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Study of Multi-Mouse Puzzle Peer Version: Answering with a Peer

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Abstract: The Multi-Mouse Puzzle (MMP) is an educational application of Single Display Groupware (SDG) developed by Luo et al. With the MMP, multiple users can solve a puzzle with a personal computer sharing one display. While it was designed for collaborative learning, each player tends to concentrate on his or her own puzzle task. A peer version of the Multi-Mouse Puzzle was developed with the intention of improving users' cooperation. In this paper, we describe the design of the system and a comparative evaluation experiment. The results showed that the system was not difficult to operate and provided more opportunities for users to help each other within a group. Through their cooperation, the majority of users felt the puzzles were easier to solve using the peer version compared to the single version.

Keywords: Single Display Groupware, Puzzle Game, Face-to-Face Cooperation, Multi-Mouse

1. Introduction

Computer Supported Collaborative Learning (CSCL) is an area that continues to be actively studied. A number of ideas in CSCL are based on multiple personal computers connected through the Internet. For people who collaborate together, there are many activities that involve simultaneously operating on content in a face-to-face situation. Scotte et al. (2003) pointed out that there is a risk that this may inhibit learners' mutual understanding process. Our research aims to support users' collaborative learning in a face-to-face environment. Single Display Groupware proposed by Stewart et al. (1999) is a framework that overcomes the risks of connected personal computers as a CSCL environment. It can support face-to-face collaboration in which multiple users have their own input device, such as a mouse, while they share information on a single display.

The Multi-Mouse Puzzle is an educational application of SDG developed by Luo et al. (2017). They found that while playing the MMP the players wanted assistance from others, and yet they did not help the other players. In relation to this problem the authors asked the question, "Does the system sufficiently show the possibility for collaboration?" To address this point, the authors developed a peer version of MMP and performed a comparative experiment. The results are presented in this paper.

2. Related Work

2.1 A Framework to Support Face to Face Collaboration

Single Display Groupware (SDG) is a technology in which multiple users control their own input devices to work together sharing one display. "One Mouse per Child", proposed by Alcoholado et al. (2012), is a concept belonging to this framework.

2.2 Systems Designed with SDG Concepts

Moraveji et al. (2009) proposed the Mischief system that supported traditional classroom practices between a remote instructor and a group of collocated students using SDG. The Exchange system designed using SDG concepts was used in teaching the concept of a triangle in elementary school (Caballero et al., 2014). Gomez (2013) carried out practice in pre-school using SDG systems.

The authors previously developed the Multi-Mouse Quiz system (MMQ). It is a SDG quiz application that allows up to four players to answer quizzes, simultaneously connecting several mice to one PC. This research found that children talk to each other more when they share one mouse cursor using MMQ (Zhou et al., 2015). From an educational perspective, the children experienced deeper learning than those in a more traditional class (Zhou et al., 2011).

It is well known that puzzle-based learning approaches are widely used in educational fields, from improving children's brainpower to motivating university students' mathematics learning (Michalewicz, Z. & Michalewicz, M. (2008). Our research achieved a system allowing multiple users to solve a puzzle simultaneously with the aims of enhancing users' awareness of collaboration.

3. Multi-Mouse Puzzle

In previous research, a quiz system called the Multi-Mouse Quiz (MMQ) allowed four users to answer a quiz simultaneously using four mice. We carried out some experiments in elementary schools, in which the school teacher typically used the MMQ in a classroom involving all the children. The children were divided into four groups. Children in the same group shared one mouse to answer the quiz.

However, through experience of using the MMQ in school teaching, we found two issues with it that could be improved. One issue is that multiple choice type quizzes used in the MMQ easily encourage interaction among users than single choice type quizzes. Well-defined quiz questions encouraged thinking rather than just recalling the answer. MMP is designed to present

Figure 1. Start Screen

Figure 2. Entry Screen

Figure 3. Main Screen

more complicated puzzle tasks to its users. For example, the users have to gather letters or 'characters' from a shared area to construct words as answers to the quiz questions.

Another issue is the number of players. MMQ allowed up to four users. Some applications in SDG cater for more users to allow all the children in a classroom to have mice, but with that many mice further problems arise such as the difficulty for each user to identify their own mouse cursor and the hiding of the background by many other users' mouse cursors. Considering these problems, the MMQ limited the number of users and made mouse cursors transparent to reduce obstruction of the background.

However, in the Japanese elementary school, there are around 30 children in one class. In addition, elementary school teachers always use the system with the whole class. Considering the regular class size in the Japanese elementary school, we needed to increase the number of users supported by a SDG application. Multi-Mouse Puzzle (MMP) is therefore designed to allow up to six players to answer puzzles simultaneously, making the use of the system more flexible in classrooms.

Figure 1 shows the Start Screen on which the facilitator clicks a button to start the system. Figure 2 is the Entry Screen on which each user chooses their own color. (Once a color is chosen, the corresponding button disappears.) Figure 3 shows the Main Screen where six users can click the puzzle pieces to complete their answer. If they click a puzzle piece, that piece will appear in their corresponding answer region. The puzzle pieces line up, in order, in the answer region. The facilitator can also use the mouse cursor to give the users some hints (Figure 4).

4. Research Question

In previous research, Luo et al. (2017) carried out an experiment to evaluate MMP's usability. The results of a questionnaire showed that, while playing MMP, each player wanted assistance from other players, but they did not help other players. This leads us to ask, "Do users have no time to answer others' questions because they are concentrating on their own task?" In other words, "Is the system sufficiently indicating the possibility for collaboration?" To address this point the authors developed a peer version of MMP (Figures 4 and 5) and compared it with the single version to evaluate the interface, the interaction between users, and the perceived difficulty of the quiz content.

In the original MMP each player independently answers the puzzle questions. Hence the relationship among the players is 'competitive' rather than 'collaborative.' We call the original MMP the 'Single Version.' The version described in this paper was extended so that several players can play in one team. We call this the 'Peer Version' of MMP.

4.1.1 Interface

Compared with the single version, the peer version allows up to 12 mouse cursors (two users can choose the same color to make six teams of two players). In Figure 5, two users (or two mouse cursors) share one answer region. The research question concerning the interface is whether the users find it confusing to share an answer area with another user.

4.1.2 Interaction

The research question concerning interaction is whether any function of the system provides opportunities for users to collaborate.

Figure 4. Entry Screen

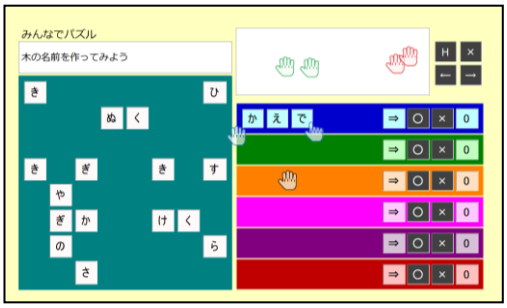

Figure 5. Main Screen

4.1.3 Perception of the Contents' Difficulty Level

Concerning the content, the research question is whether there is any difference in user's perception of the difficulty of solving the puzzle between the single and peer environments.

5. Experiment and Results

A preliminary experiment was conducted to examine the basic characteristics of the two versions of MMP. While the MMP is designed for use in school teaching, the preliminary experiment was carried out in a laboratory with 12 research participants. The research participants were graduate and undergraduate students. None of them had prior knowledge of the research or of the MMP system.

The authors explained the operation of the MMP and that the experiment they were assisting with was a system assessment experiment. Since the maximum number of users of the single version is six, and it is a comparative experiment, we had to arrange for the same participants to gain experience with both versions of the system. The participants were therefore divided into two groups. Each group played both the single version and the peer version. The details of the experimental schedule are shown in Table 1, and both groups conducted the experiment according to this schedule.

After using the MMP system, all the participants were asked to answer a questionnaire survey concerning the differences between their experiences using the two versions of the MMP. In this paper we discuss the differences between the two versions of MMP according to the answers to that questionnaire.

Table 1

Experiment Schedule

Time	Plan	System	Question Set
5 min	Author introduces the system; participants sign the acceptance of experiment	Single version; Peer version	Sample set
15 min	Participants play the system	Single version	Set A or Set B
5 min	Participants answer the questionnaire	-	-
15 min	Participants play the system	Peer version	B (If Set A already done) A (If Set B already done)
5 min	Participants answer the questionnaire	-	

Table 2

Contents of quiz question

	Set A	Set B
1	Make sets of capital and small letters from the same alphabet, e.g., ‘A a’	Collect *katakana* and *hiragana* having the same sound
2	Make words naming fruits	Make words naming colors
3	Make sets of capital and small letters from the same Greek alphabet, e.g., ‘A α’	Make three-letter IATA codes of Japanese Airports

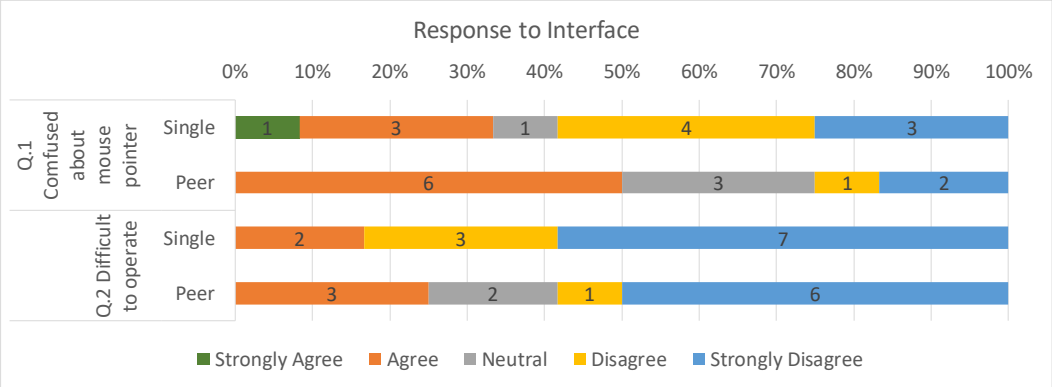

Figure 6. Response to the Interface

5.1 Contents

Two quiz sets were used in the experiment, set A and set B. Each set has four questions as shown in Table 2. The authors designed the two question sets to have the same difficulty and the same question format. However, to avoid any influence from the questions’ contents, the experiment swapped set A and set B between the groups in the single version system and peer version of the system.

5.2 Results

The results will be described as follows, divided into three parts corresponding to our research questions: interface, interaction between users, and perception of the contents’ difficulty level.

5.2.1 Interface

The participants were more confused about the mouse pointers in the peer version compared with the single version. However, in the responses to the question “Difficulty to operate” more than half of the participants did not think the system was difficult to operate in either the single version or the peer version. Two participants answered “Neutral” for the peer version, an opinion which did not occur among the responses for the single version (Figure 6).

5.2.2 Interaction

More than half of the participants asked other people for help, regardless of which version of MMP they were using (Figure 7). When using the peer version, users asked both the other person in their group and all other players for help. In comparison, participants using the single version more frequently asked all other players for help (Figure 8).

Figure 9 shows the responses to the question “Did you cooperate with others” for which more than half of the participants answered “Disagree” or “Strongly Disagree” for the single version of the system, compared to more than half who answered “Agree” for the peer version. The single version therefore received a far more negative response for cooperation. Almost all the participants

chose “Strongly Agree” or “Agree” in the peer version, indicating also that they cooperated with the people in the same group. Two users of the single version answered that they cooperated with other players of the same puzzle (Figure 10).

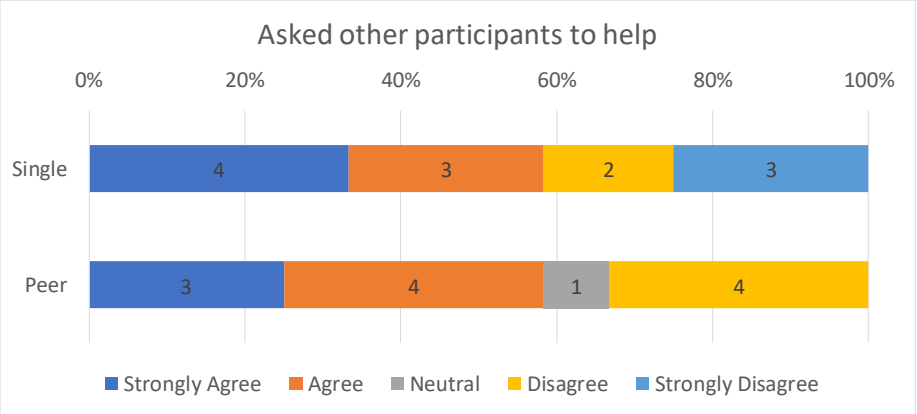

Figure 7. Results of the question “Asked other participants to help”

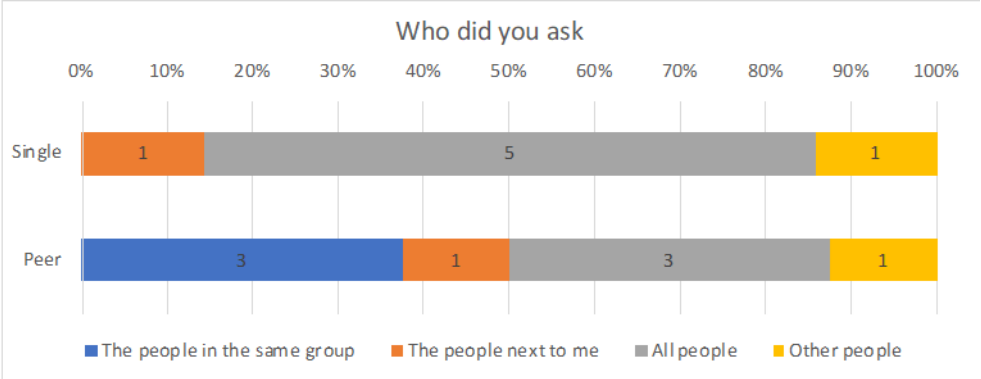

Figure 8. Results of the question “Who did you ask”

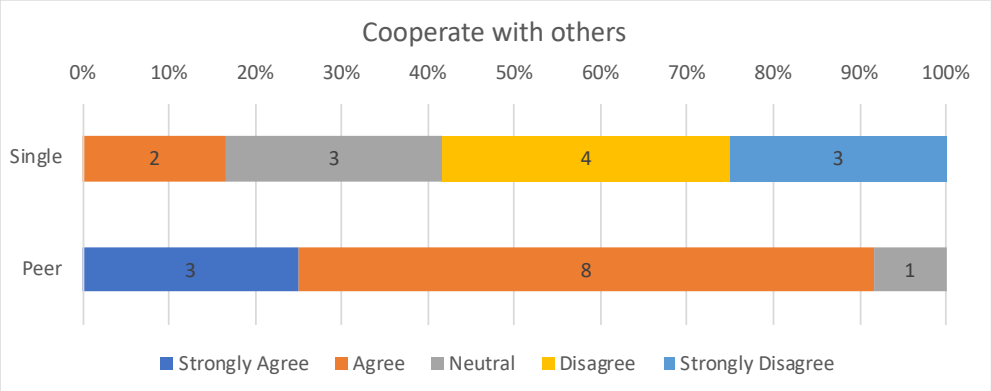

Figure 9. Result of the question “Cooperate with others”

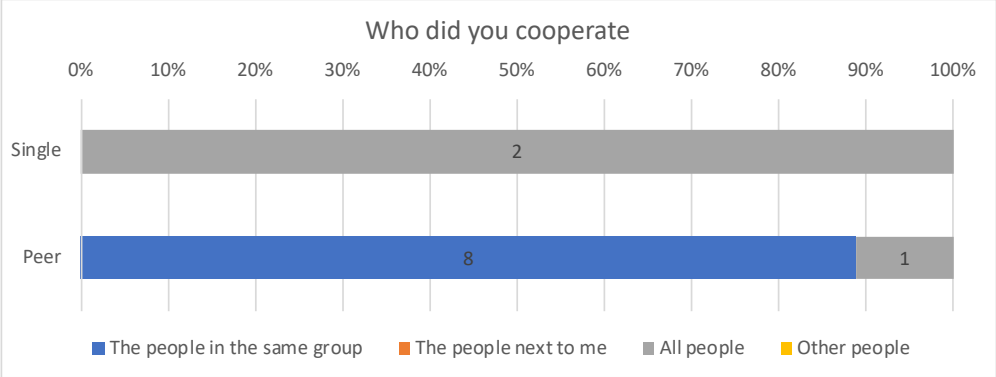

Figure 10. Result of the question "Who did you cooperate with"

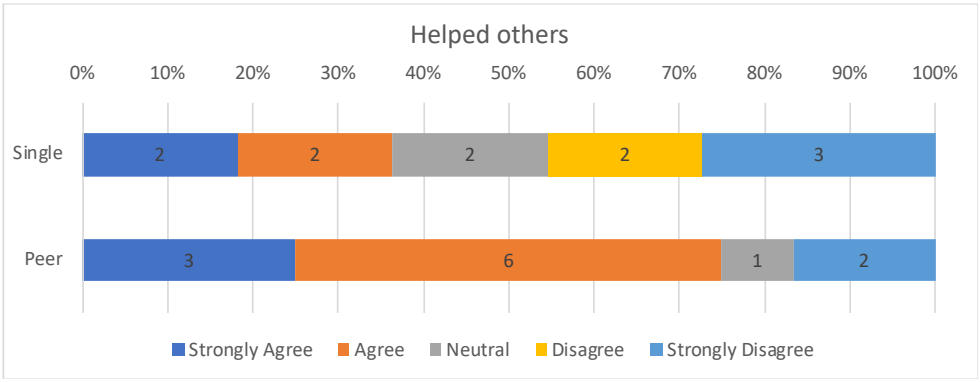

Figure 11. Result of the question "Helped others"

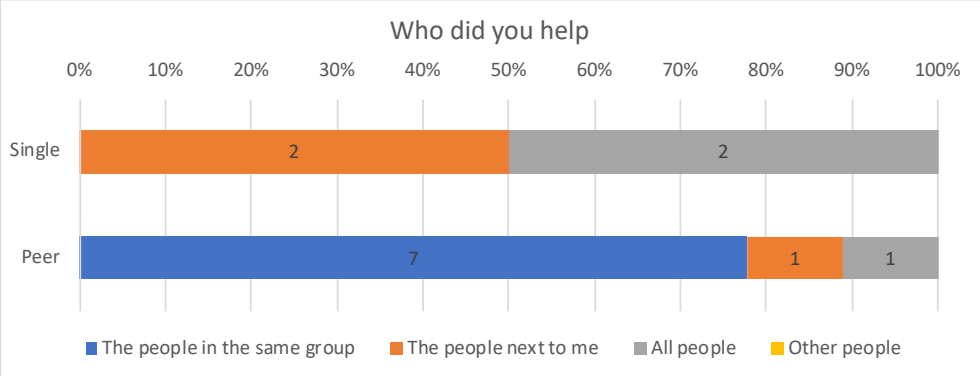

Figure 12. Result of the question "Who did you help"

Table 3

Degree of difficulty

	Single	Peer
Mean	3.14	2.84
SD	0.28	0.63

In the responses to the question "Did you help others", the rate of negative answers and positive answers are approximately equal in the single version. However, in the peer version,

negative answers were received from only two participants, with 70% of the participants giving a positive answer (Figure 11). Furthermore, seven of these participants indicated that they helped people within the same group (Figure 12). In the single version, two participants answered that they helped the people next to them and two participants answered that they helped all the people playing the quiz.

5.2.3 Perception of Contents' Difficulty Level

The question sets A and B were used for both the single version and the peer version of the system. In other words, each question set was used once for the single version and once again for the peer version. The participants evaluated the puzzle contents' degree of difficulty in the questionnaire after they played the system. There were five difficulty levels they could assign to each puzzle question, from 1 (easy) to 5 (difficult). Table 3 shows the average difficulty scores for the two versions, and Figure 13 shows the difficulty level results for every participant.

As Table 3 shows, participants felt the content was easier when they used the peer version, but the standard deviation of those results is larger than for the single version. Almost all the participants evaluated the content of the peer version as being easier than the single version, with one person (Participant I) evaluating them as having the same level of difficulty.

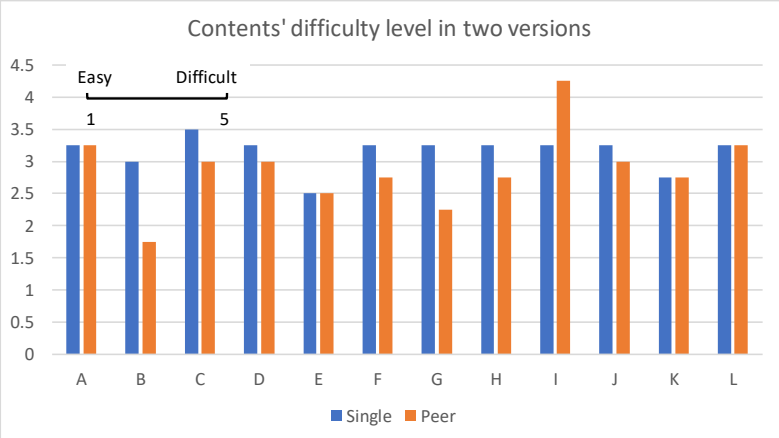

Figure 13. Degree of difficulty indicated by every participant

6. Discussion

6.1 Interface

From the questionnaire answers, at least half of the participants indicated that they were not confused by the mouse pointers and that they did not have difficulty operating either of the experimental systems. However, a few people thought that the peer version was more difficult to operate and felt more confused about the mouse pointers compared to the single version. Two opinions written in the questionnaire indicated that "In the peer version it was difficult to collaborate with other people" or that the user "could not understand what he can do with the system."

Related to the first opinion, as the order of clicking on puzzle pieces in the answers area is important, when two users share the same answer area they need to pay more attention to each other's click order to construct a correct answer, which was not an issue in the single version.

The second opinion relates to the interface design of the system. The system should have a more intuitive design, and this is part of our future work.

6.2 Interaction

From Figures 7 and 8, we see that more than half of the participants want help from other users when they are playing the puzzle system. In the single version, the users asked any one of the other participants for help. In the peer version, the replies indicated that users tended to help and cooperate with players in the same group (Figures 9 and 10). In the peer version two participants sharing the same color share the same answer region. They need to pay attention to each other's behavior and cooperate with each other out of necessity to complete the quiz successfully.

Furthermore, more than 70% of participants in the peer version indicated that they helped others. The system described by Luo (2017) is called the single version in this paper, and we obtained the same response to "Did you help others" in our experiments, but there is a huge difference when compared to the peer version. Users helped others much more when using the peer version.

6.3 Perception of Contents' Difficulty Level

Participants felt the contents' difficulty level in the peer version to be lower than that in the single version. However, a *t*-test was conducted that did not show a significant difference between the single version and the peer version. This is also related to the differences between all participants' evaluations. The standard deviation is larger for the peer version than for the single version, meaning the perceived difficulty level varied widely from person to person in the peer version. Among the evaluations from all participants, only one participant indicated that the content seemed easier in the single version.

7. Conclusion

The peer version of Multi-Mouse Puzzle (MMP), an educational application of Single Display Groupware, was developed with the aim of improving users' collaboration. The peer version allowed two users to select the same color mouse cursor and to share the same answer region. A preliminary experiment was conducted to examine the differences between the original MMP and the peer version. The results showed the following:

- The peer version of MMP was not difficult to operate. The mouse pointers were sometimes confusing in the peer version due to sharing the same answer region.
- The peer version of MMP provides more opportunities for helping people in the same group and cooperating with one another.
- Through better cooperation between users, the content was felt to be easier in the peer version.

The results presented in this paper are based on questionnaire analysis from trails performed by university students. We plan next to apply the developed system in actual elementary school teaching conditions and to use video analysis for the evaluation of user communication.

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