Study of Touch Gestures Performance in Touch Devices by Young Children

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Abstract—This research tests the performance of 16 four and five-year-old children with an iPad application with four experiments corresponding to four different gestures: Point-and-Touch, Drag-and-Drop, Zoom-in and Zoom-out, and Rotation. The results show that 5-year-old children perform better than 4-year-old children in the four experiments. The results indicate that interaction design for young children that uses point-and-touch gestures should consider smaller distance between targets, and design using drag-and-drop gestures should consider larger size of targets, as these have significant effects in the way children perform these gestures.

Keywords*-touch devices; young children; touch gestures*

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I. INTRODUCTION

Children start developing their fine motor skills as they start writingas early as 3 years old [1]. A research study indicates children are able to use technology such as mouse computers before their ability to read and write [2]. Nowadays touch devices, especially tablets, are introduced to children through learning applications and games. "There has been a rapid growth in recent years in the range of non-keyboard input devices (NKID) utilized with computer systems (e.g. trackball, touch screen, touch pad and trackpoint)" [3].

Children's interaction style with computers has traditionally been with the use of a mouse, where the main tasks they perform are point-and-click and drag-and-drop. Previous research with children has focused on these interactions [4]. However, touch devices have introduced more interaction styles to perform similar task previously performed with a mouse. The shift towards touch screens is replacing mouse and keyboard interaction methods with technology, and it is changing the user experience in dealing with technology from an indirect (mouse and keyboard) to more direct method [5]. The interaction style has changed to overcome the most common way of dealing with technology, because "it also provides an excellent alternative to the use of other hardware such as mouse, stick pointer, digital pen, touch button and keyboard". This has brought new concepts of touch gestures such as: point-and-click, drag-and-drop, zoom-in and zoom-out, and rotate [6]. Children can learn how to use touch devices easily as they can learn rapidly with no need for previous experience to perform specific skills on touch devices [7,8]. Multi-touchtechnology and direct interaction are also becoming more familiar ways to organization of content, because they use flexible touch gestures to interact with the screen [9,10]. However, touch devices are made for the mass market, general audience, and mostly for adults as they are the target customer [5]. More research is necessary in regard to children's ability to perform touch gestures, especially for young children between 4 and 5 years old [4].

II. RESEARCH GOAL

The goal of this research is to study the ability of young children to interact with touch devices and perform gesturing tasks such as: point-and-touch, drag-and-drop, zoom-in and zoom-out, and rotate. We will describe the task completion times using Fitts' Law and we will describe the effects that target size, task length have in a number of variables for all gestures studied for all age groups. We will also perform cross-age observational comparisons especially for the Zoom-in and Zoom-out and Rotation gestures, since these are the least commonly studied gestures.

III. RELATED WORK

A research study suggests that distance does not have much relationship with the accuracy of a target for children, and size instead affects the accuracy [11]. However, several problems occurred in touch screens using point-and-touch strategy compared to point-and-click. Children touch the screen and their fingers slightly slide before raising their finger off the screen, this action converts the touch-and-point to drag-and-drop action in touch screens [8]. Another problem with touch screens is related to the technical hardware/device itself. Young children tend to repeat a task if it was not performed instantly. For instance, some of the touch screens are slow in response, so children tend to repeat the task resulting in unintentional touch points [5].

Young children can perform drag-and-drop task by themselves or with a little help in directions of how to use drag-and-drop in both mouse and touch interaction styles, even though children have some difficulties in accomplishing drag-and-drop task [5,12,13]. Inkpen [14] states that children prefer to perform point-and-click tasks over drag-and-drop tasks, and children actually performed better in point-and-click experiment. The same research found more error in dropping an object compared to picking up an object. Moreover, fine motor skills development of 4, and 5- year-olds makes continued pressing on the device or holding a specific object with their fingers to drag it challenging [12]. Another problem in drag-and-drop is the way the children hold the device itself. McKnight and Cassidy note that many errors happen because of touching the edges of the device [8], as the touch devices usually record the first or/and second touch.

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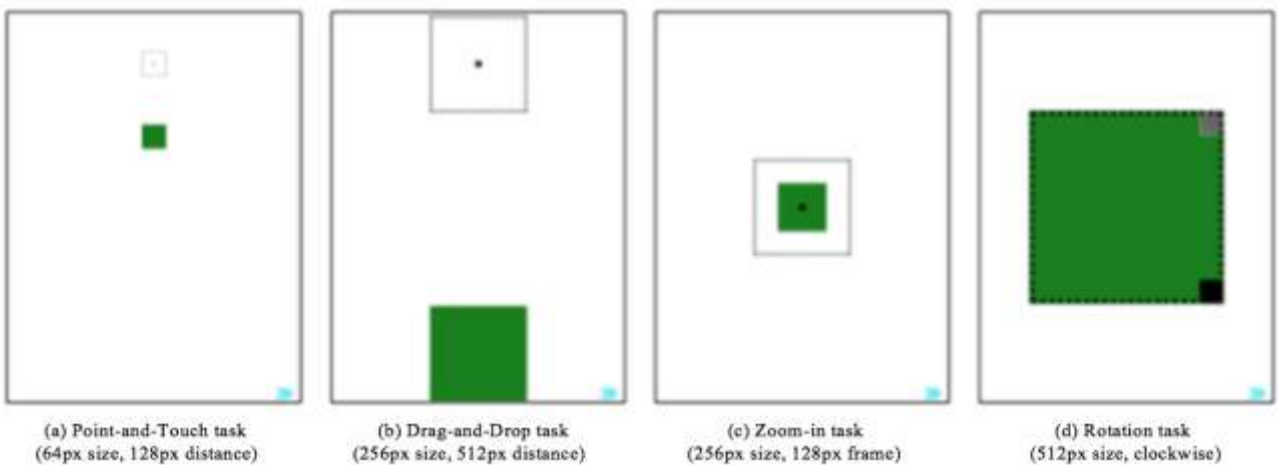

Figure 1. Research design for the four different experiments

A. *Fitt's Law*

We used Fitts' Law to analyze movement time. Fitts' Law is a model that relates the distance and size of a target to predict the movement time of a fine motor skill task [15]. The formula used for most of previous mentioned research studies is as follows:

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

Where MT is movement time in milliseconds, a and b are empirically determined constants, A is the distance between targets and W the width of a target.

IV. METHODOLOGY

A. *Participants*

We recruited 4 and 5 year-old children from different backgrounds of different areas in Minnesota in the United States. The demographics are as follows based on a total of 16 participants: 16 able-bodied children; 9 males and 7 females; 12 4-year-old and 4 5-year-old; 14 right handed and 2 left handed. Children reported using and iPad or other touch devices for average of 5.4 hours a week. All demographic information was filled by the researchers according to the answers provided by the parent or guardian of the child prior to the beginning of the study using the form shown in Figure 2.

Figure 2. Demographic information screen before starting the tasks

B. *Hardware*

The children played a touch-based interaction application that was designed for this research study. The application was designed for the iPad air, and had some game components in it to reward the children when they completed parts of the experiment. We developed the iPad application with objective-c in Xcode 5.1.1. All the data was collected in csv files. SPSS 20.0.0 was used to analyze the data.

C. *Research Design*

The experiment was designed with a portrait orientation and the child would hold the iPad vertically to perform four different tests as it is shown in Figure 1. Before the application started we collected demographic data and then the child would chose a color for the main block for all four different tests. We told the children that the test consisted of a game were they had to play with a colored block. A dotted frame with a dot in the middle was used as a target in the Point-and-Touch test and the Drag-and-Drop "games" or tasks. Similarly, colored blocks needed to be resized or repositioned in the dotted frame respectively for the Zoom- in/Zoom-out and the Rotation tasks. After completing each experiment the application would display a reward screen where they earned a "sticker". A thank you screen would display after completing all tasks (see Figure 3).

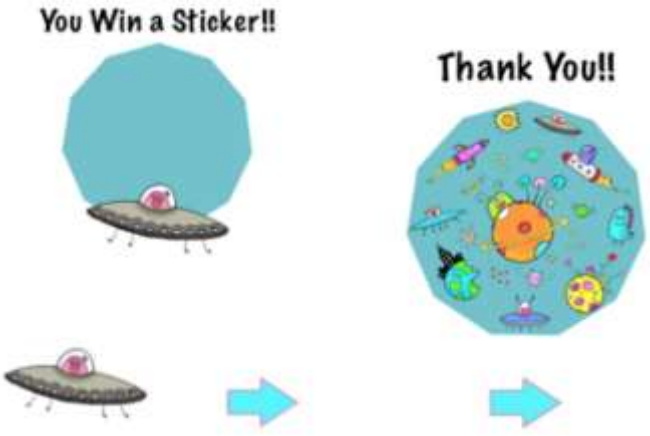

Figure 3. Experiment separation screen and end of tasks screen

1) Point-and-Touch and Drag-and-Drop tests

Children had to touch a colored block and then touch the center of the framed block for the Point-and-Touch test. Similarly, children had to drag a colored block and drop it in the framed block. (see Figure 1). In both tests we considered three block sizes, 64px, 128px, and 256px, and two distances, 128px (short distance), and 512px (long distance). Each child performed total of 30 tasks in each test selected randomly from these block- distance combinations: ten tasks of 64px-128px, five tasks of 64px-512px, five tasks of 128px-128px, five tasks of 256px- 128px, and five tasks of 256px-512px.

2) Zoom-in and Zoom-out test

For zoom-in, children had to resize the colored block to match the frame. If the frame was larger, it required a zoom-in gesture with two fingers. If the frame was smaller, it required a pinching gesture with two fingers. For zoom-in, we considered block sizes 64px and 128px, and a frame size of 256px. For zoom-out, we considered one block size of 256px and two frame sizes of 64px and 128px. Each child performed 10 tasks of each block-frame size combination, for a total of 40 tasks. Tasks were randomized.

3) Rotation test

We considered blocks of size 128px, 256px, and 512px and matching frame sizes. For each block size, we also considered initial positions that would require a rotation direction that was either clockwise or counter-clockwise. Each child performed 5 tasks for each block-rotation direction combination for a total of 30 tasks. Tasks were randomized.

D. Independent and Dependent Variables

Point-and-Touch and Drag-and-Drop experiments had size and distance as dependent variables. We studied the distance to target upon first release, the frame misses and the completion time. For Zoom-in and Zoom-out the dependent variables were image size and frame size and we looked at release distance from edge of block to frame at the corners and completion time. For the rotation test we had size of block and rotation direction as dependent variables and we looked at distance from edge of block to target block, rotation side, rotationdegree (arc length between target and release points at the corner of the blocks) and time.

V. RESULTS

As the number of participants is small n=16 we have performed data transformation to normalize the data. Keene [16] suggests that using Log transformation as the most recommended data transformation. We have used a data transformation for the data that is not normal based on procedures found here [17]. We used one-way independent measures ANOVA to analyze all the variables.

A. Point-and-Touch

The Fitts' law correlation coefficient does not indicate that Fitts' law is a good prediction model for this kind of task in children (see Table 1). Repeated measures ANOVA indicates that distance had a significant effect of p=0.007 on the distance to target upon first release variable, with release distances closer to target for shorter distances. No other variables were significantly affected by size and distance.

B. Drag-and-Drop

We adjusted the regression analysis for this experiment due to an outlier. We found that with the smallest size (64px) and the largest distant (128px) combination the task was as much as 50% harder than the next hardest task. Without this outlier, Fitts' Law can be a good time prediction model for drag and drop gestures in children, with an R-square value of 0.985.

ANOVA results indicate that size had a significant effect of p=0.015 on the distance to target upon first release variable, with release distances closer to target for larger targets. No other variables were affected by size and distance.

C. Zoom-in and Zoom-out

The analysis did not yield any significant effects for the variables studied for the Zoom-in and Zoom-out tasks.

D. Rotation

Size had a significant effect of p<.0001 in the distance from edge to block to target block. The initial rotation direction had marginally significant effect on rotation side with p=0.053. No other significant effects were found from the independent variables.

Table 1. Regression Data by Test showing Fitts' law correlation coefficient and constants a and b (milliseconds)

T est	R2	a	b
Point-and-Touch	.002	8131.2	565612
Drag-and-Drop	.0985	35475	142699
Zoom-in Zoom-out	.672	56795	164361

VI. FURTHER OBSERVATIONS

General observations have been identified in this research based on the size and distance for point-and-touch and drag-and-drop test, initial image size and frame size for zoom-in and zoom-out test, size and rotation side for rotation test. An observational note on all children is they try to drag-and-drop even if the instruction were to point and touch.Most children were familiar with drag-and-drop task and it was easier and less confusing for them compared to point-and-touch. In particular, children would drag blocks by default if the blocks were smaller regardless of the distance and task, as shown in figure 4.In the same figure we can also observe that the children were more accurate when the blocks were larger.In the drag-and-drop test we observed that the children did well when the distances were short and the block size were small, as shown in figure 5(c),and almost all children were consistent in performing this task. However, in the long tasks we noticed that the children did better when blocks were larger, a show in figure 5(a) and figure 5(b).

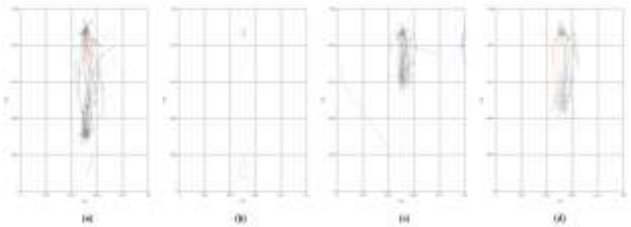

Figure 4. Point-and-Touch observations (a) 64px-long distance (b) 256px-long distance (c) 128px-short distance (d) 256px-short distance

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Moreover, the children had better motor control in drag-and-drop tasks compared to point-and-touch tasks as you can notice comparing the paths in figure 4 to the paths figure 5.

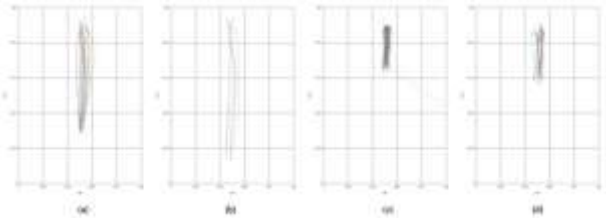


Figure 5. Drag-and-Drop observations (a) 64px-long distance (b) 256px-long distance (c) 128px-short distance (d) 256px-short distance

The first two tests were easier for the children to perform compared to the zooming and rotating tasks. As the four tests were performed on a touch device that was held vertically by all the children, pinching and spreading gestures were performed mostly aligned with the device. An observation on the zooming tasks is that the children performed better when the blockwas larger (128px) and they had to zoom-in (spread) for shorter lengths (256px frame) (see Figure 6 and compare 6(b) to 6(a), 6(c) and 6(d)). Since children have small fingers it was hard for them to spread or pinch (zoom-out). We observed how one of the children had to use two hands to spread and pinch. There were nosignificant differences between the pinching and spreading tasks in term of difficulty, as some children performed better in either zooming-in or zooming-out.

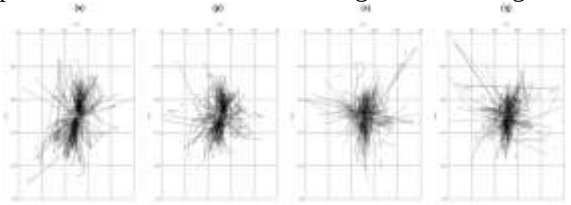


Figure 6. Zoom-in and Zoom-out observations (a) 64px block zoom in 256px frame (b) 128px block zoom in 256px frame (c) 256px block zoom out 64px frame (d) 256px block zoom out 128px frame

The rotation experiment was the hardest tasks for the children. One of the observational notes for rotation is that the children have smoother lines in rotating clockwise, especially if the blockwas smaller as shown in figure 7.

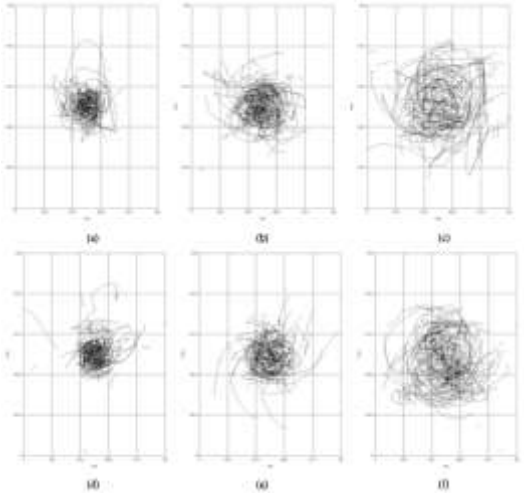
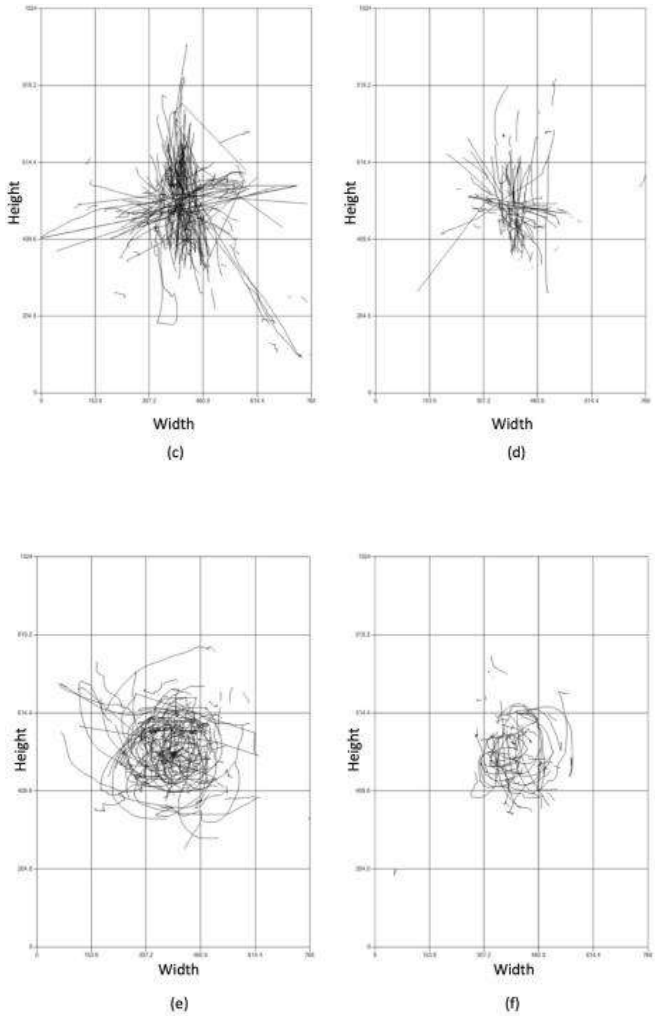


Figure 7. Rotation observations (a) 128px clockwise (b) 256px clockwise (c) 512px clockwise (d) 128px counter clockwise (e) 256px counter clockwise (f) 512px counter clockwise

We found some interesting differences between the age groups that we would like to point out, especially for the spread and pinch gestures and the rotation tasks, being that these are the least commonly studied. These comparisons are purely observational and more data is needed to substantiate any potential general claims. Some of the observational notes on the children's performance in the first experiment (see Figure 8 (a) and (b)), shows thatsome children tried to drag and drop more than touch-and-point. Some children performed better in touch-and-point and few of them tried to drag-and-drop. Zoom-in and zoom-out was one of the hard gestures for all the children to perform. As Figure 8 (c) and (d) shows that 4 year-old children spread more while zooming out and touch the edges of the screen. However, for the 5 year-old they are more focused on the block itself to zoom-out. Rotation was also a difficult gesture for children. Figure 8 (e) and (f) shows that 5 year-old children performed better with smoother rotations than 4 year-old children, and 5 year-old children were more focused in the middle of the screen.



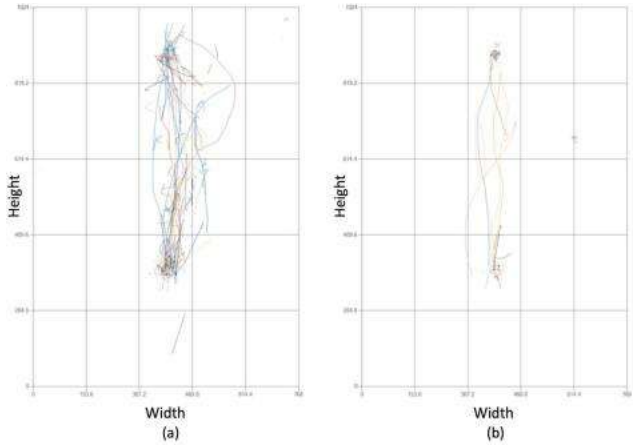


Figure 8. Four and Five-year olds observations from different experiments (a)-(b) Point-and-Touch (64px-512px) Four and Five year-olds respectively. (c)-(d) Zoom-out (256px) Four and Five year-olds respectively. (e)-(f) Rotation (clockwise, 256px) Four and Five year-olds respectively.

VII. CONCLUSION

The results indicate there are significant effects in young children's performance depending on design choices for touch gesture interactions. Point-and-touch designs foryoung children should consider distances between object, and the Drag-and-Drop designs should consider larger sizes of the objects. Designer should consider size as it affects the children's rotation gesture ability.

VIII. LIMITATIONS AND FUTURE WORK

Some limitations for this research are the design sensitivity of the experiment and the small sample size. In particular the Zoom-in/Zoom-out Rotation tests were too sensitive, and many children's tasks ended at the first touch ended for each trial, which made it harder for the children to control the blocks. Other touch gestures can be tested, such as rotation with one finger, slide, flick, tap and hold. An extensive study with a larger sample of young children can be made to study more in depth and substantiate the differences we observed in some of the gestures performed between 4 and 5 year-olds. Future research can also be focused in studying the abilities of children with motor impairing disabilities with touch devices.

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