HIGH SCHOOL EDITION
Journal of Student Research
Volume 11 Issue 4 (2022)

Impact of Note-Taking Mediums on Memory Recognition

Tamanna Khurana[1] and Jonathan Frishman[#]

[1] Mentor High School, Mentor, OH, USA
#Advisor

ABSTRACT

Note-taking has been the key mechanism for information keeping and an integral part of academic success. Given the benefits of note-taking in learning, it is very important to identify the most effective technique. Past research conducted on college students and adults have underlined some of the key methods commonly used to take down notes, such as digital note-taking or hand written note-taking, but the conclusions are insufficient in reference to the wider age group and digital redesign of the learning system.

A sample size of 33 students, between the ages 13-18 and enrolled in at least two of the advanced courses at a high school, were selected to watch a video and randomly assigned to use one of the three options of note-taking mediums—typing, handwriting or no-note taking at all. After the video, a distractor task of multiplication problems, an assessment, and a post-experimental survey were administered. A one way ANOVA test was conducted using the students' assessment scores. The results revealed that typing notes was the most efficient note-taking medium, with the highest memory retention of the material.

Introduction

Note-taking is an essential skill often practiced in our day to day lives, from scribbling down a grocery list to recording key points from a lecture in class. Though these tasks seem unrelated, they all utilize note-taking as a tool to memorize a set of information by transferring it into a visual copy to be revisited later. In the context of academics, Dung Bui, a researcher specialized in the topic of working memory, defines note-taking as a "cognitively demanding skill", often paired with a lecture which requires students to interpret the lesson, retain it in their memory, paraphrase it, and write it down simultaneously with the lecture in progress (p. 1).

Handwriting has been the traditional note-taking method but digitalization has gained immense popularity in recent times. In the technological age, a new wave of studying has shifted mediums of note-taking to incorporate electronic formats such as digital pens, tablets, laptops, as well as e-writers in addition to the traditional pen and paper notes (Igo, 2005). Particularly during the COVID-19 pandemic, technology has become increasingly assimilated into classrooms to aid in remote learning (Onyema, 2020). Adoption and globalization of digital technology has seen great tech advancement through new apps and softwares for convenient interaction between user and tech devices (Grahame, 2016). Students today are able to have a preference in the note-taking medium that they choose to utilize, for example, longhand or an electronic device.

To understand the magnitude of the impact that this shift in note-taking mediums has caused in the past decade, it is essential to observe the emergence of note-taking and its integration into the educational system throughout history. Note-taking can be traced to Mesopotamia as writings were carved on rocks, wax tablets, and papyrus sheets, but these writings were never transmitted due to the fragile surfaces they were written on (Blair, 2010). As the neolithic revolution occurred, parchment was introduced followed by paper

becoming readily available which ushered scholars to record their ideas and scientific discoveries to be transmitted during the Renaissance era (Blair, 2010). As a result, lecture styles also transitioned from orally transcribed presentations to handwritten notes used to memorize assigned readings (Blair, 2010). In schools, students were dictated by the master to write the same set of notes in the margins of printed readings and advocated to personalize their notes (Blair, 2010). The prominent medium for note-taking throughout history has been longhand (hand writing) which raises the question of how effective and potentially advantageous using an electronic device to type notes is in relation to enhancing the memory retrieval. This literature review aims to discuss the cognitive processes involved in note-taking and evaluate the gap with the past research conducted in the subject field.

Literature Review

Cognitive Load

According to the American Psychological Association (APA) Dictionary of Psychology, cognitive load is defined as "the relative demand" of mental resources "imposed by a particular task" (APA Dictionary of Psychology). Note-taking requires more cognitive load than simply comprehending the lecture as it is divided into five processes: comprehension, pinpoint of key details, relating to past material, paraphrasing, and transforming the information through either typing or writing (Jansen, 2021). This load placed on working memory is limited to "7±2 semantic chunks" and must be used efficiently with the utilization of a note-taking medium that allows for the absorption of information in an effective manner (Shibata, 2018). The difference in cognitive load for different note-taking mediums is evident in a study conducted by Hirohito Shibata and Kengo Omura, researchers and authors of "Why Digital Displays Cannot Replace Paper", which involved 24 adults ranging from ages 20 to 30 years in a dual task experiment (Shibata, 2018). They used a dual task experiment methodology where the second task is contingent on the first and the results are a reflection of the first task performance. In the first part of the experiment, users were given a set of words and then as a second part, they were made to write those words. The count of words was used to understand the inputting impact on the cognitive load and memory retention. The cognitive load comparison for typing and handwriting was used to identify the one that is the more effective medium. The count was analyzed using a mixed model ANOVA. The results revealed that handwriting had a higher recollection rate and therefore, less cognitive load than typing, as it did not "interfere with thinking or memorizing" to the degree that typing did (Shibata, 2018). However, a study conducted by Ian Schoen at Pitzer College in Claremont, California randomly assigned the college students to either take notes longhand or by typing on the content of textbook pages. They were made to attend a 16-minute lecture, followed by a distractor task, before being tested in a multiple choice format based on the content (Schoen, 2012). The ANOVA test analyzed the mean and standard deviation of the data which revealed that those who typed notes displayed higher levels of retention than those who hand-wrote notes, possibly due to a greater transcription fluency, the speed at which one can encode and take down notes, reducing the cognitive load (Bui, Schoen, 2012). The studies differ in the fact that Shibata and Omura's research aims to assess the recall while Schoen's study aims to assess the recognition. As stated by Raluca Budiu, a cognitive psychologist with a Ph.D in the field, the processes of recall and recognition are both a part of working memory with recognition including the process of recall at a later stage. The difference in cognitive load between typing and handwriting still remains unclear as both experiments deduced opposing conclusions, but share a similar understanding that simultaneous note-taking creates a higher cognitive load than only mental comprehension of the lecture.

Encoding and External Storage Effects

These studies mainly focus on the encoding effect, whether the note-taking medium enables the encoding of material, rather than the external storage effect, that covers the reviewing or rehearsal of notes (Kobayashi, 2005). To ensure that the results are only testing the encoding effect, participants are not allowed to review or study their notes by either having a copy of the notes or mentally studying the content. In order to prevent participants from doing so, a distractor task was administered during the Pitzer college experiment of having to spell out as many words with letters in the word "CLAREMONT" which isolated the factors to only test the encoding effect (Schoen, 2012). Similarly, in a widely replicated study conducted by Mueller and Oppenheimer at Princeton University in 2014, which involved 67 students watching a TED talk while taking notes, either using a notebook or laptop. After engaging in a 5-minute distractor task, participants took a test containing factual as well as conceptual questions from material covered in the TED talk (Mueller, Oppenheimer, 2014). The mixed ANOVA and content analysis of the students' notes disclosed that those who took notes longhand scored better on concept based questions but had a lower word count, while participants who typed notes took more words verbatim from the lecture rather than processing it into their own interpretation (Mueller, Oppenheimer, 2014). The influence of the encoding and external storage effects may be different depending on the note-taking medium. Transcribing the lecture by typing notes conflicts with deeper processing of the material reducing the encoding effect, but reviewing the notes would involve the external storage effect (Kobayashi, 2005). In contrast, handwriting notes applies the encoding effect since the content is paraphrased and semantically processed but the complete transcription of the lecture isn't available to review thereby reducing the external storage effect (Kobayashi, 2005).

Visual Attention and Motor Input

As stated by a professor at the University of Stavanger, Anne Mangen, the visual attention and motor input are split between viewing the screen and typing on the keyboard. On the other hand, handwriting notes maintains the visual attention on the paper and the motor input, the tip of the pen, to be very close, resulting in handwriting being a more lateralized process when compared to typing. Despite the visual attention-motor input split in typing notes, "less precise manual movements are required" when compared to handwriting which required more "motorically controlled" movements (Mangen, 2015). When taking notes longhand, "the writer has to graphomotorically form each letter," i.e. create a graphic in mind for each letter before writing it down on paper whereas in keyboard, the letters are in a standard universal format and it becomes much faster to digitally capture information (Mangen, 2015). A Slovenian case study conducted by a professor in University of Maribor with specialization in education, Metka Aberšek, emphasized that younger age groups' "visual attention is commonly restricted to precisely the point where the pencil hits the paper" when writing notes. The Slovenia research utilized mixed methods of quantitative and qualitative research as the goal was to explore note-taking modalities and memory retention with 5th grade primary school students as the main participant group in a classroom setting (Aberšek, 1970). Students were told to conduct a small research project about a biological topic and write an essay which would be scored according to the IWM test developed by the researchers (Aberšek, 1970). The study analyzed essays and concluded that note-taking modality had no effect on the word count, however, students who hand wrote notes had an elementary level sentence structure and showed a deeper understanding of the material (Aberšek, 1970). A study conducted by the same professor, Anne Mangen at Norwegian University involved 36 females between ages 19-54 who were asked to listen to word lists, consisting of target as well as distractor words, and copy down the words using either writing, typing on a laptop keyboard, or typing on a virtual touch ipad keyboard. Participants were then asked to recall as many words from the word list and to recognize those words on a scrambled list. Analysis of variance and non parametric tests such as the Mann-Whitney U test concluded that handwriting was the medium with higher recall but there was "no difference between writing modalities with respect to recognition" (Mangen, 2018). Both studies conclude

that handwriting notes may have offered cognitive benefits that typing notes did not, such as the spatiotemporal contiguous visual attention and haptic input in relation to episodic verbal memory (Aberšek, 1970).

Gap

As stated in the study conducted in Slovenia, "it was noticed that the majority of existing research was performed on samples from the adult population (university students)," indicating there is a prominent gap, given only the college students and the similar age group participants were tested in the past studies related to note-taking mediums and memory retention (Aberšek). To complement the past studies conducted with college students as the main participant group, and to expand the scope, a study will be conducted with high school students enrolled in at least two college level courses as the participant group. The study will aim to explore the effects of note-taking mediums on high school students' (ages 14-18) memory retention and answer the following question in attempt to reduce the gap in research: *Through a mixed method quantitative - qualitative study, is there a significant difference in high school students' memory retention and their recognition of the material when taking notes by hand or by typing into the QWERTY keyboard?*

Methods

Design

Replicating past research' methods in the field, a quantitative-qualitative mixed method approach would be best suited for this study as it would maximize data collection with quantitative memory retention test scores and relate it to the qualitative content analysis of students' notes along with survey responses. Specifically, data would be analyzed in a convergent parallel design where the quantitative and qualitative data would be analyzed separately but interpreted together to establish the relationship between note taking mediums and memory retention that my question is addressing. This data would be collected in an experimental design as it would allow to manipulate the variables, the note-taking mediums students are assigned to, in a controlled environment. The independent variable of the study would be the assigned note taking medium (typing, longhand, or no-notes) with the no-notes group being the control group of the study. While the dependent variable would be the participants' memory retention test scores with the higher score signifying efficient memorization of the material. Similar to previous research by Hirohito Shibata and Kengo Omura, a dual task method to assess cognitive load and the performance will be used, followed by the one-way ANOVA test to analyze the statistics. The first part of the dual experiment will be watching the video and taking notes, while the second being the test to assess the memory retention of the content. Further, the parametric equivalent of a Mann-Whitney U test, an unpaired t-test will be performed to analyze the data due to its normal distribution.

Hypothesis

Writing is still the key method used to instant capture any information. While typing is considered to be a faster method that the learner can quickly turn back to the lecture, longhand notes are defined to be more paraphrased than laptop notes and less verbatim, leading to extended processing of the material during note-taking. In view of the past research and the causation effect of the independent variable of hand writing notes resulting in the

elevated dependent variable of high memory retention test scores, it was hypothesized that the longhand is the most effective method for concise note-taking, thereby achieving greater memory retention.

Participants

There are primarily two basic sample size methods utilized in the study - the convenience sampling and volunteer sampling. Convenience sampling is a form of quota sampling but an uncontrolled non probability method while quota sampling involves certain characteristics needed to participate in the study. Convenience sampling, with introduction of certain limitations in order to have controlled results, was used to verify that the participants who volunteered were characteristic representations of the population. To volunteer for the experiment, the quota was set that required participants to be currently enrolled in at least two 5.0 courses at the school. This restriction filtered volunteers to those who are required to take more notes on a daily basis, given the rigorous level of their courses and the added time management pressures. A sample size of approximately 33 participants was used in accordance with the central limit theorem and the large enough sample rule, that the minimum sample size to measure normal distribution should be $n>=30$ where n is the sample size. It was also stated that a split plot design with two groups must require at least 10 participants per group in order to have at least 90% power when conducting the test. The sample size included Freshmen, Sophomores, and Juniors from the population of the high school which met the 5.0 course criteria.

Materials

Youtube Video

A 16 minute and 23 seconds long Youtube video titled, “The Riemann Hypothesis, Explained” by the channel, “Quanta Magazine” was used. The video was recently published on January 4, 2021 and is narrated by Alex Kontorovich, a professor specializing in mathematics at Rutgers University. In the video, Professor Kontorovich comprehensively explains the mathematical theory of the Riemann Hypothesis, which was first proposed in 1859 by Bernhard Riemann and solved by Dr. Kumar Eswaran in 2016 for a 1 million dollar prize. Topics discussed in the video include the Prime Counting Function, Logarithms, Gauss’s conjecture, the Zeta Function, Imaginary Functions, and Trivial Zeros, and the Critical Line. The video contained 5 or fewer words per slide, labeling the term with graphs and tables to visualize the relationship between the numbers.

Longhand Group

Students in the longhand group will be provided with blank sheets of college ruled lined paper paired with a No. 2 pencil to take notes.

Typing Group

Students in the typing group will take notes on the video, using a google document on the Lenovo monitors and QWERTY keyboards provided by the school district.

Procedure

A team generator web tool was used to randomly assign students and group them under one of three note-taking methods: Longhand group, Typing group, or No-notes group. Before starting the procedure of note-taking, the names of all the participants were entered into the website, which randomly assigned them into one of the three groups, with each group having an equal number (11) of participants.

The classroom was arranged with Lenovo monitors, QWERTY keyboard, a mouse, and pencil at all seats with 2 sheets of paper at a few seats. To replicate a classroom lecture setting, students participated in smaller groups of around 10-15 students each day for three days. "The Riemann Hypothesis, Explained" Youtube video was displayed onto the smart board screen in front of the students with closed captions turned on. Students were instructed to take notes on the video as they do in the class and were allowed to use as many sheets of paper or documents as needed. However, the third group, assigned not to take any notes, was instructed to only watch the video. The researcher and a teacher were present in the room to administer the experiment. After the 16 minute long video is finished, sheets of notes were collected by the experimenter and the google documents were closed after being emailed to the researcher. Participants in all three groups were then instructed to complete a set of 10 multiplication problems in five minutes (see Appendix A), as a distractor task to prevent mental recall of the information. Students were then given a memory retention test consisting of 25 multiple choice questions (see Appendix B), including factual information and vocabulary quoted from the video to assess recognition of the material within the time limit of 25 minutes. Followed by the test, they were given a post experimental exit survey consisting of questions about their note-taking strategy in class along with their demographic details such as their age, grade level, gender and race (see Appendix C).

Ethical Considerations

Due to the majority of the participants being minors, consent forms (see Appendix D) were required to be signed by the participants' parents in order for them to participate in the study and participants were free to withdraw from the experiment at any time. Participants' survey responses were kept confidential and test scores were kept anonymous to prevent any discrimination or social harm from score comparisons between the participants. Participants were all debriefed of the study after data collection was complete. The experiment was approved by the school's IRB prior to data collection to ensure that ethical issues were minimized.

Results

Quantitative

Students' memory retention test scores were graded out of a maximum score of 25, with 1 point per question answered correctly and no points deducted for incorrect answers (see Appendix E). To ensure that the data set was normally distributed, test scores were plotted onto a Q-Q plot (see Appendix F). The plot confirmed that the data was indeed normally distributed supported by the skewness as seen in Table 1 fell between -0.5 and 0.5, verifying the data was almost symmetrically distributed. The Excess Kurtosis in Table 1 was also between -2 and +2 signifying that the distribution was slightly flat but still considered acceptable for normal distribution.

Table 1. Q-Q Plot of Memory Retention Test Score Results

	M	**Variance**		**Skewness**
Test Scores	14.55	15.07	0.07	-1.38

Scores were then inputted and analyzed for descriptive statistics using Microsoft Excel as depicted in Table 2. Skewness and Kurtosis distribution for each individual group seemed within the desired parameters as stated previously. From the descriptive statistics and Q-Q plot, it was confirmed that the the tests were narrowed down to parametric tests such as the one-way ANOVA, Pearson Correlation, and unpaired t-tests for further analysis of the data.

Table 2. Descriptive Statistics Table

Note Taking Medium	n	Mean	SD	Median	Min	Max	Skewness	Kurtosis
Typing	11	16.64	2.77	18	12	20	-0.61	-1.2
Longhand	11	12	2.61	11	9	17	0.53	-0.81
No-Notes	11	15	4.65	17	9	21	-0.02	-1.62

A one-way, single factor ANOVA Test was conducted to perform an analysis of the effect of students' note-taking medium (typing, writing, and no-notes) on their test performance as seen in Table 3. The test revealed that at least two groups had a statistically significant different mean test score, therefore, the null hypothesis was rejected. For further comparison, Tukey's HSD Post Hoc Test was conducted and it was observed that the mean of the Typing group was significantly different than the Writing group. However, there was no statistical difference between the Typing and No-Notes group, as well as the Writing and No-Notes group.

Table 3. ANOVA Test Summary

Note Taking Medium	Count	Sum	Average	Variance	
Typing	11	183	16.64	7.65	
Writing	11	132	12	6.8	
No-Notes	11	165	15	21.6	
One-way Analysis of Variance					
Source of Variation	**Sum of Squares**	**df**	**Mean Square**	**F-value**	**p-value**
Between Groups	121.64	2	60.82	5.06*	0.013**
Within Groups	360.54	30	12.02		

Students' memory retention test scores were analyzed using a one-way ANOVA test *F crit = 3.32 **p<0.05

Qualitative

For the content analysis portion, participants' typed and handwritten notes were converted into a transcript to count the number of words. Word count for both the Typing and Longhand groups were inputted as the Y values in the Pearson Correlation Test while the corresponding memory retention test scores were inputted as the X

values. This was done to establish that there is a significant correlation between word count and memory retention in the experiment. In Table 4, the corresponding p-value for the correlation coefficient was statistically significant as implicated by conducting the Pearson Correlation test.

Table 4. Pearson Correlations between Memory Retention Score and Overall Word Count

		Test Score	Overall Word Count
Test Score	**Pearson's r**	-	0.5
	p-value	-	0.02*
Overall Word Count	**Pearson's r**	0.5	-
	p-value	0.02*	-

p<.05*

The transcript for the Riemann Hypothesis video was put into an n gram python program along with each participant's notes transcript to compare the number of words that were common between both documents. The number of words captured or the verbatim from the video's transcript was recorded as the "Verbatim Word Count" in Table 5. The Pearson Correlation test was conducted again, this time comparing each individual student's memory retention test score and verbatim count from their notes. The result was not statistically significant as the p-value was out of range.

Table 5. Pearson Correlations between Memory Retention Score and Verbatim Word Count

		Test Score	Verbatim Word Count
Test Score	**Pearson's r**	-	0.26
	p-value	-	0.25*
Verbatim Word Count	**Pearson's r**	0.26	-
	p-value	0.25*	-

p<.05*

To analyze the significance of the differences in overall word count and verbatim count for the Typing and Writing groups, unpaired t-tests were conducted which are summarized in Table 6. The test results indicated that the word count for typed notes was higher than for handwritten notes as the p-value falls in the acceptable range stated earlier. The t-test findings indicated that typed notes had a significantly higher verbatim information overlap than handwritten notes.

Table 6. Results of T-Tests Analyzing Overall Word Count and Verbatim Word Count

	Typing		Writing		t(20)	p-value	Cohen's d
	M	**SD**	**M**	**SD**			
Overall Word Count	211.36	87.87	96.73	61.65	3.54	0.002*	1.51

Verbatim Word Count	37.46	14.93	21.73	13.44	2.6	0.02*	1.11

p<.05*

The second segment of the content analysis covers the post experimental exit survey that participants completed after the memory retention test (see Appendix G for survey responses). The survey consisted of questions seen in Table 7. Each question was on the survey and participants were asked to respond accordingly to the Likert scale. The primary goal of these survey questions was to determine how the participants overall experience was, how they felt towards their note-taking medium - positively or negatively. Their attitude towards their medium was measured in terms of the effectiveness in their memory retention, ability to simultaneously listen while taking notes, and whether they would use the medium again in future.

Table 7. Post Experimental Questionnaire

Question Number	Question
1	The note-taking medium you used was effective in retaining information covered in video.
2	You were able to take notes and watch the video attentively without any interference.
3	It is likely that you will implement the use of the note-taking medium in the future.

The survey questions were formatted as likert scale questions with 5 option choices ranging from strongly disagree to strongly agree. The responses were then coded into numerical data for analysis according to Table 8.

Table 8. Coding Likert Scale Questions

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

In Table 9, a few participants from the typing group felt slightly negative but mostly were neutral about the effectiveness of their note-taking medium in retaining the information that was covered in the video. However, also a majority felt that they were able to type while attentively following the video. Most participants of the group also agreed that they will implement the use of typing as a note-taking medium in the future. Overall, the typing group showed inclination and felt more positive about their note-taking medium when compared to the longhand group. Data was inputted into charts as seen in Appendix H.

Table 9. Typing group post experimental questionnaire responses

Question	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	18%	18%	45%	18%	0%
2	9%	0%	18%	9%	64%
3	9%	9%	27%	36%	18%

Overall	**12%**	**9%**	**30%**	**21%**	**27%**

Overall, there were 11 responses for the Typing group.

In Table 10, the Longhand group did not feel that their note-taking medium was effective as the majority of the responses disagreed with the question. However, more students agreed that their note-taking medium enabled them to follow along with the video. The majority of students in this group turned to be supportive of their option to use the Longhand note-taking medium in the future. Overall, responses within the longhand group had a fairly mixed opinion since some felt positively about the medium while others were not so supportive. Data was inputted into charts as seen in Appendix I.

Table 10. Longhand group post experimental questionnaire responses

Question	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	9%	45%	0%	45%	0%
2	9%	18%	27%	36%	9%
3	0%	9%	18%	36%	9%
Overall	**6%**	**24%**	**15%**	**45%**	**9%**

Overall, there were 11 responses for the Longhand group.

In Table 11, the no-notes group was the only group where the higher number of participants felt positively about the effectiveness of their note-taking medium in retaining the information covered in the video. Majority also felt that their (no) note-taking option was acceptable while watching the video. They also strongly agreed that they would continue to follow the use of the not taking notes choice in the future. Overall, this group showed the most positivity about their no-note taking choice, out of the three note-taking medium groups. Data was inputted into charts as seen in Appendix J.

Table 11. No-Notes group post experimental questionnaire responses

Question	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	0%	9%	36%	55%	0%
2	0%	9%	9%	27%	36%
3	0%	18%	0%	0%	82%
Overall	**0%**	**18%**	**15%**	**27%**	**39%**

Overall, there were 11 responses for the No-Notes group.

Responses for the open-ended questionnaire regarding students' common medium of note-taking were also compiled into Table 12 where any response involving pencil and paper for note-taking was coded as longhand. For example, "Journal" and "Paper" involved a writing utensil and a physical piece of paper so they were coded under the category of Longhand. The chart in Figure 5 showed that participants primarily used the longhand medium as it comprised 81.8% of the responses.

Table 12. Participants' Experience with Note Taking Mediums

Note Taking Medium	Number of Responses	Percentage of Responses
Longhand	25	75.80%
Laptop	3	9.20%
Ipad/Tablet	1	3.00%
Journal	1	3.00%
No-Notes	1	3.00%
Paper	1	3.00%
Equally Longhand and Laptop	1	3.00%

There were 33 responses in total responding to, "What note-taking medium do you commonly use?"

It was deduced from the results displayed in Table 13 that the majority of students at least take a few notes in class as 57.6% was the highest percentage amongst the three. In total, more than 80% showed a dependency on notes taken. Overlap between the amount of notes each student takes in class as well as their note-taking medium was measured to assess for confounding variables such as previous experience with note taking with the assigned medium that may have skewed the results.

Table 13. Participants' Experience with Taking Notes

Amount of Notes Taken in Class	Number of Responses	Percentage of Responses
I don't take notes	4	12.10%
I take few notes	19	57.60%
I take a lot of notes	10	30.30%

Note. There were 33 responses in total responding to, "How many notes do you usually take in a class environment?"

Discussion

According to the statistical analysis of the data of students' test scores and the results obtained, the typing group scored the highest. There is empirical evidence that the group which typed their notes had the highest recognition rate when compared to the groups who hand wrote their notes.

The n gram python program was used to capture the word count and the results showed that the participants in the typing group had higher overall word count noted from the lecture in comparison to the longhand. The verbatim count for the typing group was also higher but non-significant Pearson correlation results winnowed out the probability of verbatim count having an influence on the individual's test performance. Evidently, the significant Peason correlation calculations confirmed that the higher word count elevates the test scores. Using deductive reasoning, the inference was drawn that the higher overall word count will have a direct influence on better performance with higher test scores. One possible explanation for this is that the transcription fluency of typing is significantly higher than of writing with the reduced cognitive load. With a relatively

fast paced video of a complex mathematical theory, using a QWERTY keyboard or actively retaining the information by simply watching may have been less time consuming compared to transcribing the video in a graphomotorik manner by handwriting content onto paper.

Similar to the study by Schoen, 16 minutes video was played to take notes, followed by a distraction task, the Anova and t-test for calculation, the results were in alignment that typing is the most effective method of note-taking. The findings of the research were in contrast with the conclusions of studies conducted by Hirohito Shibata and Kengo Omura, as well as Mueller and Oppenheimer, that reported the handwriting group to have the highest memory retention. However, the results aligned with Mueller and Oppenheimer study for they both reported the typing group to have a higher overall as well as verbatim word count and thereby high memory retention.

The typing group involvement was supported by the survey data analysis identifying the group to be most comfortable with their note-taking medium, depicted by their positive response to most of the questions, while the hand writing group was partially negative about their given choice of note-taking medium. This was in contrast to the survey results revealing that the majority of participants were used to hand writing notes in school and had the proficiency with longhand. The outcome and analysis strongly suggests that students should be allowed to utilize their preferred medium of note-taking including the use of technology and digital tools in class having the effect of higher cognitive processing and improved academic efficacies.

In response to the research question and also the hypothesis falsified, the study concluded that the high school students had significantly higher memory retention when typing notes, compared to writing, with the higher transcription fluency and therefore, resulting in a reduced cognitive load for typing. The implications of these findings suggest that typing may become the preferred lecture note-taking medium due to its high transcription fluency and memory recognition. It may also support the increasing use of technology in the education system.

Limitations

The efforts were made to minimize limitations by administering random assignment of note-taking medium and conducting multiple trials. The findings of the research were still in light of a few potential limitations that may have influenced the results. The first and the foremost in this research was the sample size. The study targeted the gap pertaining to the participant age groups as students sampled were of higher school age. However, due to the limited population to sample from, since the school only had 9th - 11th grade levels, the grade level of participants was restricted given the 12th grade students were not present to participate. The student presence count was also low due to the pandemic, again limiting the number of participants. Further, the condition of student enrollment in at least 2 college level courses was a qualifier to select participants that may require to engage deeply in rigorous note-taking. The Juniors may have had higher excellence in note-taking strategies and performed better, while the Freshmen and Sophomores may still be transitioning to rigorous learning. Another potential contributing factor could be the format of the lecture and the students' motivation. The focus of note-taking is to strategically retain maximum information in order to achieve high test grades. The activity performed was not linked to the school grades and there were no after benefits offered. The students' disinterest in the topic chosen for the video to watch and lack of tangible rewards may have caused demotivation and students' ignorance in sincerely taking notes, thereby, impacted their performance and the results. Testing a diverse age group and from different schools could be the next step to attain more conclusive results and eliminate the limitations.

Conclusion

Further research on the topic is needed to fully address the limitations of the study to conclude a correlation between note-taking mediums and a range of memory recall test scores.

As identified and emphasized by professor Aberšek, the younger age group have the visual attention restricted to the point of writing and that note-taking modality had no impact on the word count but certainly a deeper understanding of the content. To draw a valid conclusion, the sample size can be increased to cover a diverse group of participants in order to ensure the representativity of the high school student age group, and can even be expanded to elementary and middle school grade levels. It would also be beneficial to conduct this in a natural but controlled classroom environment so students would be inclined to try just as hard on the memory test as they would for a test in their classes and motivation would not be a confounding variable. This research explicates the abstracts of the debate in the current body of work concerning the use of digital technology in note taking; it further validates the past inferences, including the high school students, abridging the gap in research. The learning institutes need to plan to make added investments in digitalization and allow the students to use technology for effective note taking.

Acknowledgments

I would like to thank ABC college for enim ad minima veniam, quis nostrum exercitationem ullam corporis suscipit laboriosam, nisi ut aliquid ex ea commodi consequatur? Quis autem vel eum iure reprehenderit qui in ea voluptate velit esse quam nihil molestiae consequatur, vel illum qui dolorem eum fugiat quo voluptas nulla pariatur.

References

Aberšek, Metka Kordigel, et al. (1 Jan. 1970). “Writing versus Typing during Science Teaching: Case Study in Slovenia.” *Journal of Baltic Science Education*, Scientia Socialis, UAB. www.ceeol.com/search/article-detail?id=967580.

“Apa Dictionary of Psychology.” *American Psychological Association*, American Psychological Association, https://dictionary.apa.org/cognitive-load.

Blair, Ann. (4 Aug. 2010). “The Rise of Note-Taking in Early Modern Europe.” *Taylor & Francis*, 4 Aug. 2010, www.tandfonline.com/doi/abs/10.1080/17496977.2010.492611.

Budiu, R. (2014, July 6). *Memory Recognition and Recall in User Interfaces*. Nielsen Norman Group. https://www.nngroup.com/articles/recognition-and-recall/.

Bui, Dung C., et al. (2012). “Note-Taking With Computers: Exploring Alternative Strategies for Improved Recall.” *Advanced Cognitive Psychology*. http://psych.colorado.edu/~colunga/P4145-Fall17/.

Grahame, Jason A. (Mar. 2016). “Digital Note-Taking: Discussion of Evidence and Best... : The Journal of Physician Assistant Education.” *LWW*. https://journals.lww.com/jpae/Citation/2016/03000/Digital_Note_Taking__Discussion_of_Evidence_and.11.aspx.

Igo, L. B. B. (2005, January 31). *Exploring differences in students' copy-and-paste decision making and processing: A mixed-methods study.* Journal of Educational Psychology. https://psycnet.apa.org/record/2005-01890-010.

Jansen, Renée S. et al. (2021). An Integrative Review Of The Cognitive Costs And Benefits Of Note-Taking". *Science Direct.* https://www.sciencedirect.com/science/article/abs/pii/S1747938X17300374.

Kobayashi, Keiichi. (2005). "What Limits The Encoding Effect Of Note-Taking? A Meta-Analytic Examination". *Science Direct.* https://www.sciencedirect.com/science/article/abs/pii/S0361476X04000621.

Ltd., ICB - InterConsult Bulgaria. (1 Jan. 1970). "Writing versus Typing during Science Teaching: Case Study in Slovenia." *Journal of Baltic Science Education*, Scientia Socialis, UAB. www.ceeol.com/search/article-detail?id=967580.

Mangen, Anne, et al. (15 Oct. 2015). "Handwriting versus Keyboard Writing: Effect on Word Recall." *Journal of Writing Research.* www.jowr.org/index.php/jowr/article/view/662.

Mangen, Anne. (7 Sept. 2018). "Modes of Writing in a Digital Age: The Good, the Bad, and the Unknown." *Modes of Writing in a Digital Age: The Good, the Bad and the Unknown.* https://journals.uic.edu/ojs/index.php/fm/article/download/9419/7593.

Mangen, Anne, and Jean-Luc Velay. (2010). *Digitizing Literacy: Reflections on the Haptics of Writing*. INTECH Open Access Publisher. https://www.intechopen.com/chapters/992.

Mueller, P. A., & Oppenheimer, D. M. (2014). The Pen Is Mightier Than the Keyboard. *Psychological Science*, *25*(6), 1159–1168. https://doi.org/10.1177/0956797614524581.

Onyema, Edeh Michael, et al. (2020). "Impact of Coronavirus Pandemic on Education." *IISTE.* https://genbase.iiep.unesco.org/workspace/applis/epidoc/fichiers/EPIDOC/38698_52821_56584_1_PB.pdf.

Quanta Magazine, & Alex Kontorovich. (Jan 4, 2021). *The Riemann Hypothesis, Explained.* YouTube. https://www.youtube.com/watch?v=zlm1aajH6gY&t=777s.

Schoen, Ian. (2012). "Effects of Method and Context of Note-Taking on Memory: Handwriting versus Typing in Lecture and Textbook-Reading Contexts." *Scholarship @ Claremont.* https://scholarship.claremont.edu/pitzer_theses/20/ .

Shibata, Hirohito, and Kengo Omura. (2018). "[Papers] Reconsideration of the Effects of Handwriting:" *J-STAGE.* https://www.jstage.jst.go.jp/article/mta/6/4/6_255/_pdf.