Head-Up Displays for Note Taking: Project 2

Mobile & Ubiquitous Computing - CS4605/7470

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ABSTRACT

With many advancements in technology, the techniques for note-taking have changed drastically. Over the years, the form of note-taking has evolved from taking notes by hand, doing it with laptops, to taking notes with a head-up display. The purpose of this research is to specifically compare note-taking with laptops and note-taking with head-up displays and then determine which technique is more effective. This paper examines a completed study that our team conducted and the data analysis from that study. The experiment ran was one that was very similar to the experiment done in our pilot study with added improvements. This study involved three sittings with a total of four participants. Each sitting contained a touch typing training session, taking notes while viewing two TED Talk videos, and filling out post questionnaires as well as a NASA-TLX. During each session, the participants took notes on one TED Talk using the laptop and then took notes on the other TED Talk using the head-up display. Immediately after finishing the video, the participants were asked to rate each technique and fill out post questionnaire forms. A week following the sessions, we emailed the participants their notes and a link to both quizzes. They were allowed to use their notes while taking the quizzes. Furthermore, the quality of each participant's notes were also scored. The combination of the quiz scores, the assessed "quality" of the notes, and the feedback from all of the participants were used to determine the effectiveness of each technique. This evaluation of the effectiveness of both these techniques will allow us as a society to better utilize technology in the academic field.

Keywords: Head-Up Display, Note-Taking

INTRODUCTION

One might ask: why even complete this study? The idea from this pilot study is to be able to provide educators and students an explanation of how to best utilize technology in order to produce better quality notes. The main motivation behind completing this study is to help the upcoming generations truly retain the information they are taught as well as applying that information.

A head-up display is any transparent display that presents data without requiring users to look away from their usual viewpoints. In this sense, a head-up display will allow students to view their screen/notes and their teacher in the same field of view. Note-taking with a head-up display is a fairly new technique and is the main focus of this project. The main goal of this project is to deliver a completed study that compares note-taking with a head-up display against note-taking with a computer/laptop. Based on our project proposal, we designed and conducted a pilot study to give us some initial results as well as provide our team with a foundation on which to make improvements for the final study. In addition, the pilot study assisted us in making a final decision about our hypothesis- deciding which note-taking method is more effective.

The pilot study consisted of a mini experiment where we asked volunteers to take notes on both a heads-up display and a laptop while watching a Ted Talk video. After watching the Ted Talk videos and taking notes, each volunteer was asked to fill out forms and take a quiz about the videos they watched. These forms and quizzes were later analyzed to provide us results for our pilot study. In addition, the "quality" of the volunteers' notes were also rated based using a set of predefined criteria. Further details and results can be found in the "Our Work" section of this report. With the results and knowledge from our pilot study, our team was able to conduct an improved, more efficient experiment.

PREVIOUS/RELATED WORK

Note-taking is an intricate process that requires comprehension, selection of information, and some form of written production processing to facilitate learning and recall of information [9]. Thus, it's an important concern in education to study multiple areas of note-taking to improve learning and recall. Techniques for note-taking differ from each individual to another, so it'll be difficult to completely focus on this area to study; however, one thing remains similar. Everyone

uses some tool to record the information whether it be a laptop or through conventional means. New developments in this area could directly affect the rate at which information is recalled. Head-worn displays used for note-taking is a relatively new concept in the field and little to no studies have been conducted on such an idea.

We leverage existing studies analyzing the effectiveness of laptops vs pen and paper approaches to note-taking as a guide and foundation for our work. Past studies have shown that note-taking can be either generative (e.g., summarizing, paraphrasing, concept mapping) or non-generative (i.e., verbatim copying) in nature. Additionally, level of cognitive demand required by a note-taking task can vary depending on how deeply information is processed by the writer while capturing the notes. For example, verbatim note-taking has been shown to place a far lower cognitive demand on [4, 7, 12] on the writer then a highly synthesized summary. [5, 7].

Additional, studies have demonstrated through correlations [1, 11] and experiments [2, 2, 6] that verbatim note-taking correlates with poorer performance outcomes than synthesized or non-verbatim note, particularly when the topic matter is highly integrative or conceptual in nature.

Few studies directly analyze the potential differences in cognitive process when note-taking on a laptop or personal computer vs heads up display. Current literature does not consider the natural variation in the amount of verbatim overlap between lecturer content and students' notes on that lecture. Laptops can reduce the difficulty of verbatim transcription of lecture content because most students type much faster than they can write [3]. [8] found that students who took notes on laptops exhibited worse performance on conceptual questions than the students who took notes via pen and paper. Although a higher volume of notes can be beneficial, the laptop user's notes are more akin to direct transcriptions of the lectures rather than a synthesised summary of the key concepts. These verbatim notes proved to be detrimental to overall learning outcomes [8].

Cognitive effort is another factor that must be taken into account when discussing the quality of note-taking and the depth of encoding. The more cognitive effort put into a task results in a deeper level of encoding [7, 8]. One such study conducted on the difference between digital note-taking and paper note-taking used the NASA-TLX as a means to define cognitive load. The NASA-TLX is a subjective, multidimensional assessment tool that rates completed workload in order to evaluate a certain task or performance. It rates the task based on the following categories: mental demand, physical demand, temporal demand, performance, effort, and frustration. For example, a user might be asked "On a scale from one to ten, how physical demanding was the task?", after completing the certain task. We will be employ NASA-TLX in our study [10] for the same purpose. In conclusion, the cognitive effort required of a head-up note-taking strategy is an unknown area and leaves us much to be explored.

OUR WORK

Before performing the pilot study for this project, our team conducted research as well as completed a literature review to familiarize ourselves with the concept and question being asked: is note-taking with a head-up display more effective than note-taking with a laptop? Research by the team was done on topics including: Eyebox View, Field of View, Head-up Displays, quality of notes, and the process of IRB Review. However, much work still needed to be done before completing the pilot study.

We familiarized ourselves with the head-up display being used in the pilot study, the Vuzix Blade. This particular head-up display was chosen by our mentor, Thad Starner, as it would allow the user's field of view to be in line with the view of the video being watched. After familiarizing ourselves with the Vuzix Blade and learned how to navigate through it, we decided to use an Android app because Vuzix Blade supports Android application. After much experimentation and consideration of fairness, we decided to use the simple Android notepad app, "notepad(d)" application for the Vuzix Blade. We used Android Studio to implement the app on Vuzix Blade. We also decided to use the "notepad" application for note-taking on the laptop. By using similar applications for note-taking on each device, there will be a lower chance of skewed results. Utilizing our feedback from project 1, we connected both a Bluetooth keyboard and a mouse to the Vuzix Blade for participants to use during the study. Our team also drafted a Consent Form, Compensation Verification, Participant Recruitment Email, Post Note-Taking Questionnaire, Quizzes, Post Quizzes Questionnaire, and an Experimenter Script.

Pilot Study

The pilot study was conducted in two sessions with a total of four participants (two per session) and they were all compensated. Each experiment began with the test conductor reading the "experimenter script" along with some other common procedures to the participants. Next, the consent forms were given to both participants for them to sign. Once the consent forms were signed, the participants were given 40 minutes each to become familiar with the Vuzix Blade and practice taking notes with it. Unlike in our first pilot study, the "training session" time was extended because we realized that participants needed more time to familiarize themselves with the Vuzix Blade as well as get used to typing on the bluetooth keyboard. We also wanted to ensure that participants were able to touch type, meaning typing without looking at the keyboard. We noticed several participants in our first pilot study looking up and down as they typed while using the Vuzix. This defeated the purpose of the study, so we tried to ensure that participants were able to touch type in our second study. Another important note to add is that participants were able to use the bluetooth mouse to navigate the Vuzix Blade in this pilot study. In our first pilot study, participants found it difficult trying to navigate only using the side of the Vuzix Blade. After the "training session" was up, the experiment began. In session one, both participants watched the Ted Talk "How we're using DNA tech to help farmers fight crop diseases" simultaneously. Participant 1 took notes using the Vuzix Blade while Participant 2 took notes using a laptop. Immediately after finishing the video, each participant filled out a NASA-TLX about the note-taking experience. After the first video, both participants watched the Ted

Talk "Why are these 32 symbols found in ancient caves all over Europe?" simultaneously. However, this time Participant 1 took notes using the laptop while Participant 2 took notes with the head-up display. Immediately after watching the second video, both participants filled out a NASA-TLX and the Post Note-Taking Questionnaire. Once session one was finished, the conductor of the experiment gathered both the laptop and Vuzix Blade in order to download the notes and print them for each participant. In session two, each participant was informed to complete the quizzes and Post Quizzes Questionnaire only using their notes. After completion of the quizzes and questionnaire, the participants were released and the experiment was closed.

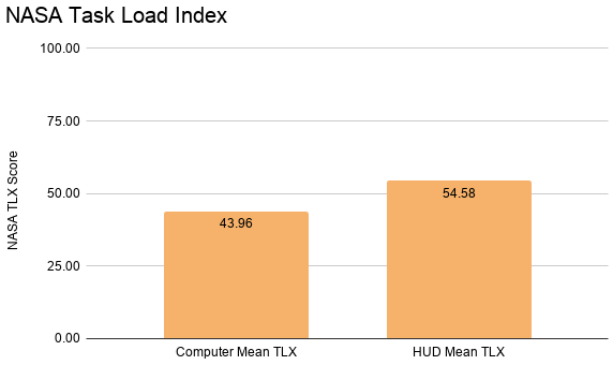

Figure 1: NASA Task Load Index

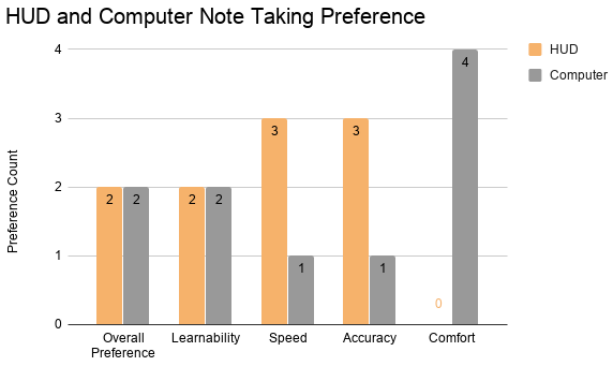

Figure 2: Post Note-taking Questionnaire

Data Analysis & Results

After tabulating the NASA task load index (TLX) scores (see Figure 1) for each participant, we discovered that the overall mean TLX score was higher for the Vuzix Blade HUD (M = 54.58) when compared with the mean TLX for the laptop computer (M = 43.96). Taking the NASA-TLX score into consideration, we can effectively say that the cognitive load is higher for the HUD than the laptop computer. Of the four participants in the Post Note-taking Questionnaire(see Figure 2), two participants preferred the HUD in regards to Overall Preferences and Learnability. However, none of the participants selected the HUD as their preferred note-taking system in regards to Comfort. Three participants preferred HUD in regards to Speed and Accuracy. Some participants found the HUD screen was blurry and uncomfortable to utilize for note-taking. However, others noted having all of the information in a single view made the task easier, and felt that their discomfort when using the HUD stemmed from their inexperience with the HUD hardware, rather than an inherent flaw in the HUD system as a note-taking medium. Additionally, some found the HUD UI difficult to focus on when AR UI elements intersected with the video screen from the perspective of the viewer.

On the quizzes (see Figure 3), no matter what device participants were using, performance was the same for factual questions. Participants displayed a slightly stronger conceptual understanding of the lecture content after taking notes via computer instead of using the HUD. When taking notes on a computer, participants demonstrated slightly better overall performance with regard to both board concepts and small details. In the Post Quiz Questionnaire (see Figure 4), the participants judged that notes from the HUD better prepared them for the quizzes than notes taken on the computer.

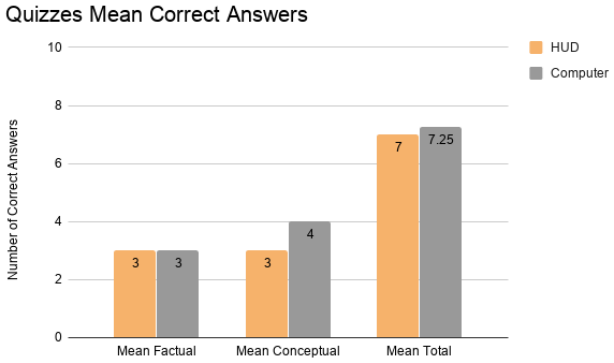

Figure 3: Quizzes Mean Correct Answers

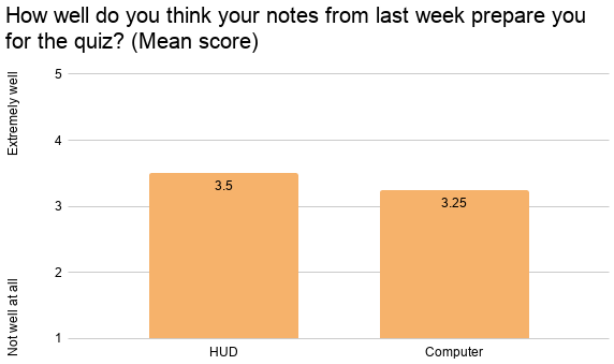

Figure 4: Post Quiz Questionnaire

DISCUSSION

After the first pilot study, we considered the feedback and made improvements like making sure participants can touch-type, and before beginning the study, giving them enough time to get used to the given keyboard and Vuzix Blade. Also, after pilot study 1, we realized it is important to have a Bluetooth mouse for Vuzix Blade. It makes it easy to nav-

igate through notepad app, easy to manage, and creates a more similar experience like the laptop. So this time we made sure to have a Bluetooth mouse for the Vuzix Blade and have limited and similar functionality for both the laptop and the Vuzix Blade. In the laptop condition, participants were restricted from using any copy-paste functionality and have limited text input to ensure the similarity in laptop and head-up conditions. By making these changes, we were able to reduce the number of confounds in our experiment.

We decided to conduct pilot study 2 with the improvements from pilot study 1. Again, we utilized a within-subject design and had a total of four participants. We held our study in a better room with fewer distractions and a large TV screen to create a proper study environment. We also changed our quiz to multiple choice questions because some participants noted difficulty in completing the open-ended questions.

When it came to our results, there was not a big difference in the accuracy of the quizzes. The participants scored about the same with both notes. On the other hand, based on the NASA-TLX and Post Questionnaire, we found that more participants had a better experience using the head-up display. The only issue was that they were more comfortable with using the laptop. However, one participant stated that using the head-up display got more comfortable as the task progressed. Another user stated that they would actually prefer using the head-up display if they became more familiar with it. Thus, our results make us lean towards the hypothesis that taking notes with a head-up display is more effective than taking notes with a laptop. In addition, our results show that there is a lot of potential for head-up displays to be used in the academic field and professors as well as students should take note of this experiment.

FUTURE WORK

Moving forward, there is still much research to be done on this concept. As of right now, we cannot say for sure which method of note taking is "better". However, based on the feedback we received from the participants, note taking with a head-up display could be preferred over note taking with a laptop if the user was given enough time to familiarize themselves with the device and its functionality. Our team believes this study can be improved drastically by increasing the number of participants, giving the participants a significant amount of time (maybe a week or two) to get used to the head-up display, and enhancing the overall organization of the experiment. These improvements will also lead to more accurate results and bring us a step closer to finding out which note taking method is more effective. In the following paragraphs, we elaborate on these improvements.

One of the key insights revealed during our analysis was the difference in keyboard used in the laptop and Head-Up Display conditions. To avoid any variability caused by different keyboards in the future, we are planning to provide the same keyboard in both conditions and restrain the participant from using the laptop's keyboard. Additionally, our pilot study can be improved by using a better software and text editor for Vuzix Blade. Based on the feedback we got from one of our participants, the current text editor always shows the built-in keyboard, which was distracting to them while making notes and thus may have affected the results. In this scenario, the screen viewed by the user while wearing the Vuzix Blade always had a keyboard displayed in the lower half of the screen and there was no way to get rid of it. Some participants also mentioned difficulty in adjusting their note-taking when switching videos. In the future, we will try to choose better videos with better content and try to ensure the speaker in each video are talking at relatively the same speed to avoid the issue.

Another critical issue we encountered was that after the typing training sessions to get used to the keyboard and to ensure touch typing, our participants may have focused more on touch typing which may have divided their attention. To ensure they are paying more attention to the video than typing, we told them about the quizzes. In the future, we will emphasize more on the quizzes, which may help them to focus more on the video, take more effective notes, and learn to perform better on the quizzes.

Finally, we realized from both pilot studies that our participants are still more comfortable using the laptop, and the Vuzix Blade is causing some discomfort and feelings of dizziness. Giving them only a small amount of time to get adjusted to the keyboard and Vuzix Blade doesn't seem to be helpful enough. In the future, it is essential to spend a lot more time to make sure participants get very comfortable with the Vuzix Blade. Learnability and comfortability are significant factors that are affecting our results. Thus, any teams in the future can use this published paper as a starting point and foundation to refine the current study and obtain higher quality results.

CONCLUSIONS

Our initial round of experimentation, although too small to draw any conclusive results, has validated the key features of our experimental design and revealed a number of small enhancements that we can make to ensure the final study accurately and effectively compares the impact of HUD-based digital note-taking systems with digital note-taking on a traditional laptop interface. Furthermore, this experiment captured some useful data on the usability issues (motion sickness, confusion due to overlapping visuals, etc) that HUD-based systems must adequately deal with to be effective tools for supporting learning. In conclusion, our team believes that this completed study has initiated the spark to truly investigate head-up displays as an enhancement in the academic field.

REFERENCES

1. Edwin G Aiken, Gary S Thomas, and William A Shennum. Memory for a lecture: Effects of notes, lecture rate, and informational density. *Journal of Educational Psychology*, 67(3):439, 1975.

2. Burke H Bretzing and Raymond W Kulhavy. Notetaking and depth of processing. *Contemporary Educational Psychology*, 4(2):145–153, 1979.

3. C Marlin "Lin" Brown. Comparison of typing and handwriting in "two-finger typists". In *Proceedings of the Human Factors Society Annual Meeting*, vol-

ume 32, pages 381–385. SAGE Publications Sage CA: Los Angeles, CA, 1988.

4. Fergus IM Craik and Robert S Lockhart. Levels of processing: A framework for memory research. *Journal of verbal learning and verbal behavior*, 11(6):671–684, 1972.

5. Francis J Di Vesta and G Susan Gray. Listening and note taking: Ii. immediate and delayed recall as functions of variations in thematic continuity, note taking, and length of listening-review intervals. *Journal of Educational Psychology*, 64(3):278, 1973.

6. L Brent Igo, Roger Bruning, and Matthew T McCrudden. Exploring differences in students' copy-and-paste decision making and processing: A mixed-methods study. *Journal of Educational Psychology*, 97(1):103, 2005.

7. Kenneth A Kiewra. Investigating notetaking and review: A depth of processing alternative. *Educational psychologist*, 20(1):23–32, 1985.

8. Pam A Mueller and Daniel M Oppenheimer. The pen is mightier than the keyboard: Advantages of longhand over laptop note taking. *Psychological science*, 25(6):1159–1168, 2014.

9. Annie Piolat, Thierry Olive, and Ronald T Kellogg. Cognitive effort during note taking. *Applied cognitive psychology*, 19(3):291–312, 2005.

10. Liuqing Ruan, Zhiyong Xiong, Lijun Jiang, and Xue Zhou. "comparison between digital and paper notetaking based on nasa-tlx". In *2015 IEEE International Conference on Progress in Informatics and Computing (PIC)*, pages 221–225. IEEE, 2015.

11. Virpi Slotte and Kirsti Lonka. Review and process effects of spontaneous note-taking on text comprehension. *Contemporary Educational Psychology*, 24(1):1–20, 1999.

12. Peggy Van Meter, Linda Yokoi, and Michael Pressley. College students' theory of note-taking derived from their perceptions of note-taking. *Journal of Educational Psychology*, 86(3):323, 1994.