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Territoriality in Collaborative Tabletop Workspaces

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ABSTRACT

Researchers seeking alternatives to traditional desktop computers have begun exploring the potential collaborative benefits of digital tabletop displays. However, there are still many open issues related to the design of collaborative tabletop interfaces, such as whether these systems should automatically orient workspace items or enforce ownership of workspace content. Understanding the natural interaction practices that people use during tabletop collaboration with traditional media (e.g., pen and paper) can help to address these issues. Interfaces that are modeled on these practices will have the additional advantage of supporting the interaction skills people have developed over years of collaborating at traditional tables. To gain a deeper understanding of these interaction practices we conducted two observational studies of traditional tabletop collaboration in both casual and formal settings. Our results reveal that collaborators use three types of tabletop territories to help coordinate their interactions within the shared tabletop workspace: *personal*, *group*, and *storage* territories. Findings from a spatial analysis of collaborators' tabletop interactions reveal important properties of these tabletop territories. In order to provide a comprehensive picture of the role of tabletop territoriality in collaboration, we conclude with a synthesis of our findings and previous research findings and with several relevant design implications.

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

Traditional tabletop workspaces have long been considered "ideal" collaboration environments for small groups. Consequently, many distributed CSCW researchers have relied on them to inform the design of collaborative virtual workspaces (e.g., [3, 20]). Tabletop workspaces can provide a high degree of workspace awareness, through peripheral awareness of others and their actions in the workspace [20]. Furthermore, the ability to orient items in various ways on a table helps mediate group interactions by enabling collaborators to define distinct regions in the tabletop workspace [7, 20].

In order to exploit the collaborative benefits of tables, while at the same time providing co-located groups access to digital information, researchers have begun developing digital tabletop systems (e.g., [4, 10, 12]). There are few "off-the-shelf" tabletop systems available; thus, most of the existing systems have been prototypes with basic interfaces and limited functionality. As the development of tabletop systems becomes easier through special purpose tabletop hardware (e.g., the DiamondTouch [4] tabletop), and software toolkits (e.g., the DiamondSpin [16] toolkit) more complex tabletop interfaces are being created.

People have considerable experience collaborating at traditional tables; thus, these interfaces should continue to support traditional tabletop work practices. A previous investigation of tabletop work practices identified orientation and partitioning both as key resources to mediate group interactions [20]. Recently, Kruger *et al.* [7] have found that orientation serves three main roles in the collaborative process on a table: comprehension, communication, and coordination. To our understanding, though, no one has carefully examined the role that partitioning plays in the collaboration process. In order to design interfaces that support this practice it is important to understand how and why partitioning facilitates collaboration. This paper addresses this issue through an investigation of collaborators' spatial interactions on traditional tables during various collaborative tasks and settings.

Our findings reveal that partitioning is part of the more complex practice of establishing tabletop territories on a tabletop workspace. Just as territories in our physical environment (e.g., a sibling's "side of a room") help mediate our social interactions [1, 6, 21], tabletop territories serve to coordinate tabletop interactions. We will detail important properties of these tabletop territories and clarify the role that they play in the collaboration process.

First, we review previous investigations of tabletop work practices, as well as several existing collaborative tabletop systems that support partitioning. Then we present a preliminary study of casual tabletop collaboration, followed by a second study of group work in a laboratory setting. Next, we present a synthesis of our findings and the literature to provide a more comprehensive view of tabletop territoriality. Finally, the paper wraps up with some design implications and our conclusions.

2. RELATED WORK

2.1 Investigations of Tabletop Collaboration

Tang's [20] investigation of work practices during collaborative design on a table revealed that orientation and partitioning of the workspace are key mechanisms used by group members to coordinate their activities. Tang reported that people vary the size and orientation of tabletop content to distinguish separate regions in the workspace. Additionally, the position of collaborators at the table influenced the location of these distinct regions, with the area closest to each person often being reserved for personal use.

More recently, Kruger *et al*. [7] carefully examined the use of orientation during tabletop collaboration through an observational study involving pairs of students collaboratively solving jigsaw puzzles. Their findings revealed that orientation of tabletop items plays three crucial roles during tabletop collaboration: *comprehension* of information, *coordination* of activities, and *communication* among participants. Kruger *et al.* observed the use of spatial positioning and orientation of the tabletop items to establish and maintain personal and group spaces. They reported that items located in the personal spaces were oriented towards the "owner" of the space. Items in the group space were oriented using a "group orientation," which was often an orientation suitable for most group members to view easily, if not ideally.

A recent review of general tabletop and co-located collaboration practices identified the importance of supporting collaborative behaviour such as interacting simultaneously, transitioning between tabletop activities, and transitioning between personal and group work [13]. We know that workspace partitioning plays a role in some of these practices, such as transitioning between personal and group work and interacting concurrently. Yet, reifying these practices in design requires an understanding of the mechanisms used to perform them. Examining collaborators' spatial interactions on a table may help clarify these mechanisms.

2.2 Partitioning in Tabletop Interfaces

Most digital tabletop systems consider the table as one large group workspace, not distinguishing between areas across the workspace (e.g., [18, 23]). Several systems, though, provide some capabilities for maintaining personal and group workspaces. The ConnecTable system [19] provides each user with a tablet-sized personal display. When two ConnecTables are placed top-edge to top-edge, the two individual virtual workspaces are extended to include the other. While this allows the transfer of digital objects from one workspace to another, the combined workspace is quite small (each display only has a 33cm diagonal) and contains a physical seam where the displays are joined, providing barriers for separate personal and group spaces to co-exist.

Omojola *et al.*'s Interactive Table [10] provides a group of museum patrons with separate personal workspaces at a round tabletop exhibit. The centre of the table contains a round, physically rotating group workspace. Users can view information selected from the group workspace in their personal spaces and influence what is displayed in the group space, but no modification of the information is supported.

Personal Digital Historian (PDH) [15] provides a variety of distinct tabletop spaces. The central, circular area provides a group workspace for sharing photos and documents. A personal view can also be invoked, which orients all items in the central workspace towards a particular user. However, the group and personal views cannot be maintained simultaneously. PDH also provides a dedicated space at the corners of the table (outside the circular workspace) for storing "personal bookmarks" to facilitate easier access to photo arrangements.

The Augmented Surfaces [12] and the UbiTable [14] systems provide collaborators with private spaces on adjacent laptops. In Augmented Surfaces, this private space is integrated with a group space that covers the entire table. In the UbiTable, these private spaces are integrated with corresponding personal spaces along the edges of the table and with a public, or group, space covering the rest of the table. In the RoomPlanner [24] system, people can display private information on the table in front of them using a hand gesture that physically blocks the information from the view of others. Private spaces allow people to control access to their digital information, allowing them to present only information they deem relevant for the given situation. This feature may be especially beneficial for those working with strangers or when one's laptop contains confidential information. However, extensive use of private spaces during group work, which might be considered antisocial, may hinder natural interpersonal interactions as well as hinder workspace awareness. This issue will be discussed further in the design implications section below.

The UbiTable [14] system also enforces strict "ownership" of content. Documents in each personal space cannot be interacted upon by others until the owner moves them into the group space. Documents are clearly marked to reflect their owner. Providing explicit ownership of tabletop content can serve to remind people of who contributed items to the group product, providing context. Moreover, enforcing ownership enables various levels of sharing: a person can choose to allow others to "view" an item from his or her personal space or allow them to modify or copy the item by moving it to the group space. On the other hand, enforcing ownership may interfere with collaboration due to the explicit actions required to grant others access to information. In traditional tabletop collaboration, ownership of objects is often mitigated by social protocol and not physical restrictions [7, 20].

The UbiTable system was built atop the recent DiamondSpin toolkit [16]. This toolkit provides developers with a variety of workspace partitioning options, including various shapes and sizes of personal and group spaces.

3. STUDY 1

To begin understanding the practice of partitioning, we performed a preliminary study to observe tabletop interactions in a casual environment. The results from this study were used to help focus our second study. The goal of the preliminary study was to explore the use of both the tabletop workspace and the artifacts on a table. This study involved individuals and groups playing various tabletop games in a drop-in activity area.

3.1 Experimental Methodology

Participants, Setting and Experimental Tasks. Three activity tables were set up in an atrium area at a local university over one afternoon and evening. During a 5-hour observational period 18 university students participated. Participation times varied from 10 minutes to several hours. Participants were between the ages of 20-30, including both males and females of varying ethnic origins.

Each table contained a different type of activity, including:

- *The Puzzle Table,* consisting of two adjoining tables (76 cm2 each). The table contained several puzzles: Tangram, a word puzzle, and a jigsaw puzzle. Tangram is a puzzle involving the arrangement of geometric shapes to form silhouettes. The word puzzle involved guessing phrases from word clues.
- *The Pictionary® Table,* consisting of a round table (94 cm in diameter) containing the Pictionary® game. In this game, teams competed to advance around a game board by identifying target phrases drawn by teammates.
- *The LEGO® Table,* consisting of one rectangular table (61x153 cm) containing a variety of Lego® blocks. Activity instructions at the table suggested re-designing the university's Computer Science building.

These activities were included because they represented a variety of McGrath's collaborative task types [9]: Planning (Tangram, Jigsaw), Creative (Pictionary, LEGO), Intellective (Tangram, Word Puzzle, Jigsaw), and Contest (Pictionary). These tasks represent a wide variety of activities that people do at a table, including manipulating items, sharing items, discussing items and ideas with collaborators, and constructing a group product. These tasks also provided the opportunity to observe both individual and group interaction at a table.

Procedure. During a 5-hour observational period, participants were free to take part in any or all of the activities and to help others perform the activities. They were free to perform the activities in any order and for as short or as long as they desired.

Data Collection. Field notes were recorded of activities from the three activity tables. Observations focused on participants' use of artefacts (i.e., what items where used and how they were used) and use of the tabletop surface (i.e., where items were used and where they were stored). Observations were taken at one table at a time, depending on where there appeared to be the most complex use of the table space (i.e., activity involving significant movement of task items was favoured over activity where people were engaged in discussion rather than tabletop interaction). Most of the observations were recorded at the Puzzle Table as it attracted more people than the other tables, often having 2-4 people at a time interacting with the puzzles.

3.2 Results of Study 1

Overall, participants' interactions with tabletop items were fluid and dynamic. They were opportunistic in their use of the table space, using whatever space was available, even nearby box lids, and chairs. Furthermore, people shared the space easily, fluidly expanding and contracting their interaction areas as the number of people and the activities changed at the table.

The field notes revealed similar patterns of tabletop interaction on the three activity tables. Whether interacting alone or in a group, participants partitioned the tabletop workspace into several interaction areas. We observed the use of three types of interaction areas: *personal*, *group*, and *storage*. These areas appeared to help people organize their interactions with both task items and with others at the table.

The boundaries between these areas were quite flexible. The areas appeared to be defined by their location on the table, but where one area ended and another began was often determined by the location of items on the table and the activity that was being performed.

Similar to the findings of Tang [20] and Kruger *et al.* [7], we observed that the tabletop area directly in front of each person appeared to be used almost exclusively by that person. By someone alone at the table, this area was used to perform the main task activities, such as assembling the jigsaw puzzle or sorting and comparing puzzle pieces. By group members, this area was used to temporarily perform independent activities, such as exploring an alternative solution to a Tangram or word puzzle. Group members tended to restrict their personal activities to a smaller area than a person at a table alone. Moreover, personal areas tended to expand and contract, depending on such factors as the number of people at the table and whether or not a person was currently working independently.

When there was a group at the table, the centre of the table and the areas between adjacent people were used by group members to perform the main task activities, such as assembling a Tangram silhouette or interacting with the Pictionary® game board. The group area was also used by people to help others perform the group task, such as clearing items from a table area to create free space for someone else to use. Some areas also appeared to be reserved for the use of subgroups, such as separate teams playing the Pictionary® game. These subgroup areas were typically located on the table edge between subgroup members' positions.

Participants appeared to reserve certain areas on the table for storing items. These areas typically emerged on the periphery of the personal and group areas, but were also located on other convenient surfaces, such as spare table edge space, nearby chairs, puzzle box lids, people's laps, and the floor. Items contained in storage areas close to the current work area tended to be accessed more frequently than items contained in storage areas further away (e.g., on the floor). Storage areas held both task-related items (e.g., pens, paper, and puzzle pieces) and non-task items (e.g., food and beverages). The items contained in storage areas were often loosely organized into piles, such as piles of related puzzle pieces. When items were stored on a mobile surface, such as a box lid, people leveraged the ability to access items while holding the surface above the workspace or setting it atop their current work area. They would then move the surface back to the periphery after retrieving the desired items.

3.3 Discussion of Study 1

The personal, group, and storage areas appeared to help people organize and perform their tabletop activities, akin to *territories* in our broader environment (e.g., a roommate's "side of the room"), which help to mediate our social interactions [1, 6, 21]. Thus, these areas appear to serve as *tabletop territories*. In order to further explore collaborators' use of the tabletop workspace, and the role that these tabletop territories play in the collaboration process, we conducted a more in-depth observational study.

4. STUDY 2

Our second study involved observing three small groups (2-3 participants each) performing a layout planning activity on a table using traditional media in a laboratory setting.

Participants and Setting. To observe various approaches to the planning process, we recruited seven university students via three different types of study notices. Group 1 comprised two self-identified "non-technology" students (1 female Business student and 1 male Medical student). Group 2 comprised two "visual arts" students (1 female and 1 male Fine Arts student). Group 3

comprised three students familiar with "computer-aided design software" (2 female Architecture students and 1 male Computer Science student).

The study took place in a usability laboratory at a local university. Participants sat at a round table (94 cm in diameter), positioned in the centre of the lab. A video camera was located in one corner of the room, with a chair beside it for the observer.

Experimental Task. The groups were asked to create a furniture layout plan for a reading room in a library. The layout plan was to be created on a white, circular cardboard Floor Plan (61 cm in diameter) located on the experiment table. Participants were given paper supplies to create the furniture layout, such as paper cutouts of furniture. At the beginning of the activity, piles of related furniture items were located on the Floor Plan and the other resources (i.e., Post-it notes, pens, and scissors) were piled on the table edge beside the Floor Plan.

The groups were also asked to incorporate several design requirements, provided to each group member on an instruction sheet. These requirements included things like: display current journals, provide space for groups to work, provide space for individuals to work quietly, and so on.

Procedure. group was brought in separately to perform the experimental task. Participants first signed consent forms and then the experimenter explained the task to them. Each group was asked to arrange the task materials to construct a furniture layout for a university library reading room on the Floor Plan. Participants were given roughly 45 minutes to complete the task. They were asked to inform the experimenter when they were done. Once the group had finished, they spent about 5 minutes presenting their final layout plan to the experimenter.

Data Collection and Analysis. Sessions were videotaped and audiotaped, and field notes were recorded. We collected 29, 43, and 38 minutes of data from Groups 1-3, respectively.

In order to analyze the participants' spatial interactions, their tabletop activity was transcribed from the video data. Transcripts included all tabletop actions, the initiator of each action, the location of each action, the location of each participant, and any conversation related to the tabletop actions. To facilitate our analysis, the tabletop workspace was divided into 16 *directional zones* (see Figure 1), and 4 *radial zones* (see Figure 2), then we coded the transcripts for:

- the directional zone of each tabletop action,
- the radial zone of each tabletop action, and
- the direction zone of each participant at the table.

4.1 Results of Study 2

As in our preliminary study, participants made use of tabletop territories to help coordinate their actions during their construction of the furniture layouts. We again saw personal, group, and storage territories emerge during their collaborative sessions. The analysis of participants' spatial interactions reveals that these tabletop territories have both spatial properties and distinct functionality. Additionally, contrary to the results of our preliminary study, the fine-grained observations enabled by the video data suggest that storage territories sit atop of the group and personal territories in the workspace and are not separate partitions in the workspace. These results will be discussed in more detail in the following sections.

4.1.1 Personal Territories

Participants' spatial interactions are shown in the activity plots and tables in Figure 3. Each activity plot shows the amount of activity one participant performed in each tabletop zone during his or her collaborative session. The size of each dot represents the amount of activity that occurred in that zone. The activity tables detail the activity by each group member in zones near each member, as well as the percentage of activity in those zones that was performed by each member. These plots and tables demonstrate that tabletop activity was strongly influenced by the participants' seating positions at the table. Across all three groups, participants dominated the activity in the *table edge* zones directly in front of them (87%-100% of the actions). Participants used the *table edge* zones nearest them for keeping furniture items they used frequently, for writing on Post-it notes, for reading their instruction sheets, and for cutting items into custom shapes. Thus, it appears that participants used the *table edge* zones directly in front of them on the table as their personal territories.

Personal territories appeared to provide each person with dedicated space on the table for performing independent activities. Ergonomically, personal territories served to ease people's reading and writing activities. They almost always used their personal territories to customize items that were later added to the Floor Plan layout. When it was necessary to modify an item, they typically removed the item from its position on the Floor Plan, made modifications to it in their personal territories, and then replaced it on the Floor Plan.

Though no group explicitly discussed reserving these areas for anyone's personal use, participants performed very few, if any, actions in their collaborators' personal territories (0%-13% of participants' actions). Thus, it appears that understood social norms dictate that the tabletop area directly in front of someone should be reserved for use by that person.

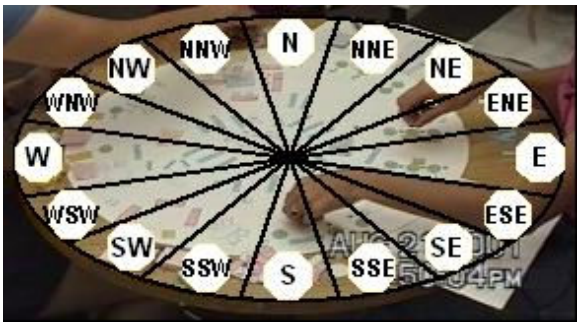

Figure 1. Directional Zones.

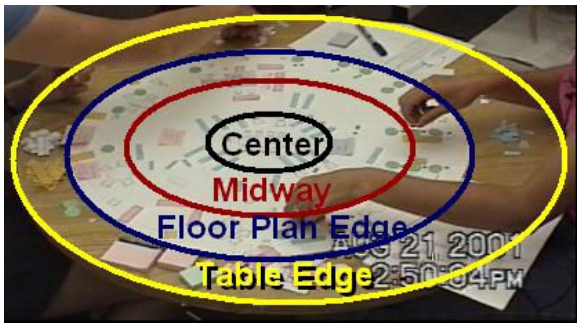

Figure 2. Radial Zones.

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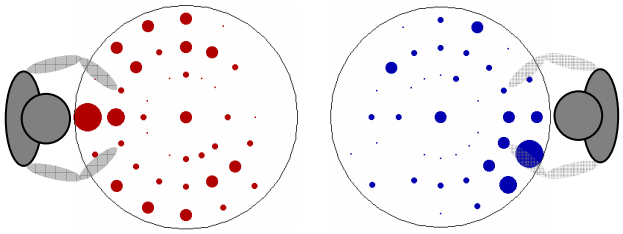
Activity Plots

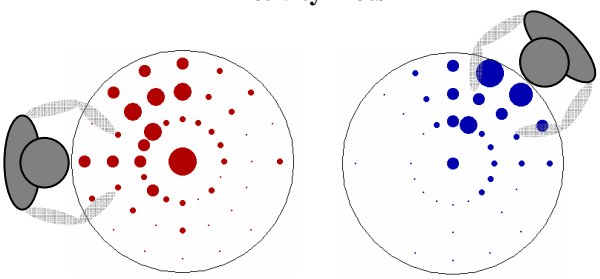


Activity Table

Participants	Central Actions	Western Actions				Eastern Actions			
		Midway	Floor Plan Edge	Table Edge	Half	Midway	Floor Plan Edge	Table Edge	Half
W	11 (55%)	7 (70%)	23 (77%)	36 (97%)	144 (83%)	5 (71%)	6 (20%)	0 (0%)	66 (36%)
E	9 (45%)	3 (30%)	7 (23%)	1 (3%)	30 (17%)	2 (29%)	24 (80%)	38 (100%)	115 (64%)

A. Group 1

Activity Plots

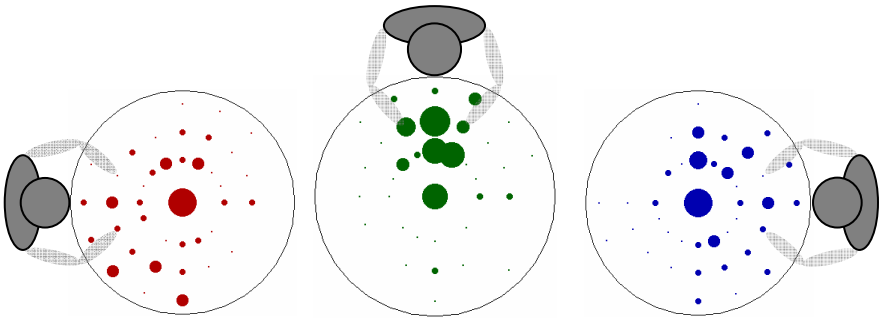


Activity Table

Participants	Central Actions	Western Actions				North-Eastern Actions			
		Midway	Floor Plan Edge	Table Edge	Half	Midway	Floor Plan Edge	Table Edge	Half
W	56 (64%)	44 (90%)	37 (100%)	29 (97%)	254 (83%)	36 (31%)	17 (18%)	26 (13%)	220 (35%)
NE†	32 (36%)	5 (10%)	0 (0%)	1 (3%)	53 (17%)	81 (69%)	76 (82%)	168 (87%)	412 (65%)

B. Group 2. † This person spent 5 minutes at N then moved to NE.

Activity Plots



Activity Table

Person	Central	Western Actions				Northern Actions				Eastern Actions			
		Midway	Floor Plan Edge	Table Edge	Half	Midway	Floor Plan Edge	Table Edge	Half	Midway	Floor Plan Edge	Table Edge	Half
W	43 (38%)	23 (68%)	25 (74%)	14 (88%)	135 (63%)	43 (34%)	12 (12%)	2 (6%)	82 (24%)	8 (40%)	6 (14%)	0 (0%)	52 (19%)
N	27 (24%)	3 (9%)	5 (15%)	0 (0%)	49 (23%)	51 (40%)	58 (60%)	29 (88%)	153 (45%)	5 (25%)	8 (19%)	1 (7%)	72 (27%)
E	42 (38%)	8 (24%)	4 (12%)	2 (13%)	30 (14%)	32 (25%)	27 (28%)	2 (6%)	107 (31%)	7 (35%)	29 (67%)	14 (93%)	146 (54%)

C. Group 3

Figure 3. Activity plots and tables for each group. Each plot shows the activity for only one person, whose location is indicated beside the plot, during their collaborative session. The size of the dots represents the amount of activity that occurred in the given tabletop zone (i.e., no dot indicates no actions, large dots indicates many actions). The activity tables show the number of actions performed by each person in the indicated location (e.g. "Midway Western" indicates WSW, W and WNW actions in the *midway* zones). The percentages show how many of the total actions performed at that location were contributed by the indicated person.

4.1.2 Group Territories

Figure 3 shows that the tabletop areas occupied by the personal territories were the only areas so consistently avoided by other group members. Thus, it appears that the remaining tabletop workspace was generally considered available for all group members to use. To varying degrees, all participants utilized most of the Floor Plan and table edge locations between participants. It appears, then, that the group territory covered the entire table to the exclusion of the areas occupied by personal territories.

The group territory was primarily used for assembling furniture arrangements in the Floor Plan. It was also used for discussing layout ideas and for assisting others to create or modify particular furniture arrangements. Moreover, it served as a place to share task resources. Participant would often pass others resource items via the group territory.

Partitioning in the Group Territory. Participants spent the majority of their time working independently, creating different furniture arrangements in separate regions of the group territory (see Figure 3). This partitioning occurred with little to no verbal negotiation. Participants typically discussed what type of arrangements should be made in the workspace rather than who should be working where.

Generally, participants took the initiative for creating and maintaining arrangements in the Floor Plan directly in front of them, illustrated by participants' dominance of the actions performed in the group territory nearest them. In the two pair groups, participants were responsible for well over half of the interactions in the group territory zones nearest them (70%-94% of the actions[1]). In the group of three, participants performed well over one third of the actions in the group territory nearest them (48%-70% of the actions[1]).

Implicit delegation of workspace areas in close proximity to someone at the table appeared to clarify each member's role in the collaborative task, helping them to coordinate their workspace activities. It appeared to be more ambiguous which member was responsible for those areas farther away from anyone at the table. In general, interaction in these workspace areas was much less dominated by any particular person and involved more verbal negotiation. Likewise, we observed that interaction in areas close to a number of people was also less exclusive and involved more verbal negotiation. For example, participants in Group 3, who were seated closer together than participants in the other groups, spent less time working independently in the group territory and more time negotiating their furniture arrangements compared to the other 2 groups.

Rotation of the Floor Plan. One group, Group 2, rotated the Floor Plan during their session. About 30 minutes into their 43-minute session, the participant at West wanted to work on an area of the Floor Plan located across the table (in the ESE direction). She asked her partner if they could rotate the Floor Plan, so together they carefully rotated the Floor Plan about 110° counter-clockwise on the table. The area she wanted to work on was then closer to her (in the N direction) and another fairly unfinished area was in front of her. She spent the remainder of the session working mostly in these areas, as indicated by the concentration of actions in the NW to N directions in her activity plot (Figure 3b). In contrast, after the rotation, the areas near her partner already contained completed arrangements.

The rotation of the Floor Plan appeared to affect the participants' sense of responsibility for particular furniture arrangements in the workspace. Before the rotation, the participant at NE seemed concerned that an arrangement his partner had made in front of her was too cluttered. He had made some minor adjustments to it, but his partner immediately readjusted the arrangement, almost back to its original state. After the rotation, this arrangement was located near him (in the E direction). He soon began removing items from the arrangement and readjusting it. His partner helped him a little, readjusting the arrangement while he removed items, but in the end, they agreed on an arrangement containing much fewer furniture items. Interestingly, his partner seemed much more open to his input on "her" design once it had moved closer to him (or farther from her) on the table. He also appeared more comfortable taking charge of the arrangement in its new position.

4.1.3 Storage Territories

Throughout their sessions, participants stored the task resources in piles at various locations on the table. These piles were relocated in the workspace at different stages of the task, depending on where participants were currently working and what task resources they currently needed. These piles of resources served as storage territories throughout the collaborative activity.

The migration of the piles of furniture from the centre of the table to their eventual placement at the table edge differed from group to group, depending on their working style. Yet for all groups, these storage territories were mobile on the tabletop workspace. For instance, Group 1 immediately moved all but one of their furniture piles to the table edge (within 30 seconds of their session). For the next 13 minutes, they moved the remaining pile around the Floor Plan as they were working, often retrieving items from it, as well as from other piles along the table edge, until they finally moved the pile to the table edge. In contrast, Group 3 spent the majority of their session (30 out of 38-minutes) with most of the furniture piles still on the Floor Plan. If a pile was in the way, they simply moved it to a different position on the Floor Plan. Group 2 gradually moved their furniture piles to the table edge over a 10 minute period (out of their 43-minute session), also moving their piles around the Floor Plan as needed.

The location of a storage territory appeared to influence who utilized the resources contained within it. Stored items were often shared among participants, especially when the pile was located along the table edge between participants or in the *midway* or *central* zones. When resources were located in or near someone's personal territory, that person often become responsible for distributing those resources. This behavior is indicated by the dominant use of the table edge zones directly adjacent to several participants' personal territories. For example, the participant at NE in Group 2 became responsible for creating and distributing customized items using the Post-it notes located on the table edge to his left (in the E-ENE direction). Relative to his activity on the rest of the workspace, he made frequent use of the table edge directly in front of and adjacent to him (44% of his total tabletop actions occurred on the table edge between N and E).

[1] This represents the activity in the three directional zones directly in front of each person. For example for participants at W, we report the *floor plan edge* and *midway* activity in the WSW, W, and WNW zones.

When participants needed items contained in a storage territory in someone else's personal territory, they would usually ask that person to pass them the item. In the few cases of a participant interacting directly in a colalborator's personal territory, they were always retrieving a resource item. These situations often resulted in the participant picking up a handful of items and then creating a new pile with the items closer to him or her.

4.1.4 Interaction between Territories

Each type of tabletop territory appears to play an important role in helping participants share the tabletop workspace while performing their task. Based on the activity patterns discussed above, though, it appears that all three tabletop territories do not exist as mutually exclusive partitions of the workspace.

Personal and group territories appear to be separate partitions, with associated accessibility properties, defined and controlled through social norms. For example, a personal territory is generally reserved for the use of the nearby person. A personal territory appears to be an extension of a person's personal space [17]; thus, it exists in the tabletop workspace directly adjacent to that person. The group territory covers the remaining tabletop workspace, including the areas in the center and along the table edge between participants. Both personal and group territories are used to perform task work.

Storage territories, on the other hand, appear to exist atop these other two territories and are mobile in the workspace. They take on the accessibility property of the territory on which they are currently located. For example, we observed that when a storage territory was located in the group territory, all participants tended to utilize the resources it contained. Whereas, when a storage territory was located on the table adjacent to someone, that person typically became the sole or dominant user of its resources.

5. TABLETOP TERRITORIALITY: THE BROADER PICTURE

The results from our observational studies have provided many useful insights into how and why tabletop territories emerge during tabletop collaboration. Yet, our experimental tasks imposed certain limitations on the behaviors we could observe. For instance, the use of a round table and a task that was fairly orientation independent in our second study provided little opportunity for observing people orienting items for reading, writing, or sharing. In order to provide a more comprehensive understanding of tabletop territoriality, this section integrates our results with previous research on the use of tabletop workspaces and on human territoriality in general.

5.1 Human Territoriality

Taylor [21] has defined *human territoriality* as:

> "an interlocking system of attitudes, sentiments, and behaviors that are specific to a particular, usually delimited, site or location, which, in the context of individuals, or a small group as a whole, reflect and reinforce, for those individuals or group some degree of excludability of use, responsibility for, and control over activities in these specific sites." [21, p. 81]

Taylor further specified that territories "range in size from chairs, seats, or sides of a table, to street blocks" [21, p 89]. Human territoriality researchers generally agree that territories serve to help people mediate their social interaction through laying claim to a space [1] or through association of a space to a person due to repeated use or the passage of time [5].

5.2 Tabletop Territoriality

Within the human territoriality literature it appears that a location, or partition of space, and a territory are considered equivalent. In contrast, we make the distinction that a tabletop territory has both *spatial properties* (i.e. size, shape, and location) and *functionality*. We further make the distinction that a tabletop territory is not necessarily a separate partition in the workspace; that is, tabletop territories are not necessarily mutually exclusive. Thus, two tabletop territories can exist in the same partition of the tabletop workspace (e.g., a storage territory and a personal territory) and a tabletop territory can contain several partitions of the workspace (e.g., a group territory can contain several distinct work areas). We make these distinctions for practical purpose to help us understand the roles (beyond who has claim over it) that each type of tabletop territory has in the collaboration process.

We observed that people naturally partition their interactions on a table with little to no verbal negotiation. Our two studies revealed that people partition tabletop workspaces into personal and group territories, as well as further subdivided their interactions in the group territory. Others have also observed workspace partitioning during collaborative design [20] and collaborative puzzle solving [7] on tables. Our studies have also revealed that people establish mobile storage territories to hold their tabletop resources. The specific functionality and spatial properties for each of these tabletop territories are discussed in the following sections.

Like human territories in general, tabletop territories appear to help people coordinate their task and social interactions. For design purposes, it is essential to understand the specific properties of tabletop territories that facilitate coordination. To help us identify these properties, we draw on Pinelle *et al.*'s [11] *coordination mechanics*, which define the core actions that people must perform in order to coordinate in a shared workspace. These mechanics refer to those actions which enable *shared access* (to tools, objects, space, and time) and *transfer* (of objects, space, and time). Table 1 lists these coordination mechanics.

In the following sections, we clarify which tabletop territories facilitate which coordination mechanics by identifying the functionalities and spatial properties of the personal, group, and storage territories that correspond to specific mechanics.

5.3 Personal Territories

***Functionality*.** Personal territories allow people to reserve a particular table area (mechanic #1), as well as task resources (mechanic #2) for their own use. Ergonomically, personal territories serve to ease a person's actions related to the group activity, such as reading, writing, and drawing. They also provide a space for people to disengage from the group activity. Tang [20] observed people using personal territories as a "safe" place to explore alternate ideas before introducing these ideas to the group. Finally, personal territories are an important group resource: our participants appeared to monitor others' activities in their personal territories, offering suggestions or modifying their activities accordingly. For example, someone waiting for a tool that another group member is currently using can look at that member's progress with the tool to determine if they should continue waiting or find something else to do in the meantime.

Table 1. Coordination related mechanics of collaboration and the tabletop territories to which they correspond †.

#	Mechanic (category)	Typical actions	Corresponding Tabletop Territories
1	Obtain resource (shared access)	Physically take objects or tools. Occupy space.	personal, group, storage
2	Reserve resource (shared access)	Move to closer proximity. Notify others of intention.	personal, storage
3	Protect work (shared access)	Monitor others' actions in area. Notify others of protection.	Group
4	Handoff object (transfer)	Physically give/take object. Verbally offer/accept object.	group
5	Deposit (transfer)	Place object and notify.	group

† Adapted from [11], which lists the full set of *mechanics of collaboration*.

Our participants typically interacted with customizable task materials in their personal territories, such as Post-it notes for drawing new furniture items or for writing notes to place in the Floor Plan. Items that had an obvious orientation (e.g., Post-it notes containing text, instruction sheets, and word puzzles) were oriented facing the nearby person. Likewise, Kruger *et al.* [7] reported that people oriented items towards themselves in their personal territories. Tang [20] further observed that people tend to write text and draw images intentionally small in these areas.

***Spatial Properties*.** Areas directly in front of people are typically used as their personal territories. Tang [20] and Kruger *et al.* [7] observed that people used the areas within close proximity for personal activities. Thus, seating position strongly influences the location of personal territories.

In our layout planning study, the personal territories typically comprised the area in front of each person, between the edge of the table and the cardboard Floor Plan (roughly a 15x30 cm area). In general, the size and shape of a personal territory appear to be influenced by a number of factors:

- *Number of collaborators and seating arrangement*. Personal territories in our preliminary study appeared to expand and contract based on the number of people at the table and how they were arranged. When one person was at the table, that person tended to use the entire table. When another person joined the table, the first person's personal territory contracted to an area directly in front of him or her. If the collaborators were seated close to each other, they generally restricted their personal activities to a small space directly in front of them.
- *Size of the table*. The size of the table determines how much space is available for sharing, as well as how many people can sit comfortably around it. A smaller table forces people to sit close together and, therefore, will generally restrict their personal territories to a small space directly in front of them.
- *Task activities*. In our preliminary study, we observed that people expanded and contracted their personal territories based on whether they were currently working independently or in concert with the group.
- *Task materials.* In our layout planning study, the task materials only required a small space for manipulation: for the most part people were writing on small Post-it notes or modifying furniture items ranging in size from 1cm^2 to 8.5x 3.3 cm. If task materials had been larger (e.g., a document), it is likely that people would have used a larger personal territory to accommodate the size of these materials.
- *Visible barriers*. Visible demarcation of tabletop regions can restrict our personal space [6]. For example, food court tables often have a line marked down the middle of them to decrease the social discomfort of sitting in close proximity to others. The white Floor Plan in our layout planning study seemed to serve as a visible barrier against the brown table. Personal territories were typically restricted to the table edge beside the Floor Plan. When people needed extra space, they used adjacent table edge areas even when the Floor Plan area directly in front of them was empty.

In general, people are very opportunistic in their use of table space: they use whatever space they can. At the same time, social protocol requires people to accommodate others at the table. Therefore, people restrict their personal territories to a "socially appropriate" area, generally refraining from using the table space directly in front of others.

5.4 Group Territories

***Functionality*.** A group territory provides a space to perform main task activities, such as assembling puzzles or creating product designs. We found that the group territory was also used to assist others in tasks such as creating or modifying particular furniture arrangements. Participants also assisted others by using the group territory to transfer task resources either by handing off items (mechanic #4) via the workspace (e.g., sliding a resource toward a person until that person took over the item) or by depositing items (mechanic #5) on the workspace for a partner to pickup later.

Interaction with task materials in the group territory appears to follow two basic patterns, depending on whether a task requires *tightly coupled interactions* or affords *loosely coupled interactions*.

When the task requires tight coupling of actions (e.g., creating a product design, assembling a jigsaw puzzle, assembling a Tangram silhouette), collaborators tend to orient items and workspace markings corresponding to separate ideas or group products [20]. When assembling jigsaw puzzles, participants tended to use one "group orientation", aligning loose puzzle pieces with the partially assembled product [7]. We observed similar behavior in the Tangram activity during the preliminary study: participants typically aligned the partially assembled Tangram silhouette with the silhouette key. In contrast, Tang [20] reported people designing a product used various orientations: they aligned new drawings to existing drawings to convey support for that idea, while they aligned other drawings facing a particular person to establish a new context or an audience with that person. Bly's [3] study of collaborative design also found group members frequently added to or modified content created by other members. Thus, when the task is tightly coupled, people use orientation to provide context and support for information in the group territory and take full advantage of opportunities to build on and use others' work.

When the task affords loosely coupled collaboration (e.g., assembling a room layout containing many distinct furniture arrangements) collaborators tend to partition the workspace. The location of these partitions is strongly influenced by participants'

seating positions. Our participants appeared to implicitly take on responsibility for the workspace area nearest them. These partitions appeared to clarify the roles of people in the workspace. Furthermore, they allowed people to easily obtain a space to work in (mechanic #1). Partitions also appeared to facilitate protection of work (mechanic #3), illustrated by Group 2's participants appearing less protective of furniture arrangements once that were located farther from them after a rotation of the workspace.

***Spatial Properties*.** In our studies, the group territory typically covered any tabletop workspace that was not occupied by the personal territories. In our preliminary study, we also observed subgroup territories being used on the table edge between adjacent team members during the team competition game, Pictionary®. Kruger *et al*. [7] reported the use of a group territory covering the middle of the table, between pairs seated facing each other.

In general, the factors that affect the size and shape of a personal territory also influence any partitions established in the group territory (i.e., number of collaborators, seating arrangement, size of the table, task activities, task materials, and visible barriers). In regards to the first three factors, it appears that they affect the size of the area for which a person implicitly takes responsibility. Ambiguity of who is inherently responsible for a workspace area appears to be introduced when several collaborators have equal physical access to a particular area, either because it is outside of anyone's direct reach or because several people can easily reach it. In such tabletop areas, we observed more explicit coordination and negotiation, as well as less exclusivity of use.

5.5 Storage Territories

***Functionality*.** Storage territories served as areas to store task resources (e.g., tools, items not currently in use, customized items, reference materials) and non-task items (e.g., food, drinks). Participants used storage territories to organize these items in the tabletop workspace. The ability to move storage territories around the group territory allows participants to easily obtain the resources they need (mechanic #1) where they need them. The ability to move a storage territory into a personal territory enables participants to reserve resources for their own use (mechanic #2).

Our results suggest that the accessibility of task materials in a storage territory is determined by the tabletop territory on which it is currently located. In our studies, task materials within storage territories tended to be loosely organized. Typically, partial orders were maintained (i.e. related items are kept in a storage territory, such as different types of "tables" or various pads of post-it notes). Reference items in personal territories were often oriented towards the "owning" person. For example, in the furniture layout study, some participants kept their instruction sheets on the table edge beside them, oriented towards them.

***Spatial Properties*.** The storage territories used by our participants were placed at various locations around the workspace, but generally migrated to the table edge as the task progressed. These territories sat atop the personal and group territories and were mobile in the workspace. We also observed that establishment of temporary storage territories (e.g., creating a pile of items on the workspace, then using all the items for the task product). Participants also replicated storage territories. For example, we saw people obtain a handful of items from a pile in front of someone else, then place these items in a new pile closer to them.

The size and shape of a storage territory depend on its contents and the current activity. Some groups kept small, tidy piles of items, whereas others kept loose, scattered piles that took up more space. People often expanded piles to search for an item and then tidied the pile back up when they had found the desired item. This expandability allows participants to quickly obtain the resources they need (mechanic #1).

6. DESIGN IMPLICATIONS

Tabletop territoriality plays an essential role in group coordination. As just discussed, there are many factors that influence the establishment of tabletop territories, such as the proximity of tabletop collaborators. With these factors in mind, as well as our understanding of the spatial and functional properties of tabletop territories overall, we offer the following design considerations for the development of digital tabletop workspaces.

Provide visibility and transparency of action. Personal and group territories were often used by our participants to monitor the activity of their collaborators. Such monitoring is an essential tool for maintaining workspace awareness during collaboration [11]. In our studies, monitoring was possible because, for every action performed on the table, group members could see that an action was occurring (visibility of action) and exactly what action was occurring (transparency of action). To understand how this applies to the design of digital tabletop workspaces, consider two possible workspace designs. One possibility is to provide each collaborator with their own laptop on the table as a personal territory and integrate it with a group territory that covers the rest of the table, as seen in the Augmented Surfaces workspace [12]. This solution, however, may decrease group members' workspace awareness to a degree that hinders the collaboration because monitoring exactly what actions were being performed in collaborators' personal territories becomes difficult. Alternatively, the laptop can provide a private space in conjunction with a personal territory on the table that offers more visibility and transparency of action, as seen in the UbiTable workspace [14].

Provide appropriate table space. As we have seen, the size of the table can affect both the personal territories established on the table and the partitions established in the group territory. An inappropriately sized table may negatively impact the collaboration because collaborators may not have enough space to effectively disengage from the group activity or collaborators may need more explicit coordination to divide up an activity on the table. For example, if four collaborators are working with a set of planning documents on a DiamondTouch table [4] (64.2x85.6cm), they may quickly run out of space if someone disengages from the group activity to search for a related document. On the other hand, such a workspace may be well suited for activities involving tightly coupled collaboration, such as a cooperative learning task.

Provide functionality in the appropriate locality. Each tabletop territory plays a specific role in the collaboration process. These roles can guide design decisions related to the location of system functionality. For example, personal territories serve to ease activities such as reading and writing. Thus, it should be easy to move items to and from the area directly in front of each person and tools related to editing task items should be located nearby. For example, a toolbar could be provided along the table edge in front of each collaborator [15]. On the other hand, collaborators appear to more closely monitor interactions of others in the group territory, facilitating protection of work. Thus, locating global

functionality (e.g., clearing the workspace) near the center of the table or along the table edge between collaborators may help people anticipate the use of such functionality, providing them the opportunity to intervene when necessary.

Allow casual grouping of items and tools in the workspace. The ability to have mobile piles of resources enables collaborators to easily access these items when and where they need them. This mobility also enables people to reserve certain items for their personal use. Malone [8] has found that piles help people organize their work, remind people of work still to be done, and provide a cognitively light-weight mechanism for people to store items that are otherwise difficult to classify. Providing these benefits to tabletop collaborators could be achieved by allowing casual grouping of content and tools in the workspace and by providing simple mechanisms to move these groups around, such as the pile management tools developed by Bauer *et al.* [2].

7. CONCLUSIONS AND FUTURE WORK

Our careful examination of collaborators' spatial interactions on tables has revealed that workspace partitioning behavior is part of a more complex practice of *tabletop territoriality*. We observed the use of *personal*, *group*, and *storage* territories in both formal and casual collaboration settings. These tabletop territories each have unique spatial properties and functionality, which we have identified through a synthesis of our findings and previous investigations of tabletop work practices.

The next stages of this research will be to incorporate these insights into the design of collaborative tabletop interfaces. Moreover, we are interested in determining whether our findings generalize to other tasks and task settings, as well as other shared workspaces, such as wall or desktop displays. A recent study involving a co-located sharing desktop workspace suggests that territoriality behavior might also exist on vertical workspaces. In that study, people strongly favored the side of the screen nearest them even though they were working with indirect input and, thus, were not restricted by physical interference [22]. These results suggest that territorial behavior extends beyond our physical world and affects our virtual interactions as well.

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