Territoriality and Behaviour On and Around Large Vertical Publicly-Shared Displays

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ABSTRACT
We investigate behaviours on, and around, large vertical displays during concurrent usage. Using an observational field study, we identify fundamental patterns of how people use existing public displays: their orientation, positioning, group identification, and behaviour within and between social groups just-before, during, and just-after usage. These results are then used to motivate a controlled experiment where two individuals or two pairs of individuals complete tasks concurrently on a simulated large vertical display. Results from our controlled study demonstrates that vertical surface territories are similar to those found in horizontal tabletops in function, but their definitions and social conventions are different. In addition, the nature of use-while-standing systems results in more complex and dynamic physical territories around the display. We show that the anthropological notion of personal space must be slightly refined for application to vertical displays.

Author Keywords
Territoriality, public, large display, shared display

ACM Classification Keywords
H.5.m. Information interfaces and presentation: Misc.

INTRODUCTION
In shopping malls, amusement parks, airports, and other public spaces, large digital displays are replacing traditional signs as the medium of choice for communicating information to the general public. These range from static digital signs, showing generic, long-term information such as a directory or map, to fully interactive systems with dynamic and personalized information. For example, a map of an amusement park can be augmented with information about promotions or events in the immediate vicinity, and people can customize this information further with explicit interactions. Building on the amusement park map example, multiple family groups could share a single wall-sized display, with each group planning their day by selecting and organizing shared information from a common map (Figure 1). Supporting information sharing and concurrent interaction among multiple independent groups is challenging.

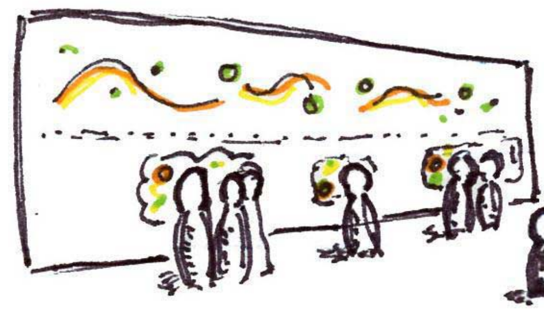

Figure 1. Artist's depiction of user groups engaging a large publicly-shared vertical display in parallel.

With shared horizontal surfaces, there have been multiple investigations [16,21] and theories established such as territoriality [21]. These results may apply to how people share information on the surface of a vertical display, but on-screen interactions are intertwined with additional considerations for how people share the space in front. Research examining space utilization around displays has proposed tailoring interaction according to an individual's distance and orientation [15,24], or adapting interaction according to proxemic relations between individuals, devices, and available displays [9], but less is known about how multiple independent groups interact around even a single public display. More generally, research on vertical and horizontal displays frequently examines individuals or single-group use (e.g. [8,12,15,24]) in limited, non-public environments such as meeting rooms and workplaces [3,8,16,17,20,21, 22]. To inform the design of large, public, interactive displays for multiple groups, a priori knowledge is needed about how these groups interact with themselves, others, and the display itself.

To address this need, this paper provides detailed accounts of the territories and behaviours that emerged both on and around displays in collaborative and non-collaborative multi-group parallel usage. Data are collected in both a field study and controlled study. In both studies, inter-group and intra-group on-screen and off-screen territories are catalogued and tracked over the duration of engagement. We find that the on-screen vertical display territories we observe are analogous to those found in tabletops, but manifest with key alterations and draw different perceived social expectations surrounding them. We discuss the implications our observations have on system requirements for group identification, interaction design, and display organization.

We explore how on-screen territory can be allocated to respond to off-screen behaviours and influence them. The data we present can be leveraged by designers of large, public, interactive displays to entice, support, and influence group actions on and around the display.

RELATED WORK

There are two main areas of research related to our work: *large-screen and public displays*, and *territoriality*.

Large-screen and Public Displays

A majority of the research on large-screen displays has focused on the benefits of a larger display surface and individual/group interaction *on* the display.

In their overview of large-screen research, Czerwinski et al. [5] summarize cognitive benefits, noting that larger displays improve information recognition and peripheral awareness making them well-suited to navigation tasks. Other researchers have noted productivity gains [4] and improved collaborative interactions [20] around large screens.

While researchers have demonstrated the cognitive benefits of large screen displays, deployments of interactive displays in open public environments are rare [5,19,20]. Many large screen systems (e.g. LiveBoard [8], BlueBoard [20], Flatland [17], Plasma Posters [3]) have been deployed, instead, in *semi-public* environments where they are accessible to small co-located groups and not the general passer-by (e.g., in the workplace). While semi-public environments often have multi-person spaces, the role of large displays in these environments is different than their role in open, public spaces. For example, in workplaces the act of taking control of an entire display and customizing it for one's own or a group's use is acceptable, assuming that display co-opting is done to support work [20]. In public, any personalization of a display must still be mindful of other users' need to access generic content. It is not clear that group behaviours in semi-public spaces like the workplace are similar to behaviours in public spaces such as malls, airports, or amusement parks [2].

One exception to this lack of public deployment of interactive shared displays is CityWall [19], a public, large-screen (2.5 m wide), multi-touch display that enables participants at large public events to upload and share photos. Researchers studied collaborative behaviours, and found CityWall provided a sense of "active spectatorship" as participants felt much more engaged at events knowing they could be photo content submitters (via a smart phone). In a follow-up study, Peltonen et al. [18] examined the social interactions that occurred while users interacted with the display. Their work presented several social concepts around large shared displays including, social learning (teamwork), conflict management and turn-taking protocols. Using a revised version of CityWall, named Worlds of Information, Jacucci et al. [14] extended the concept of social learning and formally enumerated all the observed behaviours as users assisted each other.

A possible reason for limited deployment of interactive large displays may be user reluctance to engage with these devices in public venues. Brignull et al. [2] considered the early stages of interaction with public large-screen displays. They identified root causes of both users' reluctance (e.g. fear of embarrassment) and attraction (e.g. "honey pot" effect) to use large-screen displays in public areas.

Research examining people's movement *around* a display has mainly focused on using location to enhance interaction [1,15,24]. Both Vogel and Balakrishnan [24] and Ju et al. [15] focus on adapting display behaviour based on participants' range from the display. For example, Vogel and Balakrishnan based interaction on an individual's proximity and orientation to the display: *ambient* for more distant passersby, *implicit* for peripheral awareness of passers-by, *subtle* for passers-by who focus on the display, and *personal* for passers-by who approach and interact with the display [24]. In Ju et al's [15] whiteboard system, Range, ink clustering is performed in real time, but the results of computation are displayed to the user only when she steps back from the intimate zone to the personal zone during interaction. In this way, the system does not interrupt the user with recognition results during the writing task.

More recently, Greenberg et al. [9] demonstrated how proxemics can be used as a mechanism for managing input and information display for surfaces. Ballendat et al. [1] introduced the term *proxemic interactions* to describe how an awareness of position, movement and orientation can be used to control interactions in multi-device environments. While researchers have shown the advantages of using proxemics to enhance interaction, they do not describe how people move *around* existing public displays, e.g., their orientation, positioning, group identification, and behaviour within and between social groups – a goal of this paper.

Territoriality

Territoriality must address the psychological and sociological behaviours portrayed by users if a natural fluid interaction is to take place on public large-screen surfaces. In single-display groupware, researchers have made use of proxemics zones identified by researchers in anthropology and psychology. In anthropological research, four proxemic zones have been identified by Hall: intimate (less than 1.5 feet), personal (1.5 – 4 feet), social (4 – 12 feet), and public (12 – 25 feet) [9,15]. Danninger et al. [6] studied social geometry to help infer opportunities for devices to interrupt users to minimize disruptions in a ubiquitous workplace environment.

For group interactions, neuropsychologists identify three basic zones of inter-personal space: the personal, peripersonal and extrapersonal [11]. During design studies for single-display groupware, Scott et al. [21] observed these same three zones of inter-personal space during group collaborations using a tabletop surface. Complementing this work, Marshall et al. observed all the stages of interaction with a tabletop in an uncontrolled public deployment [16]. However, little research has investigated these inherit proxemics zones on publicly-shared vertical displays and it is not clear if the theories developed for tabletops can be adopted to shared vertical displays.

Motivated by the research presented in this section, this paper examines behaviour during the complete engagement of interacting with a publicly shared display. This includes how users move around a display, how they establish territoriality, and how behaviour changes throughout the engagement. We break the problem into two parts. First, we present an observational field study focused on how people move around existing public displays. This is followed by a controlled study to examine how people manage on-display territoriality and move in the space immediately in front of the display.

STUDY 1: OBSERVATIONAL FIELD STUDY

We are interested in how people move *around* existing public displays: their orientation, positioning, group identification, and behaviour within and between social groups just-before, during, and just-after usage. Rather than build and deploy our own public display (e.g. [18] and [19]), we study behaviour around existing public devices: public kiosks and information displays. We chose these devices out of necessity since large interactive displays are rarely deployed, and when they are it is more often for novelty, rather than utility. We argue that the standard kiosks and non-interactive information displays we study have a high level of usefulness and familiarity which increases ecological validity. Moreover, the task performed on these two classes of devices corresponds very well to the multiple interaction phases of future large public displays [9, 24].

Methodology

We observed people in three public device settings:

Cinema Ticket Kiosks. At most large theatres, patrons may purchase tickets using a kiosk. In the setting we observed, there are 4 kiosks, each with a 15” touch display. The area in front of the kiosks is separated with rope barriers, forming four 1 meter wide lines. Interactions with these kiosks are short in duration and due to the theatre context, they can be surprisingly social.

Photo-Developing Kiosks. These enable customers to select, edit, and print photos stored on personal media. In the setting we observed, there were 4 kiosks, each with a 15” touch display and positioned immediately adjacent to one another. Interactions with these kiosks are generally much longer in duration, but due to the potential task complexity and social experience, multiple people often collaborate.

Mall Directories. These are large signs which guide shoppers to stores and services. In our setting, the directory is a ~100” backlit static display with the bottom half listing stores and the top half colour-coded floor plans for each level indicating the locations of these stores and resources such as elevators, washrooms, and exits. To facilitate searching the map, a standard cartographic grid system is used. This kiosk services brief information retrieval and navigation tasks and, unlike the others, its large size affords parallel, shared usage amongst multiple groups.

Observations

We visited each of the 3 settings twice. Each visit, we observed people using the kiosks or displays over 2 hours, resulting in 12 hours of observations. Written observations were manually noted, coupled with hand-drawn figures depicting the motions and positions of people.

Since we are interested in concurrent usage, we only recorded observations when two or more people used the display concurrently. We identified and tracked groups of people so we could code *intra-group* behaviour (movements within a group) and *inter-group* behaviour (movements between groups and the environment). Note that inter-group behaviours included individuals as a special “group of one” when a group of 2 or more was also present. In practice, this only occurred with the mall directory.

RESULTS

For brevity, we refer to the three settings as CINEMA, PHOTO, and MALL. In total, we observed 26 interactions involving 59 participants (29 female) for CINEMA, 9 interactions involving 21 participants (13 female) for PHOTO, and 12 interactions involving 34 participants (19 female) for MALL. Table 1 provides a summary of the groups we observed. The three settings provided a good sampling of interaction duration: typically less than 1 minute for MALL, between 1 – 5 minutes for CINEMA and between 5 and 55 minutes for PHOTO.

	CINEMA	PHOTO	MALL
Individuals	0	0	6
Groups of 2	21	6	8
Groups of 3	3	3	4
Groups of 4	2	0	0

Table 1. Observed groups broken down by setting and size.

Intra-Group Behaviours

We segment intra-group behaviours into two stages of usage, *approach* and *interaction*, to study group formations, movement, and general behaviour around the device.

Approach Stage Behaviours

The approach stage spans the period of time beginning when one or more members move towards the device until the group arrives at the device. The primary characteristics in this stage are the group formations as the *move* towards the device and as they *assemble* around the device.

We found three primary types of moving formations: *led, asynchronous delayed,* and *simultaneous*. The most common approach was where one or two group members would take the initial step and lead the group to the display with other group members following in different formations (Figure 2b,c,d). In a simultaneous approach, the group walked to the kiosk as an ensemble, maintaining a near shoulder-to-shoulder arrangement (Figure 2a). In these two types of approaches, the entire group behaves synchronously, arriving at essentially the same time. A variation of this is the asynchronous delayed approach exclusive to the PHOTO setting. Here one subset of the group approached the device first and initiated interaction, and were joined 1 to 10 minutes later by the remainder of the group. When a delayed subset contained 2+ people, the approach arrangement followed those of simultaneous and led approaches.

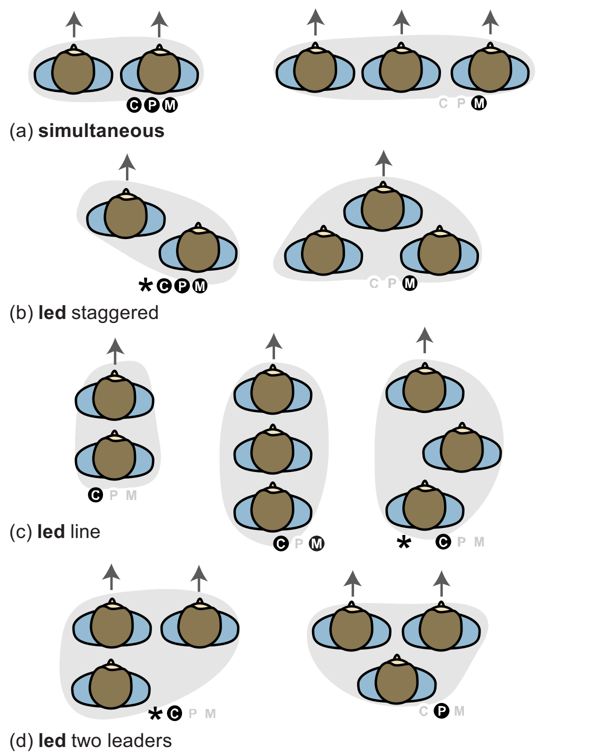

Figure 2. Moving formations: (a) simultaneous; (b) led staggered; (c) led line; (d) led two leaders. 'C', 'P', or 'M' in black circle denotes an observation for CINEMA, PHOTO, and MALL respectively. '*' denotes mirror version is also valid.

Not all moving formations were observed in all settings. For MALL, groups were more likely to approach simultaneously rather than led. However, in the CINEMA and PHOTO settings, the led and delayed approach types were more common. In the case of CINEMA, the space between rope barriers made simultaneous 3 person approaches difficult.

The different formations as groups assembled themselves around the device are depicted in Figure 3. These formations were often dependent on the moving formation. For example, with a led approach, if the lead was less than 3 steps, the leader would take a position which created space for the remainder of the group. If the lead was larger, the leader would position themselves as an individual, and then re-arrange the formation — a formation *morph* — when their companion(s) reached the display. The delayed approach sometimes also triggered morphs between assembly formations. For example, with groups of 2, the late arriving member would sometimes be accommodated by the initiator moving over (Figure 3n) or be forced to peer over the initiator's (typically right) shoulder (Figure 3e,k).

Crowded environments more often resulted in Figure 3k. With groups of 3, if there were two latecomers, the group always shuffled to accommodate them, but a single latecomer was not accommodated and forced to peer over the initiator's shoulders (Figure 3f,m). In the PHOTO setting, engaged members were *not* distracted when a latecomer arrived, and latecomers were more likely to become wanderers.

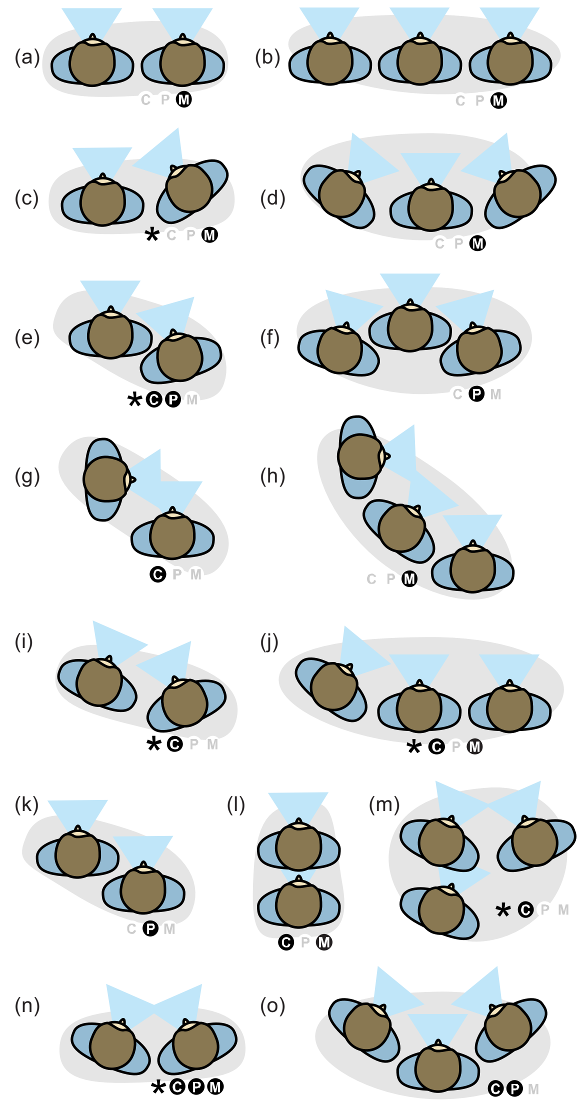

Figure 3. Assembly formations: physical layout of users once settled at kiosk or display.

Interaction Stage Behaviour

The interaction stage begins when at least one member of the group is engaged with the device. This stage encompasses more than group formation, so we also recorded how the group interacted with the system. For PHOTO and CINEMA settings, interaction was with the touch screen, but for the MALL setting we define interaction more broadly, as a directed gesture towards a display item, even without making physical contact. We call the primary member who is interacting, the *driver* [16], and the other members, *ob-*

servers. In all PHOTO cases, the first member to arrive became the driver, at least initially. With CINEMA, occasionally the second or third member to arrive became the driver. In simultaneous approaches, there was no way to predict who would become the driver. By definition, observers do not interact directly, but an observer closest to the display would often point and guide the driver. We define these observers as *active observers* rather than *passive observers* who did not interfere or contribute. In the MALL setting, there were more active observers due to the large display space and informal style of gesture interaction which often led to multiple members gesturing simultaneously blurring the distinction between driver and active observer. However, when a person approached the MALL display to touch it, others became passive. Even when multiple groups were present, only one person would touch the display at a time.

Group formations sometimes morphed during interaction, similar to how assembly formations changed to accommodate latecomers. For example, an asymmetric assembly formation generally formed because of passive observers. An extreme example is Figure 3h, where a member positioned himself perpendicular to the MALL display, ignoring the display to maintain eye contact with other members. However, these asymmetric formations often morphed to symmetric ones as passive observers become more aware of the display and sometimes fully transitioned to become an active observer. In PHOTO, passive observers often became wanderers when in a group-of-two formation like Figure 3k. In this case the formation typically did not morph as members held their positions (Figure 3e,k) until the wanderer returned. Wanderers were less frequently seen with groups of 3 and in the CINEMA setting. No wanderers were noted in the MALL setting.

Although the driver was the dominant interacting member, we observed cases where active observers became drivers, especially in the PHOTO and CINEMA settings. In fact, in nearly half of the groups, the driver role changed one or more times. We call this a *role rotation*. We recorded more role rotations in the PHOTO setting, so task duration and complexity likely influence whether this rotation occurs and how often. In most cases, the formation morphed dramatically during a role rotation, especially for groups of 3. For example, two women started in the formation shown in Figure 3e, but after the first driver obtained her ticket, a dramatic morphing took place to change to the formation in Figure 3g. The small interaction space with these kiosks is certainly a contributing factor. With the exception of one group of 3, the relative left-to-right ordering of group members remained the same.

In the MALL setting, group members most often interacted by pointing and touching, but also used verbal communication. To prevent gesture miscommunication, fingers were brought closer to the display to reduce parallax. Since groups of 3 generally stood just beyond of arm's reach, this meant that members leaned in slightly when gesturing.

Inter-group Behaviours

The observations above focus on behaviours within a group, but other groups and individuals modified these behaviours and introduced inter-group behaviours.

The density of people around the display affected group behaviour. Higher densities forced group members closer together, triggering formation morphing (e.g. such as Figure 3c,i to k), but it decreased the likelihood of a passive observer becoming a wanderer. In PHOTO and CINEMA, when adjacent kiosks were occupied, groups were naturally forced to together. Rather than pairs being forced next to each other, the observer typically moved to a position behind the driver and peered over their shoulder (typically on the right as in Figure 3e). With groups of three, members more often squeezed the current formation tightly together.

Since the MALL display was large and shared among multiple groups, it provided the best source for multi-group formation observations. Most of the multi-group interactions were between two groups. Groups of any size, including individuals, would stagger their positions in front of the display (Figure 4). This formed a queue of sorts, with the first group to arrive standing closest, and the last group standing the farthest away. Similar to how members in a single group morphed their formation, multiple groups also morphed their inter-group positions. The parting of one group resulted in other groups all repositioning themselves such that they were redistributed evenly. The adjustments were minor movements: sufficient for a screen of this size.

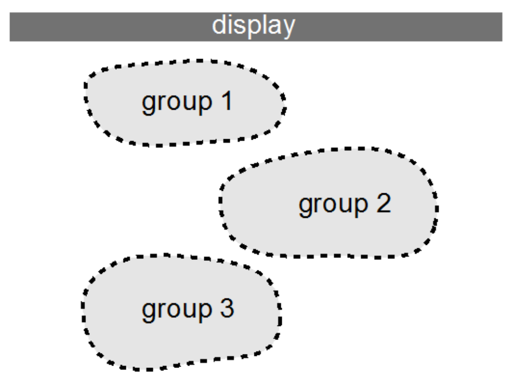

Figure 4. Multi-group positions at MALL: groups staggered their position according to arrival order.

Groups often asserted their collective interaction space with respect to other groups. At PHOTO and CINEMA settings, a group would approach a free kiosk even if members of another group were infringing on the free kiosk's space. By approaching the kiosk, the infringing group would naturally reorient themselves and compressing together into a tighter formation. This did not occur as naturally in the MALL setting. Without a clear delineation of designated kiosk workspaces, groups around the single shared MALL display could not assert their intention to interact at a particular location. This resulted in the queuing formation discussed above.

STUDY 1: IMPLICATIONS FOR DESIGN

Recall our motivational scenario of a large interactive display for groups to plan their day at an amusement park (Figure 1). Designers of such a system would benefit from our study results, especially regarding where the kiosk-like planning workspaces are located and how they are sized to accommodate different group sizes and concurrent groups. To fully realize this, the system must track groups and identify member roles. Our results contribute to this solution:

Group Tracking. Our catalogue of typical group arrangements when approaching and interacting is a first step to implementing an automated group identification algorithm. Delayed approaches by some members and wandering members while interacting make this a difficult problem. Multiple groups further complicates the matter, although the way multiple groups stagger themselves as a depth-based queue and one group will compress to open space for another are useful characteristics.

Member Role Identification. Assigning roles such as driver, active observer, passive observer, and wanderer would enable a system to make more nuanced decisions. The orientation of members and facial cues (e.g. mutual eye gaze and/or talking) may assist in this identification. Longer task durations can increase probability of wanderers.

Once groups are tracked and roles identified, the system can manage group workspace territory more effectively:

Optimize Group Workspace. Unlike a group of people around a tabletop display, vertical display groups adopt many different formations and roles when approaching and interacting. The position of the workspace must be large enough to comfortably accommodate the group taking into account led and asynchronous arrival, while optimizing multi-group usage. With limited space, the workspace can shrink from passive observers, but remain focused on the current driver. The longer and more complex the task, the more likely members will wander, so if multi-group space is limited, the system could even encourage wandering.

Support Different Roles. Workspace characteristics should adapt according to different member roles. The driver must be given the primary space, then active observers, and less so for passive observers. Role rotations should be expected and accommodated smoothly, especially during long tasks.

Leverage Group Territoriality. Optimizing display workspace may require the system to force groups to shuffle and accommodate others. Stepping up to a free kiosk asserts territorial claims, but only if there is a kiosk to step up to. The system can track a group approach and create a workspace for them to assert. If there is an infringing group, the system can leverage the natural behaviour of shuffling over to accommodate the new group by shuffling the infringing group's workspace.

Our study focused on behaviour *around* public kiosks and displays. To fully realize design implications for workspace management, we also need to understand behaviour *on* the display.

STUDY 2: CONTROLLED EXPERIMENT

The goal of this experiment is to investigate how concurrent individuals and groups use a large interactive display. To extend our field study, we focus on people's behaviour and interactions in the workspace *on* the display, paying specific attention to how those actions affect people's behaviour around the display and how the territories they adopt on the wall extend to the space around them.

In this experiment, multiple participants solved a series of real jigsaw puzzles in parallel, as two individuals or as two pairs. The puzzles were held by magnets onto a large whiteboard. We chose a physical medium rather than developing a custom application on a digital large display to avoid potential confounds from interaction design, input quality, and display resolution. A puzzle task is easy for participants to understand and helped us to rapidly prototype different study designs. Most importantly, solving a puzzle requires different kinds of personal, semi-public and public tasks like assembly, sorting, and monitoring an image of the completed puzzle.

Participants

30 adults (16 females) were recruited from the university's graduate population. 10 participants were designated as SINGLES and 20 were grouped into PAIRS such that each pair had two people with a pre-existing social or professional relationship (7 were opposite-sex pairs).

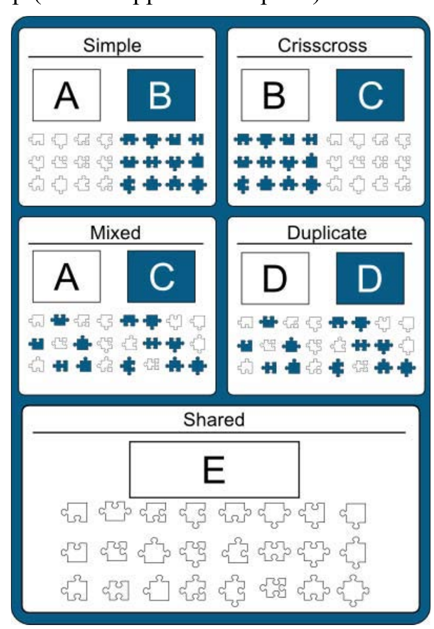

Figure 5. Puzzle layout configurations ('A' through 'E' represents a unique puzzle).

Apparatus

Six jigsaw puzzles, two of which being duplicates, were fitted with magnets to enable vertical assembly on a magnetic whiteboard. Five puzzles had 24 pieces and measured 38 x 28.5 cm. The sixth puzzle had 46 pieces and measured

91 x 61 cm. We used this as a larger workspace task for four collaborators working together. All puzzles were designed for young children (ages 3+) and depicted popular cartoon characters.

The whiteboard was divided into 2 horizontal regions. The top displayed a target image: a photo of the completed puzzle. The lower region provided 300 x 207 cm of common space to complete the puzzles (Figure 6). At the beginning of each session, the upper portion of this common space held the unsorted puzzle pieces. This layout approximates the "public in the top" and "private in the bottom" structure used in related public display prototypes [24].

Figure 6. Two pairs working collaboratively on the large shared jigsaw puzzle task.

Task

Two SINGLE participants, or two PAIRS of participants, solved jigsaw puzzles in 5 layout configurations ranging from none-collaborative to highly-collaborative (Figure 5):

- SIMPLE: pieces of two different puzzles are placed directly below corresponding target images. This forms a non-collaborative baseline.
- CRISSCROSS: pieces of one puzzle are below the corresponding target image of the other. Depending on intergroup pre-planning, this requires some negotiation.
- MIXED: pieces from two puzzles are mixed together. This may require negotiation and collaboration to organize and sort the pieces.
- DUPLICATE: pieces of two identical puzzles are mixed together. This requires more collaboration to organize and sort pieces without hoarding or stealing.
- SHARED: One large puzzle is completed collaboratively by both SINGLES or both PAIRS. This requires a high level of collaboration.

Participants were told that the experiment was not a race, and that there was no incentive for finishing first.

Design

There were 10 experiment sessions (5 SINGLES and 5 PAIRS). Each session had 5 trials, 1 for each layout configuration counterbalanced using a random Latin square.

Between sessions, participants were asked to leave the room so they could not see the puzzles being set up. While outside the room, they were asked to refrain from intergroup communication.

Data Collection and Analysis

All 10 sessions were audio and video recorded. Video was captured from three different angles: overhead, side, and rear. Video from each angle were synchronized and composited together to create a split-screen view (Figure 6). Each session lasted 34 minutes on average (SD = 13, RANGE = 27 – 71), creating close to 6 hours of video for analysis. The videos were analyzed by the first author who also transcribed the audio. Qualitative analysis used an open coding approach based on Strauss and Corbin's Grounded Theory Methodology [23].

RESULTS

We present our observations in three sections. Behaviour *on* the display focusing on workspace territory, behaviour *around* the display focusing on formations of participants when interacting, and behaviour which bridges *on* and *around* display territories.

On-display Behaviour

On-display behaviour is primarily concerned with individual and group workspaces, defined as the display space used for the *majority* of the task. Analogous to Scott et al.'s findings [21] for tabletops, participants partitioned their workspace into three territories: personal, storage and public (Figure 7). As participants completed the task, their territories grew and shrank, but we noted distinct patterns.

For the most part, PAIRS collaborated in solving the challenges. Only in one DUPLICATE layout trial with the PAIRS condition, one pair opted to complete two halves of a puzzle independently then merged at the end.

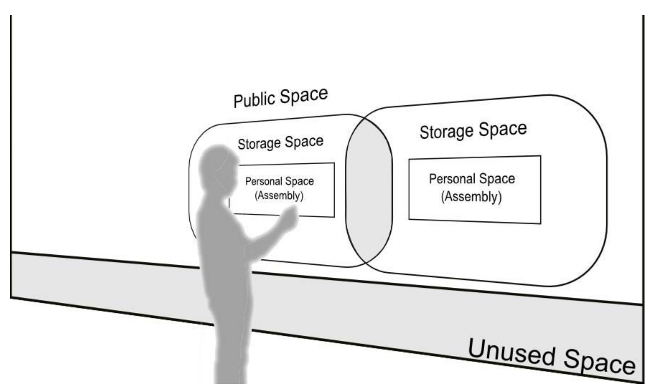

Figure 7. Three workspace territories: personal, storage, and public space. Note intersection of storage space is shared with adjacent group and space below waist is unused.

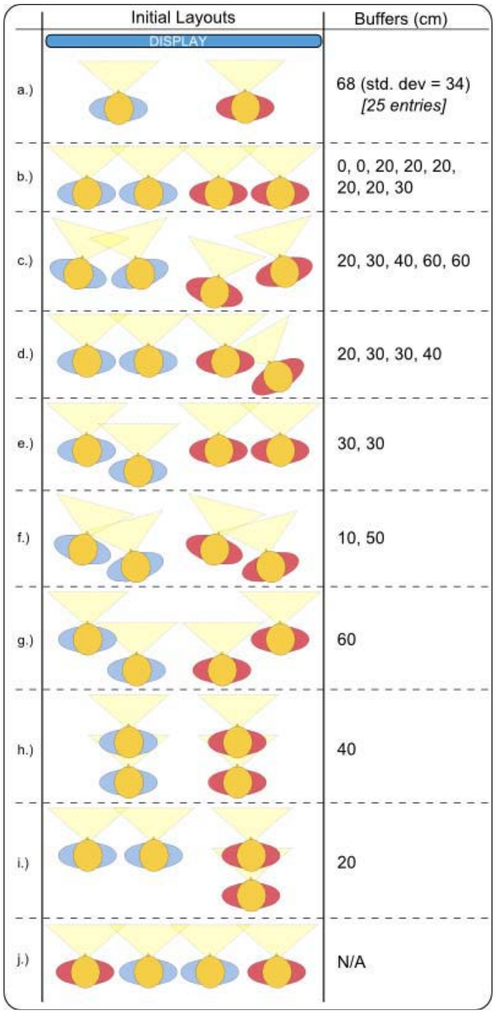

Figure 8. Initial formations and buffer sizes for all 50 trials. A buffer size of 0 cm indicates physical shoulder contact.

Personal Territory

The region dedicated to actual puzzle assembly becomes a *personal territory*. Since the puzzle's size grows as it is pieced together, we define this region by the bounding box around the area of construction. Since puzzle assembly occurred at eye-level, this space was the portion of the display closest to the face (a very personal area) and spanned within arm's length falling comfortably within 0.5 – 1.2 m which matches Hall's definition of personal space [10]. We observed no intrusions into this area by SINGLES or PAIRS.

Storage Territory

Immediately outside the personal territory marks the start of *storage territory*. We frequently observed SINGLES and PAIRS relocate pieces to a temporary area near their personal territory. These were often pieces which were likely to be used next, but we also observed participants test the compatibility of a small subset of pieces in this space rather than their personal territory – using it as a kind of sandbox. The boundary of storage and sandbox territory is less defined than personal territory. In our puzzle task it extended the width of two pieces.

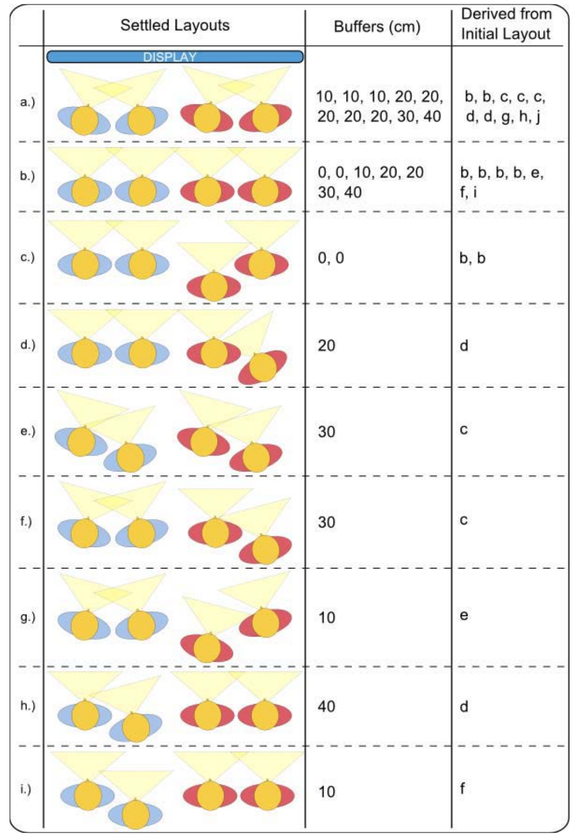

Figure 9. Settled formations and buffer sizes for all 25 PAIR trials. The initial formation leading to settled layout is included (refer to Figure 8).

Unlike personal territory, storage and sandbox territory would sometimes overlap, becoming *shared storage*. This was used to transfer or exchange pieces frequently: an average of 15.8 times per session (SD = 11.8) for SINGLES and 16.8 times (SD = 10.8) for PAIRS. Like personal territory, intrusion into unshared storage territory was very infrequent: an average of 0.4 times (SD = 0.9) per SINGLES session and only once in 4 PAIRS sessions. There appears to be an expectation that the shared storage which forms between two nearby workspaces can be almost exclusively used for transferring ownership of information.

Public Territory

All space beyond the storage territory was considered *public territory*, a communal territory. We observed participants freely interact in this space without verbal or non-verbal negotiation which suggests that this space is implicitly assumed to be available for anyone. Most obvious in MIXED, SHARED, and DUPLICATE configurations, multiple participants handled the same piece, as long as it was returned to the public territory. If a piece was taken and later replaced (e.g. deemed unnecessary, not enough storage space) that piece was assumed to be available to everyone again. Very infrequently, public territory served as an ad-hoc storage space to test the compatibility of pieces in a vacant area: 3 SINGLE individuals and one PAIR used this strategy once.

Off-display Behaviour

As participants interacted in these territories on the vertical wall, they organized themselves into a variety of formations. We describe the results of three aspects of these formations: the *initial formations* that participants chose when beginning interaction, the *settled formations* which they worked in for the majority of their time, and the *buffer zones* they maintained between each other.

Initial Formations

At the beginning of each session, all but two participants immediately approached the display, took a position, and began interacting. As soon as the final participant stopped, the formation of all participants was documented as an *initial formation* (Figure 8). The SINGLES condition could only take one formation as both participants reached the display (Figure 8a), but PAIRS had more initial layout variations.

Settled Formations

We define a *settled formation* as the formation held longest or most frequent while interacting. While SINGLES had the same initial and settled formations, PAIRS quickly, but fluidly, morphed from an initial formation into an often completely different formation (Figure 9). Within a pair, the two individuals typically held their relative left-to-right positions, but rarely demonstrated a rotation just like we saw with groups of 2 in the field study, namely for PHOTO and CINEMA.

Buffer Zone

We quantify inter-group formations by measuring the smallest lateral distance between the feet of participants in different groups when participants are within arm's length of the display (Figure 10). We call this the *buffer*. Visual markers in the scene enabled us to measure the buffer with 10 cm precision. We logged a new buffer size whenever a participant moved to a new location for at least three seconds to filter out brief movements. SINGLES maintained an average buffer zone of 61.0 cm (SD = 33.4 cm) and displaced themselves an average of 5.36 times (SD = 5.87) per trial. PAIRS maintained an average buffer zone of 28.3 cm (SD = 22.8 cm) and displaced themselves an average of 2.96 times (SD = 1.97) per trial. SINGLES evidently took advantage of the additional space and were generally more spread out and consumed more storage.

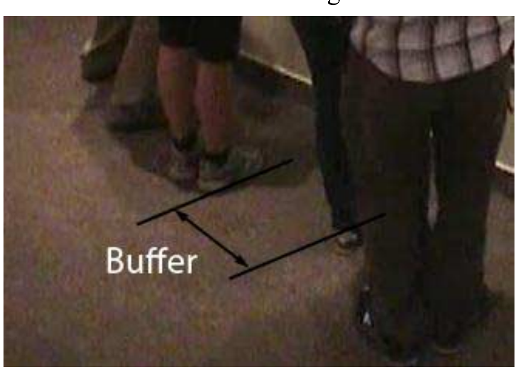

Figure 10. Defining the buffer zone.

Combined On- and Off-display Behaviour

Puzzle pieces could be widely dispersed in the MIXED, SHARED, DUPLICATE, and CRISSCROSS configurations. In these cases, pieces could be out-of-reach for a participant. Retrieving these pieces often required negotiating both on and off-display space. Since we are interested in behaviour among groups, we only coded out-of-reach pieces when they were beyond the participant's reach and within reach of the other party. There were 37 out-of-reach pieces for SINGLES, with an average of 7.4 per session (SD = 3.8). There were 45 out-of-reach pieces for PAIRS, with an average of 9 per session (SD = 4.6).

We identified three out-of-reach retrieval strategies:

Walk-and-grab. SINGLES always chose to walk over and grab pieces, even if it intruded in Hall's 0.5 m intimate space [10]. Participants in PAIRS chose to walk over and grab for 38 of 45 instances (84%).

Ask Other Party. Participants in PAIRS requested assistance from the other party using verbal or non-verbal communication 3 times.

Ask Partner. Participants in PAIRS requested assistance from their partner 4 times.

The initial arrangement of jigsaw pieces had far more out-of-reach pieces than the numbers above indicate. In practice, when participants identified a piece belonging to the other party, they largely discarded it into the shared storage space territory.

STUDY 2: IMPLICATIONS FOR DESIGN

Our results extend the design implications outlined in study 1, and introduce new contributions for intelligent workspace management for concurrent group usage which benefit system scenarios like the amusement park planning display (Figure 1).

Our quantitative results for buffer distance between groups and expanded catalogue of intra-group and inter-group formations extend information pertaining to *Group Tracking* and *Leverage Group Territoriality*. Our results extend these implications by introducing the behaviour of concurrent individuals: they are less stationary than a group of 2, they avoid information communication to retrieve distant information, and they seek a larger buffer zone. Likewise, the confirmation of left-to-right order preservation for group members, even when reaching for distant information, extends our understanding of *Role Identification*.

However, the primary contributions from this study are for on-display workspace design:

Use the Three Types of Workspaces Territories. We found strong support for the kind of territoriality observed on tabletops on large displays. A system should formally supports personal and storage territories within the common public space. In addition to being a place to gather information, the storage territory will likely also be used as a sandbox, to test out temporary information transformations before committing to the personal space. This sandbox territory should also be supported ad hoc in the public space. Finally, the natural tendency for adjacent groups to use a shared territory can be formalized and leveraged.

Consider Workspace Size and Location. Workspaces should be located near the height of an individual, or average group member height. The personal territory can be sized tightly to the expected size of assembled information and the shared territory can be sized to hold a relatively small number of information items and wrapped tightly around the personal territory. No interaction should be expected below the waist.

Expect Reaching, Support Sharing. If information is located away from an individual, they will reach for it themselves, even if this requires walking. This suggests that techniques that support virtual reaching (e.g. the virtual reaching technique in [24]) are beneficial. However, we also found that informal, almost accidental sharing using the shared storage territory occurs often. If individuals that temporarily take an item, only to realize they do not need it, will pass it to adjacent groups if the system makes this sharing convenient.

CONCLUSION

In this paper we presented two studies that examined inter- and intra-group behaviour *around* and *on* public displays. Using observations from a field study, we characterized group position and orientation around current public kiosks.

In our second study, we examined group behaviour *on* the display using a controlled experiment and demonstrated that on-screen territories for shared vertical displays are similar to those observed in collaborative tabletops [16,21]. In addition, we extend prior work in territoriality to show how the territories of groups working concurrently influence each other and how these territories change throughout the interaction.

Our results also demonstrate that Hall's [10] proximity zone classification and social practices around these zones must be modified to accommodate interactions around and on a large display given the frequency and acceptability of people violating each other's personal and intimate zones.

Collectively, results from our studies inform the design of publicly-shared displays by providing insights into group identification and tracking, role identification, allocating size and location of group workspace, and group territoriality before, during, and after interaction.

REFERENCES

1. Ballendat, T., Marquardt, N., & Greenberg, S. Proxemic Interaction: Designing for a Proximity and Orientation-Aware Environment. *Proc. of ITS 2010*.
2. Brignull, H., & Rogers, Y. Enticing People to Interact with Large Public Displays in Public Spaces. *INTERACT 2003*.
3. Carter, S., E. Churchill, L. Denoue, J. Helfman, and L. Nelson. Digital Graffiti: Public Annotation of Multimedia Content. Extended abstracts of the CHI, Pages: 1207-1210. 2004.
4. Czerwinski, M. P., Smith, G., Regan, T., Meyers, B., Robertson, G. G., & Starkweather, G. Toward Characterizing the Productivity Benefits of Very Large Displays. *Interact*, 2003.
5. Czerwinski, M., Robertson, G.G., Meyers, B., Smith, G., Robbins, D., & Tan, D. Large Display Research Overview. *Proc. of CHI 2006*.
6. Danninger, M., Vertegaal, R., Siewiorek, D. P. & Mamuji, A. Using social geometry to manage interruptions and co-worker attention in office environments. *Graphics Interface 2005.*
7. Dickie, C., Hart, J., Vertegaal, R., & Eiser, A. LookPoint: An Evaluation of Eye Input for Hands-Free Switching of Input Devices between Multiple Computers. *Proc. of OZCHI 2006.*
8. Elrod, S., Bruce, R., Gold, R., Goldberg, D., Halasz, F., Janssen, W., Lee, D., McCall, K., Pedersen, E., Pier, K., Tang, J. & Welch, B. Liveboard: A Large Interactive Display Supporting Group Meetings, Presentations and Remote Collaboration. *Proc. of CHI 1992*.
9. Greenberg, S., Marquardt, N., Ballendat, T., Diaz-Marino, R., & Wang, M. Proxemic Interactions: The New Ubicomp? *Interactions,* Vol. 18, January 2011, pp. 42-50.
10. Hall, E. T. The Hidden Dimension. *Doubleday*.
11. Holmes N.P., & Spence, C. The Body Schema and Multisensory Represention(s) of Peripersonal Space. *Cognitive Processing*, Vol. 5, 2004, pp.94-105.
12. Izadi, S., Brignull, H., Rodden, T., Rogers, Y., & Underwood, M. Dynamo: A Public Interactive Surface Supporting the Cooperative Sharing and Exchange of Media. *UIST 2003*.
13. Jacob, R.J., Girouard, A., Hirshfield, L.M., Horn, M.S., Shaer, O., Solovey, E.T., & Zigelbaum, J. Reality-Based Interaction. *Proc. of CHI 2008*.
14. Jacucci, G., Morrison, A., Richard, G., Kleimola, J., Peltonen, P., Parisi, L., & T. Laitinen. Worlds of information: Designing for Engagement at a Public Multi-Touch Display. *CHI 2010*.
15. Ju, W., Lee, B.A., & Klemmer, S.R., Range: Exploring Implicit Interaction through Electronic Whiteboard Design. *Proc. of CSCW 2008*.
16. Marshall, P., Morris, R., Rogers, Y., Kreitmayer, S., & Davies, M. Rethinking 'Multi-user': An In-the-Wild Study of How Groups Approach a Walk-Up-and-Use Tabletop Interface. *Proc. of CHI 2011.*
17. Mynatt, E.D., Igarashi, T., Edwards, W.K., & LaMarca, A. Flatland: New Dimensions in Office Whiteoards. *CHI 1999*.
18. Peltonen, P., E. Kurvinen, A. Salovaara, G. Jacucci, T., Ilmonen, J. Evans, A. Oulasvirta, & P. Saarikko. It's Mine, Don't Touch! Interactions at a Large Multi-Touch Display in a City Centre. *Proc. of CHI 2008.*
19. Peltonen, P., Salovaara, A., Jacucci, G., Ilmonen, T., Ardito, C., Saarikko, P., & Batra, V. Extending Large-Scale Event Participation with User-Created Mobile Media on a Public Display. *MUM 2007*.
20. Russell, D., Drews, C., & Sue, A. Social Aspects of Using Large Public Interactive Displays for Collaboration. *Ubicomp*, 2002.
21. Scott, S.D., Carpendale, M.S.T, & Inkpen, K.M., Territoriality in Collaborative Tabletop Workspaces. *Proc. of CSCW 2004*.
22. Shoemaker, G., Tsukitani, T., Kitamura, Y., & Booth, K. Body-centric interaction techniques for very large wall displays. *NordiCHI 2010*.
23. Strauss, A. & Corbin, J. Grounded Theory Methodology: An Overview. *Handbook of Qualitative Research, pp. 273-285*.
24. Vogel, D. & Balakrishnan, R. Interactive Public Ambient Displays: Transitioning from Implicit to Explicit, Public to Personal, Interaction with Multiple Users. *UIST Symposium 2004*.