID 5.

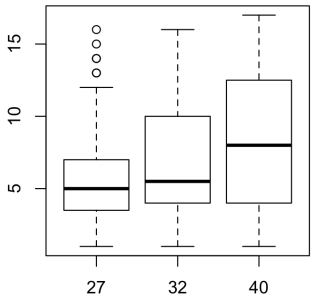
Figure 3(a) shows that the NASA TLX ratings for all tasks. The 27" setups was rated as more effective than the 40" setups, while the 40-0 setup was significantly more frustrating.

Study 2 – 27" vs. 32" vs. 40" Display Size and Resolution

The aim of Study 2 was to identify which display screen setup the participants preferred with respect to physical display screen size and resolution of the X display. The X display was angled at 30^0, based on the results from Study 1. The options were 27" (2560x1440), 32" (3840x2160), and 40" (3840x2160).



(a) Study 1 – NASA TLX.

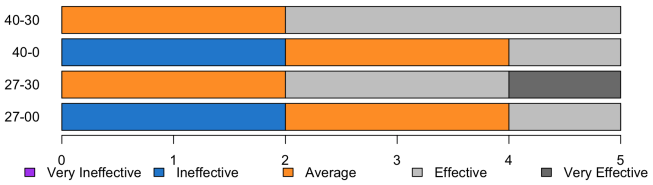


(b) Study 2 –NASA TLX.

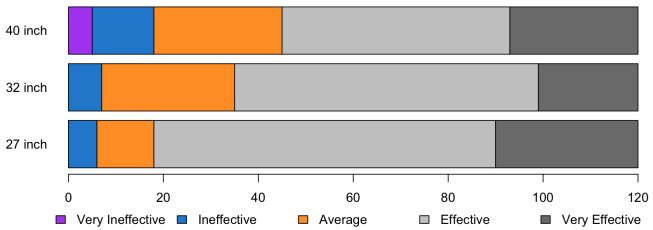
Figure 3: User Study Results – NASA TLX data for tasks in Study 1 (angle for 27" and 40" setups) and Study 2 (size and resolution for 27", 32", and 40" setups).

Figure 4(b) shows the perceived effectiveness rated by each of the participants for completing all of the tasks with the different setups (27", 32" and 40"). The results show that the 27" setup was preferred followed by the 32" and then the 40". The 27" was preferred as it allowed participants to effectively interact and complete all the tasks with the least amount of issues with respect to touch interaction, usability, and reachability.

Figure 3(b) shows the NASA TLX ratings for Study 2. The 27" setup was rated the most effective followed by the 32" and than the 40" setup. The 27" setup was rated significantly more effective than the other setups even though there were some outliers. The 27" setup appeared to perform better in Study 2, while the 40" setup appeared to perform similarly compared with Study 1.



(a) Study 1 – display angle for 27" and 40" setups.



(b) Study 2 – display size and resolution for 27", 32", and 40" setups.

Figure 4: User Study Results – Perceived Effectiveness (Very Effective to Very Ineffective) of the setups.

Discussion

We now discuss some aspects from the results regarding design decisions for an effective touch screen workstation.

Display Angle: The overwhelming preference was for a titled display with the angle to be at 30^0. Some participants commented that the angle of the 30^0 made it more effective, comfortable, and easier to use.

"27-30 is more effective and feels more comfortable" – PID 2.

While others felt that the 30^0 setup was more ergonomically comfortable and easier to work with for prolonged periods of time.

"30^0 was a more relaxing sitting posture" – PID 5.

The angle also impacted the ability to view data from a distance. This was more apparent when for example the 40" screen was at 0^0 as it made it difficult to see items that were at the opposite side of the screen from the participant. This was especially evident from our shorter participants who ended up using a higher chair to see the data on the larger screen setup.

Based on these results we can consider titled displays to be the most appropriate for data analysis activities for a single user at a workstation. This is consistent with earlier results for public museum settings [5] and computer-supported group collaboration [7].

Display Size: Our initial thoughts were that the bigger display size would be more effective for data analysis as more data can be displayed at once. Some participants felt that the bigger display helped them to see more data.

"The bigger the setup the better especially if I have lots of data" – PID 4.

The ability to reach and interact effectively with all positions on the 40" setup either at 30^0 or 0^0 while sitting down was generally too difficult for most participants, hence a smaller physical size was preferred.

"40" was too difficult to reach different items on the screen and move them about" – PID 5.

Display Resolution: The participants valued that they could touch the screen, move and manipulate objects. The 27" setup used capacitive touch technology while the 32" and 40" used optical touch technology with touch overlays. With the 4K resolution for the 32" and 40" setups it was difficult to touch very small items, manipulate them, and move them around the screen. Hence the participants preferred a smaller resolution than 4K to enable them to touch items on the screen.

"I was more effective at moving items around on the 27" setup compared to the 40" due to the resolution" – PID 5.

We did not precisely measure the time taken to complete the tasks as we were not looking for a time and errors measurement. Instead we were concerned with getting qualitative feedback. The majority of the participants performed well at completing the tasks on all the setups, but the resolution did impact the performance. Some participants noted that the 27" made them more efficient at completing the tasks.

"27" I feel I've done the tasks faster" – PID 3.

In summary, our results indicated that touch interaction for data analysis sitting at a workstation was most effective with medium sized screens (27"), high precision touch accuracy (not 4K), and a titled display (angle 30^0). More research is needed to validate these results in other contexts and configurations, and to explore the combination of the X and Y displays together for data analysis activities.

Acknowledgements. This work was supported by Project VALCRI, European Commission Grant No. FP7-IP-608142, awarded to Middlesex University and partners in 2013.

References

[1] Andrews, C., Endert, A., and North, C. Space to think: Large high-resolution displays for sensemaking. In *Proc. CHI*, ACM (2010), 55–64.

[2] Anslow, C., Rooney, C., Kodagoda, N., and Wong, W. Police analyst workstation: Towards a multi-surface user interface. In *Proc. ITS*, ACM (2015), 307–311.

[3] Groenewald, C., Anslow, C., Islam, J., Rooney, C., and Wong, W. Understanding mid-air hand gestures for interactive surfaces and displays: A systematic literature review. In *Proc. BritishHCI*, BCS (2016).

[4] Guenther, J., Volk, F., and Shaneck, M. Proposing a multi-touch interface for intrusion detection environments. In *Proc. VizSec*, IEEE (2010), 13–21.

[5] Ichino, J., Isoda, K., Hanai, A., and Ueda, T. Effects of the display angle in museums on user's cognition, behavior, and subjective responses. In *Proc. CHI*, ACM (2013), 2979–2988.

[6] Lischke, L., Mayer, S., Wolf, K., Henze, N., Reiterer, H., and Schmidt, A. Screen arrangements and interaction areas for large display work places. In *Proc. PerDis*, ACM (2016), 228–234.

[7] Muller-Tomfelde, C., Wessels, A., and Schremmer, C. Tilted tabletops: In between horizontal and vertical workspaces. In *Proc. Tabletop*, IEEE (2008), 49–56.

[8] Wellner, P. Interacting with paper on the digitaldesk. *Commun. ACM 36*, 7 (July 1993), 87–96.