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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 tabletop items or enforce ownership of tabletop 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 and the role that they play in the collaboration process.

Categories and Subject Descriptors
H5.3. [Information Interfaces and Presentation]: Group and Organization Interfaces – Computer-supported cooperative work, Synchronous interaction, Evaluation/methodology; H1.2 [Models and Principles]: User/Machine Systems – Human factors

General Terms
Experimentation, 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., [2, 19]). Tabletop workspaces can provide a high degree of workspace awareness, through peripheral awareness of others and their actions in the workspace [19]. 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 [6, 19].

In order to exploit the collaborative benefits of tables, while at the same time providing co-located groups access to their digital information, researchers have begun developing digital tabletop systems (e.g., [2, 18]). 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 [3] tabletop), and software toolkits (e.g., the DiamondSpin [15] toolkit) more complex tabletop interfaces are being created.

Because of the considerable experience people have collaborating at traditional tables these interfaces should continue to support traditional tabletop work practices. A previous investigation of tabletop work practices identified orientation and partitioning as key resources to mediate group interactions [19]. Kruger *et al.* [6] have recently revealed 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 using *tabletop territories* on a table. Similar to how *territories* in our physical environment (e.g., one sibling's "side of a room") help to mediate social interaction [1, 5, 20], 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, though, we describe previous investigations of tabletop work practices, as well as several current existing collaborative tabletop systems. Then we present a preliminary study of casual tabletop collaboration, followed by a second study of group work in a more formal setting. Next, we present a synthesis of our findings and the previous research to provide a more comprehensive view of tabletop territoriality. Finally, the paper wraps up with our conclusions and future work.

2. RELATED WORK

2.1 Investigations of Tabletop Collaboration
Tang's [19] 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 in close proximity to each group member often being reserved for personal use.

More recently, Kruger *et al.* [6] 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 usually set to a compromised orientation (i.e., 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 the following behaviors: simultaneous interaction, sharing objects; changing positions at the table; transitions between tabletop activities, transitions between personal and group work on the table, and transitions between tabletop collaboration and external work [12]. From above, we know that partitioning of the workspace plays a role in some of these practices, including 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 Tabletop Interfaces that Support Workspace Partitioning

Most digital tabletop systems consider the table as one large group workspace, not distinguishing between areas across the workspace (e.g., [17, 21]). Several systems, though, provide some capabilities for maintaining personal and group workspaces. The ConnecTable system [18] provides each user with a tablet-sized personal display that contains digital information oriented towards that user. 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 display are joined, providing barriers for separate personal and group spaces to co-exist.

The Interactive Table created by Omojola *et al.* [8] provides several museum patrons with separate personal workspaces at a large, 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) [14] 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 [10] and the UbiTable [13] 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 personal spaces covering separate edges of the table and with a public (i.e., group) space that covers the rest of the table. In the RoomPlanner [23] system, people can display private information on the table surface in front of them with 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.

The UbiTable [13] system also enforces strict "ownership" of tabletop content. Documents in each personal space cannot be interacted upon by others until the owner moves them into the group space. Also, 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, thus providing context. Moreover, just as the private space can facilitate controlling access to items, 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 fluid collaboration due to the explicit actions required to grant others access to information. In traditional tabletop collaboration, ownership of tabletop objects is often mitigated through social protocol and not physical restrictions [6, 19].

The UbiTable system was built atop the recent DiamondSpin toolkit [15]. This toolkit provides developers with a variety of workspace partitioning options, including various shapes and sizes of personal and group spaces.

3. STUDY 1: PRELIMINARY INVESTIGATION OF TABLETOP INTERACTIONS

We performed a preliminary study to observe tabletop interactions in a casual environment. The results from this study helped us focus the research questions for a second observational study. The goal of the preliminary study was to explore spatial interactions on a table, as well as to understand how artifacts are used on the table surface. This study involved individuals and groups playing various types of 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 the observational period (5 hours), 18 people participated in the various activities. Some participated for several hours, while others participated for only 10 minutes. Participants were primarily university students and all 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 (about 76 cm^2 each). The table contained several puzzles: Tangram, a word puzzle, and a jigsaw puzzle. Tangram is a puzzle involving arranging geometric shapes to form silhouettes. The word puzzle involved guessing phrases from word clues.
- *The Pictionary® Table,* consisting of a round table (about 94 cm in diameter) containing the Pictionary® game. In this game, teams compete to advance around a game board. To advance, a team must successfully identify a target phrase from a clue drawn by a teammate.
- *The LEGO® Table,* consisting of one rectangular table (about 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 collaborative task types [7]: Planning (Tangram, Jigsaw), Creative (Pictionary, LEGO), Intellective (Tangram, Word Puzzle, Jigsaw), and Contest (Pictionary). Therefore, the tasks represent a wide variety of activities that people do at a table, such as manipulating items (e.g., puzzle pieces, sketchpads), sharing items (e.g., pens, sketches), discussing items and ideas with collaborators (e.g., discussing assembly of a Tangram silhouette), and constructing a group product (e.g., the completed jigsaw puzzle). 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 a time period as they desired.

Data Collection and Analysis. Field notes were recorded of activities from the three activity tables. The observations focused on participants' use of artefacts (i.e., the types of items people used and how they used them) and use of the tabletop surface (i.e., location on the table where people used items and where they stored items). Interactions were observed at one table at a time, depending on where there appeared to be more complex use of the table space (i.e., activity involving significant movement of task items was favoured over activity where participants were currently heavily engaged in discussion rather than tabletop interaction). Most of the observations were recorded at the Puzzle Table since it attracted more participants than the other tables. Interactions of participants alone at a table were observed, but the activity of groups was favoured for observation.

4. 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, when they were in a group, with others at the table.

The field notes reveal that the boundaries between these areas were quite flexible. The areas appeared to be defined by their location on the table (e.g., a distinct area typically existed directly in front of each person at 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 [19] and Kruger *et al.* [6], we observed that the tabletop area directly in front of each person appeared to be used 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 also used this area for easing the tasks of some group activities, such as drawing a work clue for other team members in Pictionary®. Group members tended to restrict their personal activities to a smaller area than those 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 and game dice. The group area was also used by people to help others perform the group task, such as clearing items off of a table area to create free space for someone else to use. We also observed that some areas appeared to be reserved for the use of subgroups at the table, such as separate teams playing the Pictionary® game. These subgroup areas were typically located on the table edge between subgroup members' seating 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 on the table, but were also located on other convenient surfaces, such as spare table edge space, nearby chairs, people's laps, and the floor beside or underneath the table. 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 Tangram or jigsaw 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 or discarded paper.

5. 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, 20]. 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 collaborative process, we conducted a more in-depth observational study.

6. STUDY 2: EXAMINING SPATIAL INTERACTIONS ON A TABLE

Our second observational study involved 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. Seven university students were recruited via three different types of study notices. For Group 1, we recruited self-identified "non-technology" students (1 female Business student and 1 male Medical student). For Group 2, we recruited "visual arts" students (1 female and 1 male Fine Arts student). For Group 3, we recruited students familiar with "computer-aided design software" (2 female Architecture students and 1 male Computer Science student). We wanted participants with a range of skills for the potential to observe various approaches to the planning process.

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 large, white, circular cardboard Floor Plan (61 cm in diameter) sitting on the experiment table. Participants were given paper supplies such as cut-outs of furniture (tables, chairs, bookshelves, and plants) and Post-it notes (for making custom items) to create the furniture layout. 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.

Procedure. Each group was brought in separately to perform the experimental task. During the experimental session, participants first completed consent forms, and then the experimenter explained the task to them. Each group was instructed to arrange the task materials (i.e., furniture items and customized items made with Post-it notes) to construct a furniture layout for a university library reading room on the Floor Plan. They were also instructed to incorporate several design requirements, provided to each group member on a sheet of paper, henceforth referred to as the *instruction sheet*. This information sheet included requirements such as: accommodate as many people as possible, display current journals, provide space for groups to work, provide space for individuals to work quietly, and so on.

Participants were given roughly 45 minutes to complete the task. They were instructed to inform the experimenter when they felt they had completed the task. When they were done, they took about 5 minutes to present their final layout plan to the experimenter and to explain the rationale for their design.

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.

The transcripts were coded using the qualitative analysis tool QSR NVivo™ [11].

7. 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 specific functionality. Additionally, contrary to the results of our preliminary study, the fine-grained observations enabled by the video data suggest that storage territories sit on top 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.

7.1 Personal Territories

Participants' spatial interactions are shown in the activity plots and tables in Figure 3. The activity plots show how much activity each participant performed in each tabletop zone. The size of the dots represents the amount of activity that occurred in each zone. The activity tables show the number of actions performed by each participant (and the percentage that represents) in the zones close to each tabletop collaborator. These plots and tables demonstrate that tabletop activity was strongly influenced by the participants'

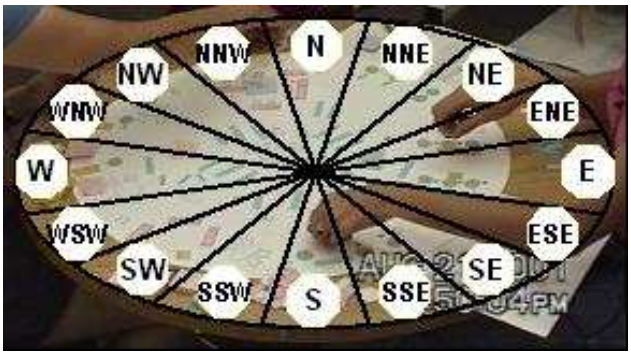


Figure 1. Directional Zones.

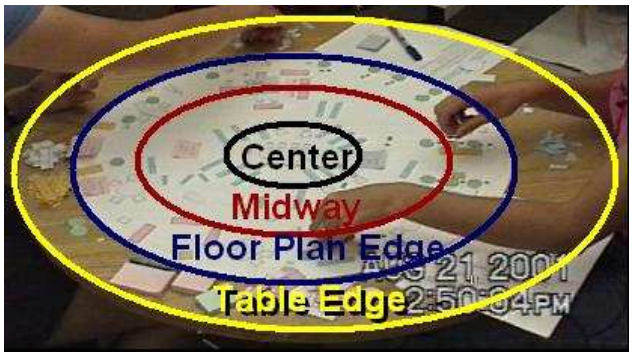


Figure 2. Radial Zones.

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). Throughout the sessions, 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 areas 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 (e.g., writing or drawing on a Post-it note or cutting out a new object) that were later added to the Floor Plan layout. When it was necessariy 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 a collaborator's personal territory (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.

7.2 Group Territories

Areas on the table occupied by participants' personal territories were the only workspace areas so consistently avoided by other group members, see Figure 3. 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 for creating the layout plan. 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. It also 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 pairs, 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.

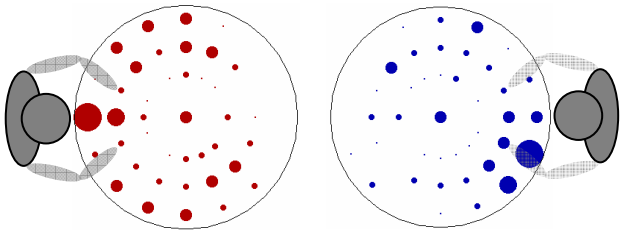
The rotation of the Floor Plan appeared to affect the participants' sense of responsibility for particular furniture arrangements in the workspace. Before the rotation, the participant at NE seemed concerned that an arrangement his partner had made (in the WSW direction) was too cluttered. He had made some minor adjustments to it, but his partner had immediately readjusted the arrangement, almost back to its original state. Once the Floor Plan had been rotated, 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 items 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.

7.3 Storage Territories

Throughout their sessions, participants stored the task resources, such as furniture items and Post-it notes 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 were used as storage territories throughout the collaborative activity.

[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.

Activity Plots

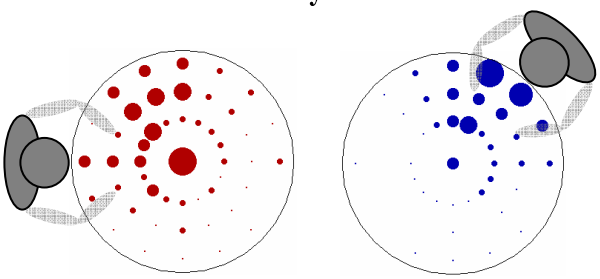


Activity Table

Participants	Central Actions	Western Actions				Eastern Actions			
		Midway	FP Edge	Table Edge	Half	Midway	FP 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

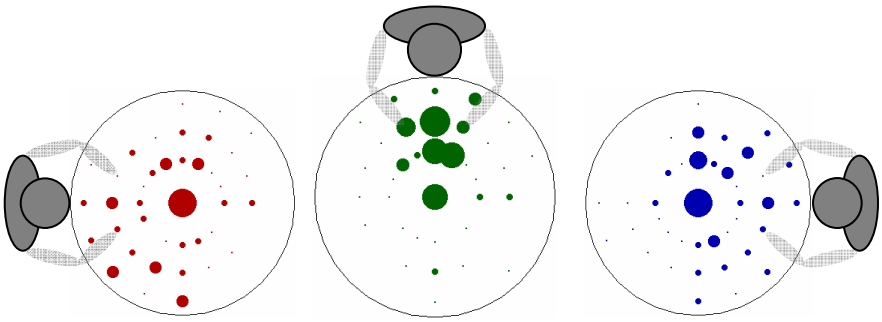


Activity Table

Participants	Central Actions	Western Actions				North-Eastern Actions			
		Midway	FP Edge	Table Edge	Half	Midway	FP 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	FP Edge	Table Edge	Half	Midway	FP Edge	Table Edge	Half	Midway	FP 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 one person, whose location is indicated beside the plot. 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 total actions performed at that located were contributed by the indicated person.

The migration of the piles of furniture from their original locations near the centre of the table to their eventual locations 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. On the other hand, 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, typically by sliding along the surface of 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* areas. When resources, such as plant items or Post-it notes, 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 tabletop actions occurred on the table edge between N and E).

When a participant wanted access to a storage territory located in a collaborator's personal territory, they would usually ask the collaborator to pass him or her the resource. In the few cases of a participant interacting in a collaborator'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 on the table edge closer to him or her, effectively replicating the storage territory. This replication serves a dual purpose: it provides the replicator easier access to the resource and it releases the other person's obligation to distribute the resource.

7.4 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 first class citizens on the table as both have an associated accessibility property, which is defined and controlled through social norms. For example, a personal territory is generally reserved for the use of the nearby person. These tabletop territories appear to be distinct partitions of the workspace and exist fairly mutually exclusive of each other. A personal territory appears to be an extension of a person's personal space [16]; thus, it exists in the tabletop workspace directly adjacent to that person. The group territory then 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, such as writing, arranging items, and sharing items.

Storage territories, on the other hand, appear to exist as second class citizens on the table and are more mobile in the tabletop workspace. They take on the accessibility property of the territory in 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 directly beside or in front of someone, that person typically became the sole or dominant user of its resources.

8. 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 decision to use a round table and a task that was fairly orientation independent in our layout planning study was made in part because we did not want orientation to become a major issue for participants. While this decision allowed us to focus on spatial use of the table surface it also provided little opportunity for observing people orienting items for reading, writing, or sharing. 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.

8.1 Human Territoriality

Taylor [20] 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." [20, p. 81]

Taylor further specifies that territories "range in size from chairs, seats, or sides of a table, to street blocks" [20, 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 [4].

8.2 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.

Our results reveal that people naturally partition their interactions on a tabletop workspace with little to no verbal negotiation. Our participants partitioned the tabletop workspace into personal and group territories, as well as further subdivided their interactions in the group territory. Similarly, others have observed the use of partitioning into distinct tabletop areas during collaborative design [19] and collaborative puzzle solving [6]. Our results further reveal that people also use mobile storage territories to hold 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 [9] *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. For instance, the mobile property of storage territories facilitate obtaining and reserving resources (mechanics #1 and #2), while the shared accessibility of the group territory facilitates handing off and depositing items (mechanics #4 and #5).

8.3 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 action when they are performing task activities required for a contribution they intend to make to the group work, such as reading, writing, and drawing. They also provide a space for people to disengage from the group activity. Tang [19] observed people using personal territories as a "safe" place to explore alternate ideas before introducing these ideas to the group. Finally, personal territories are also an important group resource: our participants appeared to monitor others' activities in their personal territories, offering suggestions or modifying their activities accordingly (e.g., someone waiting for a tool that another group member is currently using can look at the other's progress with the tool to determine if they should continue waiting or find something else to do).

Spatial Properties. Areas directly in front of people are typically used as their personal territories. Tang [19] and Kruger *et al.* [6] observed that people used the areas close to themselves for personal activities. Thus, seating position strongly influenced 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).

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 [9], which lists the full set of *mechanics of collaboration*.

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 sharing the table and how they were arranged. When one person was at the table, they tended to use the entire table. When another person joined them, the first person's personal territory contracted to cover the table area 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 be comfortably seated at the table. A smaller table forces people to sit close together and, thus, as mentioned above, 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 material*. In our layout planning study, the task material only required a small space for manipulation: for the most part people were writing on Post-it notes (7.5x5 cm) 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 [5]. For example, fast food restaurant tables often have a line down the middle of them to decrease the social discomfort of sitting in close proximity to others. In our layout planning study, it appeared that the white cardboard Floor Plan served as a visible barrier against the dark 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, we observed that people were 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.

Interaction with Content. 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.* [6] reported that people oriented items towards themselves in their personal territories. Tang [19] further observed that people tend to write text and draw images intentionally small in these areas.

8.4 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.

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.* [6] reported the use of a group territory covering the middle of the table, between pairs seated facing each other.

Interaction with Content. Interaction with task materials in the group territory appear to follow two basic patterns, depending 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 [19]. When assembling jigsaw puzzles, participants tended to use one "group orientation", aligning loose puzzle pieces with the partially assembled product [6]. 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 [19] reported people designing a product used various orientations: they aligned new drawing 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 [2] 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), as illustrated by Group 2's participants appearing less protective of furniture arrangements once they had been rotated to position farther away from them on the workspace.

In general, the factors that affect the size and shape of a personal territory also influence these group territory partitions (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. It appears that ambiguity of inherent responsibility for a space is introduced when several collaborators have equal physical access to a particular area, either because it is outside of anyone's direct reach or because people seated close together can easily reach it. In such tabletop areas, we observed more explicit coordination and negotiation, as well as less exclusivity of use.

An additional factor that appears to affect the size of a group partition is *ergonomics*. In the layout planning study, it appeared that participants took on responsibility for areas on the table within easy reach. We saw more sharing of the workspace in the *midway* and *central* table areas, which began roughly 30cm from the edge of the table. It appears then, that the area participants' took responsibility for was well within easy reach, since the average length of person's elbow to fingertip is about 45cm for men and about 41cm for women.

8.5 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).

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 (e.g., taking a handful of items from a pile in front of someone else, then placing these items in a new pile closer to one's self).

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

Interaction with Content. Our results suggest that the accessibility of task materials in a storage territory is determined

by the tabletop territory (personal or group) it is currently located on. Task materials within a storage territory 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 generally oriented facing 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.

9. 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 our own design of collaborative tabletop interfaces. Moreover, we are interested in determining whether our findings generalize to other shared workspaces, such as wall or desktop displays. A recent study involving a co-located sharing desktop workspace suggests that territoriality behavior might exist on vertical workspaces as well. This study found that participants strongly favored the side of the screen nearest them, even though they were working with indirect input (via mice) and, thus, were not restricted by potential physical interference [21]. These results intimate that our territorial behavior extends beyond our physical world and affects our virtual interactions as well.

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