TOUCH-PANEL USABILITY FOR CHILDREN

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ABSTRACT
In the past few years, touch panels have increasingly been used in children’s education, and more research has been devoted to the development of electronic schoolbag. However, children often encounter difficulties operating touch screens, possibly due to their relative lack of experience using computers or touch panels, or because of the small size of their hands. This study investigates the drag, zoom and rotation operations of 4.3-inch and 10.1-inch touch panels, aiming to provide recommendations for appropriate movement speed settings. The operating gestures used by child users were also observed. The movement rate of 30 young adults using 4.3-inch and 10 inch touch panels were taken as base values, and compared to the movement rate of 30 other children serving as test subjects. Overall, children performed better on the 10.1-inch panel than on the 4.3-inch panel, thus 10.1-inch panels are recommended for use in electronic schoolbag for children. In addition, results for the children’s average drag rate (0.039 inch) and average rotation rate (0.024 ~ 0.026 inch) on the 10.1-inch screen can be used as a settings reference. Finally, the children were found to all use gestures combining the use of thumb, forefinger and middle finger.

KEYWORDS
touch panels, electronic schoolbag, usability, children

1. INTRODUCTION
The introduction of the iPhone[1] and iPad[2] has prompted many electronics manufacturers to begin to produce touch panels, and touch panels have already become quite commonplace. Touch panels are primarily found in portable electronics products such as smart phones and tablet computers. According to the Nielsen Company[3], by February 2012 smart phones already accounted for 50% of the American mobile phone market. Current smart phones have largely followed the iPhone and Android OS phones in integrating 3.5 inch panels, but some brands are now promoting models with larger screens. Though some smart phones support panels as large as 5.3-inches, currently most screens are about 4 inches in size. In addition, aside from the 9.7 inch panel used in the iPad2, large brands such as SAMSUNG[4], ASUS[5] and ViewSonic[6] are promoting tablet computers with 10 inch screens. While some less popular devices, such as the HTC Flyer[7] and RIM’s Blackberry PlayBook[8] feature 7 inch screens, most touch panels are about 10 inches in size. The popularization of touch panels has spurred the development of touch panel-based educational applications for children. Chih-Yung and Jang-Ping [9] designed a suite of digital learning programs linked by wireless technology to an electronic schoolbag that promotes learning while reducing the weight of the bags young learners need to carry and freeing learning from time and space constraints. Compared to conventional learning materials, the digital learning programs are more lively and vivid, and thus enhance engagement with learning. Doukas, et al. [10] proposed a concept for future classrooms based on student electronic schoolbags combining wireless technology and tablet PCs. However, touch panel operation is very different from that of mouse-based interfaces. For example, while both the mouse and touch panel feature drag action, a mouse-based system
allows the speed of the mouse to be manually adjusted. In addition, on tablets the user cannot adjust the display ratio for zoom and rotation.

Fitts' Law[11] has been applied frequently in the research of human-computer interaction, thus showing that computer interface usability has received great focus. One study is about the efficiency of using different input devices, comparing speed and error rate between the mouse and touch device[12]. Mackenzie, et al. [13] compared the performance of a mouse, track ball and stylus with a tablet. In addition, some research addresses operating with a single-hand and dual-hand. Forlines, et al. [14] compared the performance of using a single-mouse, dual-mouse, single-hand and dual-hand. Brandl, et al. [15] measured bimanual pen and direct-touch interaction on horizontal interfaces and found that pen-and-touch input is superior in terms of speed, accuracy, and user preference than pen-and-pen as well as touch-and-touch input. Kin, et al. [16] compared the operational performance of using direct-touch, bimanual, and multifinger input on a multitouch workstation. The results show that direct-touch with a single finger delivers a large performance benefit; the bimanual interaction provides a smaller additional benefit; and the multifinger input shows no additional benefit for multitarget selection. Today, most research into touch screen usability is devoted to effective use among younger users. Although touch panels have already begun to be applied to education for children, these children may encounter difficulties using the devices because of their relatively limited experience in using computers and because of the small size of their hands. This study investigates the operation of 4.3 and 10.1-inch touch panels by children to recommend a more appropriate aspect ratio for child-specific touch panel use. Common touch panel actions are tested including drag, zoom and rotate, with the operation speed of a group of young adult touch panel users taken as the baseline. In addition, this study observes the hand gestures children use in interacting with touch panels.

2. METHOD

2.1. Participants and setting

Touch panels have already begun to be integrated into early childhood education. Given that Taiwan begins computer education in the 3rd and 4th grades of elementary school, this study randomly selected 30 elementary school students between the ages of 10 and 12 as test subjects. The test group included 17 boys and 13 girls, with an average age of 10.4 years. According to a 2010 investigation by the Pew Research Center [15] 93% of computer and Internet users are between the ages of 18 and 29. Therefore, this study adopted a group of 30 undergraduate and graduate students (17 male and 13 female with an average age of 23.5) from Chang Gung University as the baseline test group. The experiment took place in the Chang Gung University Digital Media lab. Lab equipment included the 4.3-inch HTC EVO 4G [16] and the 10.1-inch ASUS Eee Pad Transformer TF101 [6] tablet PC. In addition, to record test subjects’ gestures and usage habits on the touch screens, two video cameras and digital SLR cameras were used to record the experimental process.

2.2. Experiment design and process

According to Microsoft [17], touch gestures include ‘pan’, ‘zoom’, ‘rotate’ and ‘press and tap’. In the experiment of this study, we combine ‘pan’ and ‘press and tap’ together in the drag task; the other two tasks are ‘zoom’ and ‘rotation’, as seen in Fig 1. The experimental design is divided into two parts: the interface and test system. As shown in Fig 2, the system structure used a 4.3-inch smart phone and a 10.1-inch tablet computer (respectively running Android 2.3 and Android 4.0), using Eclipse 3.71 as the development platform.
In the drag test, participants were asked to perform the drag test using one hand, but were not instructed which hand to use. As illustrated in Fig 3(A), the test required users to drag three dots, one at a time, into any of three orange circles. As the test participants released the dot inside a circle, the dot and circle would disappear. The test concluded once all three dots had been placed within a circle. In the program settings for the drag test, a coverage rate of 80% or greater was considered a successful result. Coverage was determined first by the distance of the dot to the center of the circle. If the dot was not centered within the circle, their respective coordinates were used to determine whether the dot was within 80% of the circle’s original radius at the drop. If so, the current coverage was recorded. Otherwise, the dot returned to its original position. The zoom test began with a single-handed test, followed by a two-handed test. The participants were asked to use two fingers on one hand, or one finger one both hands to enlarge an image on the screen. When the image first senses contact, it begins to record time and movement paths. The participants were asked to enlarge a red circle until it filled the frame created by a larger black circle. When the two circles matched and the subject removed her fingers from the screen, the test concluded and the stop time was recorded. If the participant was unable to complete the task in the first attempt and asked for a second try, the first attempt would be recorded as a failure and the clock would be reset. As shown in Fig 3(B), the test was conducted in three stages characterized by different zoom factors: 2x, 4x and 8x. In the first stage, the test concluded when the participants enlarged the red circle by a factor of 2. At this point, the circle would return to its original size and the frame would double in size to commence Stage 2, in which the participants was asked to expand the circle by a factor of 4. This process was repeated again for stage 3, requiring the participants to expand the circle by a factor of 8. Accuracy was calculated by measuring the number of pixels in the two circles at the end of the test. If the difference in size was less than 20%, the test was considered to be successfully completed. Otherwise, the test was considered to have failed and the red circle reverts to its original size. As shown in Fig 3(C), the rotation test required participants to be able to clearly distinguish the correct orientation (including 45°, −45°, 90°, −90°, 135°, −135° and 180°) of seven images in separate single-handed and two-handed tests. The test system took events as the judgment criteria, using the vector inner product method to obtain the cos angle value. In the touchEvent case, key_down and key_pointer_down obtained the vector of two points of the user’s initial contact with the panel, and then calculated the total movement angle. The key_move case conditions allowed for the continuous measurement of new vector values. Knowing the initial vector and the movement vector obtained the pre-movement total angle values. To determine the participants' movement direction required differentiation for 45° and −45°. When the participants rotated the image to match the target image within ±3° the task was considered successfully completed, the clock was stopped and the next rotation test
commenced. Otherwise, the test was considered failed and the participants was asked to repeat the task until it was successfully completed. This process was followed for all rotation tests.

The test system recorded the time and motion path in all three tests. The clock started when the device first sensed contact and stopped with task completion, and only time in which the participants is touching the screen is included in recorded task time. In addition, subject gestures in using the 4.3 and 10.1 touch panels were recorded using video and still image cameras. In this experiment, the system will record the number of moving pixels. The drag test involves recording pixels with a moving path. The zoom test and rotate test involve recording the number of moving pixels. On a 4.3-inch touch panel, 1 pixel is approximately equal to 0.004 inch. On a 10.1-inch touch panel, 1 pixel is approximately equal to 0.007 inch. The rate use in this experiment was calculated as the moving length (inch) divided by time (second).

![Diagram](image)

3. RESULTS

3.1. Comparison of baseline & children’s operation

This study selected 30 elementary school children as its test population, using experimental data for ten young adults as a baseline for comparison. The experimental movement rate is defined in terms of pixels moved over time, thus a greater number of pixels represents a greater rate of speed, indicating that the subject is more familiar with the operation and is able to complete it more easily. The following presents (1) experimental results for young adult participants, (2) experimental results for children participants, (3) comparison of experimental results for children participants and those of the young adult participants used as a baseline.

3.1.1. Pilot result: baseline setup

Table 1 presents the experimental results for the young adult participants. Comparing the rate of using single-handed with that of two-handed rotation, the rate of young adults who operated with two-handed on a 10.1-inch panel is significantly greater than that of adults who operated with single-handed (p=0.0019<0.05). Operating with a two-handed rotation on a 4.3-inch panel is significantly greater than operating with a single-handed rotation (p=0.000<0.05). Comparing different sizes, when operating the drag task, the rate of operating on a 10.1-inch touch panel is significantly greater than operating on a 4.3-inch panel (p=0.00<0.05). The rate of operating a single-handed zoom on a 10.1-inch panel is significantly greater than doing so on a 4.3-inch panel (p=0.019<0.05). The rate of operating a two-handed zoom on a 10.1-inch panel is significantly greater than doing so on a 4.3-inch panel (p=0.002<0.05). The rate of operating a single-handed rotation on a 10.1-inch panel is significantly greater than doing so on a 4.3-inch panel (p=0.0019<0.05).
panel \((p=0.00<0.05)\). Furthermore, the rate of operating a two-handed rotation on a 10.1-inch panel is significantly greater than operating it on a 4.3-inch panel \((p=0.00<0.05)\).

### 3.1.2. Children's results

Table 1 summarizes the testing results for the children. Comparing the rate of using a single-handed with two-handed rotation, the rate of children who operated with a two-handed rotation on a 10.1-inch panel is significantly greater than the rate associated with a single-handed rotation \((p=0.005<0.05)\). Operating with a two-handed zoom on a 4.3-inch panel is significantly greater than doing so with a single-handed zoom \((p=0.005<0.05)\). Comparing different sizes, when operating the drag task, the rate of operating on a 10.1-inch touch panel is significantly greater than the rate when operating on a 4.3-inch panel \((p=0.00<0.05)\). There is no significant difference in the rates of operating a single-handed zoom on a 10.1-inch panel and on a 4.3-inch panel. The rate of operating a two-handed zoom on a 10.1-inch panel is significantly greater than it is on a 4.3-inch panel \((p=0.00<0.05)\). The rate of operating a single-handed rotation on a 10.1-inch panel is significantly greater than it is on a 4.3-inch panel \((p=0.00<0.05)\). Finally, the rate of operating a two-handed rotation on a 10.1-inch panel is significantly greater than doing so on a 4.3-inch panel \((p=0.00<0.05)\).

#### Table 1. Action rates for baseline group and child test subjects on 10.1 and 4.3-inch touch panels

<table>
<thead>
<tr>
<th>Action</th>
<th>Mean/SD</th>
<th>Baseline</th>
<th>Children</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>10.1-inch</td>
<td>4.3-inch</td>
</tr>
<tr>
<td>Drag</td>
<td>Mean</td>
<td>0.043</td>
<td>0.023</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.022</td>
<td>0.012</td>
</tr>
<tr>
<td>Zoom</td>
<td>Single-hand</td>
<td>Mean</td>
<td>0.033</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.017</td>
<td>0.017</td>
</tr>
<tr>
<td></td>
<td>Two-hands</td>
<td>Mean</td>
<td>0.036</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.021</td>
<td>0.010</td>
</tr>
<tr>
<td>Rotate</td>
<td>Single-hand</td>
<td>Mean</td>
<td>0.013</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.007</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td>Two-hands</td>
<td>Mean</td>
<td>0.017</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.007</td>
<td>0.004</td>
</tr>
</tbody>
</table>

Note: values are calculated in terms of inch moved over the time unit

### 3.1.2. Baseline v.s. Children

Table 2 shows the results of comparison from the results of the tests on the children against those of the young adult baseline group. If dividing the children's movement rate by the baseline equals 1 it signifies that the two rates are identical and that the rate at which the children performed is equal to that of the young adult group. If the value is greater than 1, it signifies that the children outperformed the young adult group and vice-versa. When operating a single-handed and two-handed rotation on a 10.1-inch touch panel, the baseline's rates are significantly greater than the children's for both conditions \((p=0.020<0.05, p=0.016<0.05)\). When operating the drag task on a 4.3-inch touch panel, the baseline's rate is significantly greater than the children's \((p=0.016<0.05)\). While operating a two-handed rotation on a 4.3-inch panel, the adults' rate was significantly greater than the children's \((p=0.000<0.05)\). Therefore, the children's rate when operating drag and zoom on a 10.1-inch touch panel is close to the baseline's. On the 4.3-inch children's rates when operating single-handed zoom, two-handed zoom, and single-handed rotate are close to baseline's rate. Overall, the children’s group performed better on the 10.1-inch touch screen than it did on the 4.3-inch screen.
### Table 2. Rate ratio for children and baseline test subjects

<table>
<thead>
<tr>
<th></th>
<th>Drag</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Single-hand</td>
<td>Two-hand</td>
<td>Single-hand</td>
<td>Two-hand</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.1-inch</td>
<td>0.915</td>
<td>0.730</td>
<td>0.717</td>
<td>0.726</td>
<td>0.762</td>
<td></td>
</tr>
<tr>
<td>4.3-inch</td>
<td>0.666</td>
<td>0.672</td>
<td>1.207</td>
<td>0.851</td>
<td>0.481</td>
<td></td>
</tr>
</tbody>
</table>

Note: values are derived by dividing the average rate for children by that for adults

### 3.2. Gesture and observation

In the experimental process, both size touch screens are equipped with cameras to record the entire testing process including the gestures used by the children participants in completing the experimental tasks. As shown in **Fig 4(A)**, most of the children participants used their right index fingers to complete the drag task for both the 4.3 and 10.1-inch touch screens. **Fig 4(B)** and **Fig 5(A)** respectively show that the single-hand zoom and rotation tasks were mostly completed using the thumb and index finger while the two-hand zoom and rotation tasks were mostly completed using two index fingers.

**Fig 4. (A) Most of the children use index finger in drag task. (B) Most of the children use thumb and index finger in single-handed zoom, while most of the children use two index fingers in two-handed zooming task.**

**Fig 5. (A) Most of the children use thumb and index finger in single-handed rotation task. (B) Most of the children use two index finger in two-handed rotation task.**

As shown in **Fig 6(A)**, several other gestures were observed in the operation of the 10.1-inch touch panel, including one child dragging with the left index finger as well as one child’s use of the index finger and middle finger in the single-handed zoom. One child used the middle finger in two-handed zoom tasks. Meanwhile, one child used the index finger and middle finger in the single-hand rotation. **Fig 6(B)** shows alternative gestures used in the operation of the 4.3-inch touch panel, including one child dragging with the left finger. One child used the index and middle fingers in the single-handed zoom. Meanwhile, one child used the thumb and index finger in the two-handed zoom. Also, one child used the index and middle fingers in the single-handed rotation.
4. CONCLUSION

The popularity of touch screens has led to them being applied to children’s education, such as in electronic schoolbags. However, current research has largely failed to investigate touch screen usability issues specific to young users, such as touch screen sizes and movement ratios. This study investigated the drag, zoom and rotate actions by children on 4.3 and 10.1-inch touch screens to provide suggestions for appropriate movement rate settings, and observed the gestures children use while interacting with touch screens. This study tested the movement rate of 30 young adults using 4.3 and 10.1-inch touch screens and set these as a baseline for comparison with that of 30 elementary school students. Overall, the children’s performed better on the 10.1-inch touch screen than on the 4.3-inch screen, which suggests that the 10.1-inch touch panel is better suited for us in electronic schoolbags applications. Experimental results show suggest that the average drag rate (0.039 inch) and average rotation rate (0.024~0.026 inch) can be taken as a reference for motion settings for electronic schoolbags devices for children. Results also suggest children performing poorly in the rotation action on the 10.1-inch touch panel, providing no reference for appropriate rotation settings. In terms of gestures, when using the 10.1 and 4.3-inch touch panels, most of children used their right index finger for dragging, their thumb and index finger in combination for single-hand zoom and rotation, and both index fingers for two-handed zoom and rotation. Gesture observation revealed that all child testers conducted the tasks using combinations of thumb, index finger and middle finger.

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REFERENCES


