Around the Table: Are Multiple-Touch Surfaces Better Than Single-Touch for Children's Collaborative Interactions?

Amanda Harris[1], Jochen Rick[2], Victoria Bonnett[1], Nicola Yuill[1],
Rowanne Fleck[1], Paul Marshall[2], Yvonne Rogers[2]
[1]Psychology Department, University of Sussex, Brighton, BN1 9QH, UK
{a.l.harris,v.m.bonnett,nicolay,r.m.m.fleck}@sussex.ac.uk
[2]Department of Computing, The Open University, Milton Keynes, MK7 6AA, UK
{j.rick,p.marshall,y.rogers}@open.ac.uk

Abstract: This paper presents a classroom study that investigated the potential of using touch tabletop technology to support children's collaborative learning interactions. Children aged 7-10 worked in groups of three on a collaborative planning task in which they designed a seating plan for their classroom. In the single-touch condition, the tabletop surface allowed only one child to interact with the digital content at a time. In the multiple-touch condition, the children could interact with the digital content simultaneously. Results showed that touch condition did not affect the frequency or equity of interactions, but did influence the nature of children's discussion. In the multiple-touch condition, children talked more about the task; in the single-touch condition, they talked more about turn taking. We also report age and gender differences.

Introduction

It is well established that collaborative activity is beneficial to children's learning and development (Webb & Palincsar, 1996). Peer collaboration now forms a significant part of a child's classroom experience. For example, the UK national curriculum identifies the ability to collaborate effectively as a key skill that should be supported and developed throughout the primary school years (Kutnick & Rogers, 1994).

Technological support for collaborative activity in schools has traditionally been limited to the shared use of single computers (Stanton, Neale, & Bayon, 2002). However, an emerging generation of shareable interfaces are being promoted as the new technology to support collaborative learning. *Shareable interfaces* allow several people in the same place to interact on the same task using their own input device. For example, *multi-touch tabletops* are horizontal surfaces that allow multiple people to interact simultaneously through touch input. These technologies offer the potential for new ways to support and structure co-located collaborative learning activities. However, there are few studies that directly examine their effect on children's interactions and we therefore know very little about their influence on behaviour.

In this paper, we report on how a multi-touch tabletop supported a classroom design task for 7-10 year olds working in groups of three. In our analysis we examined levels of participation, the degree to which interactions were equitable and the nature of collaborative dialogue in two conditions; a multiple-touch and a single-touch condition.

Background

Definitions of what constitutes collaboration centre on the notion of mutual and joint activity. Collaboration should be a reciprocal, coordinated interaction in which ideas and perspectives are explored and exchanged (Goos, Galbraith, & Renshaw, 2002). The benefit of collaboration for learning is dependent on children's level of participation in such activity. Too often, learning benefits are impaired by inequitable participation, where the contributions of some group members dominate while others are marginalized (Barron, 2003). Participation typically refers to the level of talk and dialogue that occurs between collaborating partners (Teasley, 1995). However, in the case of computer-supported collaboration, physical action is also an important indicator of participation. For example, children might indicate agreement or disagreement through direct interaction with the interface instead of explicitly verbalizing their point of view (Kerawalla, Pearce, Yuill, Luckin & Harris, 2008; Stanton & Neale, 2003).

The unique features of multi-touch tabletops offer the potential to support collaboration in new ways (Rick, Rogers, Haig, & Yuill, 2009). For example, face-to-face, rather than shoulder-to-shoulder interactions, can promote more participation and communication between group members (Rogers & Lindley, 2004). Tabletops also provide the added benefit of a larger display area and the opportunity to organize objects spatially; this allows group members to see and be aware of each other's actions more readily (Hornecker, Marshall, Dalton, & Rogers, 2008; Nacenta, Pinelle, Stuckel, & Gutwin, 2007). In addition, touch input may be a more appealing and natural means of input as users manipulate objects directly and easily with their fingers (Shen, Everitt, & Ryall, 2003).

Children's simultaneous interactions with technology have been investigated in relation to the use of multiple mice with PC software. The findings, however, have been mixed. On the one hand simultaneous input can promote more equitable interactions between children (Stanton, et al., 2002) and higher levels of task focused participation (Inkpen, Ho-ching, Kuederle, Scott, & Shoemaker, 1999). On the other hand, it can also result in parallel working, where children work on different parts of the same task, often with limited reciprocity (Stanton & Neale, 2003). This same study found that sharing a single mouse sometimes led to good collaboration if contributions and decisions were discussed before being implemented. However, shared mouse use also led to high levels of conflict and the tendency in some groups for one child to dominate. The extent to which single input interactions are collaborative or dominated by individual children is largely dependent on individual differences between children, rather than an inherent characteristic of the technology. Age and gender differences, for example, play an important role in how children manage turn taking and contribute to collaborative interactions, particularly around technology (Abnett, Stanton, Neale, & O'Malley, 2001; Inkpen, Booth, Klawe, & Upitis, 1995).

Other studies have observed children as users of multi-touch tabletops. SIDES is a tool designed for adolescents with Aspergers Syndrome to practice effective group work (Piper, O'Brien, Morris, & Winograd, 2006) and StoryTable is a system designed to support children's storytelling activity in groups (Cappelletti, Gelmini, Pianesi, Rossi, & Zancanaro, 2004). StoryTable enforces a co-operative task structure such that children can simultaneously work on individual parts of the task but are then forced to perform crucial operations together in order to progress. Similarly SIDES encourages co-operation as adolescents have to work together to build a path by combining individually owned pieces. In a further iteration to this system, turn taking was regulated and enforced in order to ensure participation from those who were disengaged from the task and to prevent others from dominating.

In the current study, we investigated participation around a tabletop interface in a typically developing sample of primary-aged children. One potential use of multi-touch tabletops is to support *collaborative design*, where users collaborate to design an artefact. Design is an established method for promoting learning. Designing external artefacts can motivate learners (Harel & Papert, 1991). The designed artefacts can embody concrete connections to the underlying domain concepts, which learners actively engage through the design process (Kolodner, Camp, Crismond, Fasse, Gray, Holbrook, Puntambekar, & Ryan, 2003). To observe how children use a tabletop interface for collaborative design, we developed the OurSpace system, which supports children in designing a seating plan for their classroom.

We used a DiamondTouch interactive tabletop that recognizes individual user's interactions (Dietz & Leigh, 2001). The software was configured to support both a multiple-touch and a single-touch mode. Taking advantage of this flexibility allowed us to investigate the value of concurrent interactions around the tabletop to a system that requires users to take turns.

Marshall, Hornecker, Morris, Dalton, & Rogers (2008) report a study of participation around a tabletop interface for adult participants who completed a similar seating design task. They found that multiple-touch input facilitated equity of interaction compared to a single-touch condition, but had no effect on levels of verbal participation. In the current study, we wanted to examine the value of different touch conditions on children's collaborative interaction. Based on related literature, there are two competing hypotheses about which condition is most conducive to useful collaboration: (i) multiple-touch mode supports better collaboration by allowing more equitable participation at the tabletop, thus allowing everyone to interact whenever they want (Rogers et al, 2009); (ii) single-touch mode supports better collaboration as it forces more turn taking, thus increasing awareness of what each group member is doing (Hornecker, et al., 2008).

Method

A within-subjects design was used in which groups completed both the multiple-touch and single-touch conditions of the task. Each mode was undertaken in a separate session approximately 2-3 days apart. To control for order effects conditions were counterbalanced, where half the groups completed the multiple-touch condition first and half completed the single-touch condition first.

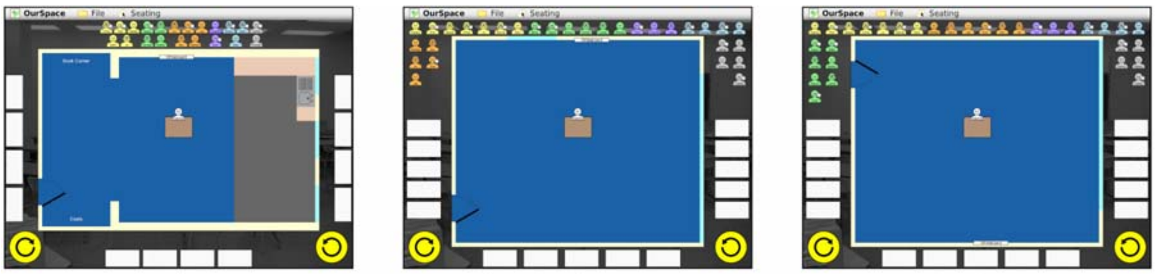
Participants

The study was conducted in two urban primary schools in the southeast of England. In total, 45 children (21 boys, 24 girls) participated in the study from three different classes (Year 3 from School A and Year 3 and 4 from School B). The Year 3 children were 7-8 years old and the Year 4 children 9-10 years old. Teachers were asked to group children on the basis of two criteria: gender and group compatibility. This resulted in 15 same-gender same-year group triads (7 boy and 8 girl groups).

OurSpace

The OurSpace software was designed to support a seating allocation task that was both meaningful to the children and challenging enough to require collaboration and compromise. A large floor plan of their actual classroom was centered on the interactive tabletop (Figure 1). Participants (seated left, bottom, and right of the screen) used their fingers to drag students and tables onto the floor plan. When a student icon was dragged over an available table seat, the seat was highlighted and the student oriented toward that seat position (Figure 2a: Frame 1); when dropped, the student icon snapped to that seat (Figure 2a: Frame 2). Once a student was seated, that student moved along with the table; students could also be dragged out of their seats and relocated. To rotate tables, users dropped them on rotation areas at the bottom left and right of the screen (Figure 2c). When on a rotation area, a table rotated 15 degrees every 600ms, pausing for an extra cycle in the more common vertical and horizontal positions. Tables that were dropped near each other (within 5 pixels) snapped together. To emphasize the need to place students into seats, students that were dropped in the room but not on a seat showed a red halo around them (Figure 2a: Frame 3).

Before implementing the software, we conducted design iteration sessions with target users (Year 4 students at School A) using cardboard pieces and a paper floor plan (Rick, Harris, Marshall, Fleck, Yuill, & Rogers, 2009). These iterations helped demonstrate the viability of the design task to engender collaborative dialog. They also revealed the criteria that children thought were important when seating students in the classroom. For example, friendship groups, level of talkativeness and eyesight were all discussed by children as organising properties of a classroom. Some children thought it was important to seat friends together while others felt this might lead to too much chatting in class. Equally some children thought it was important to separate talkative children while others thought that talkative children should be seated together at the front of the class so that the teacher could keep an eye on them. These criteria were clearly dimensions of the classroom that children had strong opinions on and a range of beliefs about, therefore, to make the task more challenging, we integrated these into the software (Figure 2b). Friendship groups were indicated by icon colour; to simplify, there were no overlapping friendship groups. Talkative students were shown with an open mouth and speech bubble. Those with vision problems were shown with glasses. To make the task meaningful, participants were told to create a seating arrangement for the class coming in the next year; the class was fictitious, but we kept to the same number of students and tables as the current class.



(a) School A, Year 3 (b) School B, Year 3 (c) School B, Year 4

Figure 1. OurSpace classroom layouts

(a) Placing student icons (b) Four friends (c) Rotating a table

Figure 2. OurSpace feature details

Procedure

The tabletop was set up in a quiet room in the school and each group of three was taken out of class for the OurSpace sessions. At the beginning of the first session, the researchers introduced the multi-touch tabletop, the task (identifying the student characteristics, the floor plan and the idea of a seating arrangement), the application (how to move students and tables, how to attach students to tables, how to rotate tables, etc.), and the scenario (create a table and seating arrangement for next year's class). The researchers remained in the room throughout the session, but did not interact with groups while they were completing the task unless in response to specific problems with the technology. The second session began with highlighting the different mode of the tabletop (single-touch or multiple-touch, depending on condition order) and then followed an identical procedure.

Measures of collaboration

Levels of participation

Transcripts of each session were used to measure levels of v*erbal participation.* First, turns of talk were identified for each participant and then divided into individual utterances based on the application of coding categories (see below). The total number of utterances made by each participant over the course of a session was summed to give a score of their overall level of verbal participation.

Systems logs were used to measure levels of *physical participation.* This was done by calculating the rate at which children added to or changed their seating design through touches to the tabletop. Each participant's total number of touches over the course of a session was summed to give a score of their overall level of physical participation.

In order to measure the relative contribution of individuals within each group we used the *Gini Coefficient* as a measure of the *equity of participation*. The Gini Coefficient sums the deviation from equal participation for all members of a group, normalized by the maximum possible value of this deviation (Weisband, Schneider, & Connolly, 1995). Values range from 0 and 1 where a low score represents greater equity. For a set of three participation rates X_1, X_2, and X_3, it is calculated as:

$$G = \frac{3}{4}\sum_{i=1}^{N}\left|X_i - \frac{1}{3}\right|$$

Nature of discussion

As well as how much children participated in the task and the extent to which that participation was equitable within groups we were also interested in the content of the group discussions and the extent to which this varied between conditions. We iteratively developed a coding scheme for the task that categorizes talk into five broad types. Table 1 lists each talk type with an operational definition and example from the transcript. Four sessions were doubled coded by a second rater and a kappa coefficient of .88 was achieved.

Table 1. OurSpace Coding Scheme

Talk Types	Definition	Example from transcripts
Task Focused	All task focused utterances relating to the design of the seating plan.	'Lets put chatty ones near the front' 'If the chatterboxes aren't with their friends they won't chat'
Turn Taking	All utterances referring to turn taking	"It my turn next, then yours" 'Stop doing it, its my turn!'
Brief Response	Short responses to suggestions or moves	'yeah, ok' 'no, no'
Evaluation	General evaluative comments about the task	'This is hard' 'This is easy' 'I like doing this'
Other	All utterances not coded as above. These included off-task comments, questions and comments about the setup of the technology, comments to the researcher and fillers.	'Is it assembly next?' 'Why do I have to stand on the mat?' 'Is this on the internet?' 'Are we going to have another turn next week?'

Results

In the following analysis we used groups (N =15) as the unit of analysis although note that results were similar when individual data was analyzed. Group scores were calculated by summing the scores of individual group members. As there was no specific time limit on the task, the length of sessions varied considerably. As seen in Table 2 single-touch sessions, which ranged from 8.7 minutes to 23.81 minutes were on average longer than the multiple-touch sessions, which ranged from 6.28 to 22.89 minutes. Although the overall difference between touch conditions was not significant there was an interaction of touch condition with session order where multiple-touch sessions that occurred second were shorter than all other sessions ($F (1,13) = 8.36$, $p < 0.05$). We have therefore included condition order as a between subjects factor in our analysis.

Levels of participation

Verbal and physical participation

Due to differences in session lengths, we calculated the mean number of utterances per minute for each group as a proportional measure of verbal participation and the mean number of touches per minute as a proportional measure of physical participation (see Table 2). Repeated measures ANOVAs show that levels of physical participation were significantly higher in the multiple-touch condition (F (1, 14) = 9.85, p < 0.01), while levels of verbal participation did not differ significantly between touch conditions. The higher rate of touches in the multiple-touch condition is not surprising given the opportunity in this mode for working simultaneously, in contrast to the one-at-a-time restriction of the single-touch condition. We also found a negative association in the single-touch condition between verbal and physical participation (r = -.56, p < 0.05); as verbal participation increased physical participation decreased and vice versa. There was no significant relationship between participation types in the multiple-touch condition.

Table 2. Means and standard deviations for time on task, level and equity of participation

		Multiple M (SD)	**Single** M (SD)
Time on task *(minutes)*			
	Session 1	16.19 (4.4)	15.56 (5.2)
	Session 2	10.41 (3.4)	14.21 (3.4)
Level of participation *(mean utterance/touch per minute)*			
	Verbal	15.46 (6.5)	16.08 (5.1)
	Physical	92.96 (47.25)	63.18 (34.19)
Equity of participation *(Gini coefficient)*			
	Verbal	.17 (.10)	.21 (.17)
	Physical	.18 (.09)	.20 (.12)

On further investigation of between subject factors, we found that participation levels (verbal and physical) in the single-touch condition were significantly correlated with the mean age of the group (see Table 3). The positive correlation with verbal participation and the negative correlation with physical participation suggest that older children tended to talk more in the single-touch condition while younger children tend to touch more in this condition.

Equity of participation

Analysis of the *Gini Coefficients* revealed no significant difference between touch conditions in levels of verbal or physical equity. In addition, verbal equity scores were highly correlated across conditions (r = .61, p < 0.05) suggesting that individual differences between groups, in relation to verbal equity were consistent regardless of touch condition. However, verbal equity was significantly related to the age of the group again in the single-touch condition but not in the multiple-touch condition (See Table 3). The relationship indicates that the younger the group the less equitable their interaction. We also found that physical equity was different for male and female groups depending on touch condition. Figure 3 shows that boys were less equitable than girls in the single-touch condition, while girls were less equitable than boys in the multiple-touch condition; the interaction approached significance (F(1, 13) = 4.3, p = 0.058).

Table 3. Correlation of age with level and equity of participation

	Multiple		**Single**	
	Verbal	*Physical*	*Verbal*	*Physical*
Level of participation *(utterance/touch per minute)*	.42	-.35	**.65***	**-.58***
Equity of participation *(Gini Coefficient)*	-.29	.36	**-.62***	-.02

* *p < 0.05*

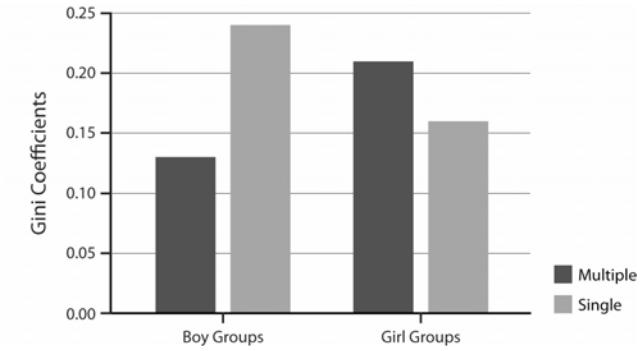


Figure 3. Physical equity by gender (lower values indicate more equitable interaction)

Nature of discussion

Figure 4 shows the proportional distribution of talk types across both conditions. In the following analysis, we focus on *task focused* and *turn taking* talk and exclude: *brief response* as it occurred equally across sessions, *evaluative* as it occurred too rarely for meaningful analysis, and *other* as it incorporated a range of behaviours not directly related to the design task. In the *other* category, off-task comments were rare across both conditions while comments relating to the technology setup were relatively frequent; children were interested in how the tabletop worked, whether their school was going to get one and related questions.

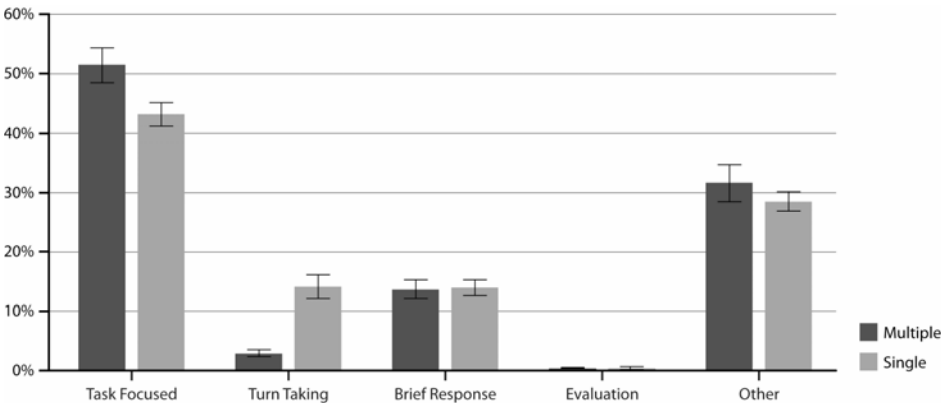


Figure 4. Proportional distribution of talk types across conditions

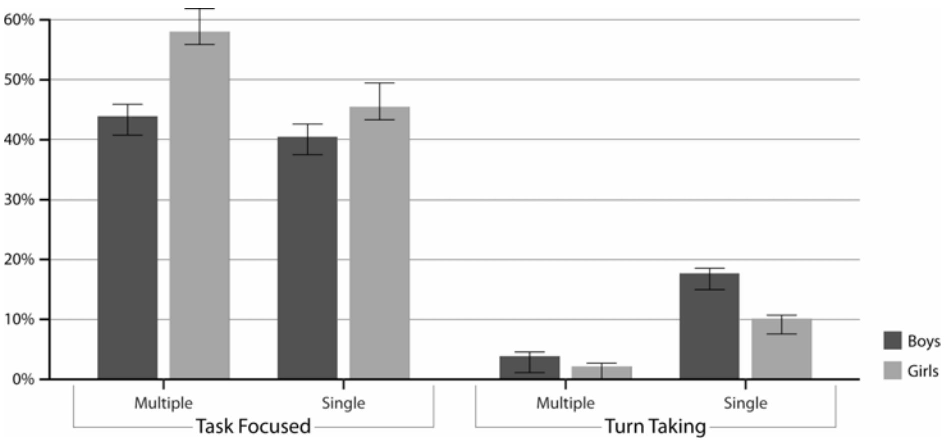


Figure 5. Task focused and turn taking talk by gender

A repeated measures MANOVA, with touch condition (multiple and single) as within subjects and talk type (task focused and turn taking) as dependent variables, revealed a significantly higher proportion of *task focused* talk in the multiple-touch condition ($F(1, 14) = 9.28$, $p < 0.01$) and a significantly higher proportion of *turn taking* talk in the single-touch condition ($F (1, 14) = 31.08$, $p < .001$). In addition, there was a negative relationship between *turn taking* and *task focused* talk in the single-touch condition ($r= -.51$, $p < 0.05$); as *turn* *taking* talk increased, *task focused* talk decreased. This relationship was not evident in the multiple-touch condition.

Analysis of between subject variables revealed no effect of age or order effect on talk type, but there was a significant gender effect. As shown in Figure 5 girls used proportionally more *task focused* talk ($F(1, 13) = 7.98$, $p < 0.05$) and boys used proportionally more *turn taking* talk ($F(1, 13) = 5.04$, $p < 0.05$) regardless of condition.

Discussion

The overall high levels of task-focused discussion we observed suggest that this task was not only engaging for children (i.e., they were motivated to achieve a good result) but was also challenging for them (i.e., due to the different constraints, there was no simple solution that satisfied all the design criteria). As a result the task elicited appropriate dialogue and discussion from our participants; elements important for learning within such a context (Yuill, Kerawalla, Pearce, Luckin & Harris, 2008). This was the case in both conditions where neither multiple- nor single-touch modes emerged as better for discussion about the task.

The degree of verbal and physical equity was also consistent across conditions. Based on previous studies with children using multiple mice (Stanton & Neale, 2003) and adults in multiple- and single-touch tabletop conditions (Marshall, et al., 2008), we had predicted that multiple-touch would enable more equity in children's verbal and physical participation. However, our results showed that overall children's interactions during this task were highly equitable across *both* touch conditions as scores tended towards zero (perfect equity). Therefore, the multiple-touch functionality of the tabletop did not result in higher levels of equity, in comparison to the enforced single-touch condition as we had predicted. This suggests that the benefits of an interactive tabletop do not depend on simultaneous input but perhaps lie in a more general quality of the form of input (i.e. touch). Marshall et al (2008) in their study with adults doing a similar design task found that multiple-touch input facilitated greater equity of physical participation, but that touch condition had no influence on levels of verbal participation. The single-touch condition in their study was implemented by using only a single conductive pad to interact with a DiamondTouch tabletop; thus, participants had to physically change location around the tabletop in order to pass control. In the study reported here, single-touch was implemented by blocking others' actions in software and therefore required no change of location. The differences between the way in which turn taking was enforced between studies adds further support to the notion that the form of the input plays a crucial role in how equitable interactions are likely to be; in our study, direct touch to the tabletop was all that was required for interaction in contrast to the change of location required in the Marshall et al (2008) study.

As well as examining levels of verbal and physical participation, we also focused our analysis on the content of discussion. Children talked more about their designs (task-focused) in the multiple-touch condition than they did in the single-touch condition. However, in the single-touch condition, talk about turn taking was more frequent and appeared to be replacing discussion about design. It is not surprising there was more turn taking talk in the single-touch condition, as children would have to negotiate how turns should be managed if all group members were to participate equally. However, we observed considerable differences between groups in children's ability to manage and regulate this type of interaction. Some group interactions were characterized by frustration and high levels of negative affect during single-touch interaction, especially when a particular child was perceived as dominating. For example:

Group1: Single-touch

Child A	*Yeah like that Beth.*
Child C	*Amy get your finger off the board!*
Child B	*It was there and you put your finger like there.*
Child C	*Beth get off! Get off!*
	Beth you already had so many turns.
Child B	*Last time you did it.*
Child C	*I think you should let Amy have a go.*
Child B	*Last time you did most of it.*
Child C	*No, not lots of it.*
Child B	*But you did though!*

Other groups were more successful at regulating turn taking during single-touch interactions. For example, some groups generated rules for the interaction and decided democratically how to manage turn taking in order that everyone had an equal opportunity for participation. For example:

Group 2: Single-touch

Child A	*No no, let's take it in turns to do it like one at a time, me or Tom first, then Jack then either me or Drew.*

Child B	*What?*
Child A	*'cause then it goes, like that (motions a circle around the group with his finger) for example or like that. (motions a circle with his finger the other way)*
Child C	*Shall I go first or you Ben?*
Child A	*Erm*
Child C	*Have a vote. Oh Joe it's not your go!*
Child A	*Ok let's let Jack go first, like that. We can take it in turns to say ideas then we can do it one at a time.*

Group 2's interaction demonstrates the kind of co-operative working that was characteristic of the single-touch condition. For example, in groups that tended to allocate rules for turn taking there was also the tendency to divide the task into subtasks and allocate responsibility for these subtasks to particular group members. This is illustrated in this second example from Group 2:

Group 2: Single-touch

Child C	*Ok, I'll do the people. Somebody does the tables, I'll do the people and somebody turns.*
Child A	*I'm doing the tables*
Child C	*Ok do you wanna turn, no, no he's doing the tables, Alex is doing the tables. (moves B's hand away)*
Child A	*Ok I'll do the people*

These extracts offer support to our second hypothesis, which predicted that single-touch would be associated with more awareness of the other group member's actions. However, the extent to which this led to co-operation or frustration and dominant behaviour was dependent on individual group characteristics.

The finding that task-focused discussion often replaced turn taking talk is illustrated by a further extract from Group 2, taken from their multiple-touch session. Here, the group were all focused on the same part of the activity and were talked together about where to seat particular students in relation to the student's attributes. Their discussion involved explicit reasoning and justifications. Compared to their talk about turns and subtasks in the single-touch condition, this interaction was more collaborative in nature.

Group 2: Multiple-touch

Child B	*OK now shall we put the people on?*
Child C	*Yeah the chatty people at the back.*
Child B	*OK.*
Child A	*But there's one with glasses and that's chatty!*
Child C	*Where?*
Child A	*There and there.*
Child B	*Then just put them at the front.*
Child C	*Well then put them still near the front because it's hard to see.*
Child A	*And they're also friends.*
Child C	*Look, no, oh yeah chatty people go on the back with their…no wouldn't they need to go on the front so the teacher can see them?*

Another important finding to emerge from this study is the importance of considering age and gender when designing for collaborative activities. We have found that differences that exist in relation to these variables seemed to be accentuated in the single-touch condition. For example, younger groups tended to engage in less dialogue and were less equitable in their verbal interactions during the single-touch condition. In addition, boys tended to talk more about turn taking than girls and were less equitable in the single-touch condition, where turn taking was necessary. It is interesting to note that these differences seemed moderated by the touch condition, as they were less evident in behaviour in the multiple-touch condition. This might be because multiple-touch provided the opportunity to work more independently; children could engage in simultaneous input without enforced awareness of other group members. The multiple-touch functionality might therefore act to mask developmental and gender related differences in which are not challenged by the constraints of the technology.

A particular strength of this study was the holistic approach we took to understanding the collaborative process. We analyzed children's physical and verbal participation, acknowledging that collaboration can occur through doing as well as talking. However, we did not underplay the importance of talk and measured both the amount of talk as well as the content of that talk. In doing this, our results suggest that tabletop working encouraged children to participate equally in both the discussion and the activity of collaborative interaction. Varying simultaneous versus one-at-a-time input influenced the nature of the discussion and allowed for the influence of important individual differences between children.

There were also a number of limitations in the findings reported here that point towards future work. First, we focused on children between the ages of 7 and 10 and found interesting age-related trends. While younger children can use interactive tabletops, their ability to use the interface and their ability to collaborate on a task is substantially different (Mansor, De Angeli, & De Bruijn, 2008). Much of the work on collaboration with multiple mice has used younger (e.g., Stanton & Neale, 2003) or older participants (Inkpen et al., 1999). It would be interesting to extend our work to both younger and older groups.

We also only focused on one kind of collaborative task – a design task with a shared integrated representation. While collaborative design is an important task, particularly in regards to learning, other tasks may elicit substantially different behaviour. Tan et al. (2008) call for a standard set of evaluation tasks to allow for comparison between different configurations of shareable interfaces, but it is unclear to what extent existing frameworks such as McGrath's task circumplex typology will be useful in classifying tasks for this new generation of tools for co-located collaboration.

Finally, we only used the DiamondTouch tabletop in the school for a short period of time and the children were excited to be able to use this new technology. Therefore, it remains to be seen to what extent findings are attributable to the novelty of the system (Rogers, Scaife, Gabrielli, Smith, & Harris, 2002). We plan to explore in future work whether our findings would extend to the situation where such technologies had become a normal part of classroom practice.

References

Abnett, C., Stanton, D., Neale, H., & O'Malley, C. (2001). The effect of multiple input devices on collaboration and gender issues. *Proc. of European Perspectives on Computer-Supported Collaborative Learning (EuroCSCL)* (pp. 29-36). Maastricht, The Netherlands.

Barron, B. (2003). When smart groups fail. *Journal of the Learning Sciences, 12*(3), 307-359.

Cappelletti, A., Gelmini, G., Pianesi, F., Rossi, F., & Zancanaro, M. (2004). Enforcing cooperative storytelling: First studies. *Proceedings of the 4th IEEE International Conference on Advanced Learning Technologies ICALT2004*. Joensuu, Finland.

Goos, M., Galbraith, P., & Renshaw, P. (2002). Socially mediated metacognition: Creating collaborative zones of proximal development in small group problem solving. *Educational Studies in Mathematics, 49*, 193-223.

Harel, I., & Papert, S. (1991). *Constructionism*. New York: Ablex.

Hornecker, E., Marshall, P., Dalton, N. S., & Rogers, Y. (2008). Collaboration and interference: Awareness with mice or touch input. *Proc. of CSCW'08*.

Inkpen, K., Booth, K. S., Klawe, M., & Upitis, R. (1995). Playing together beats playing apart, especially for girls. *Proc. of CSCL'95*. Bloomington, Indiana.

Inkpen, K., Ho-ching, W.-l., Kuederle, O., Scott, S. D., & Shoemaker, B. D. (1999). "This is fun! We're all best friends and we're all playing": Supporting children's synchronous collaboration. *Proc. of CSCL'99* (pp. 252-259). Palo Alto, California: ACM.

Kerawalla, L., Pearce, D., Yuill, N., Luckin, R., & Harris, A. (2008) "I'm keeping those there, are you?" The role of a new user interface paradigm – Separate Control of Shared Space (SCOSS) – in the collaborative decision-making process, *Computers and Education*, *50(1)* p193-206

Kolodner, J. L., Camp, P. J., Crismond, D., Fasse, B., Gray, J., Holbrook, J., Puntambekar, S., & Ryan, M. (2003). Problem-based learning meets case-based reasoning in the middle-school science classroom: Putting Learning by Design™ into practice. *Journal of the Learning Sciences, 12*(4), 495–547.

Kutnick, P., & Rogers, C. (1994). *Groups in Schools*. London: Cassell.

Mansor, E. I., De Angeli, A., and De Bruijn, O. (2008). Little fingers on the tabletop: A usability evaluation in the kindergarten. *Proc. of TABLETOP '08* (pp. 99–102).

Marshall, P., Hornecker, E., Morris, R., Dalton, N. S., & Rogers, Y. (2008). When the fingers do the talking: A study of group participation with varying constraints to a tabletop interface. *Proc. of IEEE Tabletops and Interactive Surfaces*. Amsterdam, The Netherlands.

Nacenta, M., Pinelle, D., Stuckel, D., & Gutwin, C. (2007). The effects of interaction technique on coordination in tabletop groupware. *Proc. of Graphics Interface'07*: ACM.

Piper, A. M., O'Brien, E., Morris, M. R., & Winograd, T. (2006). SIDES: A cooperative tabletop computer game for social skills development. *Proc. of CSCW'06*. Banff, Alberta, Canada: ACM.

Rick, J., Harris, A., Marshall, P., Fleck, R., Yuill, N. and Rogers, Y. (2009). Children designing together on a multi-touch tabletop: An analysis of spatial orientation and user interactions. *Proc. of IDC 2009*: ACM.

Rick, J., Rogers, Y., Haig, C., & Yuill, N. (2009). Learning by doing with shareable interfaces. *Children, Youth and Environments, 19*(1).

Rogers, Y., & Lindley, S. (2004). Collaborating around vertical and horizontal large interactive displays: Which way is best? *Interacting with Computers, 16*, 1133-1152.

Rogers, Y., Scaife, M., Gabrielli, S., Smith, H., & Harris, E. (2002). A conceptual framework for mixed reality environments: designing novel activities for young children. *Presence: Teleoperators & Virtual Environments, 11*(6), 677-686.

Shen, C., Everitt, K. M., & Ryall, K. (2003). UbiTable: Impromptu face-to-face collaboration on horizontal interactive surfaces. *Proc. of UbiComp'03* (pp. 281-288).

Stanton, D., & Neale, H. (2003). The effect of multiple mice on chidren's talk and interaction. *Journal of Computer Assisted Learning, 19*(2), 229-238.

Stanton, D., Neale, H., & Bayon, V. (2002). Interfaces to support children's co-present collaboration: Multiple mice and tangible technologies. *Proc. of CSCL'02* (pp. 342-351). Boulder: ACM.

Tan, D. S., Gergle, D., Mandryk, R., Inkpen, K., Kellar, M., Hawkey, K., et al. (2008). Using job-shop scheduling tasks for evaluating collocated collaboration. *Journal of Personal and Ubiquitous Computing 12*(3), 255-267.

Teasley, S. (1995). The role of talk in children's peer collaborations. *Developmental Psychology, 31*(2), 207-220.

Webb, N. M., & Palincsar, A. S. (1996). Group processes in the classroom. In D. C. Berliner & R. C. Calfee (Eds.), *Handbook of Educational Psychology* (pp. 841-873). New York: Simon & Schuster Macmillan.

Weisband, S. P., Schneider, S. K., & Connolly, T. (1995). Computer-mediated communication and social information: Status salience and status differences. *The Academy of Management Journal, 38*(4), 1124-1151.

Yuill, N., Kerawalla, C., Pearce, D., Luckin, A. & Harris, A. (2008). Using technology to teach flexibility through peer discussion. In K.E.Cartwright (Ed.), Flexibility in literacy processes and instructional practice: Implications of developing representational ability for literacy teaching and learning. New York: The Guilford Press

