Children Designing Together on a Multi-Touch Tabletop: An Analysis of Spatial Orientation and User Interactions

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ABSTRACT
Applications running on multi-touch tabletops are beginning to be developed to enable children to collaborate on a variety of activities, from photo sharing to playing games. However, little is know as to how children work together on such interactive surfaces. We present a study that investigated groups of children's use of a multi-touch tabletop for a shared-space design task, requiring reasoning and compromise. The OurSpace application was designed to allow children to arrange the desks in their classroom and allocate students to seats around those desks. A number of findings are reported, including a comparison of single versus multiple touch, equity of participation, and an analysis of how a child's tabletop position affects where he or she touches. A main finding was that children used all of the tabletop surface, but took more responsibility for the parts of the design closer to their relative position.

Categories and Subject Descriptors
H.5.3 [**Group and Organization Interfaces**]: Collaborative computing

General Terms
Measurement, Design.

Keywords
Multi-touch, co-located collaboration, shareable interfaces, collaborative design, touch analysis, log-file analysis

1. INTRODUCTION
Multi-touch tabletops have been used to support a variety of collaborative activities, including playing games, photo sharing, designing, and map navigation. A number of user studies have been conducted to investigate how small groups work together and coordinate their interactions when using these types of shareable computing surfaces. A few have investigated how children collaborate [18, 19, for example]. A key research question is whether a multi-touch surface affords more equitable participation compared with other kinds of single user displays [21]. An assumption often made is that the touch display provides more equal opportunity for all to contribute through allowing simultaneous interaction of digital content. Findings from adult studies of co-located groups have shown that, while very talkative people continue to dominate and reticent members remain quiet, more equitable participation takes place in terms of physical interaction with the digital information [21]. However, it is unclear whether the same happens with children. Does having concurrent access to a tabletop surface enable children to participate on the digital task more equitably? Does a child's tabletop position affect how he or she collaborates?

Our research is concerned with how multi-touch interaction and orientation affects participation. In particular, we are interested in the correlation between where a child is positioned at a tabletop and their contribution to a collaborative task. If they are at the broad side of the tabletop, does their better access cause them to interact with more of the design space than their partners at the narrow sides? Moreover, how does this affect the nature of their collaboration?

Compared with earlier *single display groupware*, where more than one child can interact simultaneously with a shared display using multiple mice [28], tabletop actions are highly visible and hence observable by the others at the tabletop. Likewise, because of their horizontal orientation, tabletops make it easier for children around them to see each other when talking and interacting. However, when on different sides of a tabletop, children do not share the same orientation towards what is presented on the display [30]. While the touch-based interface makes it easier to point to interface elements than mouse input [32], arms and hands can block both the view and access that others have. This, in turn, can be affected by where a child is positioned.

To study how children collaborate around a multi-touch tabletop, we developed the OurSpace application. Groups of three children used OurSpace to design a seating plan for their classroom. Log-file analysis was used to measure participation levels of each child's touches of the tabletop surface, namely when digital objects were moved, where they were moved to, and who did the moving. Activity maps of the children's interactions are presented and discussed in relation to whether where participants are positioned in relation to each other and the tabletop affects their participation in the design task.

2. BACKGROUND
Collaborative activity is generally beneficial to children's learning and development [2, 35]. Peer collaboration is now a significant part of a child's classroom experience. One potential use of multi-touch tabletops is to support collaborative design, where children work together to create an artifact. This kind of design activity benefits from others evaluating the design [24] and is a valuable method for learning about a domain [6, 11].

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The issue of how space is used for tabletop interaction is an acknowledged concern, with several studies previously reporting on it. How users use the interactive space is a function of user group, task type, and interface [17]. In particular, reach is an important consideration [31]. If a tabletop is too large, a user cannot reach every part of what is being presented via the display. Novel movement methods, such as providing a small radar view of the entire space where objects can be manipulated, can successfully extend the reach of users; however, direct manipulation is generally preferred by users for its similarity to manipulating physical objects [17].

One study that investigated how adults work together to create a furniture layout plan for a library reading room using cardboard materials when seated around a large circular table found the limited reach to influence use [25]. Participants used *territoriality* as an organizing principle in the design task. Participants naturally, without explicitly acknowledging it in dialogue, created personal, group, and storage territories, each of which served a different purpose in the design process.

Size of tabletop and size of group have also been investigated. Groups of two, three, or four adults worked together to assemble a poem on a multi-touch tabletop [22]. The poem application was created using the DiamondSpin [26] toolkit, which makes interface elements face outwards radially from the center of the display. Words rotated slowly around the tabletop; participants dragged these onto a virtual piece of paper to compose a poem. Activity maps of each participant's touches in a group showed different patterns of interaction depending on number of participants taking part. Specifically, a division of labor was found with the larger groups where one person earmarked part of the poem assembly task and concomitantly that part of the tabletop where it was performed. More generally, people tended to interact with the part of the tabletop they were sitting near, and often hesitated to move into other people's areas. Similarly, in another adult study, where groups of three had to design a garden layout, participants often carved off their part of the garden plan to work on at the start of the task and then, towards the end, worked together on the whole design [20].

In our recent research [16], we found that the number of inputs to an interactive touch surface influences the equity of physical participation in a task of adults creating a seating plan for the move of an academic department to a new building. The multi-touch surface was found to increase physical interaction equity and perceptions of dominance, but did not affect levels of verbal participation. Dominant people still continued to talk the most, while quiet ones remained quiet.

However, as is well known, children behave differently to adults and so it is not possible to generalize from these findings. One difference is that children are often more focused on completing a task rather than cooperating with others in their group. Hence, their tabletop behavior is likely to be different. For example, while adults might be expected to have well-developed protocols for working in a group, young children might be expected to act more in their own self interest. They are also physically different and their manipulation skills may still be developing, particularly with young children. Young children (aged 8–9) may exhibit exaggerated gestures to protect their work, such as shielding part of their design using both their arms and upper torso and pushing other children away [15]. Very young children (aged 3–4) have problems even using standard tabletop interactions, such as drag-and-drop [14].

It appears, therefore, that the way groups interact with digital content, coordinate their actions, and share a tabletop display is affected by a number of factors. A main goal of our research is to investigate how children contribute to a collaborative design task when using an interactive tabletop. A specific objective was to determine whether their participation is affected by where they are positioned at the tabletop. To address these aims we designed a study comparing groups of three children placed on different sides of a tabletop for two conditions: single and multiple touch. Concurrent access (i.e., multiple touch) is assumed to support collaboration by allowing more equitable participation at the tabletop through allowing everyone to touch the surface whenever they wanted [21]. Serial access (i.e., single touch) forces turn taking and in so doing can increase awareness of what each group member is doing [10]. Comparing across the conditions allows us to investigate the value of these interface methods.

3. EXPERIMENTAL DESIGN

3.1 The Tabletop

Two defining properties of interactive surfaces are whether multiple touches register and whether the user of that touch can be identified. Most light-based multi-touch tables [4] allow for multiple finger touches, but do not have a mechanism for identifying users. In contrast, the DiamondTouch tabletop recognizes both multiple touches and an individual participant's interactions [3]. Because of this flexibility, the software can be configured to support both single and multi-touch. In *single-touch mode*, only one user's touches register at a time; touches by other users are ignored until the active user ceases to touch. Comparing this mode to standard *multiple-touch mode*, where everyone can interact simultaneously, allows us to investigate the value of having concurrent users. We used the smaller of the two standard DiamondTouch tabletops, measuring 65 x 49 cm, so that our young participants would have access to every part of the design.

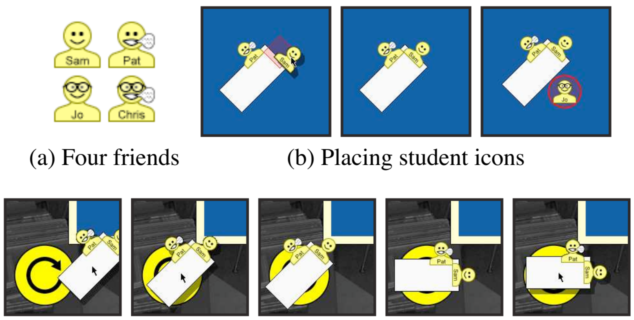
3.2 The Design Task

Tan et al. [29] have argued that standardized task types are necessary in order to evaluate the effectiveness of the new generation of devices for co-located collaboration across different user groups and situations. We developed a design task that was *shared* (the children collaborate on a single design) and *stationary* (the floor plan stays in a fixed location as the children work on it). The task requires groups of children to allocate where a class of students should sit with respect to one another at shared desks. Who should sit next to whom? Who should sit at the front, middle and back of the class? This is a task a teacher normally does; here, we provided the opportunity for children themselves to explore how to accomplish it. Hence, the task is both meaningful to the children (since they have direct experiences of being allocated to sit next to someone in a classroom) and challenging enough to require collaboration and compromise (since children must reason about the criteria for placing desks and students).

Since the task requires actual children to move virtual representations of children, the wording can be confusing. To solve this problem, from here on, we will use "students" to refer to the children being placed on the classroom plan and "participants" to refer to the children taking part in the study.

3.3 The Physical Prototype

The design process started with iterations on a physical prototype. This was done to test the viability of the seating allocation task and



(a) Four friends (b) Placing student icons

(c) Rotating a desk

Figure 1. Various operations in OurSpace

to refine the specifics of that task. Research participants were recruited from a year 4 classroom (aged 8–9) in the UK. Students worked in groups of three, seated around three sides of a rectangular table. Participants were provided with a large stationary floor-plan[1] of their classroom and proportional cardboard cutouts of existing desks and cardboard icons to represent students; they were asked to work together to position the desks and students.

Initially, the student icons were labeled with the names of the students in the participating class, and colored blue or pink to indicate gender. This scenario proved very engaging to the students, and highlighted a number of factors which they considered important in making a plan—for example who was friends with whom and which children were likely to talk and be disruptive if paired with particular other students. However, there were also some issues with this design. For example gender had been made conspicuous by the color coding of icons and was discussed a great deal possibly because of this; children tended to focus highly on their own friendship groups and preferences at the expense of considering the class in general; and certain individuals were often singled out for various reasons and left to sit on their own in the classroom plan, and there was concern this might encourage bullying.

Therefore, in a further iteration of paper prototyping, we set up the scenario as participants creating a seating arrangement for the class coming in next year. The class was fictitious, but we kept to the same number of students and desks as the current class. As gender is such an organizing property at that age [1], we did not want the groups to fixate on that as a criteria for seating; therefore, we labeled the students with gender-neutral names. Even though the names were largely meaningless, the labels were useful for both participants and researchers to refer to specific students. To make the task more difficult, we added different characteristics to the student icons, based on criteria that students mentioned when seating their own class (Figure 1a). Friendship groups were indicated by icon color; to simplify, there were no overlapping friendship groups. Talkative students had an open mouth and speech bubble. Those with vision problems were shown with glasses. This final cardboard design was run with several groups, both to confirm that this setup was successful in getting participants to sufficiently negotiate a suitable solution and as a comparison basis for a future software version.

3.4 The OurSpace Application

[1]The floor-plan was printed on paper the size of the interactive table used in this study.

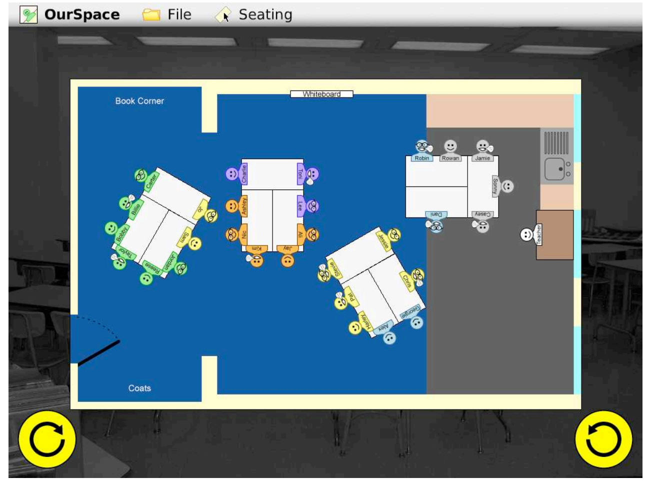


Figure 2. (School A, Year 3) How desks and students are currently arranged

A bird's eye virtual floor-plan of the classroom is placed in the center of the tabletop so that all participants, regardless of their position, have good access to it (see Figure 2). Participants use their fingers to drag icons of students and desks onto the classroom plan. When a student is dragged over an available desk seat, the seat is highlighted and the student is oriented toward that seat position (Figure 1b: Frame 1); when dropped, the student icon snaps to that seat (Figure 1b: Frame 2). Once a student is in a desk seat, he or she moves along with the desk; students can also be dragged out of their seat to relocate them. To rotate desks, users drop them on rotation areas at the bottom left and right of the screen (Figure 1c). When on a rotation area, a desk rotates 15 degrees[2] every 600 ms, pausing for an extra cycle in vertical and horizontal positions since these are most likely the wanted orientations. While there are more sophisticated methods of combining rotation and translation in the touch interface [5, for example], we did not want our participants to fixate on rotation.

A trial of the OurSpace software was run to improve its usability. This helped to refine the software in several ways. The timing of the rotation area was adjusted until it was found to be slow enough for participants to use, but fast enough not to seem tedious. In the initial version of the software, the seating snaps were confined to the desk itself (i.e., much smaller than those shown in Figure 1b: Frame 1). Consequently, participants did not intuitively understand that they were supposed to snap the students to the desks. Once told of this feature, they were able to use the smaller snaps, but larger snaps made this easier and more intuitive. To further emphasize the need to place students into seats, students dropped in the room but not in a seat show a red halo around them (Figure 1b: Frame 3).

3.5 Method

Thirty sessions were conducted with 15 groups of children, from year 3 (aged 7–8) and year 4 (aged 8–9) at two schools (A and B) in the UK (Table 1). A within-subjects design was used where groups completed both the single- and multiple-touch conditions of the task. Each mode was undertaken in a separate session approximately 2–3 days apart. To control for order effects, condi-

[2]15 degrees is a convenient increment of rotation as it allows desks to be easily rotated to 45 degrees (i.e., along a diagonal) and 60 degrees (useful for creating equilateral triangles and hexagons).

#	School	Year	Session 1	Session 2
3	A	3	Multiple	Single
3	A	3	Single	Multiple
2	B	3	Multiple	Single
2	B	3	Single	Multiple
3	B	4	Multiple	Single
2	B	4	Single	Multiple

Table 1. Number of groups per touch condition

Condition	Session 1	Session 2
All	15m 54s	12m 30s
Year 3	17m 46s	12m 36s
Year 4	12m 10s	12m 19s
Multiple	15m 11s	10m 24s
Single	15m 34s	14m 21s

Table 2. Average session time by condition

tions were counterbalanced, where half the groups completed the multiple-touch condition first and half completed the single-touch condition first.

The participants were required to stand at the tabletop, as standing greatly increases the radius of touch over sitting. The combination of small tabletop size and standing posture enabled participants to reach all parts of the interface, irrespective of their location around the tabletop.

To avoid the problems in collaboration that often occur in mixed-gender groups of that age [33, 34], participants were split into single-gender groups. Each group used the floor-plan of their classroom, the same number of desks, and the same number of students as in their current classroom. At the beginning of a session, the researchers explained the multi-touch tabletop, the OurSpace application (how to move students and desks, how to attach students to desks, how to rotate desks) and the scenario (create a desk and seating arrangement for next year's class). All sessions were videotaped from two angles (one on the interactive surface, one on the participants). In general, the researchers left the participants to accomplish the task by themselves. Occasionally, the DiamondTouch did not properly register a child's touches, because thick-soled shoes can prevent the signal from reaching the receiving pads on the floor; in that case, a researcher advised the child to take off his or her shoes.

The *coupling*, relative positions of users around the tabletop, of the groups was set up so that there was one participant at the left short edge of the tabletop, one at the bottom long edge, and one at the right short edge. Participants were allowed to switch positions between sessions. The tabletop setup was slightly different at each school, as each school had different tables in the study room. In School A, the room the study was carried out in had a rectangular table (Figure 5a). In School B, the room allocated only had a circular conference table (Figure 5b); while the participants were able to use this setup, it budged them closer to the bottom of the display and closer together than in the rectangular setup.

4. FINDINGS

This paper presents the major findings of our log-file analysis of this study, supplemented by observations from the video data. First, we present our analysis on how the touch condition affects the time participants spent completing the task, the rate at which the participants made changes to the seating plan, and the equity of participation within the groups. Second, we examine how user tabletop position affects where users touch and how much they touch. These results complement our analysis of the verbal interactions presented elsewhere [7].

4.1 Touch Condition

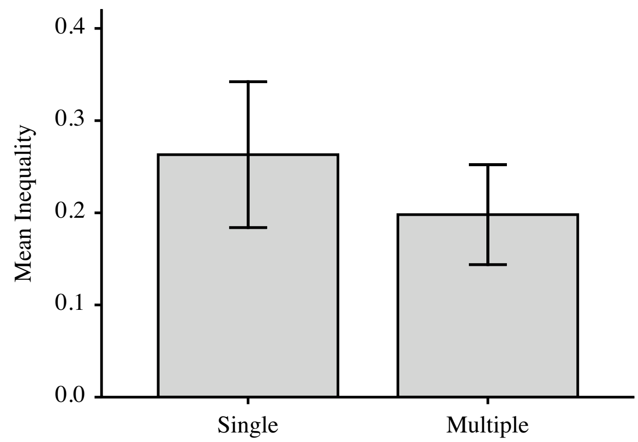


Figure 3. Inequity of participation, based on touch condition

Because the task could be more easily divided among group members in the multiple-touch condition, we predicted that it would take less time. The time spent in completing the task is shown by condition in Table 2. Times were compared with a mixed ANOVA with time in the two touch conditions as a repeated measure and with year and session order as between subjects factors. There was no overall effect of touch condition on the time spent using the interface. However, there was a significant interaction of touch condition with session order, $F(1, 11) = 1.036$, $p < 0.05$. Simple effects analysis found no difference between the scores in the first session. However, the multiple-touch interface was used for significantly less time ($p < 0.05$) if it was used in the second session.

Based on previous findings with adult participants [10, 16], we predicted that interaction would be denser and the equity of participation would be higher in the multiple-touch condition. The total number of touches by groups per minute were compared using a mixed ANOVA with touch condition as a repeated measure and year as a between-subjects factor. As predicted, a significant effect of touch condition was found with groups having a higher rate of touches in the multiple-touch condition (93.0 touches per minute) than in the single-touch condition (63.2 touches per minute), $F(1, 14) = 9.685, p < 0.01$.

We then used Hiltz et al.'s [9] measure of participation inequality I in the comparison of equity at the interface. A higher I score signifies less equity of participation at the interface. While there was a difference in the average (Figure 3), when inequality scores were compared using a mixed ANOVA with input condition as a repeated measure and with year and session number as between subject factors, this difference was found not to be significant.

4.2 Touch by User Tabletop Position

To plot out where participants were touching, we created activity maps by user tabletop position. Figure 4 shows how participants in the left, bottom, and right tabletop position touched each of the OurSpace classroom layouts. To make the maps independent of a specific design, Figure 4 combines all the touches for each of the conditions. These plots lead us to three main observations:

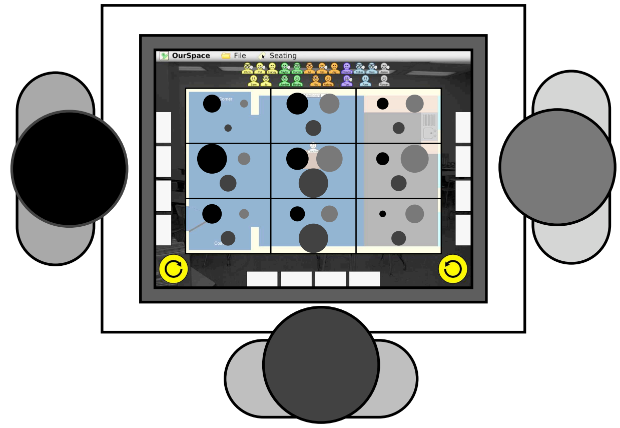
First, most design work was conducted within the classroom layout plan. Most of the touches in the border area can be attributed to the participants picking up desks and student icons, which were located there at the start of the task. Borders had been placed around the classroom layout plan to provide the participants with a staging area. While it was possible for participants to utilize this area to attach students to a desk and then move that desk into the classroom space, this was not commonly done.

Second, participants made touches all the way across the tabletop, with many of the touches extending past the center of the classroom plan. Since the desks and students carried no indication of ownership, participants felt free to select and grab them as needed, even if that meant reaching across the entire tabletop interface. To do this, participants often moved their arms under or over each others' arms, an action seldom seen with adults.

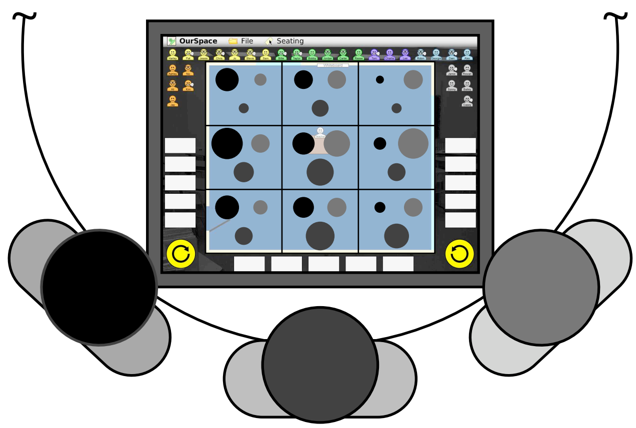
Third, there is a noticeable drop-off of touches that occurs about two-thirds of the way across the classroom plan, with participants mostly populating desks with student icons in the classroom space nearest to them. This can be partially explained by a participant's reach, since this roughly matches the transition from comfortable to uncomfortable reach [31]. At that transition, further reach requires a different posture and weight distribution. Alternatively, the participants may implicitly have taken more responsibility for the design space near them.

To further investigate how the participant's position at the tabletop affected the spatial location of their tabletop touches, we conducted a regional analysis. By this, we mean an analysis of touches in terms of their region on the classroom layout plan. Each classroom was split into a 3-by-3 grid to determine the percentage of touches in each.[3] Figure 5 shows how many of the touches (signified by circle area) were in each region by user tabletop position and classroom.[4]

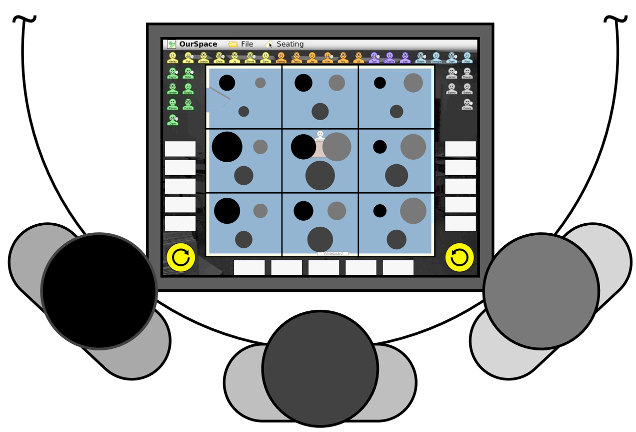
In order to assess whether user tabletop position (left, bottom, right) affected the region of touch, we conducted a multivariate analysis of variance (MANOVA), entering the percentage of touches made in each of the nine regions as the dependent variables. In total we had nine dependent variables and controlling for Type 1 error we used Bonferroni's correction, where $\alpha = 0.006$. We conducted separate analysis for the two sessions, as participants were free to choose their position at the tabletop and this sometimes differed between sessions. Results from the multivariate analysis (Wilks Lambda) suggest that position at the tabletop did have an overall effect on percentage of touches per region in Session 1 ($F(16, 72) = 6.22, p < 0.001$) and in Session 2 ($F(16, 72) = 5.02, p < 0.001$). The univariate test results showed that the only regions in which percentage of touches was not affected by position at the tabletop was the top center and middle center for Session 1 and top center,



(a) School A, Year 3



(b) School B, Year 3

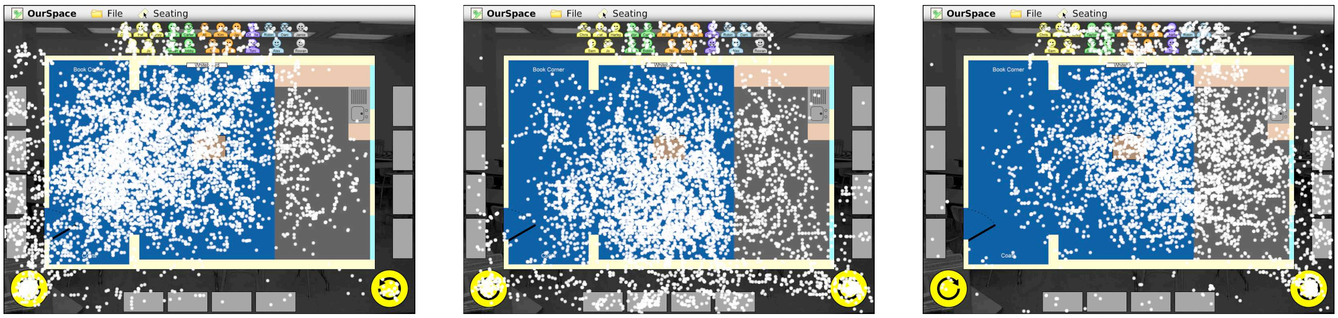


(c) School B, Year 4

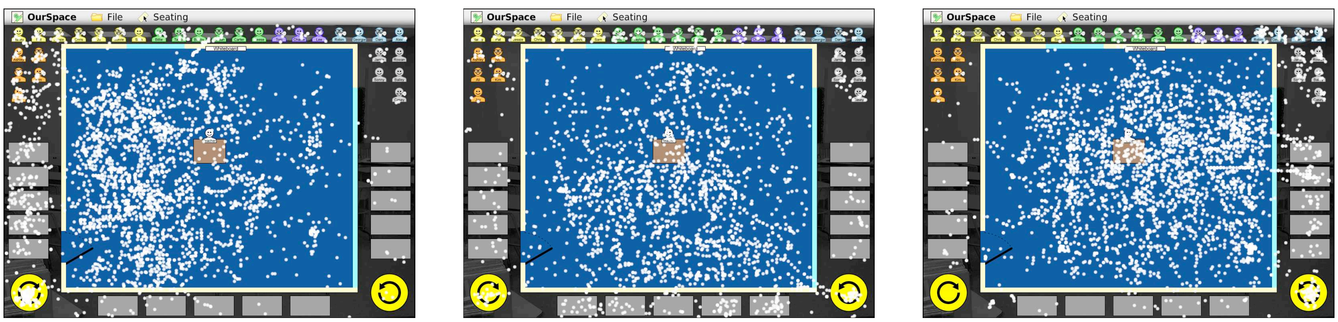
Figure 5. Left, bottom, and right touches by region

[3]We chose 3-by-3, since this separated areas into near, neutral, and far for all participants.

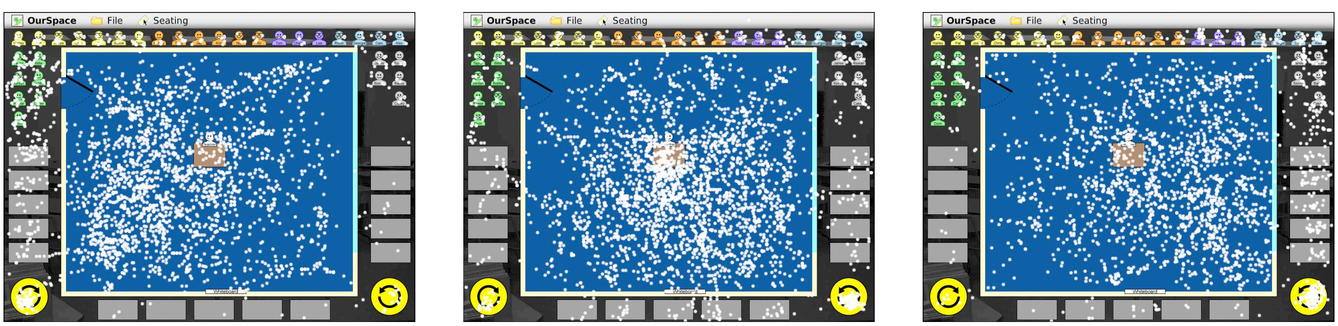
[4]As we were interested in the effect on the final design, we restricted our analysis to placing students or desks.



(a) Left, bottom, and right touches for 12 sessions from School A, Year 3



(b) Left, bottom, and right touches for 8 sessions from School B, Year 3



(c) Left, bottom, and right touches for 10 sessions from School B, Year 4

Figure 4. Activity maps showing combined touches by user tabletop position

Condition	*Distance*	*Left*	*Bottom*	*Right*
All Sessions	*Near*	52.1%	41.2%	45.7%
	Neutral	36.5%	44.3%	40.4%
	Far	11.4%	14.5%	13.8%
School A, Year 3	*Near*	50.7%	41.1%	46.2%
	Neutral	38.2%	44.7%	43.8%
	Far	11.1%	14.2%	10.1%
School B, Year 3	*Near*	56.5%	47.5%	44.1%
	Neutral	34.5%	39.4%	37.1%
	Far	9.1%	13.1%	18.8%
School B, Year 4	*Near*	50.4%	36.5%	46.5%
	Neutral	36.1%	47.7%	39.1%
	Far	13.5%	15.8%	14.4%

Table 3. Distance bias by user tabletop position

middle center, and bottom center for Session 2; note that these are the regions that are closest to being equidistant for all participants. Percentage of touches in all other regions differed significantly in both sessions ($ps < 0.005$), where the nearer to a region a participant was positioned the higher the number of touches they made in that region.

As the setup of the tabletop was different between schools, we conducted the same analysis with school (A or B) entered as a fixed factor. Multivariate analysis revealed no overall difference in region of touches as a function of school, nor any interaction between school and position for either session. This suggests that children's touches are based on relative rather than absolute physical location.

For all three classrooms plans, we found that the participant on the left of the tabletop touched the center region less than the participant on the right. One explanation for this anomalous pattern is that it is based on handedness. If the left user is right-handed (as is common), touching the middle would block the person in the middle more than a right-handed right-positioned user touching the middle. Arms getting in the way of others can be a problem with tabletop interfaces since the display is also the interaction mechanism [8]. This suggests that handedness is a consideration that future studies should consider.

To simplify this analysis, Table 3 combines three regions for each position to examine near and far relations. Multivariate analysis reveals no significant overall effect of user tabletop position or classroom layout on the difference in these values. That is, the pattern of near, neutral, and far touches are statistically indistinguishable by position and classroom. In each case, the near and neutral regions significantly exceed the number of touches in the far region. This finding furthers the explanation that touch is a function of relative proximity to the user (i.e., which regions are closer to the user). If touch were merely a function of reach (i.e., absolute proximity), we would expect there to be a significant difference between the bottom user and the others, since the bottom user has comfortable access to the entire classroom.

5. DISCUSSION AND CONCLUSION

Participants in the multiple-touch condition touched the interface nearly 50% more than participants in the single-touch condition. While that difference was statistically significant, it is far less than the one-to-three ratio of participants that could simultaneously interact in each condition. This suggests that participants were not continually working on their designs but also working together in the multiple-touch condition.

In terms of equity of participation, there was no significant difference between the touch conditions. This contrasts with our adult studies where equity of physical interaction was increased when in multiple-touch mode [16, 21]. However, in that study, the single-touch mode was defined through hardware: Only one conductive pad was connected to the DiamondTouch tabletop and users had to switch places to switch control. In the OurSpace system, the single-touch condition was implemented in software: As soon as the active user stops touching the interface, another user can take control. Thus, the overhead of switching from one user to another is largely removed.

Adults, particularly in a work situation, are much more civil about respecting each others' contributions and taking turns than children. Adult participants in the single-touch condition were often satisfied by engaging the task verbally and letting one user control the interface. The children, in contrast, were all keen to contribute by moving objects in the interface. As a result, in the single-touch condition, children spent a significant amount of time on turn taking dialogue [7]. One single-touch session had to be briefly suspended, as one participant was crying over a fight about whose turn it was. So, it is remarkable that there was no significant difference in equity of participation between the two conditions. If anything, we would have expected the higher frequency of touch and interest in using the interface to have exacerbated equity problems. This indicates that the ease of transition from one user to another is critical to the use of a single-touch system, in terms of equity of physical participation. If we consider a pen-based whiteboard where only one pen registers at a time, we would expect interaction to be more equitable if each child was given a pen than if they had to share a common pen.

When observing the videos of the groups, it was noted how the children developed certain strategies in the single-touch condition to get control of the tabletop from another child. For example, one girl worked out that if she kept her finger on a student icon and waited for the other girls to move their fingers from the tabletop, she could swiftly move hers to a seat at a desk and complete it whilst the others were not looking. Children often repeatedly stroked the desk and student icons to move them without realizing that someone else was in control. When they felt that it was their turn, they exclaimed "it's my go" or even physically moved the current user's arm out of the way. The 'sneak a go' tactic was most notable among the girls, while the explication "it's my go" was more notable amongst the boys [7].

Another main finding was the extent to which a child's position at the tabletop affected where he or she touched. The activity maps reveal that the children, irrespective of position, touched all of the tabletop. Yet, there is a sharp decline of touches in the far regions of the design space. This decline can be partially attributed to reach, as the transition from high use to low use roughly matches the transition from comfortable to uncomfortable reach for the left and right users. However, remarkably, the same pattern occurred for the bottom user, who has comfortable reach access to the entire design. This suggests that reach is not the primary factor. Participants seem to (implicitly) take responsibility for the design space closer to their relative tabletop position. When working on a joint tracing task, adult users often used their relative position as an implicit guide for splitting up the task [32]. Our findings suggest that this proximity-based way of splitting responsibilities for a visual task applies to a wide range of tasks.

The design-a-library-reading-room study demonstrated the value of providing a private space where users can work on their own part of a task before integrating it with the shared representation [25]. In that study, adults created separate territories for different purposes (e.g., a personal territory immediately in front of a person, a group territory midway between two people). In contrast, our child participants did not create separate territories. Children worked inside the classroom layout, rather than the border region. While this is partly attributable to a streamlined task, it does suggest that children are less into planning the task beforehand than adults. Furthermore, the children had no compunction about reaching over and selecting the icons from the piles directly in front of the other two children. They freely moved their arms across the others, sometimes even bashing into one another [15]. This clash of arms contrasts with our adult study where they rarely occurred. It suggests that children might be less aware of others' intentions and, if they do infer them, do not see the need to back off when seeing another's arm approach theirs. While adults are hesitant to simultaneously touch the tabletop and against touching each other [23], children appear to have no such reticence.

The software design also affects how different groups partition the work and, in turn, touch distribution. The OurSpace application was designed to be fixed in one location, whereas other studies have used designs that can be zoomed or moved around the surface. When the background or interface elements move in these ways, it appears that people tend to restrict their interaction to the area nearest where they are located [22]. For example, in the poem software, the words on the near side of the tabletop face the user, giving better access and implying ownership to the near user; therefore, participants seldom touched past the center of that interface. In sum, our study has shown that children do not hesitate to use the entire tabletop surface in a shared space design task but will work mostly in the region of the tabletop nearest to their relative tabletop position.

We are now analysing the videotaped interactive sessions in more detail, to investigate the styles of verbal interaction between single- and multiple-touch conditions, between younger and older users, and between boys and girls. In particular, a key feature of collaboration is which partners build on each other's ideas in the process of reasoning and problem solving [12]. One aspect is to examine the 'I did it!' bias [27] by touch condition. The *'I did it!' bias* is a memory bias which is evident in children after successful episodes of joint activity. When children are asked to recall who was responsible for actions during a previous period of joint activity, they often misattribute the actions of their social partner to themselves. It is argued that this represents an internalisation or appropriation of shared interactions and therefore occurs as a consequence of successful collaborative interaction [13]. Hence, while multiple-touch supports children interacting together, the extent to which children do so and remember how much they contributed and how the others participated may not match up.

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