Erschienen in: Proceedings of the 17th International Conference on Mobile and Ubiquitous Multimedia : MUM 2018. - New York, NY : ACM Press, 2018. - S. 171-182. - ISBN 978-1-4503-6594-9
https://dx.doi.org/10.1145/3282894.3282902

Mine, Yours, Ours: Coordination through Workspace Arrangements and Territoriality in Tabletop Interaction

Daniel Klinkhammer[1], Magdalena Mateescu[2], Carmen Zahn[2], Harald Reiterer[1]
[1] HCI Group, University of Konstanz, Germany
{daniel.klinkhammer, harald.reiterer}@uni.kn
[2] University of Applied Sciences Northwestern Switzerland
{magdalena.mateescu, carmen.zahn}@fhnw.ch

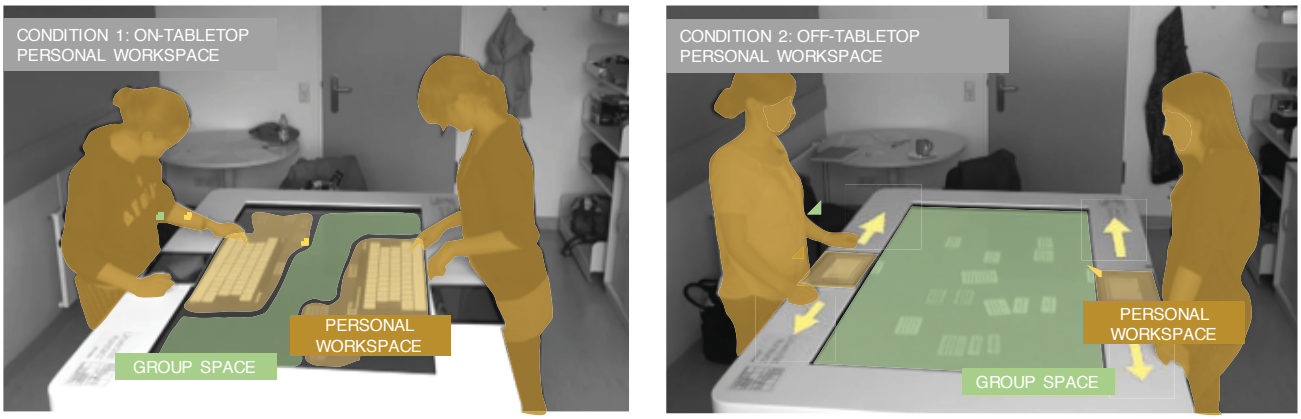


Figure 1: Study conditions: Condition 1 – All Interaction is done on the tabletop; Condition 2: Workspace is separated between tabletop (group space) and tablet (personal workspace)

ABSTRACT
Previous research shows that territories help people coordinate their task and social interaction at large interactive tabletops. However, little is known about the interplay between territorially and the reorientation of digital objects and their influence on task performance. In this paper, we advance the hypothesis that territories are states of spatial arrangements continually changing during the collaborative activity and seek to better understand their role as a main mechanism in coordinating group activities. We report results from an explorative tabletop study that compares two types of technical settings workspaces supporting a brainstorming task. Our results show evidence of different territorial strategies dependent on the two conditions. We discuss the role of territoriality and orientation of digital notes as a mechanism for coordinating group activity and their influence on task performance and outcome. Finally, we present design recommendations derived from our findings.

Author Keywords
Tabletop; tablet; collaboration; territoriality; personal space; social interaction.

CCS Concepts
Human-centered computing ~
Empirical studies in collaborative and social computing

INTRODUCTION
Tabletops' potential for optimizing computer-supported collaboration in small groups is widely acknowledged. Several studies have shown that tabletops increase the awareness of others' actions [11,29,31,34,39], add to the equity of participation [18]; provide rich information about the group [26]; encourage more cohesive ways of work [30], and ease bottlenecks in the negotiation of group resources [42].

Recently, there is a growing interest in developing scenarios for integrating personal devices like tablets with interactive tabletops [4,21,27,28,45,46]. The basic assumption is that the way the workspace is structured influences the affordances of tabletops for collaborative work. Yet, it is still an open question as to how tabletop interfaces should be structured and integrated with personal devices, when groups perform complex tasks and how a workspace composed by group and personal devices affects groups' collaborative

processes and performance. As research on small groups has put it, group collaboration and its outcome depend *"on the degree of fit between the technology and the group, its tasks, and the context within which action is taking place"* [20]. Furthermore, in order to fully exploit the potentials of such workspaces, we need to better understand the mechanism by which specific technology features influence the collaborative processes [5,30].

In this paper, we investigate this issue by observing groups' interaction with each other and with digital artifacts in different workspaces. In our experimental design, we contrast conditions with and one without personal devices (see Figure 1).

Territories and orientation of digital objects have been shown to play a major role for the collaborative work at the tabletop. Yet there are no studies focusing on how different workspace arrangements affect the territorial behavior, the orientation of the digital objects and the users' spatial positioning. In an attempt to understand the role of workspace setting, we take a closer look at two different technological implementations of the workspace (with and without personal devices) and how they affect the collaborative process with respect to territorial usage of the workspace, orientation of digital artifact, spatial positioning as well as the collaborative process and outcome.

In this paper, we present qualitative analyses of groups' behavior at a multi-user tabletop while solving a brainstorming task. We analyze the influence of two different technical settings (see Figure 1) on the group collaboration and address the following research questions (RQ):

- RQ1: How do different workspace settings (with or without tablets) affect the usage of the group space with respect to territorial behavior, digital and spatial arrangements?
- RQ2: How do different workspace settings (with or without tablets) affect the overall collaboration process?
- RQ3: How do different workspace settings (with or without tablets) affect groups performance?

Collaborative Tasks in Tabletop Interaction

Interactive-surfaces research has investigated a broad range of different tasks. Examples include playing memory games [8], assembling poems [32], psychomotor coordination games [25], mathematical tasks [12], complex learning tasks in logistics [36], planning and design tasks [14,31,30], video-based design tasks for arts education [1] and creative problem solving [2]. The importance of task structure for group performance has been widely acknowledged [10,19,23,40]. As Kraut et al. [16] point out, "even small changes in task definition are likely to influence group effectiveness". However, in interactive surfaces research, the topic of differences in task nature are not yet systematically addressed. Based on a review of interactive surfaces research with regard to the tasks used in the diverse studies we differentiate by means of McGrath`s task taxonomy [19] between two main task types: "Type 1: Planning tasks," and "Type 2: Creativity tasks." Both task types are located in the first quadrant of McGraths Group Task Circumplex [19] called "Generate", and both score high in the cooperative dimension.

Tang et al. [43] investigated the coupling of pairs when working collaboratively on a planning task (see McGrath's Task Circumplex [19]). Considering differences between task types and the importance of external representation [24] for group work, we developed a real-world-scenario task, that can be assigned to the class of creativity tasks according to McGrath's Task Circumplex [19], to investigate the influence of our technological settings in this experiment. During this task participants are asked to generate ideas, which are represented on the tabletop as digital objects (post-it notes). These post-its serve as interactive external representations (IER), defined as representations that can be easily modified or changed by an agent [33].

IERs can play different roles during tabletop interaction at both individual and group level. They have been shown to constitute resources for internal cognitive processes at individual level and to mediate communication at group level [33]. Through positioning and orientation of IERs different heterogeneous workspaces can be structured during task completion. How different layouts of post-it notes support the collaboration is a major focus of our explorative study.

Workspace Structuring

When working together at a tabletop, groups organize their workspace to support their work for both a highly coupled style (e.g., by working in the group territory) and loose coupling (e.g., by using personal territory for individual work) [6, 37,42]. Personal territories emerge in front of a person on a tabletop while working collaboratively. Tang [42] stated that users establish separate areas on a tabletop to work and interact with task resources. The approach of territoriality proposes a distinction between three types of territories: personal, group, and storage. These areas are arranged by users through the positioning and orientation of artifacts on the surface [37]. Personal territories are used for manipulation, editing, and reservation of resources; group territories provide context for the group task and hold shared artifacts; storage territories are used, for example, for items that do not belong to the current task. Fetter et al. [6] argue that personal territories, which are visually marked areas at tabletops, provide cues that help avoiding conflict and increase situational awareness in a group. As experimental studies show, even if interactive tabletops do not provide groups with salient, visually marked spaces, territorial behavior emerges [37,42]. These findings speak for the importance of providing groups with appropriate affordances to structure their shared workspace, for example by providing personal devices.

Personal devices (e.g., tablets, pads, or smartphone devices) allow group members to try out solutions to the task before sharing it. Several scenarios of workspaces combining group spaces (tabletops) and personal devices (mobile devices, tables) have been proposed and shown to foster teamwork [4,21,27,28,43]. For instance, mobile devices allow users to collaborate in a flexible fashion by offering the possibility to alternate between shared and private activities [41].

The collaborative work is dependent not only on a territorial organization of the workspace, but also on the orientation of the digital objects. Kruger et al. [17] substantiate the critical role of orientation on individuals' information comprehension on collaborative coordination and on mediating group communication. Through the two types of actions, territorial organization of the group space and (re-)orientation of digital artifacts, groups structure their workspace to better serve their collaborative activity.

We define *workspace structuring* as "intentional organization of the workspace to optimally support an agent's' interactions with that workspace in solving their task," following observations by Kirsh [15]. In the context of the experiment reported here, we differentiate between two workspace structures. In the first workspace structure (Condition 1), the workspace consists only of a large scaled tabletop. In the second, Condition 2, the workspace integrated tablets functioning as personal workspaces in addition to the interactive tabletop (group space).

Up to now there are no experimental studies concentrating on the affordances of personal workspaces. Previous experimental studies addressed configurations of the workspace with or without an interactive tabletop [45] or by comparing different tabletop sizes [46]. In this study, we contrast workspace settings with and without personal devices (tablets).

In summary, there is a large body of research focusing on combining tabletops with tablets and some concentrating on territorial behavior and orientation of digital artifacts, yet they have not been discussed together in their tangled interaction with each other. In this experiment, we presented detailed qualitative analysis that shed light on this issue.

EXPLORATIVE STUDY

The goal of this research is a qualitative analysis of relationships between basic technological settings of workspace structuring and collaboration processes and outcomes. We compare two different technological settings: In *Condition 1* no tablets as personal workspaces were used. All interaction took place on the tabletop, which served in this condition as personal and group workspace. In *Condition 2* tablets were used as personal workspaces.

According to our research questions we explore which different workspace structuring strategies (RQ1) are applied in dependence of the two technical settings. Furthermore, we want to explore the effect of technology setting on process (RQ2) and the effect of technology affordances and process on groups' performance (RQ3). In order to investigate these complex relations, we conducted an exploratory study that will be described further.

Task

For the study, a realistic collaborative brainstorming task was developed. The participants were asked to collaboratively generate innovative ideas to support productive work for a flexible office at a fictive university. In addition to clarifications with respect to the meaning of the productive work, the participants were provided with a description of employees' requirements for the office and employees' activities. More specially, the participants have to develop ideas about the locations of different zones and to furnish them according to their different functions. In doing that, the participants have to consider the requirements of the university employees as well as the type and importance of fictive university employees' activities.

The task had two phases: an individual phase and a collaborative phase. During the individual phase, participants individually generated ideas. The collaborative phase consisted in further generating ideas and in prioritizing the six most important ideas.

Experimental Design

40 students (27 female; 13 male; average age 23.68) randomly assigned to the two conditions participated in the experiment. The participants worked in pairs at a tabletop system - 10 pairs in each condition (see Figure 1). The interactive tabletop system used was based on a 65" touchscreen with 4K (3840px × 2160px) resolution. Additionally that, participants were also equipped with tablets (MS Surface Pro 3). The participants had different educational backgrounds.

In Condition 1, the creation of the digital objects during the individual phase took place on a large scaled tabletop screen (see Figure 2 - left). In Condition 2 tablets were used for the creation of digital objects during the individual phase. The notes from the individual phase were transferred to the tabletop during the collaborative phase.

The interactions available on the tabletop interface were writing notes, moving notes around and adding notes to the priority list (see Table 1). In both conditions, an on-screen keyboard for text entry was provided on the tabletop (see Figure 2 - left). By pressing an add-button the text entry was placed as a post-it object randomly on the screen. An initial random placement of digital objects was chosen to avoid a system-proposed, territorial organization. Each participant was provided with a tablet which functioned as a personal device.

In Condition 1 (on-tabletop), the tablet was only used to display the task description and to fill out questionnaires. In the second condition, the participants used the tablet for text entry in the individual phase (see Figure 2 - right).

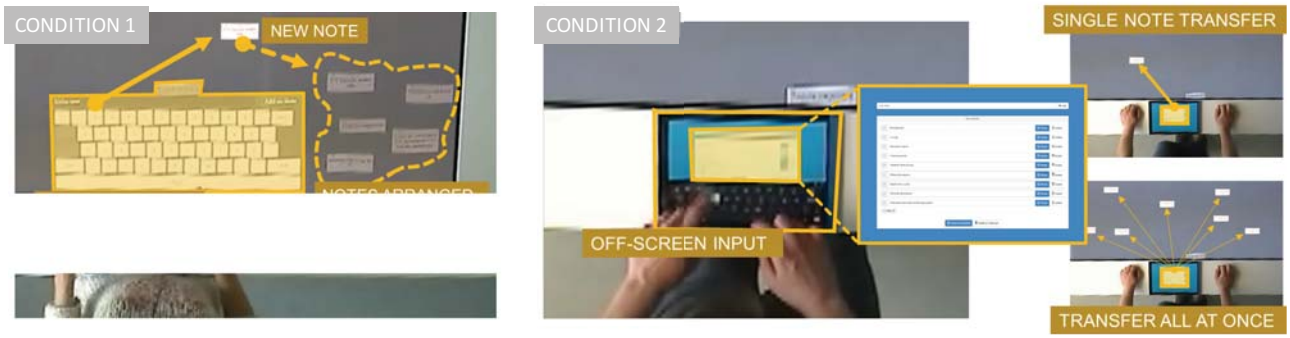


Figure 2. Detailed condition description

The text entries on the tablet were displayed in a list in Condition 2. Each text-note could be transferred to the tabletop individually (a share-button was available for each entry). Furthermore, multiple notes could be transferred at once (see Figure 2 - right) by selecting an assigned checkbox. A check-all option to transfer all post-it notes at once was available. For the individual phase, the participants were instructed to use the tablet to enter their notes. During the collaborative phase, the participants in Condition 2 could choose between text entry on tablet or tabletop.

	Condition 1	**Condition 2**
Tablet functionality	Read task Answer questionnaires	Read task Answer questionnaires **Write notes** **Transfer notes to the group space**
Tabletop functionality	Write notes Organize notes (e.g. by rotating, moving, stacking, clustering) Priorities notes	

Table 1. Overview of System Functionality

Procedure

The experimental procedure lasted approximately two hours for both conditions. First, the participants were informed about the study goals and structure (timing, sequence of events). Upon signing an informed consent, the participants were asked to complete a first questionnaire on a tablet concerning demographic data and prior experience with touch interfaces. After completing the first questionnaire, the participants were introduced to and familiarized themselves with the interfaces, both on the tabletop and on the tablet. Following training, the participants individually read the task and started working on the task. In both conditions, the participants started with an individual ideation phase (10 minutes) followed by a collaborative phase (35 minutes). In the individual phase the participants generated ideas on their own. In Condition 1 both participants generated their ideas individually directly on the table (see Figure 3 - left). In Condition 2 they used their personal tablets for the individual idea generation (see Figure 3 - right). Each idea was displayed in a list on the tablet and had to be transferred during the collaborative phase to the tabletop.

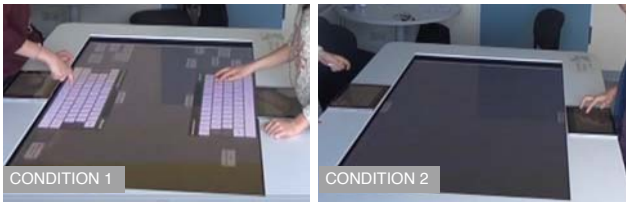


Figure 3. Individual Phase (10min)

The collaborative phase (see Figure 4) was announced by the experimenter after 10 minutes. The participants were asked to collaboratively generate further ideas and to prioritize the most important 6 ideas. During that phase, different strategies for presenting, sharing and merging the ideas are applied by the participants. These strategies were the main focus of analysis and will be described in detail.

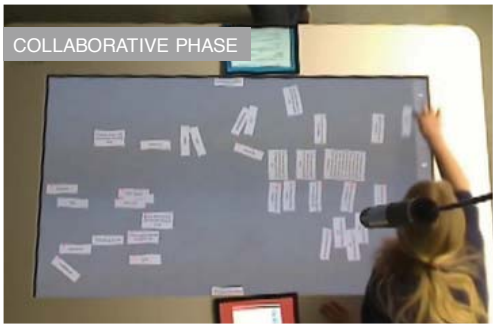


Figure 4. Collaborative Phase (35min)

DATA ANALYSIS

Several data were collected and analyzed. The participants completed questionnaires and log files were recorded. The log files collected participants' type of interaction (write note, move note, delete note) and the coordinates of the interaction. All sessions were video and audiotaped.

Log Files Analysis

To deepen our understanding of territorial usage on the table, we synchronized the log files with the video data. All interactions with post-it notes (move and rotate) recorded in the log files were coded with respect to who performed them. Inspired by the spatial action analysis proposed by Scott and Carpendale [38], we dived the tabletop into three sections: A 1/3 of the table near participant *A*, *B* 1/3 of the table near participant and *M* the middle territory. To understand the usage of the group workspace, we created summarizing plots for each condition (see Figure 9).

Video Data Analysis

Based on the video data a qualitative analysis of participants' territorial behavior was performed by two trained raters. The following behaviors were coded: (a) territorial behavior, (b) joint representations, (c) transfer method, and (d) spatial positioning.

(a) **Territorial behavior**: During the experiments' execution we could observe that some participants showed a strong territorial behavior. The major indicator for territorial behavior was the establishment of personal territories. Therefore, we coded the existence of personal territories for each participant. We defined personal territories as collections of notes owned by one user, grouped together, oriented to the notes owner, and placed directly in front of the notes owner (see Figure 5 – 1st Phase).

(b) **Joint representations**: Beside the territorial behavior we observed that some groups used the tabletop group space for rearranging the created notes. At the end of this arranging process a joint representation was created. We defined a joint representation as a collection of notes with mixed ownership. This collection was clearly recognizable by the position and orientation of the notes and the effort the participants spend into the arrangement (see Figure 5 – 3rd Phase). This representation was used to answer the task's question (identification of the 6 important ideas). Therefore, the joint representation seems to constitute the end of the collaboration process.

(c) **Transfer method**: The notes created on the tablet could be transferred to the group workspace in two ways - sequential transfer (share one note after another) or in a bulk - all-in transfer (selection and sharing of all notes at once).

(d) **Spatial positioning**: Some participants changed their standing position during the experiment, from the face-to-face positioning to a side-by-side positioning.

Collaborative Process

To analyze the effectiveness of the collaborative process a rating scheme from Meier et al. [22] was adapted for this task. This assessment method uses qualitatively defined characteristic dimensions of collaboration. Therefore, the collaborative process effectiveness was rated on the following dimensions: A. Coordination: (1) task division, (2) time management, (3) technical coordination; B. Communication: (4) mutual understanding, (5) dialog management; and C. Joint Information Processing: (6) information pooling, (7) reaching consensus. All video recordings of the groups have been rated on the seven dimensions by a trained observer. To ensure reliability of the video coding, 20% of the videos were rated by a second observer (Kappa = 0.91). To ensure the internal validity of the scale, we calculated Cronbach's alpha, which was .81 after removing the time management item. This decision is also supported by the observation that most groups were insufficiently preoccupied with time management issues.

Performance

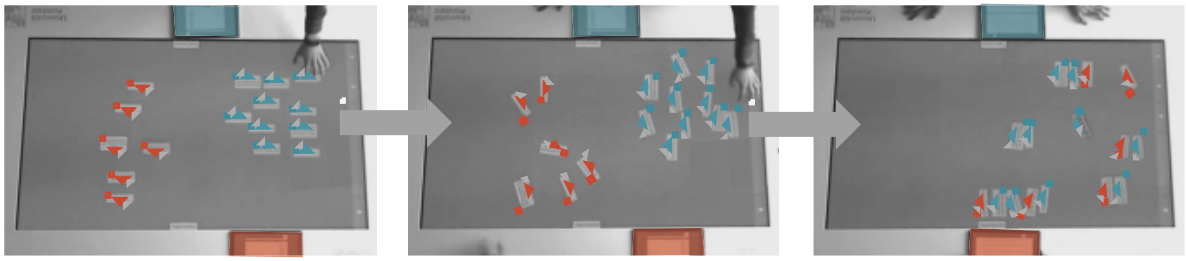
As an objective measure of team performance, we analyzed the products of the dyads participating in our study based on quality indicators: fluidity, originality and elaboration. Such measures have been used in similar studies [3,13,35]. In order to calculate these indicators, we performed a content analysis on all ideas. In calculating a composite score for performance we have taken the following steps: (1) created a database of all ideas and groups; (2) deleted duplicates, notes (direct citations from the task) as well as any text that did not make sense (nonsense); (3) calculated fluidity per group as number of ideas generated during the task; (4) calculated originality: ideas that were expressed only by one group got 2 points, ideas that were expressed by two groups got 1 point; (5) calculated elaboration (level of detailing the idea description): removed common words like (articles, prepositions), counted the number of words per idea and summed up number of words per group.

FINDINGS

In this section, we present findings from the data analysis and relate them to our previously presented research questions.

RQ1: Coordination Techniques

Recent work on territoriality proposes a distinction between three types of territories: personal, group, and storage territories [37]. These territories are created by users through the positioning and orientation of artifacts on the tabletop. *Personal territories* are established directly in front of the user and are used for manipulation, editing, and reservation of resources. Meanwhile, the *group territory* provides context for the group task and holds shared artifacts.



1st Phase: Establish personal territories

2nd Phase: Re-orientation of post-it notes – territorial flow

3rd Phase: Re-arrange the notes to create a *joint represenatation*

Figure 5. Territorial Flow. Example Session (arrows on notes indicate reading direction)

The observed territorial behaviors on the tabletop consisted in a series of changes in the spatial arrangement and orientation of post-it notes during collaborative brainstorming. With respect to participants' territorial behavior, we observed that at the beginning of the collaborative phase 8 of 10 pairs in the first condition and only 4 of 10 pairs in the second condition 2 created personal territories. In contrast, at the end of the collaborative phase 7 of 10 pairs in the first condition and 9 of 10 pairs in the second condition created a joint representation (see table 2).

Collaborative Phase	**Condition 1: No Tablets**	**Condition 2: Tablets as Personal Spaces**
Personal territory	8	4
Joint representation	7	9

Table 2. Number of pairs that coordinated themselves through rearrangements of digital notes

Figure 5 shows an example of this repositioning and reorientation process we observed during the experiments. This video-coded note-constellations symbolize the beginning (1st Phase) and the end of the collaborative process (3rd Phase). Between these states (personal territory and representation) multiple note arrangements could be observed. Beginning with clear defined personal territories in the 1st Phase of the collaborative process the participants presented their ideas to each other. This presentation process was often done by a reorientation of the notes to the reading direction of the other participant (2nd Phase). That presentation established some common ground between the participants allowing them to build a joint representation (3rd Phase). It is important to note that a joint representation was not requested for solving the task, but as already pointed out, most groups created them anyway (16 out of 20). Moreover, it is important to note the complete disappearance of personal territories even though the digital notes could have been easily duplicated and could have populated both the personal and the group space.

Based on these observations, we consider that territories are not static areas that permanently exist, but states of spatial arrangements continually changing during the collaborative activity. It seems that the (re-)arrangements of the post-it notes play an important role in group coordination. We call this type of behavior *territorial flow* (see Figure 5 – 2nd Phase). The collaborative work starts with the creation of a personal territory on the table and ends with a collaboratively created joint representation. The territorial flow is determined both by the intrinsic characteristics of the task and also by the technological support offered. Lack of personal spaces seems to have determined in our experiment the first move into the territorial flow – establishing of personal territories on the tabletop. This first move was more common in Condition 1. The second move consisted of orientating the notes so that the other participant could read them. The last move of the participants was to cluster the notes and thereby creating a joint representation. This last move seems to be prompted by the collaborative process: the necessity of establishing a common ground.

Finding 1: Dependent on the task progress a territorial flow can emerge which reflects the collaborative process.

Coordination through (re-)arrangements of digital notes into personal territories

As already mentioned, personal territories on the tabletop provided a starting point for the collaborative process. Furthermore, we observed different kinds of territorial behavior depending on the two conditions.

In the first condition, 8 of 10 pairs clustered their text-notes in personal territories (fig.6–PT) during the individual phase – see Table 2. Only one pair did not display any territorial behavior in this condition. None of the participants in this group organized the post-it notes at all, i.e., they left their notes nearly untouched as they were arranged by the system (fig.6–NO PT). In the other group classified as not displaying territorial behavior, one of the participants did not display any territorial behavior. Meanwhile the other participant displayed a more and more territorial behavior (fig.6-MIXED).

In Condition 2, all notes were entered in the individual phase on the personal tablet and transferred to the tabletop thereafter. The importance of establishing personal territories on the tabletops is revealed by the territorial behavior of the participants in this condition. 4 of 10 pairs in

this second condition established personal territories on the tabletop, in addition to the individual workspace offered on the tablet.

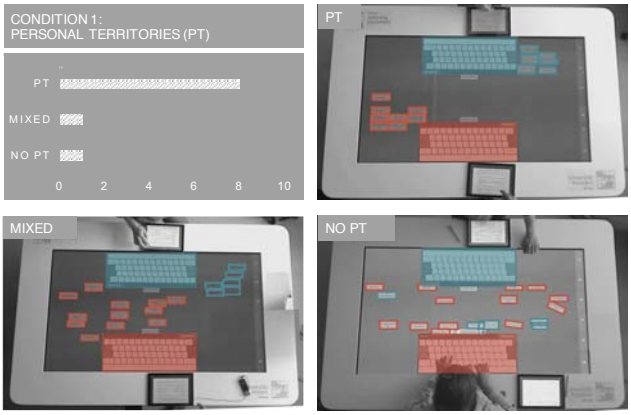


Figure 6: Types of Personal Territories in Condition 1

The establishment of personal territories is not necessarily an activity carried out individually. In both conditions, we observed that participants' territorial behavior was not restricted to their own notes. While creating their personal territories after the notes' transfer from the tablet to the tabletop, unsolicited help from the other participant was often observed.

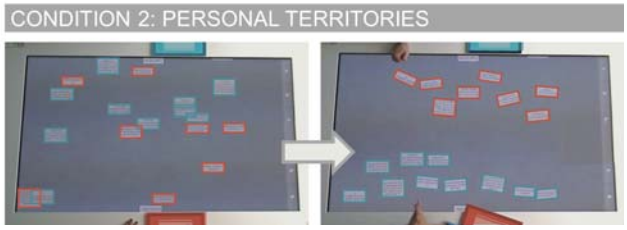


Figure 7: Example. Establishing personal territories on the tabletop. A: Random arrangement of the notes on the table B. Personal territories created by the two participants

The establishment of personal territories seems to be dependent in Condition 2 on the tablet-table transfer method used: sequential transfer and all-in transfer (see Table 3).

	Condition 1	**Condition 2**
All-in transfer	*Not applicable*	5
Sequential transfer		5
Face-to-face	9	5
Side-by-side	1	5

Table 3. Transfer strategy and spatial repositioning

Of the pairs (5 of 10) transferred all items at once from the tablet to the tabletop (all-in strategy) – see Table 3. The other half of the groups transferred their notes one-by-one (sequential strategy). The groups that used the *all-in strategy* showed a stronger territorial behavior (see figure 7) with 4 of the 5 pairs establishing a personal territory on the tabletop by positioning their notes near to them immediately after transfer. They reorganized all transferred notes by changing their position and orientation. This can be explained by the fact that transferring all items at once leads to a cluttered screen since each note is randomly placed on the tabletop by the system. Meanwhile the groups that used the *sequential strategy* tended not to make use of personal workspace on the tabletop.

Finding 2: The establishment of personal territories is essential at the beginning of the collaborative process.

Coordination through (re)orientation of digital objects

After establishing personal territories, 7 of 10 groups in Condition 1 and 9 of 10 groups in Condition 2 merged their personal territories and created what we call a *joint representation.* We define a joint representation as "the meaningful collaborative clustering of all notes generated during the individual and collaborative phase." Some groups started this process (territorial flow) by changing the orientation of their post-it notes (see Figure 5). Thereafter, they mixed their notes one-by-one in the group until they came up with a final arrangement that could be described as a joint representation. The creation of joint representations seems to be intrinsic to solving the task collaboratively with 16 of 20 pairs showing this behavior. We consider that this joint representation bears a great importance for the collaborative work, especially since it was not required by the task instructions and yet several groups created it. During the creation of the joint representation, some pairs set up a shared layout oriented to the short side of the tabletop. Such a layout allows an equal perspective for both participants on the tabletop.

Finding 3: Participants intrinsically created a joint representation for solving the task.

Coordination through participants' spatial (re)positioning

We noticed differences with respect to participants' spatial positioning both between experimental conditions as well as between pairs using different transfer strategies (Condition 2). All participants started in a face-to-face arrangement and had a standing position during the experiment. They were not instructed with respect to their spatial position at the tabletop. We considered the standing position to be more inviting for freely choosing the most appropriate position during the collaborative work, which also seems to have been the case. In Condition 2, half of the pairs repositioned themselves during the collaborative phase compared to only one in condition 1 (see Table 3).

With respect to the transfer strategy, half of the groups in Condition 2 used a sequential transfer strategy – both participants added their post-it notes one-by-one on the tabletop (see Table 3). It is also notable that 4 of 5 pairs who

preferred this strategy (sequential transfer) also changed their position at the tabletop to establish a side-by-side arrangement (see figure 8 - right). This is even more interesting considering that only 5 of 10 pairs changed their position at the tabletop in this condition and almost all of them followed the sequential transfer strategy.

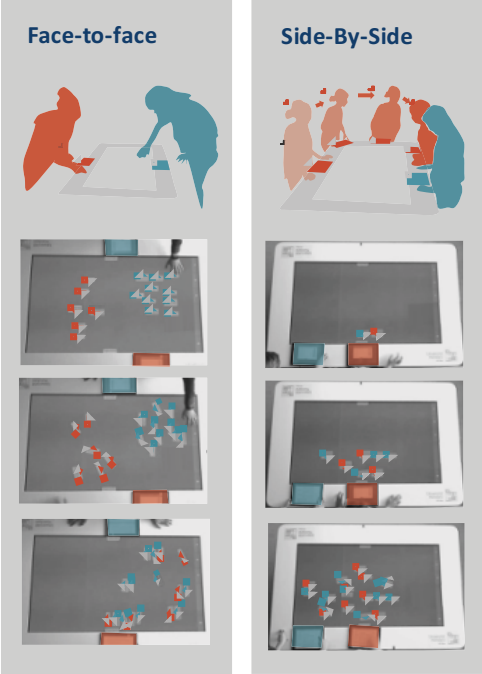


Figure 8: Face to face (left) and side-by-side (right) arrangements in Condition 2

Based on these observations, we consider that coordination also takes place through participants' spatial repositioning at the tabletop. Changing the spatial position offers participants the advantage of having the same perspective towards the digital artifacts on the tabletop as well as on the personal tablets (see Figure 8 - right).

Finding 4: Participants in Condition 2 (tablet) changed more often to a side-by-side setting than the participants in Condition 1.

Coordination through territorial behavior

Taking a closer look at participants' territorial behavior it becomes obvious that it becomes accentuated by the lack of personal territories. As already pointed out, in the first condition, the participants created more personal territories and fewer joint representations. A second observation regarding the usage of the tabletop as a group space supports this claim.

Figure 9 shows participants' interactions with post-it notes (move, rotate, and delete) on the tabletop. In condition 1, the participants (participant A – blue dots; participant B – red dots) used clearly separated spaces on the tabletop. In condition 2 the interactions show a more compound interaction on the tabletop with participants interacting not only in the workspace near to them like in the first condition, but taking advantage of the whole tabletop as a groups space. Therefore, the participants in the second condition worked more often in a closer spatial arrangement.

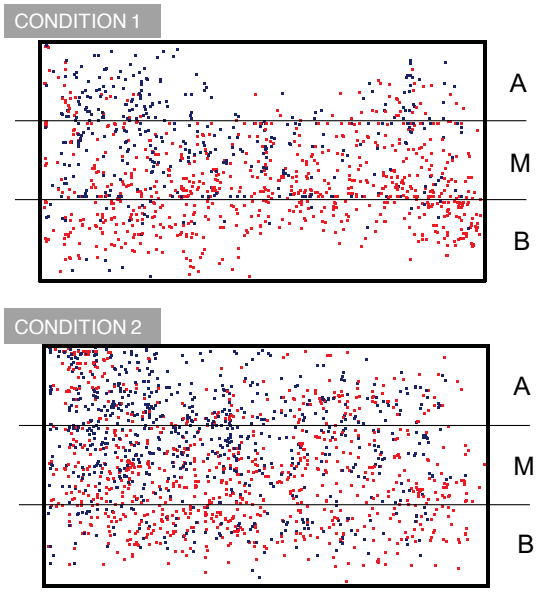


Figure 9: Interaction plots

Finding 5: Depending on the tablet-tabletop transfer method different spatial arrangements were chosen by the participants.

RQ2: Effects on process

By the measures of collaborative process, we observed significant differences between the conditions with respect to communication ($t(18) = -3.06$, $p < 0.01$) and joint information processing behavior ($t(18) = -2.9912$, p-value <0.01). The groups in condition 2 (tablet) communicated and shared information to a higher degree than the groups in condition 1 – see Table 4. Yet even though group in condition 2 seem to have coordinated slightly better – see Table 4 - there were no significant differences ($t(18) = -0.37302$, p-value >0.05) with respect to groups' task management and technical coordination.

	Coordination		Communication		Joint information processing	
	M	*SD*	*M*	*SD*	*M*	*SD*
Condition 1	7.70	3.20	**8.30**	2.31	**7.70**	2.54
Condition 2	8.20	2.78	**11.30**	2.06	**10.90**	2.23

Note. *M* and *SD* represent mean and standard deviation, respectively

Table 4: Means and standard deviations for group collaboration

Finding 6: Groups in Condition 2 showed a significantly better communication and joint information processing behavior.

RQ3: Effects on performance

Not only does process seem to be affected by the workspace setting, we also found some evidence for higher performance with respect to idea elaboration (t (18)=-3.19, p-value <0.01): Dyads in the Condition 2 wrote on average more words per idea – see Table 5 - than groups in condition 1. However, we found no difference with respect to the average number of ideas ($t_{(18)}$ = -0.83, p>0.05) and originality ($t_{(18)}$ = -0.56, p>0.05), even though groups in Condition 2 generated more ideas and generally tended come up with more original ideas – see Table 5.

	Fluidity		Elaboration		Originality	
	M	SD	M	SD	M	SD
Condition 1	25.00	5.70	**3.34**	0.99	8.00	3.53
Condition 2	27.10	5.63	**6.04**	2.49	9.00	4.47

Note. M and SD represent mean and standard deviation, respectively.

Table 5: Descriptive statistics for the objective brainstorming performance indicators

Finding 7: Groups in Condition 2 elaborated their ideas significantly better than groups in condition 1.

DISCUSSION AND DESIGN RECOMMENDATIONS

The aim of this study was to shed light on the effect of different workspace setting on territorial behavior, collaborative process and performance. We conducted an explorative study comparing two types of workspace settings: In Condition 1, the workspace consisted of a large tabletop. In Condition 2, the setting included two tables in addition to the tabletop, that were used as individual workspaces. During the experiment, the participants collaboratively solved a brainstorming task.

The empirical results show that groups in Condition 2 displayed less territorial behavior than the participants in the first condition. Additionally, they also tended to engage more in creating joint representations and collaborated more closely (better communication and joint information processing). Less noticeable were the differences with regard to task performance. Even though we did not observe differences in the number and originality of the ideas in Condition 2, participants in this condition described their ideas in more detail.

The results regarding the territorial behavior match some of the result of previous research on territoriality [37,38] but only for condition 1. At the beginning the collaborative task, most participants in Condition 1 established personal territories, which served as starting points for the given task - see Finding 2. Besides they also tended to interact more with notes placed near to them on the tabletop. With regard to participants' workspace partitioning, we observed similar results as Tuddenham and Robinson [44] but only in the first condition – see Finding 5. Previous results showed partitioning of the workspaces in the collocated condition more that those working remote. Creation of joint representations was a constitutive part of the collaborative process in both conditions. Yet, more groups engaged in this type of behavior in the second condition. The usage of external representation and its importance for the collaborative process as well as tabletops' potential to support it has been supported by previous research [24].

The different workspace settings led to differences in the collaborative process with groups in Condition 2 engaging in a more efficient communication and joint information processing. This conclusion goes along with results from previous research comparing tabletops to other settings [2,31,45] showing that the collaborative process can be improved by settings with a tabletop [2], or made more equitable in physical-digital conditions [31]. Our results shed light on the influence of personal spaces for such setting. Based on these results we claim that it is not only the tabletop that makes a difference but the whole workspace setting, with the workspace combining personal and group spaces offering more advantageous conditions for the collaborative process.

Even though the collaborative process seems to have been affected on some of its facets by the workspace setting, and is generally expected to be related to performance, our results are less conclusive with respect to the effect of the different workspace settings on collaboration. We found only evidence that groups in Condition 2 wrote more words per idea (indicator for a higher elaboration of expressed ideas). With regard to the number of ideas (fluidity) and originality, we found no significant difference, even though groups in the second condition created in average more ideas that scored higher on originality. The lack of differentiation between conditions might be due to compensatory behaviors like creating personal spaces on the tabletop, but further experiments are needed to shed light on this issue.

In addition to the discussed difference between conditions, we also observed behaviors regarding the manipulation of external representations that dominating both conditions. Recent research mainly refers to two concepts when analyzing spatial interaction in collaborative work: territoriality [37,38] and coupling styles [43]. The theory of tabletop Scott et al. [37,38] reveal that workspace partitioning behavior is part of a more complex practice of tabletop territoriality. They observed the use of personal, group, and storage territories in collaboration settings. Yet how territories arise and transform into other territories is not yet discussed by previous research. We observed that personal and group territories are not static areas but change dynamically during processing the task. To emphasize this

we introduce the term *Territorial Flow* which focuses on (re-)positioning and (re-)orientation of external representations by processing a collaborative task. Based on the observations discussed here, we conclude that the usage of different types of territories is dependent of the task activities, which may change during the overall task process. The same is true for the concept of coupling styles. Tang et al. [43] state that the six identified coupling styles are not an exhaustive list and that collaboration might be best described as a dynamic and fluid stateless system [9]. The concept of *Territorial Flow* might be seen as one step into that direction. However, just like other studies this paper concentrates on one specific task and the findings presented here need to be verified with different tasks. With this limitation in mind, we consider that our findings can yet help researchers and workplace designers in heterogeneous ways. Therefore, we distilled our findings into the following design recommendations for artefact-based collaboration interfaces:

Provide a distinct division of personal and group space. In Condition 2 personal and group workspaces were distinctly divided. The tablet was used as personal workspace and the tabletop as group space. This clear division seems to have a considerable impact on the collaborative process. The participants communicated better, and shared information processing and reached consensus much easier (Finding 6). These findings led us to conclude that the use of tablets as personal spaces in tabletop collaboration has a positive effect on the process.

Provide tablets for individual phases. Participants working on tablets wrote more words per idea and therefore elaborated their ideas better than the participants working only in the group space (Finding 7). This can be traced back to the fact that tablets offer more privacy and that this characteristic has a positive impact on the outcome. We agree with Scott et al. [37] that we should provide visibility and transparency of action, but we think that this transparency of action is only essential in the collaborative phase. During the individual phase a personal space should be handled as private space as well even if that decreases the group member's workspace awareness.

Support flexible spatial positioning. One major finding is that participants equipped with personal devices showed a flexible spatial positioning at the tabletop (Finding 4). The participants naturally changed their position to support different coupling styles. Therefore, we consider that support for flexible spatial arrangement might be beneficial as a social coordination mechanism.

Provide heterogeneous cross-device transfer options. Our observations have shown that the participants used different tablet-tabletop transfer methods. The selection of the transfer method had a strong impact on the kind of coupling style (face-to-face or side-by-side – Finding 5). Our observations and calculated measures do not hint to one of these strategies leading to a better performance. The transfer method seems to be rather an individual preference. Therefore, we think that different transfer methods should be supported to allow a flexible application of coupling styles.

Support territorial flow. In tasks including both individual and collaborative phases a territorial flow might occur. This flow can be supported by the interface design in manifold ways. For example, the creation of a joint representation can be motivated and structured by distinct areas on the table.

LIMITATIONS

As stated in the introduction *"even small changes in task definition are likely to influence group effectiveness"* [16]. This is also valid for changes in the workplace setting. The goal of the study was to shed light on an artefact-based collaboration process by comparing different workplace settings. Our observed findings are therefore bounded to a specific task and a specific workplace setting. Small changes on both can have an influence on the collaboration process and performance.

However, we think that we addressed with the presented workspace setting a common device combination and therefore the findings give some insights of the workspace characteristics and benefits. Furthermore, we tried to address a broad class of meaningful tasks. The described brainstorming task relies strongly on digital artifacts (post-it notes) and their arrangement. We think that this characteristic can be applied to other tasks that rely on digital artifacts as well.

CONCLUSION

In this paper, we presented an explorative study focusing on different workspace settings that combine group spaces (tabletops) with personal devices (tablets). We advanced the hypothesis that territories are states of spatial arrangements continually changing during the collaborative activity and made in-depth analysis of the collaborative work to better understand their role as a main mechanism in coordinating group activities and discussed design recommendations at length. We found that territories are not static states but are, rather part of a territorial flow that reflects the collaborative process. The establishment of personal territories is essential at the beginning of the collaborative process. However, as the task emerged the participants move to create joint representation of the task solution. Based on the discussed observations, we consider that better understanding participants' territorial behavior in relation to their spatial positioning is a direction worth pursuing in future research. Combining tabletops with tablets seems to support communication and joint information processing better, yet proved to be of little importance for group coordination. Regarding overall performance, we found differences only with respect to idea elaboration, whereas the number of ideas and their originality seems not to be affected. We conclude that providing users with personal devices affects their territorial behavior as well as the use of digital artifacts and communication during the collaborative process.

REFERENCES

1. Borchers, M., Mock, P., Zahn, C., Edelmann, J., Hesse. F. W. 2013. Supporting School Class Visits to Fine Arts Museums in the 21st Century: A CSCL Approach for a Multitouch Table Based Video Tool. In *Proc. CSCL 2013*, International Society of the Learning Sciences.
2. Buisine, S., Besacier, G., Aoussat, A., and Frédéric Vernier, F. 2012. How do interactive tabletop systems influence collaboration? *Computers in Human Behavior* 28, 1: 49–59.
3. Deuja, A., Kohn, N. W., Paulus, P., Korde, R. M. 2014. Taking a broad perspective before brainstorming. *Group Dynamics: Theory, Research, and Practice* 18, 3: 222-236.
4. Diez, D., Tena, S., Romero-Gomez, R., Díaz, P., Aedo, I. 2014. Sharing your view: A distributed user interface approach for reviewing emergency plans. *International Journal of Human-Computer Studies 72, 1*: 126–139.
5. Dillenbourg, P., and Evans, M. 2011. Interactive tabletops in education. *International Journal of Computer-Supported Collaborative Learning* 6, 4: 491–514.
6. Fetter, M., Gross, T., Hucke, M. 2011. Supporting social protocols in tabletop interaction through visual cues. In *Proc. INTERACT* 2011, Springer.
7. Gergle, D., Kraut, R. E., Fussel, S. R. 2013. Using Visual Information for Grounding and Awareness in Collaborative Tasks. *Human-Computer Interaction* 28: 1–39.
8. Ha, V., Inkpen, K. M., Mandryk, R. L., Whalen, T. 2006. Direct intentions: the effects of input devices on collaboration around a tabletop display. In *Proc. IEEE International Workshop on Horizontal Interactive Human-Computer Systems*, IEEE Computer Society.
9. Hancock, M. and Carpendale, S. The complexities of computer-supported collaboration. Technical report 2006-812-05, Dept. of Computer Science, University of Calgary, Calgary, (2006).
10. Hollingshead, A. B., Mcgrath, J. E., O'Connor, K. M. 1993. Group Task Performance and Communication Technology: A Longitudinal Study of Computer-Mediated Versus Face-to-Face Work Groups. *Small Group Research* 24, 3: 307–333.
11. Hornecker, E., Marshall, P., Dalton, N. S., Rogers, Y. 2008. Collaboration and Interference: Awareness with Mice or Touch Input. In *Proc. CSCW* '08, ACM Press.
12. Hwang, W.-Y., Shadiev, R., Huang, Y.-M., Cai, Y.-T., Yang, Y.-S., Su, J.-H. 2013. Effects of drag-and-response interaction mechanism of multi-touch operated tabletop technology on users' awareness and collaborative performance. *Computers & Education* 67: 130–141.
13. Kaufman, J. C., Plucker, J. A., Russell, C. M. 2012. Identifying and Assessing Creativity as a Component of Giftedness. *Journal of Psychoeducational Assessment* 30, 1: 60–73.
14. Kim, M. J., and Maher, M. L. 2008. The impact of tangible user interfaces on spatial cognition during collaborative design. *Design Studies* 29, 3: 222–253.
15. Kirsh, D. 1995. The intelligent use of space. *Artificial intelligence* 73, 1–2: 31–68.
16. Kraut, R. 2003. Applying social psychological theory to the problems of group work. In *HCI Models, Theories, and Frameworks: Toward a Multidisciplinary Science*, Morgan Kaufmann
17. Kruger, R., Carpendale, S., Scott, S., and Greenberg, S. 2004. Roles of Orientation in Tabletop Collaboration: Comprehension, Coordination and Communication. *Computer Supported Cooperative Work* 13, 5-6
18. Marshall, P., Hornecker, E., Morris, R., Dalton, N. S., and Rogers, Y. 2008. When the fingers do the talking: A study of group participation with varying constraints to a tabletop interface. In *IEEE International Workshop on Horizontal Interactive Human Computer Systems*, IEEE Computer Society.
19. McGrath. J. E. 1984. *Groups: Interaction and performance.* Prentice-Hall Englewood Cliffs, NJ.
20. McGrath, J. E., Arrow, H., Gruenfeld, D. H., Hollingshead, A. B., O'Connor, K. M. 1993. Groups, Tasks, and Technology: The Effects of Experience and Change. *Small Group Research* 24, 3: 406–420.
21. McGrath, W., Bowman, B., McCallum, D., Hincapié-Ramos, J. D., Elmqvist, N., Irani, P. 2012. Branch-explore-merge: Facilitating Real-time Revision Control in Collaborative Visual Exploration. In *Proc. of Interactive Tabletops and Surfaces* (ITS '12), ACM Press.
22. Meier, Spada, & Rummel. (2007). A rating scheme for assessing the quality of computer-supported collaboration processes. *International Journal of Computer-Supported Collaborative Learning*, 2(1), 63-86
23. Mennecke, B. E., and Wheeler, B. C. 1993. Tasks matter: modeling group task processes in experimental CSCW research. In *Proceeding International Conference on System Sciences* ,93, IEEE.
24. Mercier, E., and Higgins, S. 2014. Creating joint representations of collaborative problem solving with multi-touch technology. *Journal of Computer Assisted Learning*, 2014
25. Nacenta, M. A., Pinelle, D., Stuckel, D., Gutwin, C. 2007. The effects of interaction technique on coordination in tabletop groupware. *In Proc. of Graphics Interface* 2007.
26. Nacenta, M. A., Pinelle, D., Gutwin, C., Mandryk, R. L. 2010. Individual and group support in tabletop interaction techniques. In *Tabletops - Horizontal Interactive Displays*. Springer.
27. Oleksik, G., Milic-Frayling, N., Jones, R. 2013. Touch and gesture: mediating content display, inscriptions, and gestures across multiple devices. *Personal and Ubiquitous Computing* 18, 5: 1243–1257.

28. Rädle, R., Jetter, H.-C., Reiterer, H. 2013. TwisterSearch: A Distributed User Interface for Collaborative Web Search. In *Distributed User Interfaces: Usability and Collaboration.* Springer London, 53–67.
29. Rick, J., Marshall, P., Yuill, N. 2011. Beyond one-size-fits-all: how interactive tabletops support collaborative learning. In *Proc. Interaction Design and Children*, 109–117.
30. Rogers, Y., and Lindley, S. 2004. Collaborating around vertical and horizontal large interactive displays: which way is best? *Interacting with Computers* 16, 6: 1133–1152.
31. Rogers, Y., Lim, Y., Hazlewood, W., Marshall, P. 2009. Equal opportunities: do shareable interfaces promote more group participation than single user displays? *Human-Computer Interaction*, 79–116.
32. Ryall, K., Forlines, C., Shen, C. and Morris, M. R. 2004. Exploring the effects of group size and table size on interactions with tabletop shared-display groupware. In *Proc. CSCW'04*, ACM Press.
33. Scaife, M., and Rogers, Y. 2005. External Cognition, Innovative Technologies, and Effective Learning. In *Cognition, education, and communication technology*, 181–201.
34. Schmidt, K. 2002. The Problem with `Awareness': Introductory Remarks on `Awareness in CSCW'. *Computer Supported Cooperative Work* (CSCW) 11, 3–4: 285–298.
35. Schmitt, L., Buisine, S., Chaboissier, J., Aoussat, A., Vernier, F. 2012. Dynamic tabletop interfaces for increasing creativity. *Computers in Human Behavior*. 28, 5. 1892-1901.
36. Schneider, B., Jermann, P., Zufferey, G., Dillenbourg, P. 2011. Benefits of a tangible interface for collaborative learning and interaction, *IEEE Transactions on Learning Technologies* 4, 3: 222–232.
37. Scott, S. D., Carpendale, S., Inkpen K. M. 2004. Territoriality in collaborative tabletop workspaces. In *Proc. CSCW* '04, ACM Press.
38. Scott, S. D., and Carpendale, S. 2010. Theory of Tabletop Territoriality. In *Tabletops - Horizontal Interactive Displays*. Springer London, 357–385.
39. Stewart, J., Bederson, B., Druin, A. 1999. Single display groupware: a model for co-present collaboration. In *Proc CHI* 1999, ACM Press.
40. Straus, S. G. 1999. Testing a Typology of Tasks: An Empirical Validation of McGrath's (1984) Group Task Circumplex. *Small Group Research* 30, 2: 166–187.
41. Sugimoto, M., Hosoi, K., and Hashizume, H. 2004. Caretta: a system for supporting face-to-face collaboration by integrating personal and shared spaces. In *Proc. CHI '04*, ACM Press
42. Tang, J. C. 1991. Findings from observational studies of collaborative work. *International Journal of Man-Machine Studies* 34, 2: 143–160.
43. Tang, A., Tory, M, Po, B., Neumann, P., Carpendale, S. 2006. Collaborative coupling over tabletop displays. In *Proc. CHI* '06, ACM Press
44. Tuddenham, P., Robinson, P. 2009. Territorial coordination and workspace awareness in remote tabletop collaboration. In *Proc. CHI* '09, ACM Press
45. Wallace, J. R., Scott, S. D., MacGregor, C. G. 2013. Collaborative Sensemaking on a Digital Tabletop and Personal Tablets: Prioritization, Comparisons, and Tableaux. In *Proc. CHI* '13, ACM Press.
46. Zagermann, J., Pfeil, U., Rädle, R., Jetter, H.-C., Klokmose, C., Reiterer, H. 2016. When Tablets Meet Tabletops: The Effect of Tabletop Size on Around-the-Table Collaboration with Personal Tablets. In *Proc. CHI* '16, ACM Press.