**A Study of Efficiency Between Conventional Keyboard and Stylus Input Apple Pencil as an Example**

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**ABSTRACT**

Tablet computers are high-tech products integrating various advanced technologies and design aesthetics. In recent years, more and more companies have begun to provide people with their tablet computers due to the decline in production costs brought about by the advancement of hardware manufacturing technology. Some popular brands are Apple iPad, Amazon Fire, and Samsung Galaxy Tab. As a consequence, an increasing number of people have the opportunity to use tablets to complete the work they want to do. Based on this background, we decided to conduct a study on tablet computer input modalities using the A/B test. To be specific, we focus on the user experience and performance of the default multi-touch keyboard and stylus. Our project used a mixed-method, including pre-surveys, experiments, and post-interviews. The reason why we use the three methods is to pursue the accuracy and breadth of data points as much as possible, which might make the research more general. By this strategy, we could obtain truly meaningful findings or conclusions that could be impactful in the real world. The research investigated the nuanced difference between traditional built-in keyboard and stylus and it has a bunch of meaningful findings. We believe that this research fills in some of the previous knowledge gaps and strengthens designers' understanding of user experience. The results assist in the design of future tablets, stylus, and related software applications.

**KEYWORDS**

Built-in Keyboard; stylus; tablet; academic note-taking; input method.

**INTRODUCTION**

With the continuous technology iteration of computer hardware and the optimization of the system software, tablet computers have gradually become a technology tool that can be seen everywhere in people's daily lives. With the popularization of tablet computers, technology companies have invested a lot of resources to develop new user input modalities so that users can choose the most suitable one from a large number of input devices when using tablet computers. During the years of development, various input modalities have been developed. Direct touch and using a stylus are two main input methods that are generally accepted by users. Regarding touch technology, single-point touch was popular at the beginning. Users can only use one of their fingers to touch the screen at a time. When the tablet detects that multiple fingers are touching simultaneously, it cannot tell which one is a valid input. Later, technology companies solved this problem by inventing multi-touch technology. As the name suggests, it allows users to control the tablet with multiple fingers at the same time. On the other hand, the stylus has also experienced many revolutionary iterations. From the very beginning, the pressure-sensitive pen works by recognizing the degree of pressure on the screen when users start the input. Later, the capacitor pen functions by sensing the current of the human fingers. Currently, the newest stylus integrates a variety of complex technologies and sciences such as electromagnetism, accurate locating, and application of machine learning algorithms.

In the process of repeated replacement of input modalities, what we can see is that some old technologies are eliminated temporarily on one hand. On the other hand, a bunch of outdated input modalities have been injected with new and vigorous vitality by the innovation of new technologies and are once again active in people's sights. The popularity of one input device does not lead to the complete disappearance of the other.

Even to this day, touch technology and stylus pens are still the dominating input modalities. As far as we know, the most popular ones that can represent two input modalities are multi-touch and Apple pencil. Both of them have already experienced several upgrades as mentioned above. Meanwhile, the number of software applications and types of features carried on tablets have also experienced explosive growth. For example, the multi-window function of current tablets allows users to operate multiple applications on the same screen. What's more, users are allowed to open the same application multiple times, and the applications will be arranged side by side on the screen for users to operate.

It is foreseeable that more advanced applications and fancy features will be developed in the future. Therefore, we should urgently figure out which input modality is more acceptable to users and suitable for more scenarios and conditions. If we can investigate the influencing factors clearly, then we will have a very thorough understanding of the current tablet input modes and devices. Knowing the pros and cons of mainstream input modalities, we can make certain conclusions from these findings. Some results may help hardware and software designers to invent more efficient, user-friendly, and comfortable tablet-related products in the future.

In the following parts of this paper, we first introduced some work and findings of other researchers with similar research directions, and then we explained in detail the research problem to be solved and the method to solve it. The next part is about nuanced experiment procedures and detailed data analysis. At last, we discussed the results of our research and some meaningful achievements. We believe that these findings can provide references for future designers to help them design products and applications that are more in line with user habits, which could provide a better user experience for everyone.

**RELATED WORK**

Before our research, many researchers conducted a huge amount of research on tablets. Their research has done a detailed investigation and analysis of all aspects of the hardware and software of the tablet computer, which indirectly shows the popularity and importance of the tablet computer now and in the future.

Jan et al. investigated how input modalities would affect the user experience of iTV applications and what differences could be regarding young people and the elderly. They set six different test conditions and implemented an experiment to conduct the research. One of their final results is that the mirroring feature of tablets is the best choice for using iTV applications regardless of age effect. Its performance exceeds significantly more than two others’ (freehand gestures and remote control) [1]. Their research shows that even in this era, when new technologies are constantly being born, tablet computers are still an indispensable device for people to participate in technological life. Tablets will not die out quickly because of the birth of new technologies or devices. Therefore, our research on the input modalities of the tablet is indispensable and important.

Explorative research conducted by Ken et al. focused on investigating the subtleties of the sensing technology embedded on both tablets and stylus. They identified and combined the gestures of gripping stylus and tablet to recognize the user’s specific intention. Based on this subtle system design, they are able to avoid a set of unintentional incorrect inputs during use, which greatly improves the accuracy of user action recognition. Furthermore, they proposed a bunch of new research directions and possible application fields related to sensing technology on tablets and stylus [2]. What can be seen from their research is that although the interpersonal interaction features of stylus and tablets have been developed very powerfully, there is still huge potential for improvement. Exploring these subtle areas may raise the current user experience to another level. In addition, this research also shows that after many iterations, the stylus and tablet are already fully-developed products that integrate various software and hardware technologies.

Another research that is closely related to our direction is a study of table usage. Hendrik et al. collected the data of users’ activity information (purpose and motivation) and habits (time and occasion) of using the tablet to analyze why tablets are a valuable choice for users. One important result they found is that a tablet is a special device for many users. It can help them accomplish some specific tasks that other devices cannot complete or are not good at. This feature makes users have a soft spot for tablets. Another meaningful conclusion is about when and where tablets are used. Researchers found that most users prefer weekdays usage at home, which implies that tablets have perfectly integrated many people’s lives. In addition, Hendrik et al. also mentions that there is not much research whose topic is tablet usage so that they cannot find a bunch of related literature [3]. From this point of view, there should be many knowledge gaps that need to be filled in the field of tablet interaction research. Our work might be valuable to someone if it could enhance people's understanding of tablet usage.

**RESEARCH QUESTIONS / HYPOTHESIS**

In order to investigate the pros and cons of the two input methods we focus on in this study, stylus (Apple Pencil) with touchscreen and computer keyboard, we propose to compare the overall performance of these two methods in real-world scenarios of lecture note taking and to find out the difference between them about how well the task is done and how do the users feel when using them. Based on our interest and purpose, we regulate our research interest into two parts, the input methods’ performance and their user experience, and we develop two research questions:

(1) What is the difference between the performance of conventional keyboard input and Apple Pencil with touch screen when users complete input tasks.

(2) After users use two completely different aforementioned methods to complete related input tasks, based on their experience, which one will the user be more satisfied with and prefer?

These two questions represent and direct the following steps of our research. To answer these questions, our goal is to collect data about user experience and quantitative performance with these two input methods when using in the real case. Therefore, we decided to use experiment as our research method to observe and to record these two kinds of data in and after the process of assigning real-world note taking tasks with the two different input methods to the participants. From our past experience with these two input methods, we state the hypothesis that in our experiment, the notes taken by stylus (Apple Pencil) would have overall better performance than the ones taken by keyboard, since we believe it is more efficient in note taking assignments. Furthermore, as writing is usually a more basic skill that most people learn during their early childhood, while typing on a keyboard is a more counterintuitive task that people usually learn when they go to school, we also have the hypothesis that the participants will find the input experience with stylus method is more satisfying than with keyboard. To verify these hypotheses, we designed our experiment that provides data fulfilling our need to answer both research questions.

**METHOD**

Before we decided on our hypothesis and experiment method, we created a survey that can point us in the right direction in terms of our topic area. The goal of our survey was to get an idea of why people choose their desired note taking method, what are the reasons specifically for their choice, and why don’t they use the other note taking method. We also used this survey for recruiting participants for our experiment. In the last part of the survey, we asked the survey participants if they agreed to attend our experiment and to share their contact information.

The survey results helped us form our hypothesis which required some kind of controlled experiment, where we are able to see performance and efficiency differences between the note taking methods. We decided that doing just an interview and more questionnaires would only give us ambiguous results, especially if you take bias into account, where each participant has a biased feeling about their desired note taking method.

The participants were selected from the responses we received from our surveys. For this experiment, we made sure that the participants have experience with both stylus and keyboards, so there’s no bias in the result we get from our experiments. The age group of the participants should be over 20 and either currently enrolled in or graduated from a university. Our reasoning for this is that, by this age, students have a good idea on how note taking works.

To test our hypothesis, we designed an experiment using the A/B test method in which participants try out both scenarios. In our experiment, we created two scenarios, one scenario where a participant watches a lecture video while using a keyboard to take notes, and the other scenario, the participants use an apple pencil and iPad to take notes while watching a different video. Half of the participants try out the first scenario and the other half try the second scenario, and then we repeat this process one more time and switch the scenario for each group.

The lecture video plays a big role in this experiment, we understand that this is also a dependent variable, apart from the note taking methods and we want to control this variable so that it doesn’t negatively affect the performance of dependent variables that we are interested in. We want to choose a video that is easy to follow, not too complex, something general that everyone can relate to or understand, but challenging enough where the participant is forced to take a second to think and absorb what's being said. Since participants can be from any major, we decided to stay away from mathematics and science related lectures. Video length is also very important, because it is the main thing that takes time in our experiment so for our own and participants ease, we decided that lecture videos should be no longer than 10 minutes. We chose bit-torrent and diving as our lecture video for our pilot study, and we believe that these meet all the criteria.

After the participants have been divided into two groups, and started the experiment we are to observe them and document how exactly they take their notes and look for interesting patterns such as, how do participants handle their mistakes? What details in the lecture video do they note write or seem to not pay attention to? This observational part of the study is just to spot any irregularities, specifically find out if there is any flaw in our study or the experiment design.

At the end of the experiment when both groups of participants have tried each scenario, we conduct a short interview with each participant to get their perspective and insight about each scenario. Specifically, we ask them about the video itself if it was easy to follow. Asking participants about the video itself can be important if this experiment is being redone or replicated, the participants opinion on the video can be helpful in picking a better video next time. We ask them about each note taking method, and their opinion on which one was easier to use and more efficient overall. Our goal with this interview, part of the study, is to get participants insight about the overall experiment, how comfortable they felt in our experiment setting, anything that can improve our future trials.

We will then look through their notes, count the number of “main points” they wrote down, and look for additional details that weren't necessarily mentioned in the video. Our goal here is to see how accurately the participants' notes match up to what was said in the lecture video. As mentioned in our hypothesis, we want to compare the accuracy between these note taking methods and determine which one is better. We can create a rating system by counting the number of details mentioned in the notes, and in the end be able to see which note taking method performed the best.

**SAMPLE DATA COLLECTION**

**Survey**

In our survey we sent out, there were 6 out of 10 people who were not a previous stylus input user. Of these 6 people, half of them think that the stylus cannot meet their needs. However, only one of them thinks that the experience of using a stylus is bad. All our 4 out of 10 participants that are current stylus users consider the convenience of stylus the first reason why they are using such a product.

There are five people that were willing to participate in our experiment. However, we can only randomly choose 2 of them to participate due to time constraints.

**Experiment**

In our pilot experiment, only two participants were involved. The Following is the data we collected from two participants.

Our experiment selected two videos for our participant, the first one includes 13 key-points that we expect to be seen on the note and the second has 30 key-points. We were recording the key-points that our participants could successfully record by different methods and then calculate the percentage.

In our experiment, to meet our counterbalancing goal, the first participant was asked to take notes on video 1 by apple pencil and video 2 by keyboard. On the contrary, the second were taking notes on video 1 with keyboard and video 2 with apple pencil. As stated in Table 1 and Table 2. Participant 1 gets 11 out of 13 key-points recorded in the note with apple pencil and 24 out of 30 key-points of video 2 recorded with keyboard. On the other hand, participant 2 gets 7 out of 13 key-points recorded in the note for video 1 by using keyboard and 17 out of 30 key-points recorded for video 2 by using Apple Pencil.

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| --- | --- | --- |
| Participant 1 | Video 1 with Apple Pencil | Video 2 with Keyboard |
| Total Key-points Recorded | 11 | 24 |
| Key-points possible | 13 | 30 |
| Percentage | 0.846153846 | 0.8 |

**Table 1. Record of Participant 1.**

|  |  |  |
| --- | --- | --- |
| Participant 2 | Video 1 with Keyboard | Video 2 with Apple Pencil |
| Total Key-points Recorded | 7 | 17 |
| Key-points possible | 13 | 30 |
| Percentage | 0.538461538 | 0.566666667 |

**Table 2. Record of Participant 2.**

After calculating the percentage of key-points recorded by participants and all possible points we can get a following tendency shown by the following graph:

Chart, bar chart

Description automatically generated

**Figure 1. Graph of Input Efficiency.**

In Figure 1, we can see a tendency that when comparing the note taking efficiency between a keyboard and Apple Pencil, the Apple Pencil always has a higher efficiency even though this difference is not noticeable enough. Considering that there are different note-taking habits among different people which caused huge data differences between two participants. We can still see such a trend when compared within participants themselves that the usage of apple pencil tends to increase the number of recorded key-points, which we consider as a higher efficacy within the same time frame. This gave us an inspiration that there is a relationship between different input methods and input efficiency, especially when these two objects are keyboard and stylus.

This pilot study also noted some drawbacks of our experiment:

The first drawback is we think that this difference is not noticeable enough in out pilot experiment because of the following two reasons:

First reason is that the data size for our experiment is too small. This means less than enough participants were used in this experiment. This can be improved by increasing the size of the experiment. After that we have a larger sample size. We can not only get a more accurate result, but also do more statistical analysis such as data mean and hypothesis tests. This will also increase the external validity for our experiment.

The second drawback is the difficulty of two videos we are using for the experiment is not consistent. Both participants reported that the second video is harder to follow than the first one. This is a bias that will have impacts on our results. However, considering our counterbalancing procedure, we still think that this trend we found is meaningful for the further experiments.

**Post-experiment Interview**

In the post experiment interview, the Participant 1 reported that:

“It is harder for me to take notes via keyboard. Using an iPad (with an Apple Pencil) works better for me”

Both participants reported that using keyboard takes longer time than directly write it down with Apple Pencil

Also, both participants reported that the video 1 is easier to follow than the video 2. This can be a bias for our experiment and needs to be controlled in the future experiment.

**DISCUSSION**

In this research, we used a hybrid method to explore the user experience of Apple pencil and default keyboard related to the tablet usage according to their performance. Based on the experimental data and precise analysis, we obtained two important findings. The first finding is that although the default built-in keyboard and stylus have little difference in performance, the trend reflected from the experiment shows that the stylus always performs slightly better than the keyboard. Another finding is that, based on post-interviews, we conclude that users are more inclined to choose a stylus to complete their tasks if they have both input devices.

These two conclusions are in line with the hypothesis we made before the experiment and support their correctness. In general, this research provides researchers in this field with a detailed comparison of stylus and keyboard performance, so that readers (researchers and hardware and software designers) can better understand what users' thoughts are while using these two input modalities. Regarding future research, we may go further to test the performance difference between the stylus and the default keyboard. To be specific, we want to know how different they are in various environments or scenarios instead of just academic note-taking.

We learned a great deal about experiment and survey design through this study. During our pilot study we observed a couple things that we can improve on such as participant bias, we realized that some participants have a lot of practice with one note taking method and they might not perform as good with the other. We also had to look out for other dependent variables other than the note taking methods, such as, lecture video, note taking software and tools. We had to be extra vigilant during the experiment observation, in order to not miss any important pattern or interaction. Over all, if we had more time and access to more participants, we can replicate this study with all the possible improvements we came up with.

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**PERCENTAGE OF CONTRIBUTION**

Amaan Khan, 25%, Participated in the initial proposal and the video presentation. Designed part of the survey. Wrote method part of the final report. Wrote a part in presentation slides, Presented a part in slides.

Dingxian Wang, 25%, Participated in the initial proposal and the video presentation. Designed part of the survey. Wrote part of the final report, Implemented part of the pilot data collection.

Xiangyu Li, 25%, Participated in initial proposal writing and the video presentation, Wrote the abstract, introduction, and related work sessions of final report, Was responsible for part of discussion session (reflection of finding, the effect of results, possible future action) of final report.

Zheming Pu, 25%, Participated in the initial proposal writing for the method part and the video presentation. Designed part of the survey. Implemented the experiment and post-experiment interview. Analyze the data from the experiment and wrote up the part of sample data collection in the final report

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