

TableTrays: Temporary, Reconfigurable Work Surfaces for Tabletop Groupware

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Abstract

Most tabletop groupware systems provide a single shared display, and users must coordinate access to both resources and space. In many situations, it can be difficult to manage this shared space – for example, it can be difficult to deal with clutter, to partition the work area, to divide the task, and to work with multiple objects at a time. To address these limitations, we developed an interaction technique called TableTrays. It provides users with portable work surfaces that sit on the tabletop, and allows them to temporarily group sets of objects and organize the table area. TableTrays incorporates many of the capabilities that have been proposed for tabletop groupware into a single mechanism. In this paper we describe TableTrays and present the results of a study where six groups carried out a design task using the technique. The results suggest that they can help people manage space, objects, and collaboration in tabletop work.

1. Introduction

Tabletop groupware systems have many of the collaborative advantages found in regular tables – they are natural locations for shared activity, they provide a central focus for group work, they allow people to easily communicate with others face to face, and they provide rich awareness information.

Unfortunately, current tabletop groupware still does not provide the same level of flexibility that is found with regular tables. Regular tables let people organize the workspace in a variety of ways, allowing them to work with multiple objects through stacks and piles, and allowing them to move objects to temporary spaces such as folders, clipboards, or trays. This flexibility enables people to rearrange the table to suit the current state of the task, to protect their work, and to use mixed mode collaboration, where they move between loose and tightly coupled work styles.

Most tabletop systems, in contrast, provide users with a single shared workspace that cannot be divided or reconfigured, and provide only the most basic of mechanisms for working with objects on the table. These limitations make it awkward for users to manage

complex cooperative tasks, forcing them to carefully plan how they will coordinate access to space and resources.

Researchers have proposed a variety of techniques for improving interaction on tabletops, including Storage Bins for dealing with workspace clutter [13], rotatable widgets to allow reorientation to different positions [15], and pile and stack mechanisms to allow grouping of objects [2]. These techniques have been shown to be effective; however, they each address only one part of the overall problem faced by users of tabletop systems.

To address this limitation, we developed a general interaction technique called TableTrays that incorporates many of the capabilities proposed in previous work, and also adds new functionality. TableTrays are based on the real-world idea of a movable tray that sits on the table: objects can be placed on the tray for organization or for individual work, and then can be returned to the main table when needed. TableTrays are digital analogues of physical trays – temporary movable surfaces that exist within the main tabletop workspace. They provide five main capabilities:

- they divide the table into visually distinct regions, which aids in the organization of tasks and space;
- they are scalable, allowing users to shrink objects for storage or magnify them for detail work;
- they allow ‘soft grouping’ of multiple objects for organization or individual work;
- they allow easy copying and transfer of multiple objects to other members of the group;
- they can be reoriented to match the perspective of people located at different parts of the table.

To test the idea of multi-purpose temporary work surfaces, we carried out an evaluation where six pairs of participants used TableTrays to design and construct a comic strip using images and handwritten notes. We discovered that participants found TableTrays easy to learn, and used the trays frequently in their work. People reported a number of benefits of the technique, and particularly liked the visual boundaries created by the trays, their ability to free up space on the table, the

ease with which objects could be transferred to others, and the ability to move and reorient groups of objects during discussions with others. TableTrays are a general mechanism that can provide many of the capabilities proposed by other work, that offer additional novel functionality, and that can easily be added to many tabletop infrastructures.

2. Related work: techniques for tables

Several researchers have recognized limitations in tabletop interaction, and have proposed a variety of techniques to address some of these drawbacks. Below we review techniques for grouping, storage, reorientation, and clutter management.

Several researchers have suggested that tabletop systems should allow people to work with groups of objects, even though many techniques still do not support these operations (e.g. [6,7]). A study by Scott et al. [11] found that people working around a table will often pile paper artifacts and move these piles around for sharing and collaboration. It was observed that piling documents occurred regularly and helped people to organize the task and manage space. This supports the early findings of Malone [9] who found that people often use piles of paper to organize tasks and classify documents on their desk. Scott et al. [11] also suggest that digital table systems should allow users to move aggregated piles of items.

Some tabletop interactions techniques provide mechanisms for grouping and moving tabletop objects. Most notably, Scott et al. [12] developed Storage Bins, a technique that allows users to temporarily store objects. When an object is placed in a bin, it automatically shrinks so that it takes up less space. Similarly, Hinrichs et al. [5] describe Interface Currents, a technique that allows users to create flowing 'streams' in the workspace; items placed in the region drift around the table as if they were floating in moving water. This technique requires items to be added one at a time, and does not support aggregation and manipulation of groups of items.

Bauer et al. [2] investigated the idea of supporting flexible grouping. They implemented virtual 'clumps' and 'trays' based on the real world practice of stacking objects in piles. Clumps group digital artifacts and they maintain their spatial relationship to each other, whereas trays are more structured and are sorted and repositioned automatically. The techniques proposes several new approaches to aggregating objects, but they were not initially designed for tabletop systems, so do not emphasize important design issues such as reorientation and multi-user access.

Hartmann et al. [4] describe a tangible approach to tabletop workspace management. Their system uses physical input devices on each side of the table that

allows users to open and close virtual drawers in the workspace. The drawers are designed to help manage clutter by providing a storage area that can be resized or hidden. However, the storage areas are limited to specific areas of the table (where the hardware is installed) and cannot be moved around the workspace.

Several digital table systems allow users to reorient groups of objects. However, existing approaches do not allow users to rotate arbitrary regions of the workspace. The Personal Digital Historian [14] and Rogers et al.'s calendar system [11] have circular interfaces, and users can rotate the entire tabletop workspace as if it were a turntable. Similarly, the DiamondSpin toolkit [15] allows developers to create tabletop applications that have rotatable widgets, making it easier to add rotation to workspaces.

A related technique, called DocuBits and Containers [3], was developed to relieve clutter by allowing users to cut-out a portion of the tabletop workspace. A DocuBit is a screenshot of a section of the tabletop that can be moved to another region of the table or moved to another device.

Although each of these techniques are useful, there is no single technique that provides multiple capabilities through a simple interface metaphor. To address this limitation, we developed the TableTrays technique described below. TableTrays can save table space by allowing users to store items (benefits seen in Storage Bins), provide aggregation capabilities comparable to those described in Bauer et al.'s work, and allow easy reorientation of groups of objects in a way that is more flexible than previous rotating workspaces. TableTays combine these features in a single technique, and add several additional features that allow people to integrate them more seamlessly into tabletop tasks.

3. TableTrays

3.1 Motivation and inspiration

The design of TableTrays arose from observational work that we did with groups carrying out visual tasks around ordinary physical tables [10]. In this study, we asked eight groups of 3-4 people to carry out storyboarding tasks that used a variety of materials such as a single large poster board or a series of small poster boards, and a construction task where participants built a 3-D puzzle.

In the tasks that used large poster boards, we regularly saw that people grouped resources and reoriented the boards to enable participation by group members. However, they often had difficulties with moving the single large board, since it occluded or collided with other tools and supplies on the table. When groups used several small poster boards, movement and reorientation was much easier. The

boards were easy to handle and occlusion was not a significant problem, so people reoriented and repositioned them regularly, using them as conversational props, to partition the task and to transfer items to other participants.

In the 3-D puzzle task, the work was carried out directly on the table surface, and people could not move and manipulate puzzle pieces as a unit until they were physically connected. The absence of an underlying, movable work surface meant that when a set of separate pieces needed to be moved, they had to be repositioned one at a time.

These experiences showed that a digital technique that allowed temporary organization for sets of objects, and temporary partitioning of the table space, could be a valuable tool. Our observations also suggested that fine-grained control over these portable surfaces was needed – that we needed to provide more capabilities than what was available in existing storage techniques (e.g., [13]).

To address these needs, we developed the TableTrays technique for tabletop groupware. TableTrays allow people to create an additional surface between task objects and the main workspace; objects can be moved on and off of the tray, and trays can be rotated, moved, and resized without the objects losing their relationships to each other. TableTrays can help people avoid many of the shortcomings seen in many current tabletop systems. Our initial design goals were to enable users to:

- reduce clutter on tabletop workspaces;
- aggregate and manipulate groups of objects;
- transfer groups of objects to other users;
- create additional room in the workspace to support a variety of work configurations;
- partition the workspace, making boundaries between different areas clear to the group.

In the next sections, we describe the main operations supported by TableTrays. We implemented the technique using stylus input, but it could also be implemented for multi-touch tables.

3.2. Creating TableTrays

Users create TableTrays by using their stylus to define a rectangular region of the workspace. They place their stylus on the table to define the upper left corner of the region, and they drag down and to the right until they reach the lower right corner (Figure 1.1). When they lift their stylus away from the table, a transition region is created in the specified area. The transition region has a series of buttons that allow users to carry out three operations: cut, copy, or close (see Figure 1.2).

The cut operation, which is initiated by clicking the “X” button, creates a new tray, and it moves all objects in the transition area into the tray (see Figure 1.3).

Objects that overlap or are inside the area are moved into the tray. The new tray is given a randomly assigned color, and a full set of controls are displayed.

The copy operation can be initiated by clicking on the “C” button. Like the cut operation, it triggers the creation of a new tray. However, instead of moving the objects in the transition area into the tray, copies of the objects are created, and the original objects remain in their previous location.

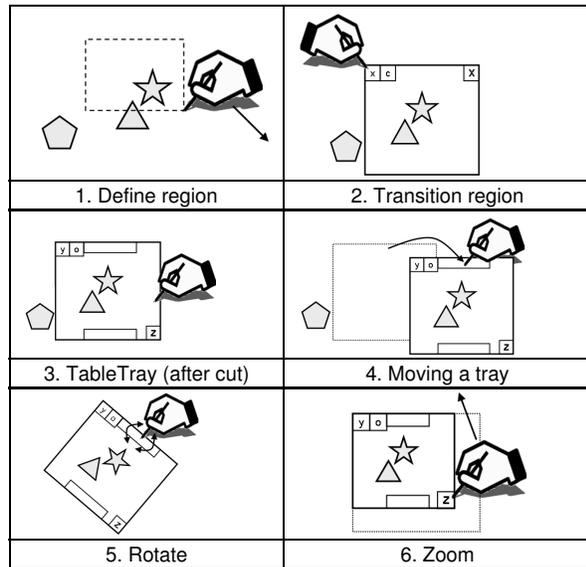


Figure 1. Create, cut, move, rotate, zoom. The user defines a region (1), a transition tray is created and the user pushes the cut button (2), and a tray is created (3).

3.3. Adding and removing objects

Users can add objects to TableTrays by clicking on an object with their stylus and dragging it into the tray. They can remove objects by dragging them out of the tray. If zoom operations were applied to an object while it was in the tray, it will retain its current size.

3.4. Move and rotate

Users can translate and rotate TableTrays (see Figure 1.4, 1.5). They can initiate these operations by either clicking their stylus on the drag bars at the top and bottom or by clicking on the background of the tray (i.e. anywhere objects are not located). The tray can be moved by clicking and dragging, and it can be rotated by twisting the stylus around the z-axis (although other rotation mechanisms are also possible).

3.5. Zoom

The zoom control can be used to change the size of a TableTray and the objects contained in it (Figure 1.6). The user clicks the “Z” button and drags away from the center of the tray to increase size, and towards the center to decrease size (the aspect ratio is preserved).

Decreasing the size of a tray can allow the user to store objects without taking up significant space.

3.6. Paste / paste original

The paste operations remove the TableTray, dropping all objects stored in the tray onto the main workspace (Figure 2). There are two paste operations. The first, initiated using the “Y” button, pastes objects back into the main workspace at their current size, location, and orientation (Figure 2). The second, initiated using the “O” button, pastes objects into the main workspace but restores them to their original size.

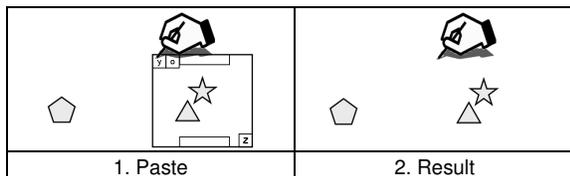


Figure 2. Paste operation.

In summary, TableTrays are a general-purpose interface mechanism that brings together many of the techniques proposed for tabletop interaction (grouping, storage, reorientation) and provides several new capabilities as well (copying, transferring, more flexible scaling). In the following section, we report on a user study that looked at how TableTrays were used in realistic tasks.

4. Evaluation

We had three main goals in our evaluation of TableTrays. We wanted to determine:

- whether the general-purpose tray mechanism was a reasonable way to provide several different interaction capabilities to users;
- which capabilities were most used for artifact-intensive visual tasks;
- whether our implementation of the technique was easy to learn and usable.

Therefore, we were not interested in comparing TableTrays to each technique that had been previously suggested, but rather in investigating how a more general approach would work in practice. To investigate these issues, we conducted a qualitative study where pairs of people used TableTrays while designing comic strips on a tabletop groupware system.

4.1. Participants

We recruited 12 paid participants, 11 males and 1 female, from a local university. Their ages ranged from 18 to 40, with a mean age of 25.3. All were Computer Science students, and all were frequent computer users (more than 20 hours a week). Participants were tested in pairs, and all pairs indicated that they knew each other, with 2 pairs stating that they were friends, and 4 stating that they were co-workers.

4.2. Apparatus

The experiment was conducted on a top-projected tabletop system with 1024x1536 pixel resolution, and a display area of 118x178cm. A custom study system was built in Java and ran on an Intel Core 2 Duo running Windows XP. Input was handled using a Polhemus Liberty tracking system with two pens.

4.3. Task

Pairs of participants worked together to design a comic strip (see Figures 3,4,5). They were asked to select one of four themes for their comic strip: science fiction, western, horror, or fantasy. A series of 80 images corresponding to the chosen theme were then placed on the table in random positions and orientations. They were also given 20 virtual notes that they could write or draw on using their stylus.

Participants were asked to create a comic strip by choosing a series of images and arranging them so that they told a coherent story. They were instructed to use the notes to augment the narrative of their story, by adding text, arrows, and custom artwork, so that the story would be understandable to an outside observer.

TableTrays were implemented as part of the application. Participants had access to all of the controls described earlier (cut, copy, paste, zoom, etc.).

4.4. Procedure

Participants were given training with the table and the input devices. The experimenter explained the application, and demonstrated how to interact with objects on the table. He then explained TableTrays and demonstrated the controls. Participants completed a 15 minute training trial, where they were encouraged to create TableTrays and to experiment with the controls. After the training session, they completed a 25-minute session, where they worked together to develop a comic strip. Groups were encouraged to use TableTrays during the session. Participants completed a questionnaire at the end of the session, and sessions were videotaped for later analysis.

5. Results

In the next sections, we describe the results of the study. We begin by reporting qualitative observations, and then we report results from the questionnaires.

5.1. Observations

We analyzed video from the sessions to investigate how people used the system and how they collaborated during the session. We were primarily interested in how they incorporated TableTrays into their activities and in any problems that they had while using them.

All groups used TableTrays extensively. All participants indicated that they felt comfortable using

trays by the end of the training session, and they did not have noticeable problems with the controls while carrying out the task. In the next sections, we discuss our main observational findings.

5.1.1. TableTrays to manage space

Most groups (five of six) began the task by clearing space for the activity, but people used several different strategies. Three groups used the cut operation to move a large number of images into a tray, and then shrank the tray using the zoom controls. Trays were then placed out of the way, in the corner or at the side of the table, until they were needed again. Two other groups cleared space by cutting images from their personal territories, and then pasting the images on top of others in the center of the table.

One group (group 5), did not attempt to clear or sort images early in the task. Each group member created a tray and placed it immediately in front of them, and began working in the trays, dragging notes and images into them. Since they did not clear space on the table prior to beginning the task, the trays occluded a large number of notes and images that were located beneath them. Early in the task, each user moved their tray around the workspace to try to see the objects that were positioned beneath it. As the task progressed, they began moving images out of their immediate personal territory to free space and minimize occlusion.

All groups sorted objects into categories early in the task, and TableTrays often played a major role in their sorting strategies. Five groups began by separating the notes from the images, placing them in a separate stack, with four of the groups putting the notes in trays so that they could move them around the table. People then sorted the images using two main strategies. Three groups categorized objects based on the content of the image, such as monsters and people, and faces and places. In all cases, the categories were kept in separate trays. For example, group 1 sorted images into “good guy” and “bad guy” trays:

User 1: “Let’s group some good guys and group some bad guys ...so when I see good guys I will give them to you, and you group them, and I’ll group bad.”

User 2: “...maybe we should put them in a tray? We can use a tray to move them around.”

All groups used TableTrays to clear the table once they had chosen most of the images for the comic strip and construction was well under way. People regularly selected unused objects and cut them into trays. They usually shrank the trays substantially and then placed them on the periphery of the table.

5.1.2. TableTrays as work surfaces

All groups used TableTrays as work surfaces, and built part or all of their comic strip in a tray. There was a

surprising degree of variety seen in the strategies that were adopted by the groups.

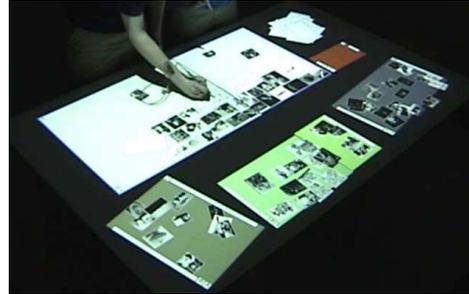


Figure 3. Transition tray (top) is used in comic strip construction. Trays (bottom) are used to group images.

Five of the groups built their comic strip in a single location. After sorting images, they discussed how they would put the story together, including the general narrative of the story and the images they would use. Groups built their stories on trays, but surprisingly, three groups built them on transition trays rather than cutting the images into a movable tray (see Figure 3). This shows that some groups did not feel the need to move their work around once they began to build the comic strip. Most comic strips were large, spanning either the length or width of the table, so moving it could cause occlusion problems, where the tray would overlap objects located in other regions of the table.

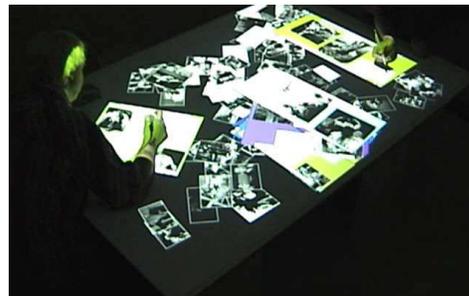


Figure 4. Group 5 built the comic strip on a series of trays (stacked in middle of the table).

The transition trays provided visual partitions that were recognized by group members, and the group seemed to benefit, even though the tray functionality was not used (three groups also used transition trays to sort images). The transition trays seemed to help divide the workspace, especially when several groups of objects were created next to each other—the boundaries of each group were clearly defined by the edges of the transition tray, whereas creating groups without the use of the tray could potentially lead to irregular and overlapping boundaries.

Two groups built their comic strips on movable TableTrays. In one case, a group used a single large tray, and in the other they used several trays (see Figure 4). In both groups, people adjusted the position of the tray on the table, but only minimally.

5.1.3. TableTrays and transfers

Participants also used TableTrays to group items and transfer them to their partner. People frequently worked with groups of objects, both in early stages where they were sorting images and later in the task when they were constructing the comic strip. They used trays to either show their work to the other user or to pass them a set of objects that they needed for their current activity. Trays also allowed people to partition the task, and allowed them to work in parallel and to later merge their work (e.g. the strategy employed by group 5, discussed in the previous section).

There were several instances where people transferred trays to the other user. These transfers were seen in three groups, and an example of this is seen in Figure 5, where a participant is shown transferring a group of photos across the table to another user. In this group, users worked in parallel on the comic strip. The user on the left constructed the comic strip in the space in front of him, and occasionally passed unused images to the other user. The user on the right sorted images and passed them to the user on the left, usually in trays, so that they could be added to the comic strip.



Figure 5. Person on left transfers a tray holding several images to the person on the other side of the table.

TableTrays also helped people to discuss the task. Four people showed the other user a tray of images, and they discussed how they related to their comic strip. For example, one person began building the initial part of the comic strip in a tray, and then showed it to the other user:

User 1: "Okay, let's just zoom this down, this is our entrance. See what you think."

He shrinks his tray, and passes it to User 2. User 2 uses the zoom controls to increase the size of the tray so that he can see the details.

User2: <reads a note that User 1 created in the tray> "...They stumbled across the Egyptian treasure.' Nice job."

User 2 hands the tray back to User 1.

5.1.4. Scaling and copying objects

People used the zoom and copying features in ways that we did not anticipate, and made use of TableTrays to make up for limits in other areas of the system. We initially expected the zoom feature to be used to change the size of groups of objects, which was done

regularly in all groups. However, people also used the zoom feature to change the size of individual objects. For example, one participant created a series of trays, each of which held a single note, and he used the zoom feature to increase the size of the notes prior to writing on them. Other people changed the size of individual images prior to adding them to their comic strip. This use of trays seemed to require extra work on the part of the user since they were not concerned with aggregating objects, but with performing a simple transformation on an individual object.

5.2. Questionnaire results

The questionnaire asked participants to answer several questions about TableTrays using a seven-point scale with semantic anchors in the middle and at the endpoints (see Table 1). The scale ranged from "made it much easier" with a value of 1, "no difference" with a value of 4, and "made it much more difficult" with a value of 7. The questions asked people how TableTrays affected their ability to: work together, understand the location of objects, move and edit groups of objects, and manage clutter.

Table 1. Questions from the questionnaire. Participants answered each question using a seven-point scale.

How did TableTrays affect:
1 ... your ability to work together as a group?
2 ... your ability to understand where objects are located?
3 ... your ability to move and edit groups of objects?
4 ... your ability to manage clutter on the table?

The results are summarized in Figure 6, and the average score is shown for each question. TableTrays were ranked favorably in all areas. The questionnaire provided people with an opportunity to comment on each of the scale questions. People gave TableTrays favorable ratings for its effect on their ability to work together as a group, and they described two main collaborative benefits of using TableTrays: improved organization and the ability to exchange groups of objects with the other person. Six people indicated that it had a positive impact on their ability to organize shared work on the table, for example: "allowed us to gather up related items to either share or put aside", "it helped to organize the table top: group notes/pictures together to clean up some space", and "easy to group pics and talk to each other in terms of groups." Five people wrote that one of the main collaborative benefits was that it was easier to exchange groups of items with the other person, for example: "sharing groups of images while keeping the tabletop organized was very beneficial to the work" and "it was easy to pass multiple images back and forth."

All participants indicated that TableTrays made it easier to move and edit groups of object. Responses included: "moving groups was a huge improvement

and adding / removing elements of a group was very easy” and “without trays, I couldn’t move a group of objects.” All participants also indicated that trays helped them to manage space and clutter on the table. For example: “good for grouping and shrinking to create space” and “the zoom feature allowed us to reduce the table real-estate that unwanted items use.”

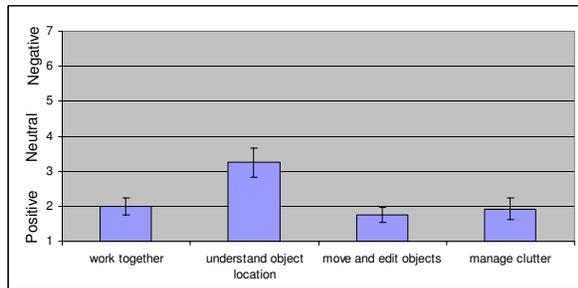


Figure 6. Scale responses. Bars show standard error.

The lowest score was for how well TableTrays help people to understand object location. Several people felt that they improved their ability to track objects on the table since they were able to group similar things. Examples include: “we grouped images by themes in trays” and “you could tell, at a glance, where a pile was.” Two people (both from group 5) indicated that trays occluded other objects in the workspace, making it difficult to tell what was located underneath them: “they could sometimes obscure elements” and “I found the trays sometimes obscured items.”

We also asked people to describe the benefits and drawbacks of using TableTrays. We grouped similar questionnaire responses and list the categories in the next two sections. For each category, we list the number of people that provided a response, and we give examples from the questionnaires.

Benefits

- *Improved organization (5 people)*: “easy to organize at the end if all components were kept in trays”, “I can categorize pictures easily”
- *Moving groups of objects (9)*: “move and edit multiple items in one action”
- *Reducing clutter / freeing space (6)*: “change zoom to gain working space, reduce clutter”
- *Resizing objects (6)*: “can use trays to make pictures larger when it fits the storyline”
- *Creating multiple copies (2)*: “copy and paste so you don’t have to write the same thing twice”

Drawbacks

- *Not useful for editing a small number of objects (4)*: “could not resize a single image without putting it into a tray”
- *Includes all objects overlapping edge of tray (2)*: “grabbing an image with 1 pixel in the tray”

- *Occlusion (4)*: “things could get lost more easily if they ended up underneath a tray”

6. Discussion

Our findings provide useful insights that can be applied to the design of tabletop groupware systems, and that can be used during the development of other interaction techniques. In this section, we summarize the main insights we gained through the study.

6.1. Landmarks

One of the main benefits of using TableTrays is not related to the underlying functionality that we provided; instead, it is the result of the visual boundaries that the technique adds to the tabletop workspace. The use of transition trays provides significant insight here. Several groups left trays in their transition state, where they could not be repositioned, and they carried out their work on top of the transition region. One of the most common uses of the transition trays was to define the area where the comic strip would be assembled, so movement may have been undesirable due to the awkwardness of reorienting such a large region.

Even though the transition trays were not functional partitions, the visual boundaries affected how people structured their work. This can be seen in Figure 3, where people are lining up storyboard elements inside the transition area. Similar behavior was seen in other sessions, where images and notes were stacked somewhat haphazardly outside of the transition region, but were organized within.

This behavior suggests that digital table systems that support complex group tasks could provide a similar mechanism for managing the workspace. This mechanism could be as simple as allowing users to define large rectangular areas in the background to provide landmarks that they can use to define the roles of different areas on the workspace.

6.2. Aggregation and collaboration

Several groups used TableTrays to facilitate cooperative activities that would have been more difficult without a flexible aggregation mechanism. One of our main findings was that people reoriented trays toward other users to aid communication, so that they could show them a set of images or the work that they had completed on the comic strip. These findings are similar to those of Kruger et al. [8], who found that people use object orientation during communication. Our study adds to this knowledge by showing that people are interested in reorienting and discussing aggregated groups rather than just individual objects.

People also used TableTrays to transfer items across the table to their partner. Here, aggregation plays a key role in allowing people to coordinate their activities

more closely. For example, in some groups one person sorted images and then transferred them to another; in another group, people worked separately and later merged the work that they had separately done in a series of trays. This effectively provides a mechanism for splitting the workspace into several separate parts and for merging it again later by pasting the artifacts into the main workspace.

These findings suggest that the aggregation mechanisms provided by TableTrays can play an important role in mixed focus cooperative work, where people switch between individual and shared work. This style of work is common, and has previously been supported in many distributed groupware applications, where separate modes are supported for individual and shared work. Tabletop groupware developers can enable people to shift between these modes of work more seamlessly by providing flexible aggregation strategies, where groups of objects can be added and removed from transient work surfaces.

6.3. Aggregation for managing space

People used trays to manage space on the table. One common practice was to shrink groups of images, either to store them for later use, or to put them aside for the rest of the task. These uses are similar to the actions supported by Storage Bins [13], but our technique allows people to select large areas, and lets them scale them to an arbitrary size.

The other main way people managed space was to stack a series of trays on top of each other, and then retrieve the needed tray later in the task. This approach is similar to what is used in desktop windowing systems; even though we did not provide a mechanism for cycling through the stacked trays, people did not seem to have significant problems with retrieving the one they were searching for. This may be partially the result of the unique appearance of each—TableTrays usually have unique colors, they usually have different sizes, and people can easily see what is stored in them.

Other researchers have discussed the idea of using simple piles for grouping objects [1,2,12], but our findings suggest that this idea can be pushed further. Our approach allows users to stack groups of objects, and to do so in a way that allows users to determine the internal logic of each. Further, it gives users flexibility in determining where they will be located. Tabletop designers can use similar strategies, by allowing users to create weak temporary groupings between objects and to allow them to overlap in the workspace, with variable stacking orders.

7. Conclusion

Since most tabletop groupware systems use a single shared workspace, it is often difficult for people to

organize their work. People can have problems dealing with clutter, partitioning the work area, dividing the task, and working with multiple objects. To address these limitations, we developed TableTrays, a new interaction technique that provides portable work surfaces that sit on the tabletop, and allows people to temporarily group sets of objects and organize the table area. TableTrays incorporate many of the capabilities that have been proposed for tabletop groupware into a single mechanism. They allow users to group, move, rotate, and resize objects, and they can later be pasted back into the main workspace. In this paper we presented the results of a study where six pairs carried out a comic strip design task using a TableTrays implementation. The results show that trays help people to manage space, partition work, transfer objects to others, and communicate about the task.

8. References

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