ResearchGate

See discussions, stats, and author profiles for this publication at: https://www.researchgate.net/publication/2416858

The Effect of Turn-Taking Protocols on Children's Learning in Mouse-Driven Collaborative Environments

Article · February 1998

Source: CiteSeer

CITATIONS
71

READS
318

4 authors, including:

Kori Inkpen
Microsoft
207 PUBLICATIONS **6,419** CITATIONS
SEE PROFILE

Joanna Mcgrenere
University of British Columbia - Vancouver
101 PUBLICATIONS **2,762** CITATIONS
SEE PROFILE

Kellogg Booth
University of British Columbia - Vancouver
46 PUBLICATIONS **1,102** CITATIONS
SEE PROFILE

Some of the authors of this publication are also working on these related projects:

Project HCI and Accessibility View project

Project Attentional tokens in dynamic displays View project

All content following this page was uploaded by Joanna Mcgrenere on 27 November 2013.

The user has requested enhancement of the downloaded file.

Turn-Taking Protocols for

Mouse-Driven Collaborative Environments

Kori Inkpen[1], Joanna McGrenere[2], Kellogg S. Booth[1], Maria Klawe[1]

[1]Department of Computer Science
The University of British Columbia
Vancouver, British Columbia, V6T 1Z4, Canada
+1 604 822 8990
inkpen@cs.ubc.ca, ksbooth@cs.ubc.ca, klawe@cs.ubc.ca

[2]Department of Computer Science
The University of Toronto
Toronto, Ontario, M5S 1A4, Canada
joanna@dgp.toronto.edu

ABSTRACT

This study compared the influence of turn-taking protocols on children's behaviour and learning when they used either one shared mouse or two individual mice in a collaborative problem-solving environment. The two-mouse case was investigated for both a *give* protocol, in which the child with control voluntarily relinquishes it, and a *take* protocol, in which the child without control preemptively acquires it. Children in the study took part in two sessions. In the first collaborative session, children played a problem solving puzzle game with a partner using one of the three protocols (one-mouse *shared*, two-mouse *give*, or two-mouse *take*). This was followed by a second solo session in which each child played the puzzle game alone. The results of the study revealed that the choice of turn-taking protocol can have a significant affect on children's achievement and behaviour in a collaborative problem-solving environment. For girls, the protocol affected achievement in the game during the collaborative session: using the two-mouse *give* protocol girls solved more puzzles on average than they did using either of the other two protocols. For boys, the protocol affected their access to the mouse, which in turn affected their achievement in the second session when they played alone: a significant correlation was found between the amount of time each boy had control of the mouse in the collaborative session and the number of puzzles that same boy solved in the subsequent solo session. In the two-mouse *take* condition boys exhibited a more equal division of mouse control than did boys using either of the other two protocols.

KEYWORDS: Computer Supported Collaborative Learning (CSCL), children, computers in education, gender, interaction styles, mouse, turn-taking.

INTRODUCTION

Children naturally gather in groups around computers, especially to play games. Previous research has shown that children can be more successful when they play with a partner than when they play by themselves [6]. Numerous researchers have also noted the social and achievement benefits of having children work together in small groups [4, 7]. One of the difficulties in having small groups work together on computers is that contention arises over sharing input devices, such as the mouse used to control many computer games [6, 2]. Our study was designed to explore children's sharing patterns, using three turn-taking protocols for sharing control of a mouse-driven cursor, in a single-user problem-solving puzzle game. The turn-taking protocols were: (1) two children sharing a single mouse; (2) two children, each with a mouse, using a *give* protocol to transfer control between the two mice; and (3) two children, each with a mouse, using a *take* protocol to transfer control between the two mice. The amount of time each child had control and how often control switched between the partners was measured along with the children's achievement in the game. In an earlier study, we looked at these same three turn-taking protocols but only measured achievement in the collaborative session. We found that girls solved the most puzzles using the two-mouse *give* protocol but boys solved the most puzzles using the two-mouse *take* protocol [5]. Our new study was designed to investigate this issue in more detail and to attempt to quantify the degree to which the turn-taking protocol affected children's learning in the game, something that was not examined in our earlier study.

Whether or not control of the mouse is a good indicator of how well a group is working together has been previously explored. Cole conducted a qualitative study in which mixed-gender groups of four children worked together on one computer [3]. Cole concluded that although the mouse plays a significant role in group dynamics, it is not a reliable indicator of group collaboration. For some groups, the children who controlled the mouse performed actions directed by other members of the group, and thus had very little control of the game. For other groups, the children who controlled the mouse explored only their own ideas in the game.

In Cole's study there were many factors other than control of the mouse that could have significantly affected a group's level of collaboration. One factor was the use of mixed-gender groups in the study. Previous research has shown that mixed-gender groups can have a significant impact on the outcome compared to same-gender groups [8]. Another factor was size. The groups in Cole's study were composed of four children; there could have been as many as four competing ideas about how to play the game, so that the child controlling the mouse might have had to devote a large amount of time to deciding which idea to explore and following other children's direction, leaving little time for the child to concentrate directly on the problem at hand.

While qualitative observations are important to understand how groups interact with each other, possessing control of the mouse may have effects on the children that an observer cannot see. Our study performed a quantitative analysis, examining same-gender pairs of children working in the collaborative problem-solving environment of a mouse-driven computer puzzle game. We wanted to determine if control of the mouse effects children's learning. Our restriction to same-gender pairs removed the added complexity of mixed-gender groupings: by limiting the collaboration to just two children we minimized the amount of collaborative administration required of the players (whose idea will be tried?, who will operate the mouse?).

METHOD[1]

Subjects and Setting

The study took place in four elementary schools on the East Side of Vancouver, British Columbia, during May and June of 1996. The time spent at each school ranged from two to four days depending on the number of classes participating in the study. In total, 252 students (126 girls and 126 boys) ranging in age from nine to twelve years old, chosen from twenty Grade Five and Grade Six classes, participated in the study. The students from these schools comprised several different cultural groups. None of the students had previously played The Incredible Machine [10], the commercial computer game used in the study. Students were arbitrarily placed into one of three experimental conditions and were randomly assigned a same-gender partner from the same class.

The sessions were run in the computer laboratories of the schools, all of which had IBM-compatible computers. A Silicon Graphics Personal IRIS workstation was brought into the laboratory to support the two experimental conditions that required multiple mice. Regular use of the computer laboratory was restricted during the majority of the time the study was being run.

Software

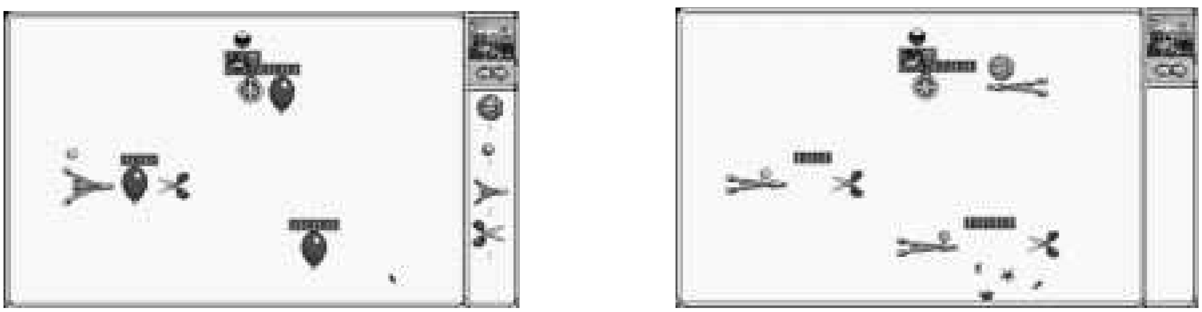
The software used in the study was The Incredible Machine, a puzzle-solving game produced by Sierra [10]. The game features a series of challenges in which a player must construct various Rube Goldberg-type machines to achieve particular goals such as breaking all of the balloons depicted on the screen or making “Mort the Mouse” run in his mouse cage. A host of entertaining objects such as balls, trampolines, balloons, scissors, and cats are available to be placed on the screen in a variety of ways to achieve these goals when the machine is “run”. Students position the objects, test the configuration by running the machine, and then re-position objects as required until they discover a solution. Many of the puzzles have more than one solution. An example of a puzzle and one of its solutions is shown in Figures 1a and 1b. Upon completion of a puzzle, the student can move on to the next puzzle.

A brief example of The Incredible Machine is illustrated in Figure 1. The goal of Puzzle #3 in the game is to build a machine that will break all three of the balloons that appear on the screen in the puzzle. The initial configuration shown in Figure 1(a) will break the leftmost balloon when the machine is started by the student clicking on the "run" button that appears in the upper right-hand corner of the screen. This turns on gravity, which makes the baseball and some other objects start to fall. As the baseball drops on the bellows, the bellows contract and blow the balloon into the pair of scissors, causing the balloon to break. A similar configuration of tennis ball, bellows and scissors can be

[1] For a more detailed report on the experimental design of this study, see [9].

used to break the balloon on the bottom right. Students must discover this and drag one of the bellows, the second pair of scissors, and the tennis ball to the appropriate positions on the screen from their initial location in the toolbox on the right side of the screen. Because both pairs of scissors are needed to break the first two balloons, the gear attached to the mouse motor must be used to break the third balloon. The cannon ball sitting on top of the mouse motor will cause Mort the Mouse to run in his cage, which then will in turn cause the gear to spin. If the basketball and the third bellows are positioned to the right of the top balloon, the bellows can be used to blow the balloon into the spinning gear as the basketball drops onto the bellows. This breaks the third balloon. Figure 1(b) shows the completed machine running.

Figure 1. ***(a) The Incredible Machine playing screen Puzzle #3*** ***(b) Solution to Puzzle # 3***



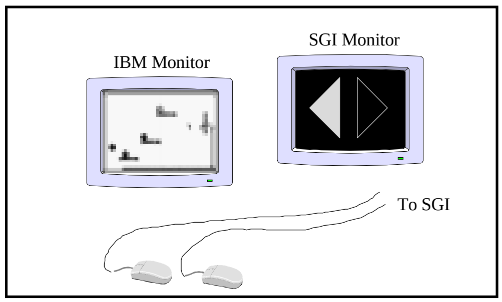
Procedure

The study was conducted in sets of two sessions. The first session involved having students play The Incredible Machine using one of three turn-taking protocols (the collaborative session). The second session involved the students playing alone (the solo session). Each session lasted approximately forty minutes (one class period). The second session took place one to three days after the first session.

The three experimental conditions in the collaborative sessions were: (1) one-mouse *shared* play, in which two children played together on one machine sharing a single mouse; (2) two-mouse *give*, in which two children played together on one machine, each with a separate mouse, using a *give* protocol in which turn-taking had to be initiated by the child currently in control of the game cursor; (3) two-mouse *take*, in which two children played together on one machine, each with a separate mouse, using a *take* protocol in which turn-taking had to be initiated by the child currently not in control of the game cursor.

In order to allow for the use of two mice in the game, a Silicon Graphics Personal IRIS workstation was used to receive input simultaneously from two serial mice and to determine which of the two mouse inputs would be sent to the IBM-compatible computer running the game software (see Figure 2). The game software was not modified in any way for the two-mouse conditions. There still was only one cursor visible on the screen and only one mouse was active at a time. Instead of physically passing the single shared mouse between two partners, control of the cursor was transferred between the two mice by the click of a button. The serial mice used in the experiment had two buttons. The game software only uses one of the mouse buttons, so the other button was reserved for exclusive use by the turn taking protocol. To provide feedback on turn-taking, the IRIS workstation screen displayed a large arrow to indicate to the children which mouse was active.

Figure 2. Experimental set-up for the two-mouse conditions

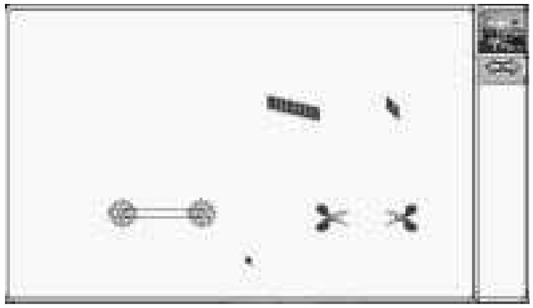


The two-mouse *give* and *take* protocols were implemented using a two-button mouse. The left button controlled the normal operation of the game, as in the one-mouse *shared* condition, while the right button transferred control back and forth between the two mice. In the two-mouse *give* condition, when the partner in control of the game cursor pressed the right mouse button, control of the game cursor would be passed over to the other partner's mouse (nothing happened if the partner not in control of the game cursor pressed the right button). In the two-mouse *take* condition, either partner could take control of the game cursor by pressing the right mouse button at any time (for the partner who had control, this would be a "no-op", but the software permitted this action).

The first experimental session consisted of welcoming remarks by a researcher, a brief introduction to the experimental study and to the game The Incredible Machine, a hands-on interface training session, and twenty-five minutes of time playing The Incredible Machine. The interface training session was intended to teach the students how to manipulate objects in the game in order to help eliminate problems with the user interface during the session.

The interface training session was conducted individually so that all children became familiar with the interface. It showed children how to begin playing a puzzle, how to move objects from the toolbox onto the playing screen, how to hook objects together, how to flip objects, how to size objects, and how to run the machine by clicking on the appropriate icon on the screen. Each child was required to duplicate a picture of a practice machine (see Figure 3) to ensure that the child was able to perform all operations required to play the game. Upon completion of the interface training session, children were placed into pairs with their collaborative partners and given twenty-five minutes to solve puzzles in the game. When the children solved a puzzle, a researcher recorded the time at which the puzzle was solved and then helped the children start the next puzzle in the game.

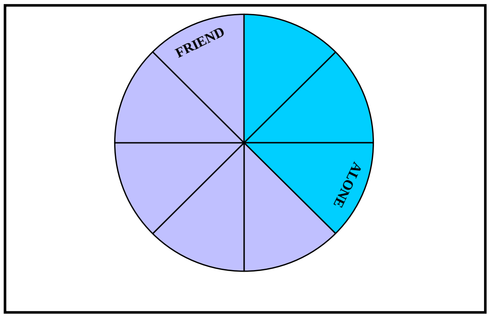
Figure 3. A Practice machine used for the interface training session for The Incredible Machine to familiarize children with the game and its mouse-driven user interface.



The second session took place one to three days after the first session. In this solo session, all of the children played The Incredible Machine individually for twenty-five minutes. If a child completed a puzzle, the child was responsible for recording the time at which the puzzle was solved and for recording a password that the game provided after each puzzle was solved. In this second session, the game automatically advanced to the next puzzle without intervention by the researcher each time a puzzle was solved.

After the solo play session, the children were also asked to rate on an eight-point scale whether they would prefer to play The Incredible Machine alone or with a partner. To facilitate accurate responses from the children, they were given a pinwheel on which to demonstrate their preference [1]. The pinwheel consisted of two different colored cardboard circles, each sectioned into eight pie-shaped pieces. Each circle had a slit on one of the section lines going from the outer edge of the circle to the centre. When the two circles were joined using the slits, the resulting pinwheel could be turned to show various amounts of each color. If children preferred to play alone, they could turn the pinwheel so that more of the alone color was showing. If children preferred to play with a friend, they could turn the dial so that more of the friend color was showing (see Figure 4).

Figure 4. The Pinwheel used by children to rate preference on an eight-point scale.



During both sessions of play, a small subset of children were randomly selected for qualitative observations performed by one of the researchers. The qualitative observations examined the children's collaborative behavior, their discussions, and the amount of their engagement in the game as judged by the observer.

RESULTS

Mouse Control

Mouse control was measured by how long each partner had physical control of the mouse in the one-mouse *shared* condition or logical control of the game cursor in the two-mouse *give* and *take* conditions. Table 1 summarizes the results for mouse sharing in the three collaborative conditions. The two mouse control columns present the average percentage of time each partner had control of the mouse; the first number is the percentage of time the mouse was controlled by the child within a pair who had control of the mouse for the shorter total time, while the second number is the percentage for the child who had control of the mouse for the longer total time.

The exchanges column (the third number) in Table 1 is the average number of times control was passed between the two children. In the one-mouse *shared* condition, an exchange of control was considered to have occurred whenever the single shared mouse was physically passed from one child to the other. In the two-mouse *give* and *take* conditions, an exchange of control was considered to have occurred whenever control of the game cursor was switched from one mouse to the other by pressing a right mouse button.

Table 1. Mouse control represents the average percentage of time each partner had control of the mouse. The first value represents the percentage of time the mouse was controlled by the child within a pair who had control of the mouse for the shorter total time. The second value represents the percentage for the child who had control of the mouse for the longer total time.

Girls	Mouse Control		Exchanges
Shared	30%	70%	13
Give	33%	67%	25
Take	30%	70%	29

Boys	Mouse Control		Exchanges
Shared	24%	76%	18
Give	33%	67%	22
Take	38%	62%	46

Distribution of Mouse Time

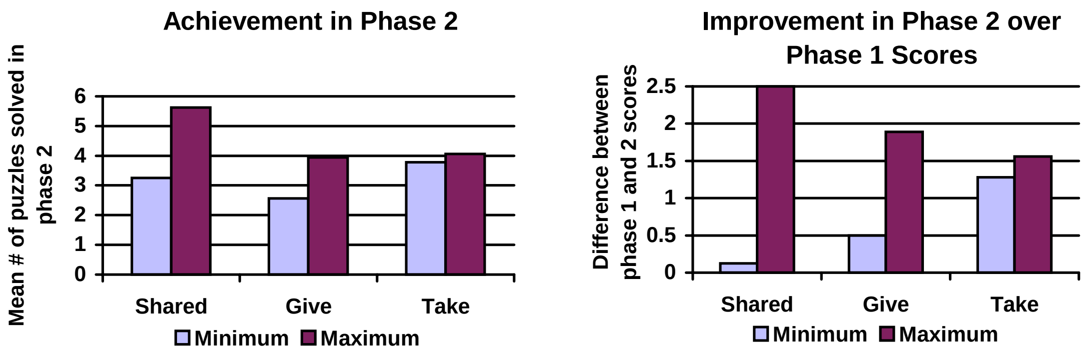
For girls, there was no significant effect of turn-taking protocol on the amount of time a partner controlled the mouse although girls in the two-mouse *give* condition did exhibit a slightly more equal distribution of control. For boys, a significant effect was found for the amount of time a partner controlled the mouse, p<.05, with a medium to large effect size of .126 and a power of 76%. The post-hoc analysis revealed a significant difference between boys in the one-mouse *shared* condition and boys in the two-mouse *take* condition. Our earlier study had also found evidence for this.

The new study added a second, solo session. A significant correlation was found for boys between the amount time a partner had control of the mouse in the collaborative session and the number of puzzles he was able to solve in the subsequent solo session, p<.01, Pearson Correlation .30. Figure 6(a) shows the average number of puzzles solved in the solo session by condition, for both the partner that had control of the mouse the shorter total time (minimum) in the collaborative session and the partner that had control of the mouse for a longer total time (maximum) in the collaborative session. A significant difference was found between the scores in the solo session of the children who had control of the mouse for a longer period of time in the collaborative session and the children who had control of the mouse for a shorter period of time in the collaborative session, p<.01 with an effect size of .07 and a power of 82%. Figure 6(b) shows children's improvement in the solo session over their collaborative session scores. A significant difference was also found for this improvement of solo score over the collaborative score between the partner within a pair who had control of the mouse for the shorter time versus the partner that had control of the mouse for the longer time, p < .01, with a medium effect size of .10 and a power of 85%. Further analysis revealed that these differences were significant for boys in the one-mouse *shared* and the two-mouse *give* conditions, but not for boys in the two-mouse *take* condition.

BOYS

Figure 6. *(a)* *The average number of puzzles solved in the solo session for the boys within a pair who had control of the mouse for the shorter total time (minimum) in the collaborative session and for the boys who had control of the mouse for a longer total time (maximum) in the collaborative session.*

(b) *The difference in the number of puzzles solved in the solo session as compared to the collaborative session between the boys that had control of the mouse the shorter total time (minimum) in the collaborative session and the boys who had control of the mouse for the longer total time (maximum) in the collaborative session.*



Number of Mouse Exchanges

The number of exchanges by condition, as shown in Table 2, for both girls and boys showed significant differences, $p < .01$, with a large effect size of .17 and a power of 88%. The post-hoc analysis revealed a significant difference in the number of exchanges for girls between the one-mouse *shared* condition and both the two-mouse *give* and two-mouse *take* conditions, $p < .05$. The post-hoc analysis for boys also revealed a significant difference in the number of exchanges between the one-mouse *shared* and the two-mouse *take* condition as well as between the two-mouse *give* and two-mouse *take* conditions, $p < .05$.

A correlation was found for boys between the number of exchanges in a collaborative session and the percentage of time each partner had control of the mouse in the one-mouse *shared* and the two-mouse *give* conditions, $p<.01$ and $p<.05$ respectively. In these two conditions, a higher number of exchanges correlated with a more equal distribution of time that each partner had control of the mouse. The Pearson Correlation coefficient for the boys' one-mouse *shared* condition was .66. For the boys' two-mouse *give* condition it was .51. No significant correlation was found for the girls' mouse exchanges by condition, although a trend similar to the boys did emerge in the one-mouse *shared* condition, $p < .08$.

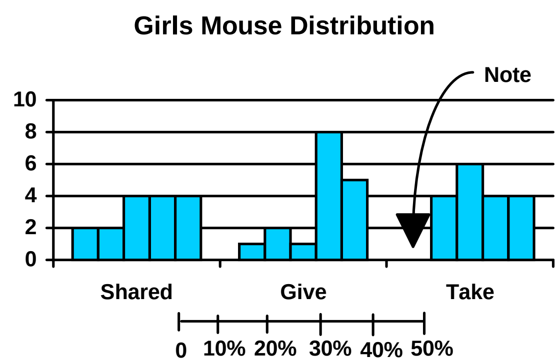
DISCUSSION

Mouse Control

Girls

The average percentage of time each girl in a pair had control of the mouse was identical for the one-mouse *shared* and two-mouse *take* conditions, 30% / 70%, but in the two-mouse *give* condition girls had a slightly more equal distribution of control, 33% / 67%. Further analysis of each pair's distribution of control is shown in Figure 7 which presents the percentage of mouse time for the partner within a pair of girls who had control of the mouse for the shorter total time. The histogram is divided into five sections, each representing a range of 10%: (a) 0 - 10%; (b) 10% - 20%; (c) 20% - 30%; (d) 30% - 40%; and (e) 40% - 50%.

Figure 7. Histogram of percentage of mouse control for the partner within a pair of girls who had control of the mouse the shorter total time.
Note: in the 0 - 10% interval for the take condition, the count is 0.

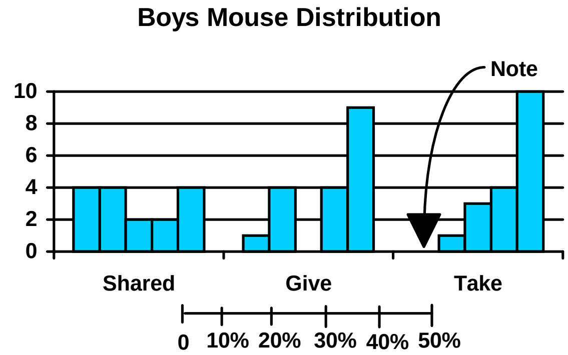


The histogram for the one-mouse *shared* condition revealed a similar number of pairs appearing in each of the divisions. The two-mouse *take* condition also had a similar number of pairs appearing in all but the first division. Interestingly, no girls in the two-mouse *take* condition had control of the mouse for less than 10% of the time! The histogram for the two-mouse *give* condition showed that the majority of the girls had control of the mouse for at least 30% of the time. This demonstrates that more pairs of girls in the two-mouse *give* condition exhibited a roughly equal distribution of mouse control than did pairs of girls in the other two conditions.

Boys

The distribution of mouse control time for boys ranged from a distribution of 24% / 76% in the boys' one-mouse *shared* condition to a more equal distribution in the two-mouse *take* condition, 38% / 62%. Further analysis of the distribution of mouse control for the individual pairs is shown in Figure 8 which presents the percentage of mouse time for the partner within a pair of boys who had control of the mouse the shorter total time. The histogram is divided into five sections, each representing a range of 10%: (a) 0 - 10%; (b) 10% - 20%; (c) 20% - 30%; (d) 30% - 40%; and (e) 40% - 50%.

Figure 8. Histogram of percentage of mouse control for the partner within a pair of boys who had control of the mouse the shorter total time.
Note: in the 0 - 10% interval for the take condition, the count is 0.



The histogram for the one-mouse *shared* condition revealed a similar number of pairs appearing in each of the divisions, with 50% of the boys having control of the mouse less than 20% of the time. The histogram for the two-mouse *give* condition showed that a few boys who had control of the mouse less than 20% of the time but the majority of the boys had control of the mouse for more than 40% of the time. In contrast, the two-mouse *take* histogram only revealed one boy who had control of the mouse less than 20% of the time. Over 55% of the boys had control of the mouse for at least 40% of the time using *take*. This shows that the boys in the two-mouse *take* condition had a fairly even distribution of mouse time. Like the girls, no boys in the two-mouse *take* condition had control of the mouse for less than 10% of the time.

Exchanges

Both girls and boys exhibited different sharing patterns using the various turn-taking protocols as shown by the number of times the children exchanged control. For both genders, the least number of exchanges occurred in the one-mouse *shared* condition while the highest number of exchanges occurred in the two-mouse *take* condition. These results might be attributed to the ease of obtaining control of the game cursor. In the one-mouse *shared* condition, gaining control is typically more difficult because a child must physically obtain control of the shared mouse. In contrast, obtaining control in the two-mouse *take* condition is relatively easy because a child only needs to press a button on the mouse to gain control.

For girls in the two-mouse *give* condition, the number of exchanges was close to the number of exchanges in the two-mouse *take* condition. This suggests that girls in the two-mouse *give* condition may have experienced easier access to control of the cursor, as in the two-mouse *take* condition. One the other hand, the average number of exchanges for boys in the two-mouse *give* condition was close to the average for the one-mouse *shared* condition. This suggests that boys in the two-mouse *give* condition may have had a harder time obtaining control, as in the one-mouse *shared* condition. The number of exchanges for boys also correlated positively with an equal distribution of mouse control. As the number of exchanges increased, the distribution of mouse control between two boys became more equal.

Lessons Learned from the Mouse Control Results

Our goal in this study was to find out more about the choice of turn-taking protocol influences achievement and behavior. We were especially interested in measuring learning that took place in the collaborative session. Achievement in the subsequent solo session was our measure for estimating this.

Girls

The turn-taking protocol appeared to influence girls' achievement in this study. Girls were most successful working in pairs in the two-mouse *give* condition, which is the condition in which girls displayed the most equal distribution of mouse time. This does not necessarily mean that girls learned more when they had control of the mouse, because no significant correlation was found between mouse control and achievement in the solo session. In fact, the opposite could be true; perhaps girls learn more when they do not have control of the mouse. A system that promotes equal distribution of mouse control time also provides an equal distribution of non-mouse control time. What this result may suggest is simply that a more equal distribution of mouse control indicates that both partners are engaged or participating equally in the task.

Boys

The fact that a positive correlation existed between the amount of time a boy had control of the mouse in the collaborative session and subsequent achievement in the solo session indicates that control of the mouse and manipulation of the environment may be important for boys' learning. The results for the one-mouse *shared* and two-mouse *give* conditions show that the children who had control of the mouse for a longer total time during the collaborative session scored higher in the solo session and improved significantly over their collaborative session scores compared to their partners who had control of the mouse for a shorter total time in the collaborative session. In contrast, the results for the two-mouse *take* condition showed that the performance of both partners in the solo session was very comparable.

CONCLUSIONS

The results of this study show that seemingly similar ways of sharing limited resources (in our case turn-taking for mouse-driven control of a game cursor) in a collaborative environment can have significant influence on the participants, both in terms of achievement and behavior. In this study, the protocol for controlling turn taking affected girls' achievement while playing collaboratively. For boys, the turn-taking protocol affected their ability to perform the task on their own later, which may suggest that boys' learning during collaborative play was influenced by the turn-taking protocol.

One important observation that arises from this study is that boys and girls interact quite differently using the various turn-taking protocols. Because of this, we must realize that the turn-taking protocol that best suits one gender may not be the best for all children; gender does appear to make a difference. It could be argued that the two-mouse *take* protocol was most suited for boys because it allowed for the most equitable access to control of the game cursor and thus was of mutual benefit for both partners given the way that boys play the game. In contrast, the girls performed best using the two-mouse *give* protocol. This generalization does not hold true for all girls or for all boys, but it does indicate that we should be extremely careful when designing collaborative environments, especially if they are to be used in educational settings. If we want to ensure that the environment is equally appropriate for both girls and boys, we may have to provide more than one turn-taking protocol to support effective collaboration.

A limitation of our study is that the children only took part in the study for two forty-minute class periods. The behavior reported here may change when children work in collaborative environments for a longer period of time. As children become familiar with the turn-taking protocols and with the software application, we may see different behavior patterns arise.

Our study focused on quantitative analysis of mouse control time and the number of exchanges that took place. As Cole's study suggests, it is also important to investigate children's behaviors qualitatively to further test our hypothesis [3]. Our informal qualitative observations during this study, and observations in our previous studies [5, 6], indicate that most of the time both partners were engaged in the task.

Three areas for future research include generalizing the *give* and *take* turn-taking protocols for more than two children, investigating methods for collaboration when children interact simultaneously with the system, and examining collaboration that occurs over a distance. We looked only at two children playing together because this reduced the number of confounding issues. If more than two children play, the *take* turn-taking protocol extends in an obvious way, but the *give* turn-taking protocol would have to be more complex because it would require some mechanism to specify the child who was to assume control of the game cursor.

Our study deals with children interacting with the system sequentially, using a turn-taking protocol. A system that allows both children to interact in parallel with each other might allow for children to be more engaged and to become more actively involved in the game, but it might also diminish some of the need for collaboration, which is promoted by the need to share limited resources, and thus some of the benefits of collaboration might be lost with parallel interaction. Parallel interaction might also foster excessive competition and aggressive behavior in the form of a race to see which partner can accomplish the most in the puzzle.

The collaborative environments examined in this study were implemented using a single machine, where both partners worked side-by-side. An interesting extension to this study would be to have children work together using the two-mouse *give* and *take* turn-taking protocols operating over a distance, perhaps in a networked environment. It is important to ask whether the sequential nature of *give* and *take* will be as effective when the children are physically separated. Auxiliary support, such as audio or visual feedback, might provide a sense of presence for the collaboration to offset the lack of side-by-side awareness. This needs to be investigated further to understand what other parameters are required for developing turn-taking protocols that can be used effectively in collaboration over a distance in educational settings. This has important implications for distance educational and telelearning.

ACKNOWLEDGMENTS

This research was supported in part by the Natural Sciences and Engineering Research Council of Canada through Postgraduate Scholarships and a Cooperative R&D Project Grant, and by Electronic Arts, the TeleLearning Network of Centres of Excellence, the BC Advanced Systems Institute, and the Media and Graphics Interdisciplinary Centre at the University of British Columbia. Special gratitude is extended to Dr. Shelley Hymel for her assistance in the design of this study and to all of the teachers and students in the schools we visited for their participation in our research.

REFERENCES

1. Borys, S., and Perlman, D. (1985). Gender differences in loneliness. *Personality and Social Psychology Bulletin*, 11, 63-74.
2. Bricker, L.J., Tanimoto, S.L., Rothenberg, A.I., Hutama, D.C., and Wong, T.H. (1995). Multiplayer Activities that Develop Mathematical Coordination. *Proceedings of CSCL '95*. Lawrence Erlbaum Associates, 32-39.
3. Cole, K. (1995). Equity issues in computer-based collaboration: Looking beyond surface indicators. *Proceedings of CSCL '95*. Lawrence Erlbaum Associates, 67-74.
4. Hymel, S., Zinck, B., and Ditner, E. (1993). Cooperation versus competition in the classroom. *Exceptionality Education Canada*, 3, 1&2, 103-128.
5. Inkpen, K., Booth, K.S., Gribble, S.D., and Klawe, M. (1995). Give and Take: Children Collaborating on One Computer. *Proceedings of CHI '95*, Conference Companion. ACM press, 258-259.
6. Inkpen, K., Booth, K.S., Klawe, M., Upitis, R. (1995). Playing together beats playing apart, especially for girls. *Proceedings of CSCL '95*. Lawrence Erlbaum Associates, 177-181.
7. Johnson, D.W., Maruyana, G., Johnson, R.T, Nelson, D., and Skon, L. (1981). Effects of cooperative, competitive, and individualistic goal structures on achievement: A meta-analysis. *Psychology Bulletin*, 89(1), 47-62.
8. Lockheed, M., and Hall, K. (1976). Conceptualizing sex as a status characteristic: Applications to leadership training strategies. *Journal of Social Issues*, 32(3), 111-124.

9. McGrenere, J., Inkpen, K., Booth, K., and Klawe, M. (1996). Experimental design: Input device protocols and collaborative learning. Technical Report 96-11, Department of Computer Science, University of British Columbia, Vancouver, BC, V6T 1Z4, (45 pages).

10. *The Incredible Machine*. (1993). Electronic Game. Sierra, On-Line, Inc.

View publication stats