

Designer's Choice: Constructing a Study to Compare Display Interfaces for Early Design Sketching

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Abstract

Digital design tools provide several advantages over pen and paper, including a virtually unlimited workspace and easy design storage, transportation, duplication and access. However, the benefits of new tools are limited by the physical interfaces that are used to interact with them. In this paper, we describe and conduct an exploratory study designed to illuminate strengths and weaknesses of three digital sketching interfaces: Separated Overview+Detail (two standard desktop screens), Separated Focus+Context (one standard desktop screen with one large screen), and Single Large-Screen. The experimental tasks focus on the domain of early sketching and prototyping. Users performed one of three tasks on all three displays. Our results suggest that the Focus+Context system elicits higher user satisfaction, and possibly incurs fewer costs on perception resources and performance. Given the exploratory nature of this study, we close with suggestions for further research directions.

Categories and Subject Descriptors (according to ACM CCS): H.5.2, H.5.4 [Information Interfaces and Presentation]: User interfaces – ergonomics, Evaluation/methodology, Sketching, Single large screen, Overview+detail, Focus+context, Display strategies, Group and organization interfaces, Interfaces – computer-supported cooperative work, Early prototyping

1. Introduction

Imagine, for a moment, an adventurous designer who is ready to embark on a new and exciting project. He is eager to get started but before he does, he must select the right set of tools to use in order to be quick, productive, and creative. In the past, the materials he needed included an appropriate canvas and a set of sketching utensils. Today, his choices are more elaborate and complicated. To be quick, he needs the ability to duplicate and save various stages of his project with ease. To be productive, he must be able to undo and redo changes, to cut and paste from his earlier sketches and to distribute the work to his employer for reviews. To be creative, he needs the ability to view his work quickly from various angles and levels of detail.

That is why the field of digital design is expanding rapidly. A variety of tools exists to help designers express their ideas. Most, if not all, provide the ability to sketch directly in the digital medium rather than requiring a designer to import his paper sketch into the digital domain. Augmenting the traditional workspace with digital tools provides many benefits:

easy storage, sharing and transportation, countless options for editing, and virtually unlimited workspaces. Often a limited commodity on the computer screen, the workspace is where a designer sketches ideas or early prototypes in the earliest stages of design.

With a larger workspace comes the need to effectively navigate and utilize the space. Numerous approaches have been created to overcome the physical limitations of standard desktop computer screens and still allow designers the freedom of space promised by the digital domain.

While research has been done to compare certain aspects of various digital tools, there are three in particular that we wish to better understand. Each one presents the user with a different perspective (or set of perspectives) on his design. The tools' methods for navigation across the workspace, as well as general management of the workspace, also differ. The single large screen environment offers a bigger physical space than the standard desktop computer screen, yet the interaction requires the designer to physically stand and move in front of the canvas. The Overview+Detail system

(dual desktop screens) allows the designer to sit comfortably at the desk while using two distinct views to orient himself in the design environment. The focus+context environment attempts to utilize both a large screen and a desktop computer screen to allow better management of the designer's workspace.

What advantages and disadvantages does each display configuration present to designers performing various tasks? Are specific displays more suited to certain tasks? How does a designer utilize the interface to complete a task? How much time and effort is spent actually working on the task versus manipulating the interface? Must the user spend and potentially waste valuable time trying to understand the interface rather than focusing on the intended work?

2. Contributions

Our primary goal is to develop a study to compare and evaluate three graphical sketching interfaces (mentioned above) in the context of early sketching and prototyping. We have designed a set of sketching tasks that represent realistic early design processes while forcing users to navigate a virtual workspace that is sometimes larger than the physical display.

In this paper, we review previous works that compare various display configurations. We then describe the exploratory study that we conducted and its results. The study serves to help refine our initial experimental design. Resulting lessons from the study highlight points of interest that should be studied in more detail.

We anticipate that a full user study resulting from the lessons in our exploratory study, once completed, will reveal the tradeoffs among the different systems and aid in the creation of more efficient interfaces.

3. Related Work

Various attempts have been made to combine the advantages of paper and pencil with the advantages of digital tools [GUI03,HHT99]. In an effort to create better tools for design, some groups have used an ethnography approach [LM95,LNH*00], observing, interviewing, and surveying designers. Both studies found that the designers begin with simple representations that become more detailed through iterations, an important process that occurs rapidly. Designers indicated that they tend to first think of the overall structure of their product before focusing on details (colors, shades, arrangement etc.). For example, graphical user interface (GUI) designers make use of maps, storyboards, or thumbnails of individual components [LM95]. In our implementation, we take these factors into consideration when designing tasks that would appropriately test the limits of each digital tool.

Several other research groups created tools for sketching

and design on a digital platform [FB04,LTL02]. [FB04] introduced a focus+context screen system while [LTL02] developed a visual language for sketching. Both groups ran experiments to evaluate the advantages of their systems. The tasks described in their studies required designers to complete portions of a provided work.

In particular, [FB04] performed an in-depth evaluation of the focus+context screen system, which is one of the three systems that we examine. Much can be learned from [FB04] in terms of the introductory material about other interfaces (zooming, single large canvas, etc.), as well as about many of the experimental procedures that are applicable to our experimental setup. While egocentric/exocentric view and paper/scroll mapping are not parameters that we address specifically, we take the results of this paper into consideration when deciding the view and mapping specifications of the interfaces for our user study.

Courtyard [THY*94] is a shared large screen overview and per-user individual detail screen system that was built to support cooperative work for monitoring and controlling large amounts of information. It allowed operators to focus on the details of a large system without being overwhelmed by the amount of information presented on a large display. The implementation of Courtyard parallels the separated focus+context system mentioned previously; however, it has not been studied in detail and its usability potential, as compared to other systems, is unknown.

In addition, a number of zoomable interfaces have been implemented and studied in prior years [GF04,KBPO2,KF03,RCS04]. Research has been conducted on navigation patterns and usability in various configurations. [KBPO2] compares zoomable interfaces that have an overview versus those that do not have an overview. [GF04] compares zooming without an overview to fisheye and panning. Results suggest that a zoomable interface with an overview is more desirable than a zoomable interface without an overview. However, zooming without an overview is more desirable than both fisheye and panning. These studies applied zooming in specific domains, including reading and navigation of maps. Our study further strives to investigate usability of a zooming technique with overview (overview+detail) in the context of early sketching as compared to a large screen and focus+context implementations.

Three articles [ELL02,FS91,TGS*03] deal with implications of different types of large, non-conventional computer displays. [FS91] evaluates a head-mounted display integrated with a flat-screen display that serves as a high-resolution "sweet spot." The article's conclusions on the small- and large-screen system provide some insight for our comparable system, but the article's age and its conceptual differences (using a head-mounted display) cause its findings to have only limited relevance to our work. [ELL02] compares a standard monitor, a tablet, and a "digital desk"

(a single large display). Regarding the large display, the primary difference between this work and ours is that our single large display interface will use a vertical SmartBoard that requires the user to stand while operating it. In contrast, [ELL02] used a slanted, easel-type display where the user must be seated. The article found that the height of the user and the sensitivity of the pens had a significant effect on the user's satisfaction of the "digital desk." The results of our study may be affected by these and similar factors.

The study also found that while the large display had a significantly lower number of pixels per square inch, the benefit of the larger overall display space compensated for this discrepancy. Given the non-conventional resolution of the SmartBoard display, our study pays special attention to preserve coherence between different setups and takes the relative resolutions and screen dimensions of our small- and large-screen displays into account as we discuss the advantages and disadvantages of each environment.

Additionally, [TGS*03] have conducted a study into the effects of large screens on spatial orientation of users in textual and graphical environments. While there was no significant difference in performance on a reading comprehension task, users performed significantly better on a spatial orientation task when using a large projected display as opposed to a standard desktop monitor with a similar visual angle. We anticipate this work to complement our own research especially when comparing overview+detail and focus+context setups.

To address the need of a high-resolution work area within a lower resolution workspace, [BGS01] implemented a "fisheye" focus+context screen technique. The work presents a physical prototype of the approach and concludes with an informal user study. Interestingly, to date, fisheye views have not yet entered the mainstream for managing large workspaces. It should be noted that the term "focus+context" refers to different physical layouts in [BGS01] and [FB04]. Our own implementation lies closer to [FB04] due to the relatively unconventional setup used by [BGS01] that could not be widely and rapidly duplicated.

Further, an overview+detail, a fisheye, and a linear interface have been investigated when visualizing electronic text documents [PLV00]. The study suggests that the overview+detail system is most effective and most preferred by users when navigating text onscreen. Our goal is to extend this research into the sketching domain and compare these interfaces (minus fisheye) when navigating and creating sketch-based components. We deliberately leave the fish-eye visualization technique out of consideration due to the fact that it is the only technique that introduces distortions into a user's field of view [BGS01].

DEMAIS is an informal sketching design tool. [BK03] evaluates it as a tool for multimedia designers to communicate design ideas to others. The authors compare DEMAIS to two common methods of performing the same task:

Macromedia's Authorware software, and traditional pencil and paper. While DEMAIS is not concluded to be better than the others in all aspects of multimedia design, it does provide certain advantages. Our work parallels [BK03] in that both are efforts to learn about the specific aspects that make some design tools better than others. However, these two studies differ in focus. DEMAIS is a specific multimedia design tool that operates in a single screen space with limited ability to change views. Its functionality is also specific to multimedia design. Our work focuses more on early design sketching in general. It does not attempt to evaluate a set of software packages, but rather different interfaces (combinations of single- and multi-screen environments) to determine the advantages and disadvantages of each. The tasks used in [BK03], however, provide a good representation of common design tasks that we parallel in our study.

Our study employs a number of techniques to measure usability characteristics of different interfaces. Landauer [LRP95] and Baecker [BAE00] provide a good basis for selecting appropriate methods in experimental setups. Both go into detail about the specific steps one must take when designing and evaluating an experiment. Several other sources [GC95,MAC95] touch on some considerations that are important to us as well. They describe an appropriate breakdown of design phases and elaborate on the steps each design phase might involve.

4. User Study

We created a study to evaluate the benefits and drawbacks of three interfaces for early design tasks.

- Single Large-Screen (Figure 3)
- Separated Overview+Detail (Figure 4)
- Separated Focus+Context (Figure 5)

Our focus is to address concerns that a user might have when choosing an interface for work in the domain of early design and sketching. Which interface is the most accommodating, adaptable, and affordable in this domain? What are the specific advantages and disadvantages of the different interfaces? Are certain display configurations better suited to certain tasks?

In order to answer these questions, we conducted an exploratory study to preliminarily investigate the advantages and disadvantages of the three display configurations. The results obtained from this study will be used to direct further work in this area. They will also refine the design and structure of a full user study that will determine which interface(s) is most effective for early design tasks.

In the current study, we direct our attention to the users' interactions with their tasks and the systems they use. Do the interfaces influence how users complete their tasks? Are users able to work on their tasks without significant overhead, or must they spend considerable time and effort trying to orient themselves in the workspace?

4.1. Tasks

In our study, we are comparing three display configurations using three different tasks. The tasks are representative of those a user may typically perform in the studied domain. Each task is performed three times, once with each of the three sketching interfaces (see Figure 1). Due to time constraints, each user only performed one task.

A different role-playing scenario is used for each of the three interfaces to prevent the users from becoming experts in any given scenario. Users are randomly assigned to roles, scenarios and tasks.

Every experiment requires two users: one to perform the task (either a sketcher or an arranger, depending on the task), and one to play the role of a third party (a reviewer). The sketcher/arranger performs his task while the reviewer becomes familiar with his role, the given task, and the particular interface, in another room. In the cases where the sketcher/arranger is provided pre-drawn material for the task, the reviewer also has a chance to review it during this time. The sketcher/arranger then uses the interface to explain his work to the reviewer.

		INTERFACES		
		Single large screen	Overview+detail	Focus+context
T A S K S	Freeform sketching	Scenario 1, user pair A	Scenario 2, user pair A	Scenario 3, user pair A
	Annotation	Scenario 4, user pair B	Scenario 5, user pair B	Scenario 6, user pair B
	Storyboard arrangement	Scenario 7, user pair C	Scenario 8, user pair C	Scenario 9, user pair C

Figure 1: Task/interface breakdown.

4.1.1. Pre-Experiment

Prior to each task/interface combination, the user is given a brief introduction to the particular interface that he is about to use, along with the list of keyboard commands. The sketcher/arranger then has three minutes to perform a warm-up task to become familiar with the system before the actual experiment begins.

4.1.2. Task 1 - Annotations and Design Review

In this task, the sketcher and the reviewer are given role-playing scenarios for an annotation task. The three scenarios are:

- The sketcher is a board game designer and needs to annotate a partially completed board game (Figure 2).
- The sketcher is instructed to allocate space for an office building by appropriately annotating the floor plan.

- The sketcher is given a partially completed, illustrated set of instructions for making scrambled eggs, and he is asked to complete it by annotating it.

For each experiment, the scenario description and a pre-drawn sketch in black ink are presented to the sketcher. He is given 15 minutes to add as many textual and graphical annotations as he wishes, as long as he meets the requirements of the scenario. The sketcher's annotations appear in red. Examples include drawing arrows, crossing out sections, adding comments or questions, and sketching freely. After each task, the sketcher and the reviewer are given three minutes to discuss the sketch and possible alternatives.

4.1.3. Task 2 - Arrangement of Unordered Data

In this task, we present the arranger with a description of a role-playing scenario for a storyboard arrangement task. The three scenarios are:

- A set of comic storyboards is out of order. The arranger is asked to examine each storyboard and put them back in the correct order.
- A set of storyboards representing the cloud/water cycle is out of order. The arranger is asked to examine each storyboard and put them back in the correct order.
- A set of storyboards representing seasonal tree/flower changes is out of order. The arranger is asked to examine each storyboard and put them back in the correct order.

We present the arranger with 15 pre-drawn, randomly arranged storyboards in a 5x6 checkerboard layout on the screen. The arranger's task is to logically assemble them by rearranging them on the screen. He does this by clicking once to select the source cell and clicking again to select the destination cell, which switches the content of the two cells. The source must be a storyboard, but the destination can be a storyboard or a blank space. After the first click, the selected storyboard is highlighted by a dark rectangle. The arranger is allowed to utilize the empty spaces of the checkerboard as holders for the storyboards that he wishes to rearrange. The end goal is to have an ordered series of storyboards with no gaps between each one. The focus of this experiment is not to determine whether the arranger has come up with a perfectly correct ordering, but rather to see how well he can manipulate the objects on the screen and communicate his work to the reviewer (we stress this to the arranger during the pre-experiment phase). The arranger has 15 minutes to complete each task. After each task, the arranger and the reviewer are given three minutes to discuss the arrangement and possible alternatives.

4.1.4. Task 3 - Freeform Sketching

In this task, the sketcher is presented with a description of a role-playing scenario for a freeform sketching task. The three scenarios are:

- The sketcher is a consultant who develops and presents smoothie recipes to cafes and restaurants. He needs to create storyboards to visually and textually illustrate the process of making a particular variety of smoothie.
- The sketcher is a children's book author and has been instructed to create storyboards to depict the life cycle of a butterfly.
- The sketcher has been contracted by an elementary school to sketch a depiction of the sun, the nine planets, and other interesting objects in our solar system.

In this experiment, the sketcher is asked to sketch freely for 15 minutes. In the first two scenarios, we instruct him to create approximately seven storyboards (the sketcher is free to decide the dimensions of the storyboards). In the third scenario, he is instructed to use the entire workspace to create one single sketch. After each task, the arranger and the reviewer are given three minutes to discuss the sketch and possible alternatives.

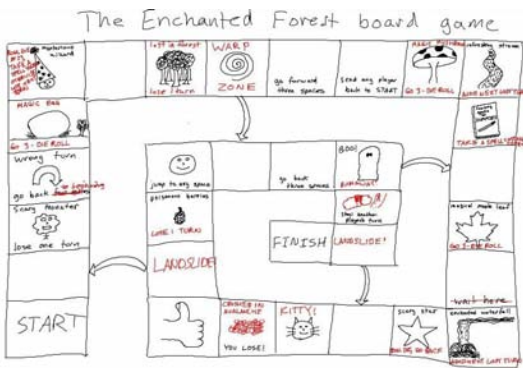


Figure 2: Screen shot from a sample annotation task. Annotations made by the user are shown in red.

The common objective across all tasks is to tax the screen space such that the user must perform some workspace navigation (i.e. changing the current view) to successfully complete the tasks. This is particularly relevant to the conditions with two screens, where the secondary display provides an overview of the entire workspace. If no detail were lost in this situation, there would be no need to change the current view on the primary screen by zooming and panning. If there were no need to change the current view, a secondary screen providing a perspective of the entire workspace would not be necessary. Therefore, whether the task is storyboard arrangement, annotation of an existing design, or freeform sketching, we designed the task scenarios with sufficient detail to purposely force the user to zoom and pan repeatedly to complete the task.

4.2. Materials

4.2.1. Single Large-Screen

The single large-screen display is a SmartBoard with a resolution of 1360x768 (the actual used screen space for the study was 1024x768). This is the primary and only display in this setup. It supports direct pen-based input, and the user must occasionally take steps to reach different areas of the screen.

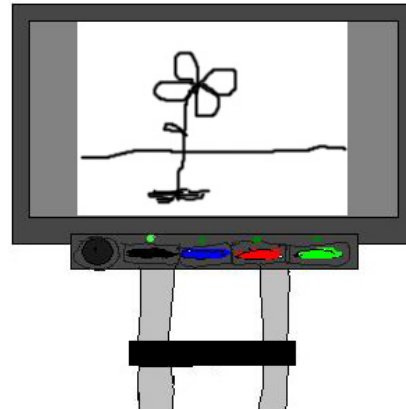


Figure 3: Single Large-Screen interface.

The interface does not allow panning or zooming; the viewable area of the screen is fixed to always show the entire workspace. A compelling argument for allowing panning and zooming is that if we have designed the tasks to specifically tax the screen space, a fixed perspective presents a great disadvantage. However, we chose the fixed view because keeping a perspective of the entire workspace is very important in these tasks, regardless of how much detail may be visible. Allowing a single screen to pan and zoom would cause the user to quickly lose perspective of his overall workspace, and we feel that this is the most important aspect to maintain for all interfaces tested.

4.2.2. Separated Overview+Detail

The separated overview+detail interface uses two screens side by side: a WACOM Interactive Pen Display with a resolution of 1024x768 (the "detail") serves as the primary display, while a flat LCD screen with a resolution of 1024x768 (the "overview") serves as the secondary display. Users only interact with the detail screen, using a stylus and seven keyboard commands (pan up, pan down, pan left, pan right, zoom in, zoom out, and undo). The overview screen provides a fixed view of the entire workspace, with a blue rectangle that continually updates to show the current view of the detail screen.

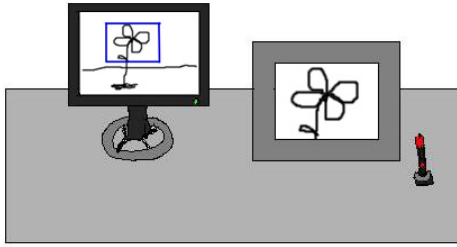


Figure 4: *Overview+Detail interface.*

4.2.3. Separated Focus+Context

The separated focus+context interface uses one small screen as the "focus" (the same WACOM Interactive Pen Display as mentioned above), and one large screen (the same SmartBoard as mentioned above), as the "context." The focus screen is equivalent to the detail screen (primary screen) in the overview+detail setup, with the same keyboard commands to pan, zoom and undo. The context screen is equivalent to the overview screen (secondary screen) in the overview+detail setup, except that it is the physically larger SmartBoard and is placed behind the focus screen, instead of a side-by-side layout. The same blue rectangle on the context screen represents the area of the workspace that is currently being viewed in the focus window.

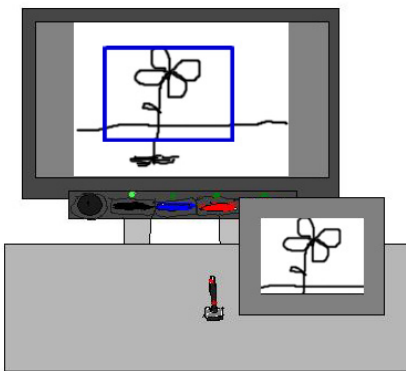


Figure 5: *Focus+Context interface.*

All of these interfaces are viable options for sketching and early prototyping tasks. While several other alternatives such as a fisheye/telescoping system are available, they employ image distortion techniques and are thus not well suited for a direct comparison with the aforementioned systems. We do not include paper and pencil in the study as it is not necessary for comparing the systems to each other.

The implementation of the three interfaces and three experimental setups was created by modifying an existing soft-

ware tool called SCWID. It was designed to allow simple, multiple-screen, multi-view sketching across a network. We adapted it to handle a setup that provided all the functionality needed for our tasks.

4.3. Users and Procedure

Six users, five male and one female, voluntarily participated in our exploratory study. With the exception of one English major, all participants were either undergraduate- or graduate-level computer science students. All participants were regular and proficient computer users. The participants were not compensated monetarily, but refreshments and drinks were provided.

The users were divided up into three pairs. Each user pair was introduced to each other and to the researchers. They then received a brief description of the study and were given the opportunity to ask questions. As previously mentioned, role assignments and task-condition pairings were chosen at random. The reviewer was then taken to a separate room, and both the sketcher and the reviewer were given role-appropriate task descriptions. At that point, the sketcher was provided with a warm-up task to familiarize himself with the interface. The experiment began once the sketcher successfully completed the warm-up task.

After completing each task and subsequent review session, both users in the pair were asked to fill out a questionnaire specific to the particular task/interface combination that they had just completed.

4.4. Measurements

Metrics were recorded during the user sessions. Of note are the total number of strokes drawn during a task, the amount of time spent looking at each display during a task, and the number of times users switched focus from one display to another. The total number of strokes was recorded automatically by the system, while the focus switching was observed afterwards using a videotape of the session.

Users filled out surveys for each display configuration. Questions probed users' satisfaction with the interfaces as well as perceived ease of use (regarding completion of the task, ability to view content, and ability to navigate).

During user sessions, a researcher also sat at a moderate distance to observe user behavior and take notes.

5. Results

Given that our study was exploratory and was designed to refine our experimental design, we did not perform a detailed statistical analysis. There were, however, several observed effects that warrant further study.

- In both sketching tasks (free form and annotation)

users consistently created more strokes when using Focus+Context than when using Overview+Detail. (Figure 6)

	Freeform	Annotation
Focus+Context	317	445
Single Large-Screen	151	273
Overview+Detail	215	187

Figure 6: Number of marks drawn by the user during the Freeform and Annotation tasks. Users consistently made more individual marks when using the Focus+Context display configuration than any other.

According to [TGS*03], a larger display provides a "greater sense of presence" that prompts better performance from users on spatial orientation tasks. Our results seem to further confirm [TGS*03] and suggest that having a larger display as the secondary screen provides users with a better sense of workspace orientation, allowing more efficient navigation and more work completed. Further study can more fully identify the implications of such user behavior.

- In both the Focus+Context condition and the Overview+Detail condition, users spent more time looking at their primary display than at their secondary display. (Figure 7)

	Freeform	Arrangement	Annotation
Focus+Context	12.10	1.71	3.82
Overview+Detail	8.08	81.50	4.27

Figure 7: Ratio of time users spent looking at their primary display versus their secondary display. All users spent more time looking at their primary displays in all conditions and with all scenarios.

This is likely because users can see the details of their work better in their primary display, which has zooming capabilities.

- More specifically, in two of the three tasks, attention on the primary screen is notably higher in the Overview+Detail condition.
- Users in the same two of three tasks also switched their focus between primary and secondary displays more frequently while using Focus+Context. (Figure 8)

	Freeform	Arrangement	Annotation
Focus+Context	17	14	45
Overview+Detail	22	5	21

Figure 8: Number of changes in visual focus. Each number is the sum of single movements in either direction (primary to secondary or vice versa).

The difference in the number of focus shifts is especially significant for the arrangement task. Switching between displays requires physical effort, which requires time. Additionally, the user must orient himself on the workspace after a switch from one display to another, incurring further time cost and breaks concentration.

Observations from the study suggest that Focus+Context incurs a smaller usage cost on the user than does Overview+Detail (allowing the user to employ the larger secondary display more freely). This makes the Focus+Context configuration viable and effective for large design projects.

The focus-switching trends and higher use of the secondary display in Focus+Context might arise due to an overlap of form and function of the Overview and Detail screens. Generally, a user is likely to use the secondary display to survey completed work and work left to do, as well as to move through the workspace. However, in our Overview+Detail setup (side-by-side displays), the secondary screen is comparable in size and level of detail to the primary screen when it is fully zoomed out. Thus, it is possible that the user is not as compelled to use the secondary display.

The effect could also show that the Focus+Context system is more confusing than the Overview+Detail system, and users must look up at the context more frequently to regain their bearings. This does not seem likely, however, due to the fact that Focus+Context received on average higher satisfaction ratings than Overview+Detail.

The effect is reversed in the Freeform condition, likely because the specific task scenarios readily afford particular display usage behaviors. In the specific situation of this user session, two free sketching task scenarios asked the user to section off the canvas into storyboards, while one did not.

The Focus+Context condition used a scenario with storyboards (Butterfly time-lapse free-form sketch). The user first sectioned off the canvas by drawing rectangles. He then zoomed the Detail view to the first storyboard, drew the storyboard, and proceeded to draw each remaining storyboard one by one. By fitting and centering each storyboard onto the primary display, the user drastically lessened the need to zoom, and panning was only required to switch from one storyboard to another. This decreased the user's need to move

across the workspace, also reducing the need to use the secondary display for navigation.

Other less noticeable effects may also have partially resulted from the specific scenario of the task performed by the user (rather than an effect of the display configuration). In a larger full-scale study, each scenario will be run multiple times on each display, eliminating these uncertainties.

5.1. Surveys

Surveys filled out by users regarding display setups suggest that both two-screen setups are preferred to the single screen setup, and the focus+context setup (with the large context screen) is more comfortable for collaborative parts of the tasks. In all survey items, Focus+Context received the most positive feedback while Overview+Detail was either even with or slightly higher than Single Large-Screen.

These initial results suggest that all three configurations can be effective. Having the use of a large secondary screen, however, appears to be favored by users. Benefits are especially noticeable during collaboration, when multiple users are viewing the displays. Having a larger screen enables both users to view the same screen without the discomfort of sharing limited space around a small display. Both users can lean back or forward at the same time. Given the prominence of the larger display, there is also less confusion as to which monitor is the current focus of the other party.

5.2. Additional Observations

During user sessions, we also observed effects that were not addressed in surveys or previously determined measures. With the Single Large-Screen, users easily negotiated space usage during collaboration. Because of its size, however, users occasionally had to bend down or reach up beyond comfort to complete tasks. This physical limitation, combined with the poor resolution and poor pen input tracking of the technology, make the Single Large-Screen a questionable option for designers.

In Overview+Detail (dual small screens), users looked at the secondary display while panning and zooming but focused more on the primary display for non-navigational activities. When both the sketcher and reviewer were looking at the work, however, there was sometimes confusion regarding which screen to use. In one case, the speaker (either the presenter or the reviewer) tended to use the screen directly in front of himself to discuss and point (Figure 9). This forced the listener to shift his gaze away from his preferred screen. The observation suggests that Overview+Detail can cause confusion when the workspace involves collaboration.

The Focus+Context system encountered similar usage patterns and confusion, but users were consciously more inclined to use the large secondary screen to discuss the work.

The sketcher tended to keep his focus on the smaller primary screen, perhaps out of habit, but discussion always moved to the large screen. Combined with the previously discussed survey responses and measured usage trends, Focus+Context provides the benefit of using dual displays while overcoming the limitation of having only two small screens.

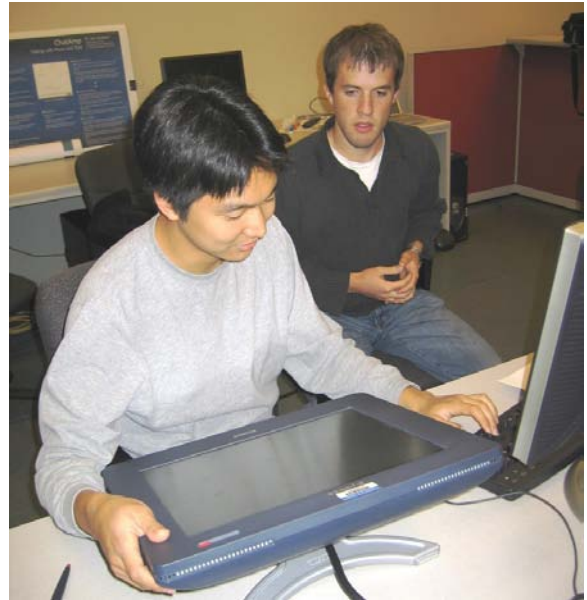


Figure 9: A sketcher and a reviewer using the Overview+Detail display configuration.

6. Conclusion

Designers are faced with an ever-increasing set of options to augment their workspace. Digital tools provide many advantages but also many ergonomic and interface barriers. In terms of available design space, virtual workspaces are effectively limitless. However, our interaction with them is limited by the physical interfaces that provide access to them. Solutions include single displays and combinations of displays of various sizes. Some options, such as single large displays, can be costly. Other solutions impose difficulties such as the negotiation of personal space among multiple users during collaboration over a small screen. Of the myriad tools available and possible display configurations, how does a user make an educated selection? How can a designer make the most cost-effective and work-efficient decision?

In this paper, we have initiated a study to help answer these questions. The exploratory study helped us to refine our experimental design. During observation of user sessions, we determined that future work should include measures for subjective evaluation of quality and creativity of

the work, as well as users' physical proximity to each other and to the displays.

While the single large screen alone provides some benefits, given other options available today, it is not ideal for most design task situations. The large screen is physically large, but its resolution is comparable to a typical small screen: the pixels are simply larger, meaning that it provides no more information than a standard display. This results in poor direct stylus interaction as compared to small-screen stylus interfaces.

Zooming can be enabled for the single large screen interface to provide access to more detail, but the overall context view of the canvas is lost. Ergonomics is also a concern when interacting with large screens. Regardless of height, users need to physically reach or bend to use outlying sections of the display. Direct stylus interaction with a small screen on a desk, where the user can work from a sitting position, seems to be better. A secondary screen, of any size and used for output only, can be used in conjunction with the primary screen to provide a persistent context view while the detail work is done with a stylus on the primary screen.

The issue now lies in the secondary screen. Our study offers two possibilities: a focus+context system where the secondary screen is a large screen (the same as described above in the single large screen system), and an overview+detail system where the secondary screen is a typical monitor. As previously mentioned in the Results section, based on both user questionnaires and our observations during the study, it seems that the focus+context system was more effective and preferred for both the individual user task sessions and the collaborative review sessions.

The strong drawback to Focus+Context, as it appears in our study, is its cost. Currently, the large display (SmartBoard) costs thousands of dollars, while a normal monitor for the overview+detail is only a few hundred. So how does one choose between lower cost and a seemingly better system? Perhaps there is a compromise. We did not explore this setup specifically, but a digital projector and screen could replace the large display in the focus+context system. The cost of that type of system would still be greater than the overview+detail system, but it would be significantly less than the focus+context system in our study.

The full scale user study to follow this exploratory one should include that system; if it is concluded that the large (SmartBoard) screen offers no significant advantages over the projection screen, that type of focus+context system may be a viable compromise between the monetary cost and effectiveness of the systems that we studied. However, a full scale user study incorporating lessons learned is needed to reach more substantial conclusions about the particular display configurations and how they affect users, workflow, and resulting works.

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