The LunchTable: A Multi-User, Multi-Display System for Information Sharing in Casual Group Interactions

Miguel A. Nacenta[1,3], Mikkel R. Jakobsen[2], Remy Dautriche[3], Uta Hinrichs[3], Marian Dörk[3], Jonathan Haber[3] and Sheelagh Carpendale[3]

[1]University of St Andrews
United Kingdom
mans@st-andrews.ac.uk

[2]University of Copenhagen
Denmark
mikkelrj@diku.dk

[3]Innovis Group, University of Calgary, Canada
Remy.dautriche@caladan.fr,
{uhinrich, mdoerk, jmhaber, sheelagh}@ucalgary.ca

ABSTRACT
People often use mobile devices to access information during conversations in casual settings, but mobile devices are not well suited for interaction in groups. Large situated displays promise to better support access to and sharing of information in casual conversations. This paper presents the LunchTable, a multi-user system based on semi-public displays that supports such casual group interactions around a lunch table. We describe our design goals and the resulting system, as well as a weeklong study of the interaction with the system in the lunch space of a research lab. Our results show substantial use of the LunchTable for sharing visual information such as online maps and videos that are otherwise difficult to share in conversations. Also, equal simultaneous access from several users does not seem critical in casual group interactions.

Categories and Subject Descriptors
H5.2. Information interfaces and presentation: User Interfaces – Graphical User Interfaces (GUI), Input devices and strategies.

General Terms
Design, Human Factors.

Keywords
Multi-display user interfaces, large displays, casual interaction, surface computing, multi-touch, multi-user.

1. INTRODUCTION
Mobile devices allow people to access information via the Internet in almost any location and situation; it is not uncommon to observe people checking facts on their smartphones during casual conversations, for example, during lunch at work. Access to information anywhere/anytime may contribute to casual group interactions. However, the design of mobile devices makes them less than ideal for interaction in groups: the screens are so small that information can barely be shared among more than two people, they can be comfortably interacted with by only one person at a time, and their private nature discourages sharing.

Large displays, in contrast, are easily shared by multiple users: they can present large amounts of information and are large enough to be comfortably used by several people at the same time. Large displays have been studied in public [17] and semi-public [3] settings, but little is known about their support for group conversations in casual settings. Our observations of non-mediated casual interactions at a research lab, where multiple people regularly gather around a table for lunch, triggered a number of questions: How can a large-display interactive system be designed to support group conversation in casual, semi-public settings (e.g., lunch time breaks at a workplace)? Which factors and considerations can guide such a system's design? How will people interact around and appropriate such a system?

We present the LunchTable, a multi-user multi-display system designed to enrich the ways in which people interact with one another and with digital media in a casual, semi-public social setting: during lunch in the workplace (see Figure 1). Our design aims to enable equal, simultaneous access for all participants, to support sharing of rich information, and to provide simple and unobtrusive interaction mechanisms adapted to a lunch setting (i.e., with food and other objects on the table). Our prototype system uses a two-meter wide vertical display with 4.7 Megapixels for showing rich visual data. An interactive multi-touch display embedded within a regular lunch table is used for controlling the information on the vertical display.

This paper contributes: a) the design of a multi-user, multi-display interface to support casual conversations during lunch breaks, b) a description of a multi-display system that implements the interface in an existing lunch space, and c) our reflections on the design based on results from a weeklong observational study of its real-life use.

Figure 1. A group of people at the LunchTable.

2. Related Work
The literature on public displays, situated displays, and multi-display environments is extensive; in this section we provide an overview of relevant work, focusing on research about semi-public displays and casual group interaction.

2.1 Public, Semi-Public and Situated Displays
The potential of interactive digital displays to support human activity was identified early on. Notable examples include Xerox's Liveboard [5] and Tivoli [26] based on a touch enabled vertical display, as well as Colab [29] and GroupSystems EMS

PerDis 2012, June 04 - 05 2012, Porto, Portugal
Copyright 2012 ACM 978-1-4503-1414-5/12/06…$10.00.

[24] that combined public and personal displays. These systems, as well as many that followed [e.g., [6],[15],[18],[30],[32], are mostly focused on specific activities such as work meetings, design tasks, programming, and learning.

A recent wave of large-display and multi-display research has focused on supporting more opportunistic scenarios, often removed from the workstation or the meeting room. For example, semi-public display systems have been developed to support people's information needs when not at the desk [28] or to maintain awareness of small groups of people that are co-located or distributed [7],[13]; Müller et al. developed an information flow model for relevant information on public displays (e.g., announcements); interactive [4] and ambient displays [11] located in well-traveled locations of organizations have been designed to facilitate non-intrusive sharing of information; and multi-touch tables have been embedded in the home to enable the collaborative control of media [31]. Another direction of research has also explored the installation of large displays in public locations that allow strangers to interact with information and, in some cases with each other [e.g., [17],[11],[20].

Previous work relates to the LunchTable system in many ways, such as the interactive configurations (multi-touch, multi-display, multi-user), and the casual settings. However, our work differs from this previous work in that we focus on synchronous co-located meetings (not general awareness) between specific groups of people in a scenario where computer use is not the main activity (the people in our group use the system to support information access while their main activity is lunch). These differences impose specific constraints on our design.

2.2 Displays Supporting Casual Groups

Probably the most related to our work is the Dynamo surface [16], a large display system designed for shared sociable spaces. Dynamo was deployed in the common room of a high school, where 17-19 year olds share time between classes, including during lunch time. A study found that the display was mostly used for sharing video and images. Both Dynamo and the LunchTable support semi-public use and provide multi-user input. However, we focus on smaller groups of people, on synchronous interaction, and on sharing of information from the Web.

TViews [21] is an interactive tabletop designed for social interaction in a home environment. The scenario of TViews, where several people sitting at a table in a home, is close to ours but different to a research lab, and their applications were mostly focused on games and picture sharing (not information access).

Finally, there has been work on developing interfaces for food-related situations such as ordering at restaurants [e.g., 1].

2.3 Guidelines and Relevant Studies

In addition to the extensive list of work on public, semi-public and situated displays and the studies that often accompany those systems' development, some work is emerging that discusses and distills lessons learnt and design guidelines discovered across multiple projects. We derived useful guidance from Huang et al.'s Secrets to Success and Fatal Flaws [14], Brignull and Rogers' studies on how people interact with large public displays [3], Hornecker et al.'s analysis of shareability [12], and Wallace and Scott's contextual design considerations for tabletops [33].

3. DESIGN OF THE LUNCHTABLE

The design of the LunchTable system was in part motivated by our informal observations of casual conversations in our own lab: discussions often evolve during lunch breaks around a large variety of topics, and people often use their phones during these casual conversations to consult the Internet (e.g., Wikipedia) about the current discussion topic. However, information on a phone's small display is hard to share with others at the lunch table. Our motivation with the LunchTable is to better support information sharing during casual conversations.

3.1 Design Goals and Constraints

The main design goal for the LunchTable is to help people access and share information in a common social situation such as lunch. Based on the problems identified earlier, and drawing on findings in related work, we derived the following goals:

Equal, simultaneous access: The interface should enable equal participation, providing simultaneous access for group members to influence the presentation of information. Single-user input implies turn-taking, and Marshall et al. [19] found that multi-user touch input increases equity in participation with a shared tabletop display. Thus, to reduce the need to negotiate for access, the system should allow multi-user input.

Sharing of rich visual data: The interface should allow rich visual data to be shared among the group; the small screens of mobile devices are not well suited for showing rich data or for sharing among more than a few people.

***Simple, sit-down-and-use interface*:** The interface should be easy to learn and use for a wide variety of people using the system, reducing the risk of embarrassment that might keep people from using new systems in semi-public situations [3].

Avoid clutter: A collectively managed interface might be susceptible to clutter; the interface design should avoid clutter.

We also had to work with constraints derived from the scenario and the resources available:

Reduce interference with lunch: The system should not interfere with the key activities in the space; people must be able to eat lunch and bring things to the table.

Stable and easy to maintain: The system should be robust enough to work in the lunch environment, where people might spill fluids.

3.2 Design Decisions

We collaboratively sketched the system and its interface given the above goals. The system was then built iteratively, with several cycles of implementation, testing and informal critiques. Below we describe the decisions made throughout the design process.

After considering different configurations, we focused on large shared displays and did not explicitly include mobile devices. In a future iteration, considering the incorporation of cellphones and tablets is a promising extension to our setup. We decided to use a large vertical wall display to present information and a horizontal multi-touch display for input and window management.

The vertical display supports *sharing of rich visual data*, while the horizontal display supports *equal access* (everybody sitting around the table would be able to touch the interactive area), *a simple interface* (people are increasingly familiar with touch interfaces), and also *reduce interference with lunch* because it does not require additional devices (pens, handheld devices, keyboards). These considerations also reflect findings from existing research indicating that multiple private screens discourage equal participation during common activities [8].

The physical design of the LunchTable combines a large vertical display placed at table height and a touch interface embedded within a lunch table (see Figure 2). This configuration of displays involves a trade-off in input and visibility: People sitting between the table and the display have to turn around to use the table or view the display, resulting in a disadvantage of control for these individuals. We considered presenting information on duplicate screens at different angles from the table, but this might split the visual attention of people, which has been shown to be detrimental to group work [25]. We also considered using a high-resolution display on the table itself, but horizontal displays are affected by problems of orientation and perspective [23].

As stated, one of our design goals was equal participation. In keeping with this goal we decided against using a single mouse and keyboard as applied in earlier setups [3]. We also decided against providing multiple physical mice and keyboards because several physical devices (to support multi-user input) could create clutter and interfere with food and other objects. Although physical input devices may be faster for input tasks, performance considerations appear less important in casual interactions.

For the interactive display integrated into the lunch table, we decided early on to use a commercially available system. The SMART Table is a *stable and easily maintainable* multi-touch display that tolerates spills. Given the size of the SMART Table, it can be integrated in the center of a regular table, leaving sufficient space for food and other objects.

The software interface design for the LunchTable focuses on providing a simple, easy-to-use interface that enables simultaneous multi-user manipulation of common information sources while avoiding clutter. A key decision in our design is the division of the horizontal surface into a window-management area that replicates the vertical display, an area where virtual input devices can be created and distributed according to people's needs, and an area from which new applications can be launched.

In LunchTable, we have focused on providing access to common web-based information sources, but the interface can be extended to any application that responds to mouse and keyboard events.

4. IMPLEMENTATION

This section describes the physical setup, the software platform, and the interface of the LunchTable system.

4.1 Hardware and Software Setup

The lunch table and the wall display were installed in the lunch space of our research lab (see Figure 1), which provides a small kitchen and a round table where lab members gather to eat their lunch and socialize. We replaced the existing table in the lunch space with an oval table (68"×58", height 29") that embeds in its center a rear-projected SMART Table (frame approx. 36"×29", screen 23"×17.25", 1024×768 resolution), which supports up to 120 simultaneous touch points. The SMART Table surface sits approx. 1.25" above the surface of the rest of the table. The SMART Table is rugged and tolerates spills. The non-interactive part of the table's surface at the perimeter is between 20 and 22.5" deep, enabling placement of dishes, cutlery, and food. Up to ten people can sit around the table, which provides enough space for the legs of those sitting at the table.

The vertical display is composed of six back-projected 28.75"×21.5" screens in a 3×2 tile arrangement for a total size of 86.25"×43". Each screen is powered by a 1024×768 projector for a total resolution of 3072×1536 pixels. The bottom edge of the display is 30" above the floor. The vertical display is situated 51" from the edge of the table so that there is room for people to sit all around the table. A single computer equipped with a multi-headed NVidia GeForce GTX 280 card and two Matrox TripleHead2Go adapters drives the six vertical screens and the tabletop display.

The interface is implemented in C# on Windows 7 using WPF. Microsoft's Desktop Window Manager API is used to control windows on the large display as well as to replicate windows on the horizontal surface. Elements in the horizontal surface are implemented using the SMART Table SDK.

Figure 2. A general view of the LunchTable

4.2 Interface

The system allows users to manipulate application windows within the wall display space (see Figure 3) by interacting with the horizontal surface (see Figure 4). Windows contain web browsers that can be used to navigate to any web page or application. The horizontal surface interface contains a window manager showing a scaled down representation of the window display contents, an application launcher, and a space for virtual input devices.

4.2.1 The Wall Display Space

The wall display space is composed of a 3×2 grid of back-projected screen tiles. Application windows snap to one or more tiles within the grid and thus cannot overlap. Up to six windows can be manipulated by up to six people at the same time. Windows can be configured to cover 3×2, 2×2, 2×1, 1×2, or 1×1 tiles. Figure 3 shows the wall display with three windows.

The colored border of a window indicates its relationship to a window in the tabletop window manager and to input virtual devices. Windows have their own separate cursors, displayed in the same color as the window border.

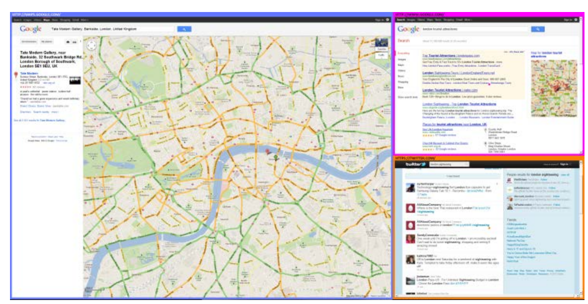

Figure 3. Screenshot of the wall display space showing a window covering 2×2 screen tiles and two 1×1 tile windows.

The Window Manager

The center of the horizontal surface interface is occupied by the window manager, which shows a thumbnail of the content in the large vertical display updated in real-time (see Figure 4). The window manager is a 3x2 (280×146 pixels) fixed grid that represents the six tiles of the vertical display.

Windows are manipulated by dragging their thumbnails. Several windows can be manipulated simultaneously. A window can be moved to another tile by dragging it and releasing it in the center of another tile. If the release point is in between two tiles, the window will expand to occupy the adjacent tiles (see Figure 5). This mechanism allows people to move and resize a window in one single-finger gesture. This design was preferred to the standard pinch gesture because two-finger interaction becomes harder at a distance.

Figure 4. The window manager in the center of the horizontal display shows the wall-display contents (see Figure 3) and is surrounded by an application launcher. Virtual input devices have been opened for controlling each of the three windows.

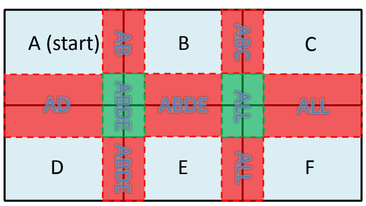

Figure 5. Window manager behavior for a drag on a window that occupies tile A. The letters in each area indicate the tiles where the window will be moved/expanded if a drag starting in A ends in that area.

In order to avoid clutter, the window manager does not allow overlapping of windows, or several windows stacked on the same tile. When a user attempts to do so (e.g., by trying to move a window into an occupied tile), the system provides feedback and the window returns to its original location.

4.2.2 The Launcher

The area immediately surrounding the window manager contains the launcher, a slowly revolving train of icons: nine application icons, a wastebasket icon, and a trackpad icon. The main motivation of making the icons rotate around the window manager is to make them more accessible to people sitting around the table, in a similar fashion to Interface Currents [9].

An application icon can be dragged onto any of the regions of the window manager (see Figure 5), which result in the application being opened at the desired tiles. A window is removed by dragging its thumbnail from the window manager onto the wastebasket icon.

Applications included in the launcher are Google search, YouTube, Gmail, Google Docs, Google Maps, Facebook, Twitter, Flicker, and Wikipedia. Applications were selected to cover a range of activities that people might want to engage in either individually or together during conversations.

Finally, the trackpad icon on the launcher can be dropped onto an existing window, which creates a virtual input device to control that particular window. The virtual input device appears near the thumbnail of the connected window in the window manager.

4.2.3 Virtual Input Devices

A virtual input device (VID) consists of a trackpad and an on-screen keyboard that can be used to control an application window (e.g., entering text or navigating). A VID is visually connected to its window thumbnail in the window manager with a line (see Figure 4). In addition, the VID frame, the window thumbnail, and their connection line, as well as the corresponding window frame and cursor on the vertical display, all share a unique color (see Figures 3 and 4).

The trackpad behaves in the same way as a standard laptop trackpad with a separate click button. For cursor control we contemplated creating direct-input versions of the trackpad, where a miniature copy of the content of the window could be interacted with through touch in an absolute way; however, we found that the resolution and obliqueness of the table as well as the fat finger problem made it very difficult to interact with applications that are designed for the precision of relative input devices. The on-screen keyboard uses a QWERTY layout. The keyboard can be minimized to gain space.

VIDs can be enlarged, shrunk, or moved to any position or orientation within the tabletop workspace surrounding the window manager through the standard one- or two-finger rotate, resize, and translate manipulations.

VIDs send all input to the application as mouse and keyboard events (e.g., mouse move, mouse click, key down). In contrast to a standard operating system, different input devices can send events to separate application windows simultaneously, and each window has its own cursor. Touch events within the VID are transformed into events that are directed to specific windows routed at the operating system level.

5. OBSERVATIONAL STUDY

We conducted an observational study of the real-world use of the LunchTable system in the lunch space of a university research lab.

5.1 Methods, Measures and Participants

For seven work days, during lunch time (between 11am and 2pm), we recorded video of the tabletop area and the general lunch area (two cameras) while one of the authors was present and took notes of activities taking place. Further, activities around the lunch area and interactions with the LunchTable were identified from the video recordings, and grouped into open-ended categories. The system logged all interactions taking place on the LunchTable for a total of 17:43 hours. We analyzed the logs to describe quantitatively how often the system was used; what applications participants used and the web domains they navigated to; and the number, location, and size of windows shown. In total 16 participants took part in this study, all of which were undergraduate or graduate researchers working at the lab.

People sitting around the table within the context of their regular activities were considered as study participants, and consent from them was sought individually. After the study, we sent all participants a questionnaire via email, asking them about their experience with the system and the type of activities they found it useful for. We received six responses.

5.2 Results and Discussion

5.2.1 Usage and Applications

As we highlighted in Section 3, the main goal of the LunchTable is to support group conversations. A total of 4302 window events were recorded (drags, scrolls, moves) distributed across all seven days (see Table 1). Activity varies much between days, but there is no apparent decrease in usage over the period of the study. These data, combined with our observations, suggests that the LunchTable provided enough value for participants to grant sustained use throughout the period. It is difficult to extrapolate from these results to longer-term use of the LunchTable; for instance, the novelty of the system during the study period might influence the usage, representing a limitation of our study.

Table 1. Number of interaction events (and events that occurred concurrently), number of windows and virtual input devices that were opened.

Day	1	2	3	4	5	6	7	ALL
Events	858	786	501	215	1229	658	55	4302
Concurrent	125 15%	108 15%	0 0%	0 0%	0 0%	0 0%	0 0%	233 5%
Windows	11	19	2	6	12	4	9	63
VIDs	8	12	2	3	8	2	5	40

Our observations and the comments from the participant questionnaires suggest that the most popular uses of the table were viewing maps, photos and videos with other people and, to a lesser extent, looking up topics or facts to share in conversations. These observations are corroborated by our analysis of the web domains that participants navigated to: The second most used application was *maps.google.com,* which was shown in 10 of the 63 windows that were opened during the seven days of the study—Google search was used the most often, but not surprisingly, it was typically used only briefly, to search for and navigate to another page. Other visually rich sites that were frequently used are *www.flickr.com* and *www.youtube.com* (opened in 5 and 4 windows, respectively). This supports our expectations that users gain the most from sharing graphical data (maps, pictures, video) on situated large-display systems such as the LunchTable. Sharing textual data with others is easy to do verbally after a search on a mobile device whereas sharing maps, photographs or videos is challenging with mobile user interfaces.

Social network sites such as Twitter and Facebook were also frequently opened. It seems participants did not mind sharing their data on these sites, probably because participants know each other and already share data. In contrast, Gmail was opened only once.

5.2.2 Social Use Patterns

One goal with our design was to provide equal, simultaneous access to all participants, and we therefore analyzed the degree of concurrent interactions with the system. Based on findings in previous research [12] we expected that the multi-user input features of LunchTable would result in a significant amount of concurrent activity. For example, someone could search for a topic while someone else was manipulating a map to highlight a geographical location. However, most often participants did not interact with the system simultaneously. Typically, only one participant controlled the system or participants took turns interacting with the system. We instructed participants in the multi-user interaction features, and we saw some simultaneous use, but only during the first two study days. This is supported by the log data, which shows that concurrent events (determined as events from different VIDs that happen within five seconds of each other) only happened during the first two study days (see Table 1). Also, participants reported in the questionnaires that concurrent interaction did not occur.

This indicates that, in casual situations such as ours, the multi-user features of our system are largely unnecessary. It is possible that the patterns of sharing seen in previous single access point systems [e.g., [3],[27] are not due to the limitations in input, but to differences in the social situations. This result is supported by some comments from the questionnaires, which highlighted that it might be impolite to interact while someone else were having the floor, or by the frequent occurrence of explicit handovers and coordination of the group to carry out actions on the display (rather than just carrying them out individually).

5.2.3 Low-level Interface Elements

The virtual input device worked well and prevented the precision problems that most direct-touch input devices suffer from. However, it does have drawbacks. Most importantly, we found that it requires more visual attention than a physical mouse or keyboard, because it does not give tactile feedback on the boundaries of the device. Also, navigating the wall display using the VIDs was found to be tedious by some. These issues may have influenced the amount of interaction we saw in the study.

Windows were mostly configured to 1x1 or 2x2 tiles and never to 2x1 or 3x1 tiles (see Table 2). One possible reason why participants did not to use windows that had aspect ratios wider than 4:3 is that the web applications fit poorly to such formats. This supports the portrait placing of large displays (e.g., [4]) for this kind of application if only one piece of information is shown, and might allow simpler designs of the window manager where the most awkward configurations are not possible.

Table 2. The relative time that windows were set up in different screen tile configurations.

	Window size in screen tiles					
	1x1	1x2	2x1	2x2	3x1	3x2
Time	73%	5%	0%	18%	0%	4%

5.3 Limitations

Our findings are relevant for the design of systems that support casual interaction scenarios; it points to behaviors and system design consequences that can greatly affect the value of such interventions, and inform the design of similar systems in the future. However, as with most studies of this kind (e.g., single target group, single design, non-controlled environment, short-term study), the results of our observations cannot be applied to other scenarios, systems, and time periods without careful analysis and consideration for the goals and purpose of the system.

We also note the potential risk of disrupting highly valuable social environments by introducing technology. Several participants commented that displays could change the dynamics of lunch in the lab environment, making the interface itself become the object of conversation, or detrimentally dominating the conversation. On the other hand, one of our participants commented that the large display was "*less isolating than laptops*" and it provided "*rich interaction with people*". While we believe that interactive displays as presented here can enrich a social situation, we also share the concern that technology can have undesirable effects that we need to better understand. Further design iterations and longer running studies will shed more light on how to harmonize technology's power to focus attention with the rich dynamics found in casual conversations.

6. CONCLUSION

It is increasingly common to access information from the Internet on mobile devices in social situations. This can be useful to share facts or visual content; however, in casual group scenarios with more than a few people, mobile devices provide very poor support for these tasks, mostly due to their small size and private nature.

To address this problem we designed, implemented, and evaluated a multi-user system that supports casual group interactions during lunch in a research environment. The system incorporates a large situated display that allows people sitting at a large table to easily share visual information, as well as a multi-touch interactive tabletop with input and windows management mechanisms for equal, simultaneous control of the large vertical display.

An analysis of data from a seven day study (including observations, video recordings, logs, and questionnaires) showed sustained levels of activity on the system. More importantly, the data revealed limited concurrent activity (replaced mostly by social protocols) and a focus on visual media rather than text. The results raise questions about unintended effects of interactive displays on dynamics of conversations.

7. ACKNOWLEDGMENTS

We would like to thank NSERC, SMART Technologies Inc, iCORE, CFI and SurfNet for research support and T. Ballendat and J. Kiemer for their help in the initial phases of the project.

8. REFERENCES

[1] E-table interactive. http://www.e-table-interactive.com/. LR:01-2012

[2] J.T. Biehl, W.T. Baker, B.P. Bailey, D.S. Tan, K.M. Inkpen, and M. Czerwinski. Impromptu: a new interaction framework for supporting collaboration in multiple display environments and its field evaluation for co-located software development. In *Proc. of CHI*, pp. 939-948, 2008.

[3] H. Brignull and Y. Rogers. Enticing People to Interact with Large Public Displays in Public Spaces. In *Proc. of INTERACT*, pp. 17-24, 2003.

[4] E.F. Churchill, L. Nelson, L. Denoue, J. Helfman, and P. Murphy. Sharing multimedia content with interactive public displays: a case study. In *Proc. of DIS*, pp. 7-16, 2004.

[5] S. Elrod, R. Bruce, R. Gold, D. Goldberg, F. Halasz, W. Janssen, D. Lee, K. McCall, E. Pedersen, K. Pier, J. Tang, and B. Welch. Liveboard: a large interactive display supporting group meetings, presentations, and remote collaboration. In *Proc. of CHI*, pp. 599-607, 1992.

[6] A. Fass, J. Forlizzi, and R. Pausch. MessyDesk and MessyBoard: two designs inspired by the goal of improving human memory. In *Proc.of DIS*., pp. 303-311, 2002.

[7] S. Greenberg and M. Rounding. The notification collage: posting information to public and personal displays. In *Proc. of CHI*, pp. 514-521, 2001.

[8] J.-B. Haué and P. Dillenbourg. Do Fewer Laptops Make a Better Team? In *Interactive Artifacts and Furniture Supporting Collaborative Work and Learning*. pp. 1-24, 2009.

[9] U. Hinrichs, S. Carpendale, S. D. Scott and E. Pattison. Interface Currents: Supporting Fluent Collaboration on Tabletop Displays. In *Proc. of Smart Graphics*. Springer Verlag, pp. 185-197, 2005.

[10] U. Hinrichs, D. Fisher, N. Henry Riche. ResearchWave: An Ambient Visualization for Providing Awareness of Research Activities. In Proc. ACM DIS, pp. 31-34, 2010.

[11] U. Hinrichs, H. Schmidt and S. Carpendale. EMDialog: Bringing Information Visualization into the Museum. *IEEE TVCG*, 14(6):1181-1188, 2008.

[12] E. Hornecker, P. Marshall, and Y.Rogers. 2007. From entry to access: how shareability comes about. In *Proc. of Designing Pleasurable Products and Interfaces*, pp. 328-342, 2007.

[13] E.M. Huang and E.D. Mynatt. Semi-public displays for small, co-located groups. In *Proc.of CHI*, pp. 49-56, 2003.

[14] E.M. Huang, E.D. Mynatt, D.M. Russell and A.E. Sue. Secrets to success and fatal flaws: the design of large-display groupware. *IEEE CG&A*, 26(1): 37-45, 2006.

[15] E.M. Huang, E.D. Mynatt and J. Trimble. Displays in the Wild: Understanding the Dynamics and Evolution of a Display Ecology. In *Pervasive Computing*, 3968, pp. 321-336, 2006.

[16] S. Izadi, H. Brignull, T. Rodden, Y. Rogers, and M. Underwood. 2003. Dynamo: a public interactive surface supporting the cooperative sharing and exchange of media. In *Proc. of UIST*, pp. 159-168, 2003.

[17] G. Jacucci, A. Morrison, G.T. Richard, J. Kleimola, P. Peltonen, L. Parisi, and T. Laitinen. Worlds of information: designing for engagement at a public multi-touch display. In *Proc. of CHI*, pp. 2267-2276, 2010.

[18] B. Johanson A. Fox, T. Winograd. The Interactive Workspaces project: experiences with ubiquitous computing rooms, In *IEEE Pervasive Computing*,1(2), pp. 67- 74, 2002.

[19] P. Marshall, E. Hornecker, R. Morris, S. N. Dalton, Y. Rogers. When the fingers do the talking: A study of group participation with varying constraints to a tabletop interface. In Proc. of TABLETOP, pp. 33 - 40, 2008.

[20] P. Marshall, R. Morris, Y. Rogers, S. Kreitmayer, M. Davis. Rethinking 'multi-user': an in-the-wild study on how groups approach a walk-up-and-use tabletop interface. In Proc. of CHI pp. 3033 - 3042, 2011.

[21] A. Mazalek, M. Reynolds, G. Davenport. The TViews Table in the Home. In *Proc. of TABLETOP*. pp.52-59, 2007.

[22] J. Müller, O. Paczkowski, A. Krüger. Situated public news and reminder displays. In *Proc. of Ambient intelligence*, pp. 248-265, 2007.

[23] M.A. Nacenta, S. Sakurai, T. Yamaguchi, Y. Miki, Y. Itoh, Y. Kitamura, S. Subramanian, C. Gutwin. E-conic: a perspective-aware interface for multi-display environments. In *Proc. of UIST*, pp. 279–288, 2007.

[24] J. F. Nunamaker, A. R. Dennis, J. Valacich, D. Vogel, and J. George. Electronic meeting systems. *Comm. ACM,* 34(7), pp. 40-61, 1991.

[25] C. Plaue, J. Stasko. Presence & placement: exploring the benefits of multiple shared displays on an intellective sensemaking task. In Proc. GROUP '09. pp, 179-188. 2009.

[26] E. Rønby Pedersen, K. McCall, T.P. Moran, and F.G. Halasz. Tivoli: an electronic whiteboard for informal workgroup meetings. In *Proc.of CHI '93*, pp. 391-398, 1993.

[27] D. Russell, C. Drews, A. Sue. Social Aspects of Using Large Public Interactive Displays for Collaboration. In *Proc. UbiComp '02*. LNCS 2498, Springer, pp. 663-670. 2002.

[28] D. Russell, R. Gossweiler. On the Design of Personal & Communal Large Information Scale Appliances. In *Proc. of Ubicomp,* pp.354-361, 2001

[29] M. Stefik, G. Foster, D.G. Bobrow, K. Kahn, S. Lanning, and L. Suchman. 1987. Beyond the chalkboard: computer support for collaboration and problem solving in meetings. *Communications of the ACM* 30(1), pp. 32-47, 1987.

[30] J. Schneider, J. Derboven, K. Luyten, C. Vleugels, S. Bannier, D. De Roeck, and M. Verstraete. 2010. Multi-user multi-touch setups for collaborative learning in an educational setting. In *Proc. of Cooperative Design, Visualization, and Engineering*, pp. 181-188, 2010.

[31] T. Seifried, M. Haller, S.D. Scott, F. Perteneder, C. Rendl, D. Sakamoto, and M. Inami. CRISTAL: A Collaborative Home Media and Device Controller Based on a Multi-Touch Display. In *Proc. of ITS*. pp. 33-40, 2009.

[32] N.A. Streitz, J. Geißler, T. Holmer, S. Konomi, C. Müller-Tomfelde, W. Reischl, P. Rexroth, P. Seitz, and R.Steinmetz. i-LAND: An Interactive Landscape for Creativity and Innovation. In *Proc. of CHI*, pp. 120-127, 1999.

[33] J.R. Wallace, S.D. Scott. Contextual Design Considerations for Co-located, Collaborative Tables, In *Proc. of TABLETOP*, pp.57-64, 2008.

[34] D. Wigdor, C. Shen, C. Forlines, and R. Balakrishnan. Effects of display position and control space orientation on user preference and performance. In Proc. of CHI, pp. 309–318, 2006.