Effects of Tablet Tilt Angle on Children's Handwriting in Elementary School

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Tablets and mobile devices are used in various situations in everyday life. Several researchers have reported the effectiveness of tilting a tablet in enabling a high degree of usability. Tablets are also increasingly popular in elementary school classrooms. The use of tablets in schools is considered to be different from their common use in daily life because students have many opportunities to take notes in schools. Furthermore, it is particularly important to hold a pencil or pen properly with correct posture in elementary schools. The aim of this study was to determine the tilt angle of tablets most beneficial for children's handwriting in elementary school. An experiment was conducted with fourth-graders at a public elementary school. Twenty-eight students used tablets with three different tilt angles: 0°, 10°, and 20°. Participants were required to write a Kanji character at six positions on the tablet screen and then rate their responses on a 4-point Likert scale. The results indicated that there was an overall preferred tilt angle of 10° and that bottom part of the screen was more difficult to write on than the top. In particular, the difficulty score of a tilt angle of 20° in the bottom part was significantly higher than that of other two tilt angles. Moreover, there were several comments from participants that the second level of tilt angle (i.e., 10°) was the most comfortable position for writing.

Keywords: tablet, education, ICT, children, tilt angle

1. Introduction

In recent years, tablets and mobile devices have been used in various situations in everyday life. One of the main reasons for the widespread use of these devices is the fact that recent rapid advances in display technologies have enabled the presentation of high-quality images with an added feature of portability. For example, display manufacturers have already produced 4K tablets with horizontal resolutions on the order of 4,000 pixels, four times that of high-definition images. Another reason is that these devices are becoming easier to use than before. They are becoming lighter, thinner, and more compact so that people are able to use those devices in a wider array of settings.

Besides being incorporated into everyday activities, tablets are being used in the field of Information and Communication Technology (ICT) in education. Tablets are also becoming increasingly popular in the elementary school classrooms as a means of improving educational quality. In Japan, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) is promoting the use of ICT in education with a large project that investigates the educational effectiveness of tablets and other educational equipments by conducting practice classes (MEXT in Japan, 2015). In particular, the educational effectiveness of tablets and other educational equipments, such as digital projectors and interactive whiteboards, have been investigated in practical education settings. In the educational project, each student uses a tablet one by one, while teachers use digital educational materials in classes at specific schools where the project is conducted. Furthermore, MEXT in Japan has a clear agenda that tablets will be incorporated into the classroom in all schools by 2020 to achieve the goal of having each student in Japan use the tablet one by one in class.

Obviously, it is important to investigate the educational effectiveness of using tablets and other educational equipments in schools. Furthermore, it is important to investigate the usability of tablets from an ergonomics viewpoint because tablets are used by children in schools and the usage environment is considered to be different from a tablet's common use in daily life. In 2014, MEXT in Japan released a guidebook for using ICT equipment in schools from an ergonomic viewpoint. The guidebook deals with effective methods of glare control and prevention, comfortable viewings of interactive whiteboards and tablets, children's posture when using tablets on a desk, and so on (MEXT in Japan, 2014). Glare is the specular reflection of a light source on the screen. One solution to avoid glare on the screen is to tilt the tablet.
In this study, the author focuses on a tablet’s effects on children’s handwriting because students have many opportunities to take handwritten notes in schools. Furthermore, this is essential because of the importance of correct form and posture for elementary school students when holding a pen or pencil. The aim of this study was to determine the tilt angle of tablets most beneficial for children’s handwriting in elementary school.

2. Methods
An experiment was conducted with students at a public elementary school to examine the relationship between the tilt angle of a tablet and the position of its screen regarding handwriting difficulty levels.

2.1 Participants
Twenty-eight fourth-graders participated in the experiment. All had normal visual acuity at a reading distance, ensuring that they could see and read characters on the tablet screen. Twenty-six participants were right-handed, while the other two were left-handed. All participants had an experience of using the tablet that was used in the experiment and were accustomed to aspects of dealing with the tablet including writing with a stylus pen.

2.2 Apparatus
Participants used a tablet that was designed and developed for learning (Tenobo, Sony Engineering Corporation). The tablet had two display screens, one was for displaying textbook and the other was for displaying notebook (Figure 1). The displays had a resolution of 1024 × 768 pixels and 10.4-inch screen size. In this study, the right screen was used as a notebook for the right-handed participants and the left screen was used for displaying instructions pertaining to the experiment. For the left-handed participants, the tablet’s left screen was used as a notebook.

![Figure 1. Tablet used in the experiment. Scene in which a participant evaluated the degree of writing difficulty.](image)

2.3 Images on the screens
On the textbook screen, i.e., on the screen of the non-dominant hand side, the instructions of the experiment were displayed (in addition to the oral instructions previously given) (Figure 2: left). Three Kanji characters in the center of the screen were the model for good writing. The characters were used as practice to write on the tablet before the evaluation of handwriting. The middle of the three characters, which is sounded Hana and means “flower” in Japanese, was used for evaluation. At the bottom of the screen the picture of a
student holding a pencil shows how to hold a pencil correctly, based on a school textbook of Japanese. As mentioned in the introduction section, it is important to hold a pencil or pen properly with correct posture, particularly in elementary schools. The instruction of holding a pencil properly was intended to guide the participants to use a tablet pen just as one would use a pencil on a paper notebook in a normal classroom setting.

On the notebook screen, the Kanji characters *Hana* were displayed using light gray for evaluation (Figure 2: right). The characters were at the following six positions: top left, top center, top right, bottom left, bottom center, and bottom right.

![Screens on the tablet. Instructions for the experimental procedure and proper writing style (left) and six character positions on the tablet screen (right).](image)

Figure 2. Screens on the tablet. Instructions for the experimental procedure and proper writing style (left) and six character positions on the tablet screen (right).

### 2.4 Conditions

Three experimental conditions for tilt angle of the tablet were examined. Tilt angles were 0°, 10°, and 20° (Table 1). Tilt angle of 0° indicates that the tablet was lying flat on a desk. In the 10° and 20° conditions, the tablet was tilted and fixed by blocks (Figure 1). The ordering of the conditions was counterbalanced and randomly assigned to participants. The experimenter confirmed that glare was not visible from the assumed viewing range by participants in all three conditions of the tablet tilt.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Tilt angle of tablet</th>
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<tbody>
<tr>
<td>A</td>
<td>0°</td>
</tr>
<tr>
<td>B</td>
<td>10°</td>
</tr>
<tr>
<td>C</td>
<td>20°</td>
</tr>
</tbody>
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### 2.5 Procedure

The experiment was conducted in an elementary school classroom. At the beginning of the experiment, participants were instructed on the experiment description while viewing the screen of the tablet. They were also given a questionnaire sheet, which was used for the evaluation of handwriting difficulty on the tablet. Next, participants were required to trace three types of Kanji characters near the center of the notebook screen of their tablet as a practice session.

During the evaluation, participants were required to trace a Kanji character *Hana* at six positions on the notebook screen (Figure 2: right) and then rate their responses on a 4-point Likert scale, where “1” indicated...
the same level of difficulty as usual writing or practice and "4" indicated that the character was very difficult to write. A similar evaluation was conducted for each character. Thus, participants repeated a combination of tracing a character on the tablet and answering a "difficulty to write" on a questionnaire sheet six times for each experimental condition. Participants were instructed to trace characters as carefully as possible.

Having completed three iterations, participants provided comments on another questionnaire sheet regarding their impressions about the effects of different tilt angles and character positions on writing difficulty.

3. Results

Unlike common tablets, the tablet used in the experiment had two display screens. Which screen used as a notebook was determined by each participant's dominant hand. In other words, right-handed participants used the screen on the right side and left-handed participants used the screen on the left side. In the analysis of the results, the data from left-handed participants were placed symmetrically to control a situation of using the tablet. This means that data in the top-left and bottom-left from left-handed participants were handled in the same way as the data in the top-right and bottom-right from right-handed participants, respectively.

Figure 3 plots the results from the questionnaire averaged across participants and across character positions. The results showed that all scores were relatively low and there was a tendency toward a tilt angle of 20° being the most difficult to write on and a tilt angle of 0° being second in difficulty (p < .10). Thus, this indicates that a tilt angle of 10° was the most preferred overall.

One of the interests in this experiment was to examine the relationship between tilt angle and position on the screen. In particular, the author had a hypothesis that the difficulty in writing on the bottom of the screen depended on tilt angle, which was based on the observation of elementary school students using the tablet. To examine this, the author averaged scores across participants, separately for each of the top and bottom parts of the screen. The results showed that bottom part of the screen was more difficult to write on than the top part (p < .01). Moreover, the scores for a tilt angle of 20° in the bottom part was significantly higher (more difficult) than the other two tilt angles (p < .05; Figure 4).

![Figure 3](image-url)  
Figure 3. Results of subjective difficulty to write (overall comparison).
To observe the details, the results from six positions on the tablet are shown in Figure 5. Note that the data from the two left-handed participants were placed symmetrically in the analysis. Therefore, the right and left charts in Figure 5 show cases of right-handed participants. In other words, the right position on the screen is on the side of edge of the tablet and the left position on the screen is inside of the tablet.

The results showed that the top part of the screen was easier to write on than the bottom part, despite the horizontal position. However, there was a tendency that tilt angles of 0° and 20° on the right side of the screen were relatively difficult to write on ($p < .10$). At the center positions, there was no difficulty compared to left and right positions in either of the top or bottom parts.

Figure 6 graphically shows the results of the experiment based on subjective evaluation. The numbers in the figure represents the scores obtained from the evaluation. First, the screen area was divided into nine parts, and the average scores obtained from the experiment were used for the three top areas and the three bottom areas, respectively. Three scores in the second row from the top were calculated as the average score between the top and bottom rows of the same column.

The color is related to the difficulty of writing characters on the tablet. Green represents that writing is easy and red represents difficulty in writing. Note that all scores were relatively low in the experiment, indicating that there was no severe situation regarding difficulty in writing on the tablet. Thus, color coding indicates relative severity of writing on the tablet.
Figure 6. Comfortable writing area on tablet based on the experiment. Note that the tablet with two display screens was used in the experiment. This figure was described with the assumption of the person being right-handed. The right position on the screen is on the side of the edge of the two-display tablet and the left position on the screen is inside of the two-display tablet.

From the comments regarding their impressions about the difference of tilt angles and character positions, it was found that most participants preferred the second level of tilt angle (i.e., 10°) for writing. Furthermore, most participants had the impression that the degree of difficulty of writing differed depending on the position of the screen and tilt angle.

4. Discussions
The results of the experiment clearly indicate that bottom part of the screen was more difficult to write on than the top part. This is considered to be because of the thickness of the tablet, particularly when using the tablet with an angle of 0°. The tablet used in the experiment was approximately 11 mm thick, which is thicker than a common paper notebook. A difference in the level on the desk could produce uncomfortable writing when participants wrote characters on the bottom part of the screen. The most important point of this argument is that the uncomfortable writing can be improved by tilting the tablet a little. This is considered to be because of the fact that a pen can easily touch the slanted screen. However, if the tablet is tilted too much, the writing situation becomes less comfortable. This may be because of the fact that users are forced to bend their hand upward unless they move their hand away from the desk. The results of the experiment suggested that proper tilt angle of tablets was approximately 10°.

Another result showed that tilt angles of 0° and 20° on the right side were relatively difficult conditions to write under. This is considered to be related to width of the frame of the tablet, likely because participants could not put their hand on the frame of the tablet with much stability. Furthermore, it is presumed that they could put their hand on both the frame of the tablet and a desk in the condition of 0°, i.e., in the flat condition. Therefore, the thickness of the tablet could have an effect on the performance of writing as well. In the condition of 10° tilt, participants were able to avoid putting their hand on an unstable and multilevel place because the tablet was tiled from the desk. However, when the tablet was tilted to an angle of 20°, participants were be forced to bend their hand upward, thus making the writing situation potentially less comfortable.
In addition to the results of the subjective evaluation by rating, most participants agreed with the statement that tablets tilted at an angle of 10° were easier to write on. Albin and McLoone studied the effect of tablet tilt angles on target-tapping performance and have concluded that tablet tilt angles should include a range of 20°–50° at minimum (Albin and McLoone, 2014). Furthermore, another study reached a similar conclusion that it is most suitable for users to perform pen-based input operations when the tilt angle of a tablet is 30° (Bao et al., 2010). The data derived from such investigations is of great importance in using tablets comfortably and extensively. The important difference between previous studies and this study is that the experiment in this study was conducted by children in elementary school under the assumption that tablets would be used for learning in schools.

5. Conclusions
This study examined the relationship between tilt angle of a tablet and the position of the tablet screen. The results of the experiment suggested that proper tilt angle of a tablet for elementary school students was approximately 10° in terms of minimizing the difficulty of handwriting on tablets. Tilting the tablet had a positive effect on writing performance as well as having the effect of increasing the visibility of the screen and the glare control and prevention. Therefore, it is suggested that the use of tablet tilting support is effective in comfortable learning with the utilization of ICT in schools.

The findings of this study can be valuable for developing the use of ICT in education. However, as described in the discussion section, the results could be affected by the specification of the tablet used in the experiment, such as the thickness of the tablet and width of the frame. Therefore, a further study should investigate the relationship between the thickness and width of the frame of tablets and its effects on the difficulty of writing for a more conclusive finding.

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References