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Research Article

Ability of Children to Draw Mathematical Numbers through Computer Mouse

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Abstract: In this study, the ability of kindergarten children to draw mathematical numbers using a computer mouse was investigated. About 25 children from a kindergarten school located in Skudai, Johor was participating in this study. The number '1' with two different font sizes were used to represent a low level of difficulty as it requires children to drawing a straight line, whereas number '2' with two different font sizes were used to represent a high level of difficulty due to have a curved line. The results showed that the performance of kindergarten children in drawing the number '1' (straight line) were more accurate compared to number '2' (curved line). The size of the objects could affect the accuracy and the speed (completion time). However, the presence of errors in the drawing is due to the psychological motor of children, which is still developing.

Keywords: Children Development, Child-computer Interaction (CCI), computer mouse, Human-computer Interaction (HCI), input device

INTRODUCTION

Nowadays, children are exposed to computer at an early age. Child Trends Databank (2015) had reported the percentage of children ages 3 to 17 in using computer had steadily increased. This is due to widely used of computer as one of the education tools in the schools. Computer mouse had been determined as the most suitable indirect input modality for children in controlling with the computer (Donker and Reitsma, 2007; Wood *et al*., 2004). Therefore, lots of researchers have focused on designing a suitable task in using computer mouse to overcome the limited motor skill of children.

In order to designing the tasks for children in using computer mouse, it is involved two different procedures. These procedures are click-move-click and drag-and-drop (Donker and Reitsma, 2007; Gillan *et al*., 1990; Inkpen *et al*., 1996a, 1996b; Revelle, 2003). Click-move-click procedure consists of click on the object and move the computer mouse without pressing the computer mouse button and click again when it reach to the target. While Drag-and-drop procedure consists of clicking and moving the object simultaneously while pressing down the computer mouse button (drag) then letting go the button after the object is placed at a desired position (drop). However, maintaining the pressure on the mouse is motor demanding. Thus, drag-and-drop might introduce more errors in drawing (MacKenzie *et al*., 1991; Strommen, 1993) because the users are not aware of the mistakes their make (Joiner *et al*., 1998).

The children motor skills continue to develop as they grow up. The speed of their hand movements will be increased as well only until they are reaching 12 years old (Kuhtz-Buschbeck *et al*., 1999). Different methods of developing children's motor skills could influence their performance of the refined movements, which involve eye-hand coordination. The children's motor skills will be improve gradually through writing to an extent of being able to carry out another motor tasks related activities by using computer mouse (Lindemann and Wright, 1998). As computers are used more often by the mature children, it is also expected that the ability to use a computer mouse improves with the age (Crook, 1992; Donker and Reitsma, 2007; Joiner *et al*., 1998; Wilton and McLean, 1984). Apart of this, previous experience could also influence children performance in the term of accuracy and time taken when using computer mouse in completing the task given (Lane and Ziviani, 2010).

Lane and Ziviani (2010) suggested biggest size of target could increase children aiming and controlling computer mouse performance. This suggestion was fulfilled the requirement of the Fitts Law. Fitts'Law is used to calculate the pointing movement time based on target size and distance (Fitts, 1954). This equation has been modified and improved by Welford (1968) and MacKenzie (1992) and was published as a part of the ISO 9241 standard (MacKenzie, 1992; Welford, 1968) in the form of:

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$$MT = a+b \log_2 (A/W+1) \quad (1)$$

where, MT represents the movement time, A represents the object distance, W represents the object width while a and b represent the constants. In simple terms, this equation implies that more time will be needed to point at far away small objects. The following equations are also connected to the Fitts' Law:

$$ID = \log_2 (A/W+1)$$
$$IP = ID/MT$$

where, ID represents the index of difficulty of the typical task and IP represents the index of performance of the participant. Various merging of A and W values may produce the same index of difficulty. The performance index had used to contrast the performance of either different groups of people (under the same conditions) or different conditions (within the same group of people). It can be concluded that IP is equivalent to 1/b after MT is substituted into Eq. (1) when a = 0.

Fitts' Law is only applicable to an error-free performance but children often make mistakes when controlling the computer mouse. This study was conducted to examine the competency of children's when drawing using a computer mouse in term of accuracy and errors. Drag-and-drop procedure is involved when using a computer mouse in drawing. Drop errors may happen when children fortuitously 'drop' the cursor (release the computer mouse button) during drawing (Inkpen *et al*., 1996a), which is probably due to the difficulty of pressing the computer mouse button continuously (Inkpen, 1997; MacKenzie *et al*., 1991; Strommen, 1993). Drawing errors might occur when they are drawing outside the specified area.

MATERIALS AND METHODS

Participants: Twenty-five kindergarten children from Skudai, Johor were recruited in order to conduct this study, whereby 13 of the children were boys and 12 of them were girls. The average ages of the recruited kindergarten children were 5.42 years old. All of the children have a computer in their homes. Nevertheless, there was only one child who was good in operating the computer due to his family educational background. Additionally, he had been sent for training at a computer center. However, he was not excluded in the analyses as his performance was accepted within the range of the data obtained. Furthermore, Joiner *et al*. (1998) noted that number of practices can improve the computer mouse controlling performance especially for children who aged from 7 to 8 years old. Previous experience was not an influential factor to success in the performance at the younger ages (between five to six years old). The children were given a pack of snack as compensation for taking part in this experiment. All the participants had to use a computer mouse on their right-hand side. Donker and Reitsma (2007), Peters and Ivanoff (1999) and Woods *et al*. (2003) reported that left-and-right-handers did not affect the action of controlling the computer mouse. Hence, this factor was eliminated in the present study.

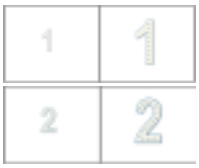

Fig. 1: The typical projected screen of the prototype software

Apparatus and tasks: In order to test the competency of the kindergarten children in drawing number '1' (straight line) and number '2' (curved line) using the computer mouse, a prototype was running on a computer. A simplified software environment using the general presentation tools-Microsoft Power Point was used to design this prototype. The two-buttons of a scroll wheel infrared mouse and the output of a 15-inch screen computer laptop were used to conduct the experiment. Since this experiment only required a computer mouse, the kindergarten children were not allowed to operate the keyboard. Nonetheless, the children were allowed to put the computer mouse at anywhere according to their comfort. The lines used in this experiment were represented by two different numbers, which was displayed on the screen. Both numbers were created using a regular Arial font but with two different font sizes: 100 pixels and 200 pixels (Fig. 1). Simple numbers were selected instead of complex numbers such as '5' and '8' because some kindergarten children have not exposed to such complex numbers yet in their learning syllabus. The children were required to draw the lines guided by the dot using the computer mouse, in which the drawing must be made inside the area of the number.

Procedure: The test was conducted in a quiet room as prepared by the kindergartens' authorities to avoid disturbance throughout the experiment. Before the experiment began, the experimental procedure was briefed to the participants. The proper way to draw the lines using the computer mouse was demonstrated. The children were asked to draw the numbers by following the dotted lines in between the specific area. Both numbers reflected different difficulties of drawing a line. There was only one angle involved when drawing the straight lines, while many angles were involved when drawing the curve lines.

The time allocated for each child to conduct this experiment was approximate twenty minutes. The time

taken to complete each task, including time spending for trial and error such as drop error and drawing error was recorded. Drop error occurred when a participant dropped the objects accidentally before reaching the end of the dot. Drawing error, on the other hand, occurred when a participant draw outside of the specific area accidently. The drawing was completed successfully if and only if participants can draw the number by moving the computer mouse with a continuous and un-break sequence of click and move and release eventually. The drawing accuracy was counted based on the number of dots being connected during drawing. The equation can be expressed by:

$$A = C/T$$

where,
A = The accuracy
C = The total number of dots drawn on the target number
T = The total number of dots on the target provided

Thus, by calculating the accuracy, the performances of the children can be determined.

RESULTS

For font size of 100 pixels, the average time taken for the kindergarten children to draw a number '1' was 6.25s and number '2' was 9.93s. On the other hand, the average time taken for children to draw number '1' and number '2' completely with font size of 200 pixels was 9.25s and 14.71s respectively. It should be noted that the time spending for trial and error was also included in the total time taken. As expected, children performed faster in drawing number '1' (straight lines) compared to number '2' (curved lines) even with different sizes of the objects. This indicates that drawing a curved line is harder than drawing a straight line. Therefore, more time was taken to draw the curved line. A significant difference in the time taken for straight line (M = 9.25s, SD = 3.62s) and curved line (M = 14.71s, SD = 6.15s) conditions; t (24) = -6.58, p < 0.001. Table 1 shows the average time taken for drawing different sizes of objects.

The average accuracy for kindergarten children to draw number '1' and number '2' lines in 100 pixels was 54 and 36% respectively. In 200 pixels, the average accuracy for drawing number '1' was 74%, while the average accuracy for drawing the number '2' was 45% only. A paired sample t-test was conducted to study the difference in accuracy of drawing both number '1' and '2' in 200 pixels. The results showed that there were significant effects on the performances since drawing straight lines were more accurate than drawing the curved lines, whereby t (24) = 5.509, p<0.001. The paired sample t-test was also conducted to observe the difference in accuracy of drawing the objects in 100 pixels. The results depicted that there were no significant effects of accuracy in drawing the straight lines and curved lines, where t (24) = 3.903, p<0.0005. Based on the results, it can be deduced that the accuracy of kindergarten children in drawing a straight line was more accurate than drawing a curved line in the large-sized objects. However, in drawing small-sized objects, there were only subtle differences in accuracy.

Table 1: Average time taken to draw different sizes of number '1' and '2'

Size (pixels)	Number	Time in Seconds (SD)	Accuracy (SD)
100	1	6.250 (3.54)	0.54 (0.17)
	2	9.930 (4.82)	0.36 (0.17)
200	1	9.250 (3.62)	0.74 (0.29)
	2	14.71 (6.15)	0.45 (0.14)

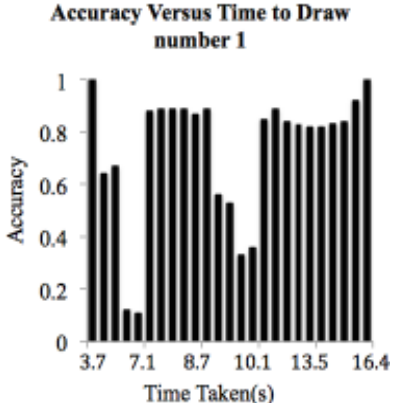

Fig. 2: Children's drawing performance for number '1'

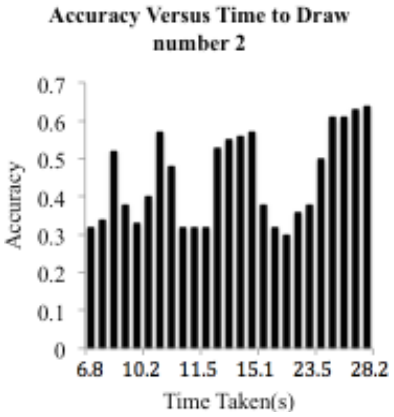

Fig. 3: Children's drawing performance for number '2'

In Fig. 2, most of the children reached above 80% of accuracy in drawing number '1', but none of them reached above 80% in drawing number '2'. By comparing both results, Fig. 2 and 3 proved that most of the participants performed well when drawing the straight lines with less time taken than drawing the curved lines. However, the longer the time taken, the better the performance achieved by the children in drawing both straight and curved lines. Therefore, it can be said that the time taken by children to draw the

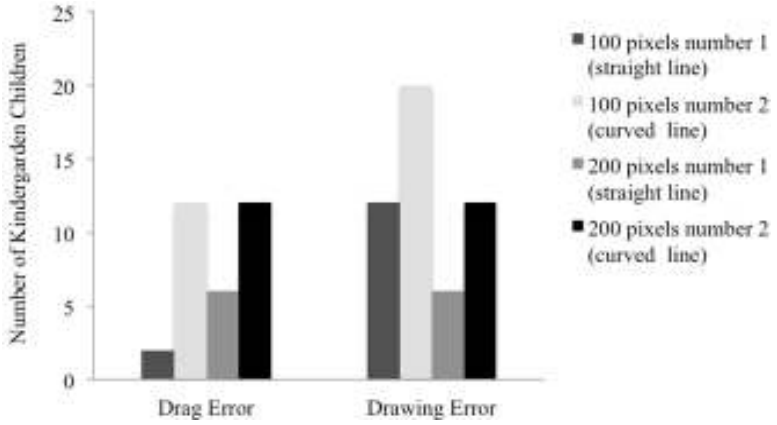

Fig. 4: Number of children who made errors during drawing

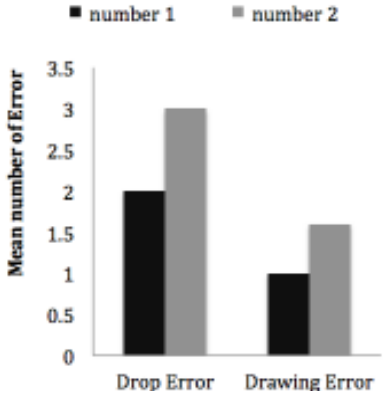

Fig. 5: Mean error when drawing on 100 pixels

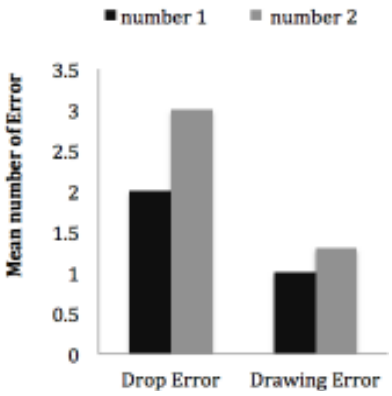

Fig. 6: Mean error when drawing on 200 pixels

Fig. 7: Drawing results for number '1'

Fig. 8: Drawing results for number '2'

objects could affect the drawing performance. This result was expected and in line with other previous researchers (Donker and Reitsma, 2007).

Based on Fig. 4, it can be seen that the participants produced more errors when drawing the objects in 100 pixels. As expected, more errors occurred in drawing smaller targets. Based on Fitts' law formula where ID = $\log_2$ (D/W+1), the index of difficulty decreases when W (size or width of target) increases. However, Fig. 5 and 6 shows increasing the size of targets will not decrease the number of errors produced by the children. All paths taken by the participants in drawing number '1' and number '2' in different scales illustrates in Fig. 7 and 8.

DISCUSSION

This study evaluated the children drawing ability using an indirect interaction device. The results showed that kindergarten children were capable of utilizing a computer mouse to draw straight line and curve line on the screen which represented by number '1' and number '2' respectively. However, more times are needed for the children to complete the task in order to achieve higher accuracy. Occasionally, there were a number of participants showed the behavior of direct interaction by pointed and moved their finger on the screen to show the drawing direction. Children at this aged are tended to an intuitive and direct interaction rather than indirect interaction.

Besides, the results also showed that children required more time to complete task in drawing number '2'. This indicates that children have more difficulties when drawing curve line compared with straight line. One of the reasons is because the structure of number. The number '1' has simple structure which is straight line, is more easy and comfortable to draw. The number '2' has the multiple angles on the line that make children feel uncomfortable and difficult to move the mouse in different angles.

Another difficulty that kindergarten children faced during draw the numbers using computer mouse is their strength of motor skills. The motor skills of the kindergarten children are not yet fully developed in this aged. Hence, they have a weak motor skill which causes interaction problem using the mouse. In the observation of performing the task given, it was observed that some of the participants tended to control the movement of the mouse using two hands since they found it is hard to control the computer mouse. Therefore, computer mouse is not suitable input devices in use for kindergarten children.

CONCLUSION AND FUTURE DIRECTION

This study was conducted to investigate the ability of kindergarten children in drawing mathematical numbers with the different level of difficulties using the computer mouse. These difficulties were represented by number '1', which symbolized lower level of difficulties since it requires drawing a straight line only and number '2', which symbolized higher level due to the present of a curved line. This study is essential due to the importance of input devices for the usability of education software. The results obtained confirmed that kindergarten children were capable of using the computer mouse in terms of both speed (time taken) and accuracy. It was also evident that they could draw on straight-lines more accurately compared to curved lines. Overall, it can be concluded that most of the kindergarten children could use a computer mouse to draw a mathematical number, even though they did not perform the correct way in controlling the computer mouse.

According to Fitts' law, the index of difficulty is expected to decrease when size or width of the target increase. Surprisingly, the number of errors occurred did not decrease even when the participants were drawing the same objects in bigger scales. Thus, the existing input devices do not fit to the children usage. In order to reduce this error, it is suggested an alternative technology to assist the current education technology for kindergarten children that will improve the children's skills in drawing mathematics number. For example, there are researchers creating a new device by combining the both direct and indirect input modality in the field of game and technology (Arroyo-Palacios and Romano, 2010; Rosas *et al*., 2003; Chowdhury *et al*., 2013; Strommen, 1993). Development in 'nouse' technology can be applied as it translates the cursor movements through the nose movements (Gorodnichy and Roth, 2004). These devices are more applicable and suitable for young children used compared to the computer mouse. Nevertheless, further study should be conducted before implementing the proposed input modality for the educational purpose. By proposing new input modality with flashcard and natural gestures, it is believed that these advanced features can create self-learning opportunity for children to learn the mathematical numbers in an efficient way.

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