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Investigating Tabletop Territoriality in Digital Tabletop Workspaces

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ABSTRACT
Within the digital tabletop research community there is a growing understanding of the fundamental interaction behaviors that digital tabletop workspaces should enable in order to facilitate effective collaboration. Some of these understandings have theoretical basis such as tabletop territoriality, which is grounded in the theoretical understandings of human territoriality. From this developing theoretical understanding, design guidelines have emerged and prototype systems have been created. The next step in this research progression is to use these theories as the basis from which to analyze interaction data from digital tabletop use to understand if the existing tabletop interfaces and interaction techniques support these fundamental interaction behaviors. This paper describes one such analysis, in which the data from an observational study of a tabletop interface component, called storage bins, is examined to determine how well it supports tabletop territoriality, as well as another known beneficial interaction behavior, casual piling of workspace content.

Categories and Subject Descriptors
H5.3. [Information Interfaces and Presentation]: Group and Organization Interfaces – Computer-supported cooperative work, Synchronous interaction, Evaluation/methodology

General Terms
Design, Human Factors

Keywords
co-located collaboration, observational studies, qualitative analysis, CSCW, tabletop displays, territoriality

1. Introduction
Recent advances in display and multi-user input hardware [3, 8, 10, 15] have increased the feasibility of interactive digital tabletop systems. Unlike the original DigitalDesk [27] and the initial proof-of-concept collaborative tabletop displays (e.g., [23, 24]) that only provided low-resolution, single touch interaction, these next-generation interactive digital tabletops enable simultaneous multi-user support on increasingly high-resolution displays. The increased capability of these systems has fueled renewed interest in tabletop displays, in particular from the co-located collaborative research community (e.g., [9, 17, 19, 22]).

Constructing a tabletop display, however, is only the first step toward providing interactive support for collaborative tasks. Standard software interfaces are not well suited to large-screen tabletop displays [21, 22]. For instance, their large display surface can make items automatically placed along a particular edge of a screen (e.g. the Windows ‘start bar’) difficult to reach. Also, horizontal displays introduce orientation issues because people can approach the display from different sides [11]. The state of standard interface components can become ambiguous when viewed upside down or from different angles [21]. Thus, in order to create effective collaborative tabletop interfaces, more appropriate basic system components are needed. These new components would be the tabletop equivalent to standard interface components that are available to desktop application developers, such as buttons, menu bars, and dialog boxes.

The fundamental components of any interactive system should enable the activities (i.e. tasks and goals) that the users wish to perform, in a way (i.e. using known skills and processes) that they wish to perform them [4, 13]. Therefore, redesigning the interface and interactions for a tabletop display requires an understanding of *what* activities people will perform in that environment and *how* they wish to perform them.

Given the considerable experience people have using traditional tables for collaborative activities, it is likely they have established certain practices for working with and sharing items in a tabletop workspace that are commonly understood and expected by others. Just as sharing a verbal language can help people communicate with each other, such work practices can help people collaborate more effectively. The overarching goals of this research is to investigate *what* work practices might exist and *how* they are used during traditional tabletop collaboration and to apply this knowledge to the development of more suitable collaborative tabletop display technology.

To address these goals we have performed in-depth investigations of people’s work practices during traditional tabletop collaboration tasks such as game playing [11, 20] and collaborative design [20]. These investigations have uncovered several beneficial tabletop work practices, including the practice of tabletop territoriality [20], which is theoretically grounded in the more general practice of human territoriality. Our understanding of these work practices has formed the foundation of design guidelines for digital tabletop systems [20] and has motivated the development of several new tabletop interface components and interaction techniques [9, 12, 21]. The next step is to use this knowledge as the basis from which to analyze study data. In this paper, we take the data from an observational study of a tabletop interface component, called storage bins [21], which have been designed to support tabletop territoriality, and instead of performing a usability analysis as in [21], we examine the extent to which storage bins support tabletop territoriality [20] and casual grouping [14, 20].

To provide further context for this analysis, we first briefly describe these two work practices and their respective benefits. Next we describe some problems our previous investigations uncovered with the practice of casual grouping with traditional media that the storage bins’ design attempts to mitigate, while still providing the benefits of this practice. Then, we briefly describe the design concept of the storage bin interface component. Finally, the methodology and findings from the exploratory study are presented.

2. Traditional Tabletop Work Practices

2.1 Tabletop Territoriality

In-depth investigations of workspace interaction during traditional tabletop collaboration revealed the practice of tabletop territoriality [20]. This work practice involves the establishment and maintenance of various tabletop territories on a shared tabletop workspace, typically including: *personal*, *group*, and *storage* territories. These investigations also revealed that the three types of tabletop territories have dynamic spatial properties that fluidly change as the task activities evolve. This work also revealed that tabletop territoriality facilitates collaborative interactions on a table by providing commonly understood social protocols that help people:

- share the tabletop workspace by clarifying which regions should be used for joint task work and for assisting others and for disengaging from the group activity,
- delegate task responsibilities,
- easily coordinate access to task resources by providing lightweight mechanisms to reserve and share task resources, and
- organize the task resources in the workspace.

Figure 1 summarizes the general concept of establishing personal, group, and storage territories on a shared tabletop workspace. In general, when group members arrive at a table, the table surface is available for sharing and, thus, forms the group territory. A personal territory is then established in front of each group member at the table, expanding and contracting and occasionally shifting to the right or left as necessary. Storage territories, on the other hand, are established in a variety of locations on the table and appear to sit atop the personal and group territories. Storage territories are also moved around the tabletop workspace to suit the current task needs.

2.2 Casual Grouping of Workspace Content

These in-depth investigations also revealed that items contained within the storage territories tend to be fairly casually organized [20]. Storage territories often contain both loose piles of resource items as well as individual items loosely arranged in the storage territory region. These casual grouping activities provide many task and collaborative benefits to tabletop collaborators. For example, being able to casually group resource items can help collaborators quickly organize the workspace and access task resources when and where they are needed. In a study of piling behavior on office desks, Malone [14] found that this type of casual workspace organization helps people organize their work, reminds people of work still to be done, and provides a cognitively lightweight mechanism for people to store items that are otherwise difficult to classify.

The investigations of traditional tabletop collaboration also revealed that the ability to move storage territories around in the workspace provides several benefits for task interactions (e.g., easy access to resources) and for the collaboration process (e.g., allows people to easily reserve or share resources) [20, 22]. The ease of moving storage territories around on the table to coordinate group members' access to tabletop resources is in stark contrast to the mechanisms typically used by groupware systems to manage access to shared items. These systems often assign 'ownership' of system resources to a group member, requiring that person to explicitly release control of an item before another group member can access it (e.g., [17]). Such explicitness may hinder fluid group interactions since it appears to contradict the socially mitigated process used in traditional workspaces [20, 22].

3. Problems with Casual Grouping using Traditional Media and Digital Solutions

Although the ability to casually group traditional media within storage territories on the table provides many collaborative and task benefits, our earlier investigations also revealed several issues associated with this practice during our investigations of traditional tabletop collaboration. Groups of stored items often occupied valuable working space on the table, especially if there were many items contained in the storage territory or if the stored materials were large. Furthermore, people often had difficulties searching for specific items within a storage territory because the stored items were often overlapped and haphazardly organized (see Figure 2, notice some of the 'messy' piles of items being stored in the workspace). Thus, the ease of being able to loosely organize stored items often hindered the later retrieval of those items.

Unlike the fixed size of workspace items in the physical world, the size of digital items can be adjusted. This property can be leveraged to help alleviate some of the problems that people encountered with casual organization of traditional media. Several existing interface techniques make use of item scaling for stored items to help create more display space for the main task activities.

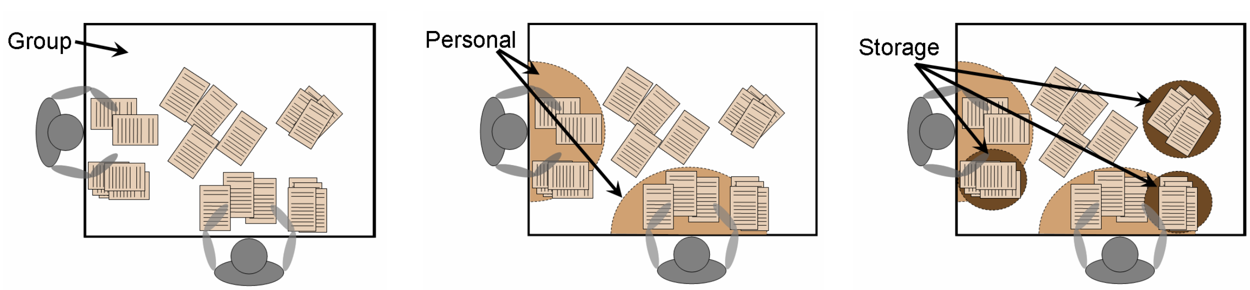

Figure 1. Conceptual diagram of the three types of tabletop territories.

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One approach is to 'squash' out-of-focus items against the workspace edge by pushing another item against it, creating more working area while at the same time minimizing overlap between items [16]. Another approach is to scale workspace items placed inside a visible 'storage' area along the periphery of the main workspace. For example, on Stanford's interactive wall, any workspace item moved into a storage area spanning the top edge of the display, called the ZoomScape, is scaled to 25% of its original size [7]. Similarly, any application window that is placed in the storage area surrounding the main workspace of the Scalable Fabric desktop system will also be reduced in size [18]. Reducing the size of stored items can also help minimize search issues because many small items can often be spread out in an available space before occlusion becomes an issue.

However, providing storage areas along the periphery of the workspace only partially supports the storage behavior observed in our investigations of traditional tabletop collaboration. Being able to store resource items anywhere in the workspace and to move them around can be critical for coordinating task and group interactions on a table [20]. To facilitate this storage behavior in a digital tabletop workspace, a mobile storage mechanism, called a *storage bin*, was developed which provides the space-preserving features of existing storage mechanisms, while also providing the capability to relocate stored items in the workspace. The following section provides an overview of the functionality of storage bins (a more detailed description can be found in [21]).

4. Storage Bins

A storage bin is a mobile, adjustable container widget that provides users with a lightweight interaction mechanism to store and retrieve workspace content anywhere in the workspace. The main interface and interaction characteristics of storage bins include:

Container capabilities. Storage bins provide the capabilities of a container, allowing items to be added or removed as a group or individually. They are also resizable to easily accommodate varying amounts of stored items.

Mobile. To provide easy access to stored contents, all items in a storage bin can be readily relocated in the tabletop workspace simply by moving the storage bin.

Visually subtle with flexible boundaries. To minimize distraction from users' main task activities, transparency is used to make storage bins visually subtle in the workspace. Storage bins also have curved, adjustable boundaries to enable flexibility in users' casual grouping behavior. Figure 3c shows a storage bin.

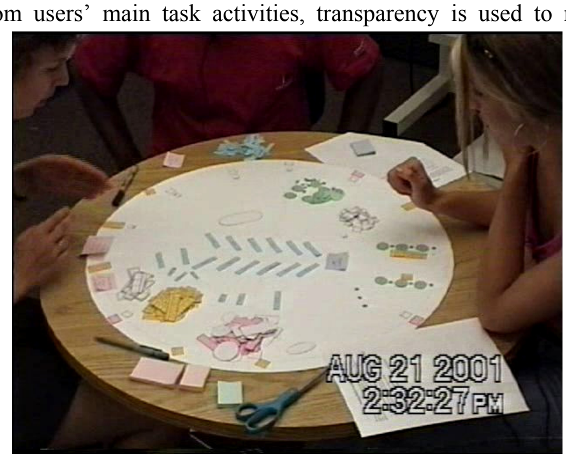

Figure 2. Storage territories containing various casually grouped resource items.

Space-preserving storage. To conserve screen real-estate for the main task activities and minimize item occlusion among stored items, scaling is applied to items placed inside a storage bin. Items are scaled by 35% to a minimum of 80x80 pixels (to maintain recognizability). Items are considered 'inside' the storage bin when the current touch point (i.e. current location of the user's finger or pen) is within the storage bin. Figure 3a illustrates the act of storing an item in a storage bin and Figures 3b and 3c show two views of the same 10 images demonstrating how scaling can help with occlusion: the full-sized images (Figure 3b) have considerable overlap and scaled images in a storage bin (Figure 3c) are not occluded.

In summary, storage bins are graphical user interface container components that can be used to hold other workspace items, such as images, documents, and thumbnails. Its mobility and adjustability in size and shape allow people to share resources and transition between resources. Moving a storage bin allows a person to bring a collection of stored items into and out of the current focus of activity. Being able to expand and collapse a storage bin allows people to dynamically customize their working area: when they are actively using a collection of stored items, the storage bin can be expanded to provide easier access those items; when they are finished with the collection, the storage bin can be collapsed to free up that area of the workspace.

5. Exploratory User Study

In order to understand the advantages and disadvantages of both mobile and peripheral storage mechanisms, an exploratory user study was conducted. In this study, small groups performed a collaborative photo layout task on a digital tabletop system containing either storage bins or a peripheral storage area that spanned the perimeter of the tabletop workspace.

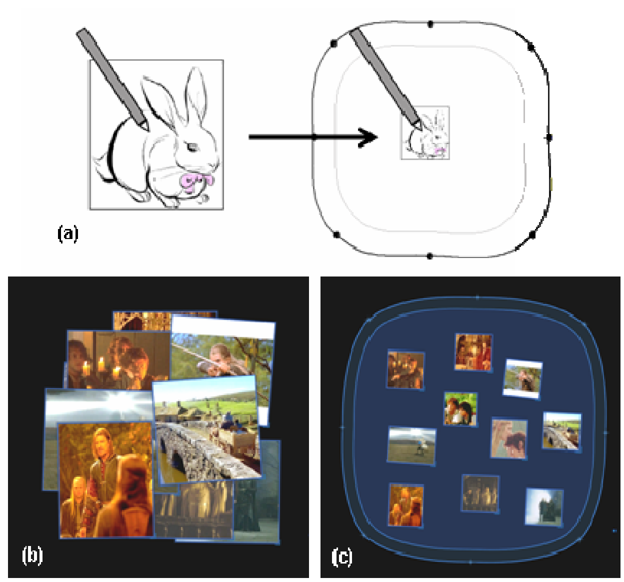

Figure 3. Storing an item in a storage bin (a). The same collection of photos are shown at full-size in (b) and inside a storage bin in (c) (images from [11, 12]).

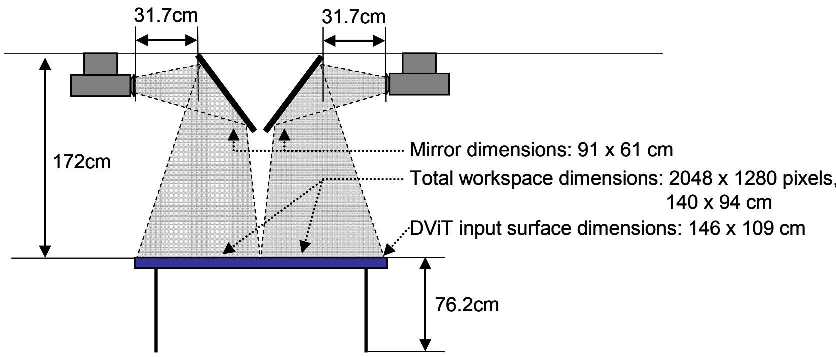

Figure 4. Schematic diagram of the digital tabletop setup.

Figure 5. A photo layout created on the theme page for 'Romance'.

5.1 Experimental Methodology[1]

Participants. Six pairs of university students (3 male groups and 3 female groups) participated in this study. All participants rated themselves as frequent desktop computer users, although only four were computer scientists. Only four participants had previously used a digital tabletop system. Participants all had previous experience collaborating at a table using traditional media and were familiar with the two popular shows (Friends and Lord of the Rings) used as the content for the experimental task (described below). Only one pair of participants knew each other prior to the study.

Apparatus. Participants performed the experimental activities while seated at a large (152.4cm x 121.9cm), high-resolution (2048x1024 pixels) tabletop display in a university laboratory. Participants sat at adjacent sides of the table during the study and stood when it was necessary to reach something across the table. During one session, participants ended up standing on opposite sides of the table for most of the session. The tabletop system enabled multi-user touch interaction by using a 4-camera[2] SMARTBoard™ DViT 1810 interactive whiteboard that recognized up to two simultaneous touches on the board surface. The software ran on a Xeon™ 2.80GHz Windows XP personal computer. Figure 4 illustrates the digital tabletop setup.

A digital video camera was setup at one end of the table to record the participants' interactions with the tabletop surface and with each other. Small, clip-on microphones were also used to record participants' conversations during the sessions.

Experimental Design. Each pair completed the experimental task twice: once with storage bins and once with the peripheral storage area. The order of presentation of the storage mechanisms was counterbalanced. In addition, two sets of photo content were used in the study, one for the television show 'Friends' and one for movie trilogy 'Lord of the Rings'. Participants used different photo content in each task trial. The order of presentation of the photo content was also counterbalanced.

Experimental Task. The experimental task involved creating several photo collages on template layout pages in a tabletop workspace. During each task trial, participants were provided with four theme pages (512x512 pixels each) and 100 photos (125x125 or 256x256 pixels each) loosely clustered in the middle of the tabletop workspace. The photos and layout themes used for each task trial related to a popular television show ('Friends') or movie ('Lord of the Rings' trilogy). The goal of each task trial was to create a photo layout for each of the four theme pages in the allotted time. Figure 5 shows a sample layout on the 'Romance' theme page from the 'Friends' TV show.

Collaborative Tabletop Workspaces. Participants performed the layout task using two different workspaces: one containing storage bins and one containing a peripheral storage area.

In the storage bin workspace, nine storage bins were provided: one in each corner and five clustered directly between the participants' initial seating positions. The latter five storage bins were intentionally positioned between collaborators, and likely 'in the way,' to create the opportunity to see if people would move them to a more 'suitable' location and, if so, where that would be. Figure 6a shows the storage bins used in this study and their initial configuration relative to the participants' seating positions.

Storing an item (or group) in the peripheral storage area was identical to storing an item (or group) in a storage bin. Unlike the storage bins, though, the peripheral storage area was permanently fixed to the workspace edge. A larger or smaller storage area could be created by resizing the peripheral storage area. Each side could be resized independently to allow different sized storage areas on each side of the table. Figure 6b shows the peripheral storage area used in this study, with and without task content.

The experiment software was implemented in Microsoft Visual C# and OpenGL, using the Tao.OpenGL library (www.taoframework.com). To provide software support for multiple users at the tabletop display, Tse's DViTtoolkit (an extension of the SDGToolkit [26]) was used.

Along with the storage mechanisms described above, the tabletop groupware also contained several features useful for performing the layout task. The photos and theme pages could be easily resized via a resize handle on the lower right corner of each item.

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[1]A very brief version of this methodology was reported in an earlier paper discussing the usability issues of storage bins and preliminary findings of this study.

[2] The DViT 1810 model comes in a 2-camera and a 4-camera version. Only the 4-camera version can robustly track two simultaneous touch points.

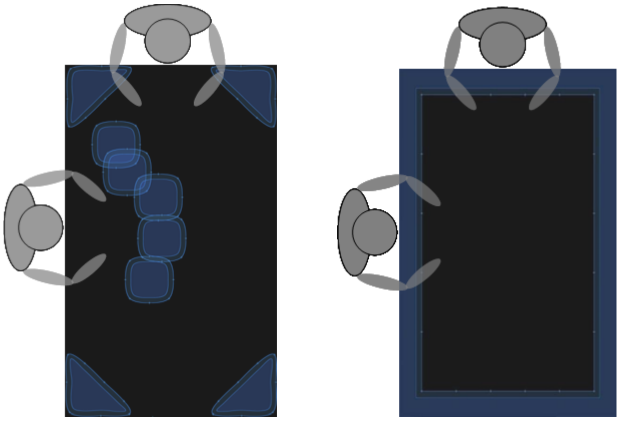

Figure 6. Initial configurations of the two storage areas in the workspace: (a) the storage bins, and (b) the peripheral storage area.

Groups of items could be created and selected by dragging a bounding box around several items. To facilitate reorientation of tabletop items on the table, touching and dragging an item (or group of items) in the workspace invoked an interaction mechanism called Rotate 'N Translate (RNT) [12]. RNT allows an object to be simultaneously rotated and translated in a single fluid motion using a single touch point. To enable easy passing of items to someone across the table an enhanced version of RNT was used, which provided the ability to toss items across the workspace with a simple 'flick' action performed on an item.

Procedure. Each session began with an introduction from the experimenter. Participants then completed background questionnaire gathering information on general demographics, computer experience, and collaboration experience. Next, the tabletop system was introduced and participants were shown how to use the first storage mechanism. They were given 15 minutes to perform a practice layout session using one theme page and 45 photos. Once the practice session was complete, the group was given 20 minutes to create the four theme layouts in the actual task trial. After the task trial, participants completed a post-trial questionnaire that elicited their reactions to the storage mechanism and the interface in general. This procedure was then repeated for the remaining storage mechanism. Finally, participants completed a post-experiment questionnaire gathering their final reactions on the two storage mechanisms. Each session took roughly 90 minutes to complete.

Data Collection. Participants' interactions in the digital workspace were logged to a data file and their interactions with the tabletop and with each other were captured on audio- and videotape. Field notes were also recorded during the session to note any particularly interesting interaction behaviors or emerging patterns. Preference data was also collected on the post-trial and post-experiment questionnaires.

Data Analysis. To understand how the storage mechanisms were used during the layout task and how their designs impacted participants' interactions, as well as the overall collaboration – especially as it relates to the emergence of territorial behavior – it was necessary to know what actions each person performed in the workspace. However, the SMARTBoard DViT touch surface does not distinguish between different users touching the surface; it only knows that one or two touches are currently on the surface and where each touch is. Therefore, the initiator of the workspace actions could not be recorded in the corresponding logfiles.

Thus, in order to interpret the interactions that occurred during the layout sessions, visualizations were produced from the actions recorded in the logfiles. Visualizing the actions that occurred across and on the storage mechanism (i.e. boundary interactions) was found to be useful for identifying interesting episodes and interaction trends during the sessions. These boundary interactions included: storage or retrieval actions (i.e., any instance of an item (or group) being moved inside or taken out of a storage mechanism), and resize, reshape, or move actions performed on the storage mechanism.

Figure 7 shows a sequence of visualizations which correspond to a series of interactions in one of the storage bin trials. Each image in the sequence shows the cumulative boundary activity (i.e. any storage or retrieval actions) between storage bin events (i.e., a move, resize, or reshape). The small black plus and red minus symbols show storage and retrieval of individual items, while the larger symbols show the storage and retrieval of a group of items (participants were seated to the left and top of each image). The rough outline of the current location, size, and shape of the storage bins are shown, along with all storage and retrieval actions associated with each storage bin while they were in the indicated positions. Storage bin relocation is indicated by a green 'tail' showing its path from its initial position to its new position.

Figure 8 shows a series of visualizations for one of the peripheral storage area trials. Each image shows the cumulative storage and retrieval actions on the peripheral storage area during different phases of the task: sorting photos (left), and assembling theme layout pages (middle & right). Again, the participants were seated

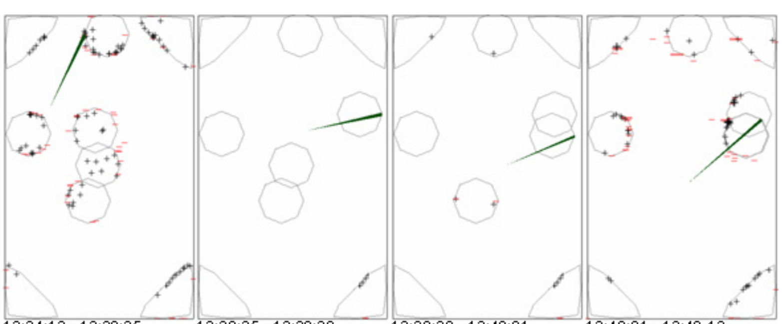

Figure 7. A sequence of workspace visualizations from one of the storage bin trials.

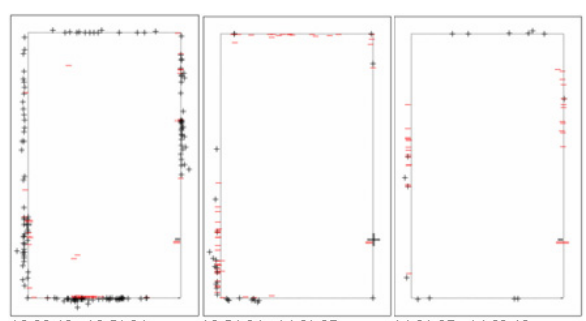

Figure 8. A sequence of workspace visualizations from one of the peripheral storage area trials.

to the left and top of each image. No manipulations were made to the storage mechanism during this trial.

These visualizations were used in conjunction with the video data to understand the participants' tabletop interactions. For each trial, the visualizations were reviewed for interesting interaction patterns. Once particular episodes were identified, the corresponding video segments were reviewed to help further understand these interactions and to precisely identify which participants were performing these interactions. The videos were also viewed in their entirety several times to gain an overall understanding of the interactions in each trial, especially with respect to the different working styles used within and across groups and across storage mechanisms.

6. Preliminary Findings

Some preliminary findings from this study were included with the introduction of the interface component, storage bins [21]. These initial findings focused on the usability of storage bins and on how the two storage mechanisms were used to perform the collaborative layout task. The findings revealed that participants frequently took advantage of the ability to move stored items in the workspace, and that the mobile storage bins better facilitated the different individual and collaborative working styles that occurred throughout the study. The peripheral storage mechanism, however, was found to be better at facilitating task activities that required fairly loose spatial organization, such as the initial, quick sorting of photos into the four layout themes that each group performed at the beginning of their layout sessions. In general, storage bins appeared to provide tabletop collaborators more flexible support for performing task activities associated with fine-grained organization of the workspace, while peripheral storage mechanisms provided better support for more the casual interactions involved in coarse-grained organization of the workspace.

The preliminary findings also revealed that the storage bins were more effective at supporting variations in collaboration styles than the peripheral storage area because the storage bins enabled localized interactions. That is, the adjustability and mobility of storage bins enabled group members to interact with them without interfering with their collaborators' current tabletop activities. This finding is particularly relevant because this localized interaction, is a critical aspect of enabling the practice of tabletop territoriality.

An example of this localized interaction is illustrated in the

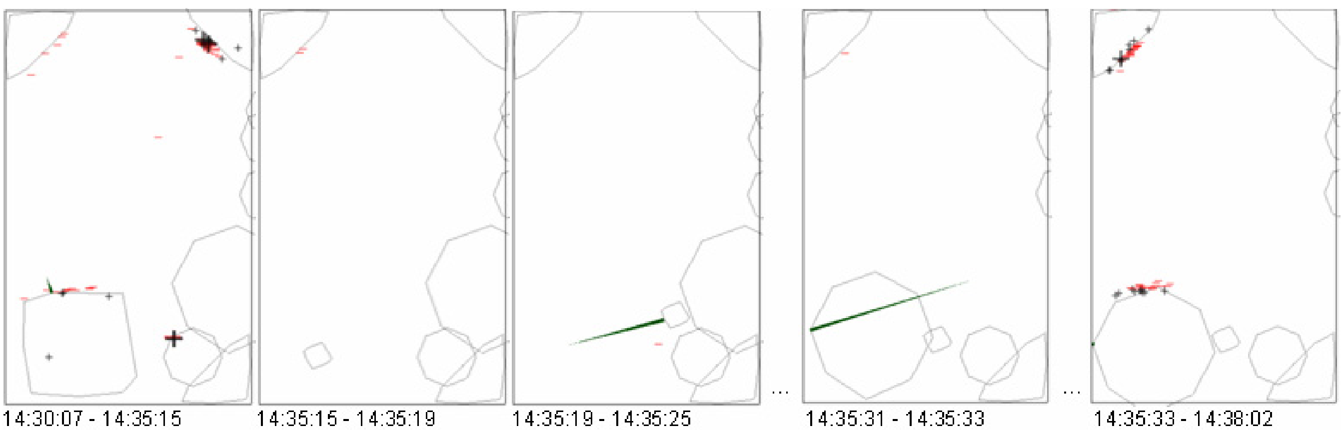

Figure 9. A sequence of workspace visualizations illustrating localized use of the storage bins for the group shown in Figure 9. The first image in the sequence includes interactions shown in Figure 9a. The resizing of the lower left storage bin in the second image corresponds to resizing of storage bin 1 in Figure 9b. The last image includes the interactions shown in Figure 9c. Note the continued use of the upper left storage bin by one partner as the other partner used different storage bins near the left table edge.

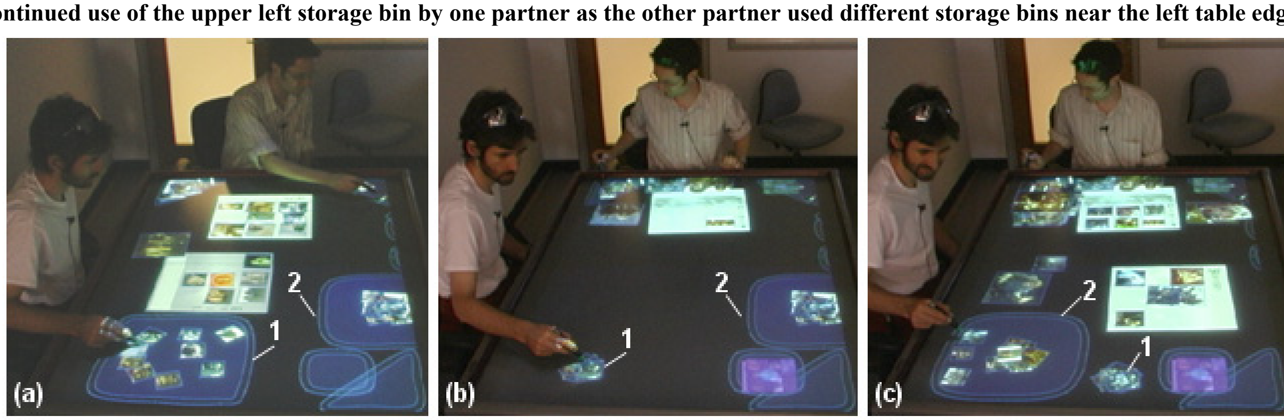

Figure 10. Localized use of the storage bins: (a) participants select photos from separate storage bins, (b) the participant on the left collapses a storage bin, and (c) then he selects photos from a different storage bin while his partner continues using the same storage bin (images from [20]).

sequence of workspace visualizations show Figure 9 and corresponding sequences of actions from the video data shown in Figure 10. These sequences show a participant (on the left) first using photos from an expanded storage bin (Figures 9(first) and 10a), then collapsing the storage bin (Figures 9(second) and 10b), and finally using photos from a second expanded storage bin which he has repositioned from the opposite table edge to the table in front of him (Figures 9(last) and 10c). His interactions have not affected his partner's access to the stored photos in the upper left corner of the table. In contrast, if the first group of photos had been in a peripheral storage area in front of him, collapsing this group would have collapsed all photos being stored along that table edge, including the photos his partner was using in Figures 10b and 10c.

7. Findings

7.1 Enabling Casual Grouping of Task Media

Participants made use of both types of storage territories to support casual grouping activities. They were both used to casually create groupings in that participants could add and remove items individually or in groups of items. Having a container removed the frequent moded interaction that requires people to create a group all at once. With storage bins, a grouping could gradually accumulate as a task, such as sorting, proceeded. Both types of storage appeared to help people organize their workspace and keep track of what was finished and what was still to be done. Storage bins were used to locate resources when and where they were needed. Storage bins were also used to create a space in which participants could place items that they did not think they would use – thus keeping this process cognitively lightweight as would be predicted by Malone's findings [14]. Through discussion participants arranged to use regions of the peripheral storage for this purpose.

The mobility of storage bins was used frequently to support such collaborative activities as: providing easy access to resources; allowing people to easily reserve resources for later use; and moving resources to a better location for sharing items. Participants seemed to work well with this facility of loose, flexible container based storage, in that it enabled them to share items with little or no conflict. This issue is discussed in the literature as a need for ownership and hand-off mechanisms [17]. Human territoriality theory would predict that if the right mechanisms are in place well learnt behavior about territoriality will help to smooth collaborative sharing [1].

The fact that items are scaled down in size upon being placed within storage was remarked upon as being useful for tidiness and was also used to clear large items such as the layout pages themselves out to the working space. The group depicted in Figure 12 particularly liked this feature, declaring "perfect" after the layout page (currently being selected by the person on the right) was placed the in storage bin (currently being moved by the person on the left).

Having a container in which to create casually grouped items allows participants to casually shuffle through items without having to group or ungroup them. Again, the reduced size facilitated this interaction behavior since there was less overlapping to contend with (see Figure 10a for example). Causal grouping within a storage bin did not appear to hinder later retrieval. An advantage that the peripheral storage mechanism had over storage bins for enable casual grouping was that it was possible to toss an item across the table into the peripheral storage without being concerned about over shooting the storage area. With storage bins, participants often 'missed' storage bins when quickly sorting the photos during the initial stages of the layout task, especially when tossing items across the table.

7.2 Enabling Tabletop Territoriality

In general, the ease of manipulating workspace content in the tabletop groupware interface supported the establishment of personal, group, and storage territories during the layout sessions. The localized interactions enabled by the storage bins, however, provided more flexibility for tailoring these tabletop territories to more precisely meet participants' task needs.

7.2.1 Personal territories

Establishing a personal territory on the table allows collaborators to perform independent task activities when desired and to reserve task resources. Personal territories typically, but not always, comprise the area on the table directly in front of each person.

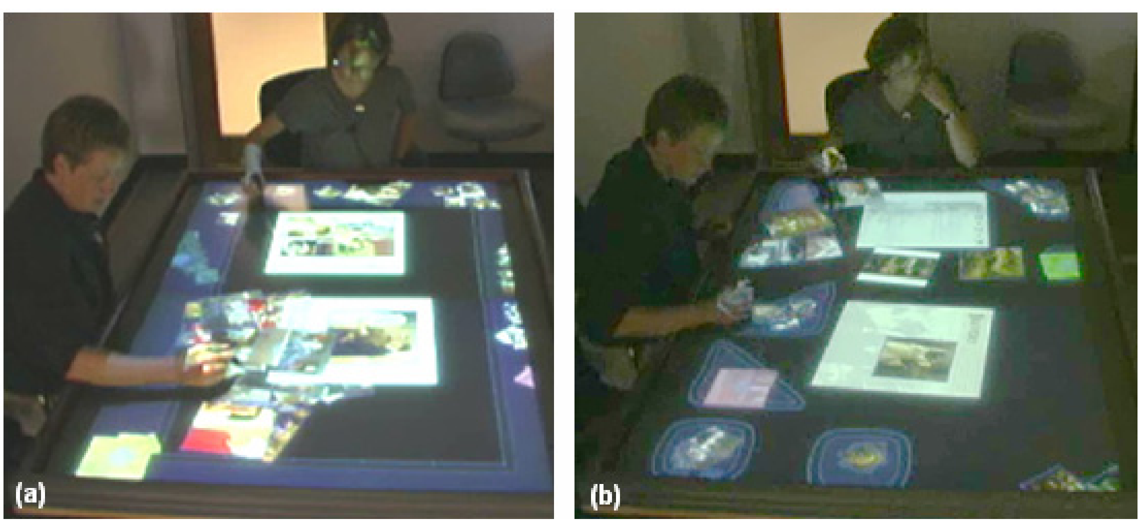

Figure 11. One group using the two storage mechanisms. Note how much closer the theme page is to the participant at the top of the scene when she is using the storage bins (b).

However, because the peripheral storage area occupied the entire table edge, this area was unavailable for working on the layout with that setup. With peripheral storage, participants working in parallel usually placed their theme page just above the peripheral storage area but still close to themselves and arranged their candidate photos beside the theme page in the main workspace. They typically placed the theme page as close to the table edge as possible without moving it into storage.

On the other hand, when using the storage bins, group members working in parallel typically placed either a theme page or a storage bin that was actively being used for choosing photos directly in front of them on the table, in close proximity to the table edge. For example, the upper participants in Figures 10b and 10c have placed their theme pages close to the table edge as they are working on them, while the side participants in the same figures have placed storage bins close to the table edge for choosing their candidate photos. Contrast this to Figure 11a, where both participants are forced to work with their theme pages quite far from the table edge.

Thus, it would seem that, when possible, people preferred to establish personal territories close to the table edge when working in parallel during the layout task on the tabletop. The mobility of the storage bins provided people with the choice to either have the theme page or the stored photos close to them in their personal territory. In contrast, the fixed nature of the peripheral storage area did not offer people the choice to work on their theme pages in this space, unless the entire storage area was collapsed; thus, preventing access to any stored items along that entire table edge.

The localized interaction enabled by storage bins has important implications for the establishment of personal territories. Enabling localized interactions allows people to effectively disengage from the group activity when desired without interfering with their collaborator's workspace actions. Simultaneously, storage bins still provide visibility and transparency of action which enables people to monitor their collaborator's activities in their personal territories, which facilitates group members offering assistance to their partners when appropriate [20]. Figure 12 shows an example from the study where one participant (at the top) suggests that her partner include a photo that was stored in a storage bin in her partner's personal territory. She points to the photo to clarify her suggestion and her partner then incorporates that photo into her layout.

7.2.2 The group territory

Both storage mechanisms enabled participants to use the central region of the table to perform the layout task, to share task resources, and to assist each other in performing the task. The storage bins, though, allowed participants control and flexibility when structuring the bounds of group territory, enabling participants to place shared resources within easy reach of where the participants where actually working, as opposed to having the group territory predefined by the physical perimeter of the tabletop workspace. For example, Figure 13 illustrates how one group has arranged the storage bins all along the bottom of the workspace, and away from the side edges to accommodate their layout activities in the group territory. This figure also provides an example of how storage bins can facilitate people assisting each other in the group territory: The participant (on the left) passes a storage bin unsolicited to his partner to put the finished layout page in.

7.2.3 Storage territories

Both storage mechanisms supported the establishment of storage territories – both inside and outside of the actual storage mechanisms. This parallels real world situations such as people making puzzles often using auxiliary surface such as puzzle lids for mobile storage [20]. Participants in this study created casual groupings of digital content both within the storage mechanisms and in the main workspace. Also, just as people assembling puzzles take advantage of the convenience of moving the box lids around the table in order to easily gain access to stored puzzle pieces, participants in this study leveraged the ability to move groups of items contained within a storage bin. Thus, storage bins allowed participants to easily move a group of photos into and out of the focus of activity as the task required. One group also took advantage of the mobility of storage bins to loosely arrange several storage bins together at one end of the table to establish a large storage territory (see Figure 13).

Figure 12. A group member providing assistance in a storage bin located in her partner's personal territory.

Figure 13. Participants have rearranged the storage bins to accommodate their interactions in the group territory.

In summary, the mobility and adjustability of storage bins allowed participants to design and re-design their territories. Storage bins were frequently re-purposed, serving as part and helping to define either personal or group territories and then being relocated for different reasons such as less active use or when changing from one participants personal storage to group shared storage.

8. Related Work

8.1 Casual Grouping on a Digital Tabletop

Several techniques have been proposed for supporting casual grouping in digital tabletop workspaces. Grant et al. [6] have investigated a number of automated 'pile' layouts for digital photo organization tasks on a digital tabletop. Their study involved gathering preference ratings and general feedback on mock-ups of eight proposed pile layouts, ranging from very casual, overlapping arrangements to highly-structured, grid style arrangements. Their results revealed a strong preference for the highly-structured arrangements. However, no subsequent study has been published of people using these piling arrangements during an actual digital tabletop activity. The grouping behavior observed in our storage bin study suggest that people might find different piling layouts at different stages of an organizational task: looser arrangements may be preferred early in a task when ideas are just being formulated and more structured arrangements may be preferred as the ideas and task activities become more refined.

More recently, Wu et al. [28] have described gesture-based tabletop interaction techniques for multi-touch digital tabletops, including a 'Pile-n-Browse' gesture which enables the collection of a group of workspace items into a digital pile using a two-handed containing gestures around the items. The pile of items can be collapsed to preserve space using a two-handed scooping gesture or expanded by pulling two hands away from each other on the tabletop over the pile. A pile can be moved using a visual icon over the pile. Using gestures for creating or manipulating piles provides a fairly casual mechanism for organizing workspace content, and it enables localized gestures similar to the mobile storage bins. However, it is unclear whether this grouping technique enables users to easily change pile membership without having to unregister the pile, move a new item nearby and re-register the pile, and likewise for removing only one item from the pile that a user might be interested in using. Furthermore, it is also not clear whether this method enables pile level actions, such as scaling all piled items to minimize item overlapping within the pile.

8.2 Tabletop Territoriality

The practice of partitioning the workspace, which is part of the more complex practice of tabletop territoriality [20], has been repeatedly observed in both traditional [11, 25] and digital workspaces [5, 19]. Eden et al. [5] observed workspace partitioning while investigating urban planning on a digital tabletop system. Their participants tended to take responsibility for different areas of the virtual map covering the tabletop workspace. They also observed that areas of responsibilities tended to shift as the task progressed. Also, participants located close to certain interface items often became responsible for interacting with them (e.g., becoming responsible for a button for switching the current mode).

Workspace partitioning was also observed in Ryall et al.'s [19] investigation of different sized groups performing a 'magnetic poetry' assembly task on different sized tables. In their study, participants often partitioned their interactions in the workspace while searching for word tiles on the tabletop, tending to take on responsibility for searching the word tiles nearest them on the table. Their results revealed that the activity in the areas near each person was dominated by that person. Finally, notice the overlap of participants' activity near the centre of the table and the edges of each person's area. The authors attribute this behavior to the phenomenon called Diffusion of Responsibility [2]: areas on the table where more than one person could reach were often considered the responsibility of "someone else" by each user, and thus no one took responsibility for these areas. Groups needed more explicit coordination to interact in these areas. Ryall et al. [19] also noted that groups using the smaller table in the study tended to have more overlap in their interactions and required more negotiation to share the table.

The combined implication is that while performing activities which afforded loosely-coupled interactions in the workspace (i.e., a task which could be easily divided into sub-tasks), the responsibility for different areas of the workspace was divvied up among group members (either implicitly or explicitly). Similar to the analysis of the storage bin study, Ryall et al.'s findings indicate that tabletop territoriality also occurs in digital tabletop workspaces. Their study also indicates that providing a sufficiently large table can facilitate the coordination of group members' interactions on a shared tabletop workspace by providing fewer overlapping reach areas and, thus, fewer areas where group members' sense of responsibility is diffused.

9. Conclusions

Overall, this paper has illustrated that an in-depth understanding of established traditional tabletop work practices such as tabletop territoriality [20] and casual grouping of workspace content can be a valuable resource for designers to use as a foundation for developing new interfaces and interaction techniques for digital tabletop workspaces. From this perspective we analyzed an observational study of magazine layout tasks involving peripheral and mobile storage bin tabletop interface components.

The findings from this study demonstrated that tabletop interface tools must be flexible enough to support a variety of task and collaboration styles throughout the evolving phases of a collaborative task. The study results also revealed the importance of enabling localized interactions in the workspace. Tabletop interface components that allow group members to interact independently in the workspace will facilitate tabletop territoriality because they allow group members to disengage from the group activity without interfering with their collaborators' interactions, as well as to easily redefine the actual working areas without being constrained to the physical boundaries of the tabletop workspace.

The storage bin tabletop interface component described in this paper is only one step toward developing a full set of fundamental interface components upon which more complete tabletop groupware applications can be built. Further work is also needed to begin integrating these interface components within more complex task environments.

10. References

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