Four Lessons from Traditional MDEs

Anthony Tang **Sidney Fels**
Human Communication Technologies Lab
University of British Columbia
hct.ece.ubc.ca
{tonyt, ssfels}@ece.ubc.ca

ABSTRACT
While many researchers are interested in developing and designing technologies for multiple-display environments (MDEs), a core problem remains: we do not fully understand the *role* these display technologies can play in real-world activities. Our approach has been to study traditional MDEs (i.e. offices and laboratory environments) to understand both the *tasks* supported by traditional displays, and the *roles* the displays play in these tasks. We discuss a set of lessons from studies of traditional displays, and discuss how designers of MDEs can learn from these lessons in their designs. In so doing, we contribute to the growing understanding of the potential role of MDEs in supporting real-world work, and MDE design.

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION
Our work focuses on addressing the problem of finding appropriate task and application domains for MDEs. While several researchers have engaged in the design and development of technologies, applications and displays for MDEs, it is unclear whether these are optimal task spaces, and whether the designs themselves are optimal. We take a step back from this position to consider existing, successful MDEs: office spaces and laboratory environments.

These spaces are teeming with traditional displays: whiteboards, chalkboards, bulletin boards, and flip-charts. In many cases, even generic metallic surfaces (such as the sides of filing cabinets) are made into display surfaces. It is in these spaces where we consider such semi-public, large displays to be well integrated into workers' everyday practice: workers understand how the displays work, and their role in the social and ergonomic context of the overall workspace and work activities. It is from these contexts that we draw upon for inspiration and understanding: What are traditional display surfaces doing in these contexts? What tasks are workers using them for? How does the display surface support that task—that is, what roles do the display surface play in that task?

Other researchers have also been interested in the role of traditional displays in the workplace (e.g. [8]), in the meeting room, as well as in war-rooms (e.g. [9]). We are also influenced by researchers who have examined particular artefacts such as the whiteboard (e.g. [6]) as well as case studies of particular traditional displays (e.g. [10, 11]). We extend this earlier work with a perspective that is informed by real-world deployments of both prototype and mature digital display technologies (e.g. [1, 3]). Our aim has not been find deficiencies in work practice and design technologies to "improve" or "optimize" them; instead, our assumption has been that workers already implicitly employ these display surfaces optimally in their work practice—our role is to understand what affordances provided by these traditional display surfaces support these work practices. To our surprise, our analysis has revealed that *while many fundamental limitations of traditional display technologies can be easily overcome with technology, many of these limitations* can*, and in many cases* are *exploited by users*.

We discuss four lessons that we learned from studying traditional display surface use: the role of visually persistent information, functionally fixed display surfaces, the semantic construction of displays, and information transfer from displays. We frame each of these lessons within the physical and social context of use, and discuss how they inform digital display design. Digital technologies can enhance the utility of the large, semi-public displays we are interested in; however, until we have a good understanding of what, where, why and how displays are used, it is difficult to provide appropriate designs. The studies and related work we summarize here feed into a design process for digitally augmented displays.

RELATED WORK
Because we are interested in finding appropriate roles for MDEs generally, our work is conceptually linked to work by researchers interested in building and deploying digital MDEs (e.g. [3,1]). In the present context, however, we are more specifically interested in work that parallels our approach where design insight is uncovered from study of traditional displays. We briefly review this work,

	Relevant Factors	Functional Benefits
Visual Persistence *Content stays visually persistent unless explicit action is taken to remove it.*	• Ownership of display • Location of display	• Content can be easily reviewed intentionally and unintentionally
Fixed Function *Many displays' function is fixed.*	• Users of display • Location of display • Other, similar displays in context	• Cognitive and physical partitioning of task space • Dependable constant display
Semantic Construction *Users construct meaning by what is displayed and how.*	• Functional and expressive primitives	• Displays used across working modes • Functional conversion of displays
Immobility of Information *Content is generally difficult to move across displays.*	• Affordances of display technology dictates its functional use	• Differentiates use of displays

Table 1. Summary of lessons learned from traditional MDEs.

Perry and O'Hara [8] provide a taxonomy of display-based *activity* that focuses on ready access to information, social orientation, and coordination/planning. The account focuses on the practice of *displaying information* for others, and how the needs of the "displayer" modify the method and mechanism by which the information is displayed.

Mynatt [6] focused on *personal whiteboards* in an office context, exploring how space on whiteboards was managed by users to facilitate multiple parallel tasks. This work revealed how space (when partitioned into segments) helps to organize work, especially when allowed to persist for long term (e.g. for reminders). Teasley et al. [9] provide convergent evidence from *observations of "war room" whiteboard use*, reporting that whiteboards provide a space for asynchronous communication, acting as a shared awareness display about a team's status or current activity.

Xiao et al. [11] present a case study of the use of *whiteboard in an emergency room ward*, illustrating how its location and visual persistence afforded many different styles of use. For instance, the whiteboard captured the current state of the ward, providing awareness to a casual passerby, while its location dictated the nature of the content, and facilitated centralized coordination between nurses.

Whittaker & Schwarz [10] report on a study comparing the use of two scheduling boards: one digital, and the other traditional. Their work revealed both that the location of the traditional whiteboard encouraged commitment and participation from those who used the information. It also enabled collaborative problem solving, and provided users with awareness of ongoing changes.

STUDYING TRADITIONAL MDES

In our work, we have conducted two probes into the space of traditional display surfaces: one involving the study of the whiteboard artefact as it is used in users' everyday work, and another involving in situ observation of the use of several displays in a laboratory environment. We briefly outline these studies as a means of contextualizing our understanding.

Focusing on the Whiteboard

The whiteboard is a commonplace display artefact found both domestically and in the workplace. Its use is highly diversified: in many contexts, it simply operates as a sketching surface (as in many meeting rooms); in other contexts, it operates as working memory or task list for office workers, storing information as both ready reference and in a persistent manner until such time it is needed. We conducted a survey of 135 whiteboard users (who self-identified as "using whiteboards at least once a week regularly") and 10 in-situ interviews with "heavy" whiteboard users. In so doing, we collected data about 250 whiteboards, what they were used for, who used them, and so forth. The study revealed that whiteboards were a useful tool because they facilitated activity across different work modes (independent vs. collaborative activity and synchronous vs. asynchronous activity), as its use allowed users to easily transition between these modes.

Investigating a Lab Environment

In parallel work, we investigated the use of traditional multi-display environments by teams of undergraduate engineering students who were enrolled in a year-long team-based learning program. These teams were assigned two time-shared workspaces: a meeting room containing whiteboards, a table, computers and filing cabinets, and a laboratory workbench with shared chalkboards, computers and table space. We observed these teams for at least four work sessions (each lasting three to four hours), collecting data about how they made use of the whiteboards, chalkboards, etc., and how these display surfaces played different roles in their activities. This study allowed us to classify different conceptual forms of display-based activity, and to understand the role of the display surfaces in those activities.

FOUR LESSONS FROM TRADITIONAL MDES

In our two investigations of traditional display surfaces, our focus was on how the display surfaces supported the actions of users around the displays (Table 1). Across the two studies, four common themes arose from our observations, reflecting both "deficiencies" in traditional display surfaces, and how these deficiencies facilitate users' activities. Accordingly, many observations reflect actual deployment of other researchers' MDEs. By reflecting on these four lessons, we intend to sensitize designers to properties of traditional display surfaces that they may exploit in their design and development efforts.

Role of Visual Persistence

Traditional display surfaces are visually persistent in that content or information on these displays remains persistent until explicit action is taken to remove it. Visually persistent display surfaces afford fundamentally different tasks and roles compared to displays that are considered dynamic, or cannot be depended upon to be persistent. Such displays allow ambient, awareness information to be presented unobtrusively: status information, reminders, notices, etc. are common on displays that can be relied upon to be visually persistent.

Visually persistent display surfaces support *easy viewing of content intentionally and unintentionally*: when the information is desired, it will be visible with little more than a glance, and even when the information is unbidden, it may be visible by an incidental glance around the environment.

Thus, the notion of *visual persistence* for a user extends beyond the physicality of how information is presented on the displays (e.g. whiteboard ink)—it also reflects the social and physical context of the display itself. For instance, a user may implicitly ask several questions of the display before *depending* on it as a visually persistent display: Who else uses this display surface? Who "owns" this display surface? Can I depend on them to retain this content later? Where is this display located, and when will I be able to see it? Will I be able to see it when I want to? Is the display surface and display content large enough for me to see it?

Our studies revealed how several of these factors come into play. For instance, whiteboards that are more "owned" (in the sense that an individual or small group of coworkers feel a sense of ownership towards the board) tend to have more reminders and visually persistent items on display. This illustrates the role of users in determining whether the display can be depended on as visually persistent. Similarly, schedule boards, or task lists were placed on whiteboards that were visually prominent based on their location and the flow of users through the space.

Accordingly, many successful deployments of digital display applications rely on their being visually persistent in a technological way: IMPROMPTU [1] and [7] are examples of how the visual persistence allows work practices to develop around the displays. In contrast, Huang et al. [3] report on some display applications that are not reliably persistent, which meant that similar practices could not evolve around similarly functioning displays.

Role of Fixed Function Displays

Users dedicate many traditional display surfaces to a fixed task function. Doing so allows users to distribute their task and information space among display surfaces, thereby facilitating contextually appropriate task switching, or peripheral monitoring of other tasks. A common example of such a fixed function display include in/out boards (often located near the front of the office), which provide office inhabitants awareness of coworkers presence. Other examples might include a whiteboard dedicated to outstanding software bugs that need to be fixed before a given deadline, or a group schedule board.

Fixed function displays allow users to partition their tasks spatially, allowing cognitive partitions to be realized in the physical world. Further, artefacts relevant to the function of the display can be positioned nearby (e.g. the telephone message whiteboard near the telephone in a home setting). When users consider a traditional display surface to be of or for a fixed function, users no longer conceptually consider the display as a "display surface"; instead, their conceptualization of the display and its function become fundamentally linked. Our whiteboard study provided data to support this position: when asked to "name" their whiteboards, many participants provided function-based names for their whiteboards (e.g. "my task list"). Similarly, others have observed such dedicated displays in other real-world contexts when shared between a well-known group of individuals (e.g. [10, 11]).

Similar to visually persistent displays, there are also social, and physical contextual factors that impact whether a display is used for fixed function, and indeed what function: Who will see/use this display? What are the needs of the users of this display? Is this the only display (of its kind) in the environment? Where is this display located? What is the display located near? How frequently is this display used in the same way by the same group across time?

To be clear, many traditional surfaces are *not* fixed function: a good portion of whiteboards were given names that reflected their location (e.g. "meeting room whiteboard") rather than a function. Nevertheless, when given the opportunity, users partition their work across displays (e.g. [2]), and there appear to be performance benefits of doing so [5]. Accordingly, there should be cognitive benefits of partitioning work according to display in this manner: it more rapidly allows users to understand what the display is for, and how to adopt it into their work practice.

Semantic Construction of Displays

Most traditional displays do not unnecessarily constrain what is displayed, or how the display surface can be used by its users: users construct meaning by what they place on the display and how. Meaning can be applied to spatial layout of content, colours, partitioning, or even by what content is attached to the display. This allows representations that can be used across a variety of task modes and task settings (e.g. collaborative, independent, etc.). It also facilitates the use of multiple constructions on the same display. In contrast, most digital display technologies arrive with an application or technology for which it is to be used, meaning that it is difficult for users to flexibly appropriate the technology for themselves (e.g. to connect to other information sources, to highlight, link, or to allow information to mean something else, etc.).

Users' ability to construct traditional displays dynamically means that the intent, function and use of the display are controlled by the users of the display itself. Thus, a user can change the use of the display by simply adding/removing/changing content. For instance, a whiteboard in a meeting room may be used for a transient brainstorming session, but then the brainstorm could be made persistent and become a persistent reference display by placing the marker, "Please leave on" on the display. This fundamentally changes the role of the display (albeit temporarily).

Similarly, the design tension for designers of displays is to provide meaningful, usable primitives without dictating their use. Many large display technologies tend too far on either side of this design tension: either by providing primitives that are too simplistic, or by limiting users' expressivity with those primitives. Furthermore, an additional challenge in the digital realm is that information may arrive from outside sources, so primitives need to provide a means for transferring and remixing these.

Mobility and Immobility of Information

Content on most traditional display surfaces typically has low to no mobility—content originally placed on one surface is difficult to take off or move to a different display surface. As a consequence, users make conscious choices about the type of media that information is presented on or distributed through. For instance, users may choose to use a whiteboard for displaying a persistent schedule for a team because it facilitates easy updating, and can be referred to and updated in a specific location (e.g. [10]), while information that needs to be circulated and scrutinized may be pinned to a bulletin board so that it can be removed by whomever needs the information [8].

The differential capabilities of display surfaces provide users with a means to differentiate their use of the display, and more importantly, the function of those displays in their work. Thus, users make conscious choices about how which displays they will use depending on their needs. Information is moved across display surfaces when the affordances of the originating surface no longer meet the perceived needs of the users, or when the display surface is needed for some other task. In both cases, the cognitive and temporal costs are relevant—the benefit of moving or removing the information from the original surface must outweigh the cost of doing so.

This observation again points to the notion that display surfaces play many different *roles* in workers activities. These roles are derived from their contextual location, and the physical affordances that they are capable of providing. Often, a display surface will play a single role (as in the case of an in/out board), yet they may also play several roles (e.g. the brainstorming whiteboard that contains the phrase "please leave on").

FUTURE DIRECTIONS

The core message this work suggests is that we can derive design understanding by studying and understanding the roles of traditional displays in traditional MDEs. We have outlined four lessons from our own study of traditional MDEs: visual persistence, fixed function, semantic construction, and mobility of information. These observations may be considered as "limitations" of traditional MDEs, though we suggest that designers instead consider these observations as a means of insight into how users functionally employ traditional display surfaces. By studying the role of these display surfaces in traditional MDEs, we gain insight into potentially powerful application areas for future digital displays. Our current work involves understanding the intersection of "knowledge work" displays and ambient displays, and what affordances need to be provided to allow users to transition between different modes of activity.

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