

The Effects of Writing Medium on Learning & Retention

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Abstract

Recent years have seen a surge in the use of eWriters in college classrooms. Many studies on the topic have shown that taking notes with a laptop on the same lecture result in significantly lower scores than those who took notes by hand. Contemporary research on the use of eWriters in a similar setting, however, has been lacking. Using random assignment and a sample of Georgia Tech undergraduate students (N=194) as participants, we tested whether taking notes on an eWriter would result in higher scores on exams that measured conceptual understanding and basic recall. Additionally, we studied if color-coding on notes had an impact on exam performance as well. We found that participants taking notes on an eWriter scored significantly higher averaged scores basic recall and conceptual understanding exams compared to scores of those taking notes by hand. There was no significant effect of color-coding on exam performance. Our findings show that eWriters allow for better learning over simply taking notes with a pencil and paper and sets the precedent to open up newer studies into eWriter notetaking.

The Effects of Writing Medium on Learning & Retention

In light of previous research, there is an established belief that laptop notetaking is inferior to handwritten notetaking for learning and retention (Mueller & Oppenheimer, 2014). However, in today's academic world, the use of eWriters, devices that allow for electronic notetaking, has steadily increased (Singer, 2015). While there is a somewhat extensive body of research regarding the benefits of handwritten notes over laptop notes, the same does not exist for eWriter notetaking. There is a wide range of possibilities using an eWriter with a stylus, such as adding in images or graphs, and using different colored pens that could benefit learning and retention. Given that an eWriter offers electronic aid to handwritten notes, we would like to find whether using an iPad, a type of eWriter, with an Apple Pencil, a type of stylus, to take notes is statistically better or worse for basic recall and conceptual understanding of material when compared to using pencil and paper when also factoring color-coding in notetaking to supplement the process.

Currently, there exists limited literature that has explored the effect of eWriters on learning ability. One preliminary 2019 study compared handwritten, laptop, and eWriter notes and their effect on exam performance (Morehead *et al.*, 2019). After participants took notes on TEDTalk lectures with their assigned medium, researchers administered immediate and delayed exams on the content. The results found that there was not enough substantial evidence to determine which mediums may be superior or inferior to others. Thus, opening up the stage for further research.

Our team takes on the challenge to extend on previous research that has shown the inferiority of electronic notetaking when compared to handwritten notetaking and observe if

electronic aided notetaking, or eWriting, can do better than standard handwritten notetaking in basic recall and conceptual understanding. In addition to simply examining which notetaking medium results in significant differences in these two categories, we also aim to observe the extent to which notetaking behaviors, like color coding, may amplify the effect. The findings of our study will rebound to the benefit of society to redefine the role of electronic notetaking in modern education and lead to more recommendations of an effective method of notetaking for learning.

Background

It is impossible to understand our efforts without first having a grasp of what has been established in the past. Regarding the use of the iPad, Bennet (2017) found that there was not a noticeable difference in the performance of the students using paper and pencil versus with the iPad. In our study, we hope to find different results by introducing a stylus, the Apple Pencil, into our study. We believe that if the writing mechanics of taking notes are brought to electronic devices, we could see an increase in achievement for eWriter users. With companies packing more and more technology into the styluses used for their devices, such as the Apple Pencil, there is even more potential for research into this area of study.

Expanding on using eWriters with styluses, we found that Rody (2013) compared traditional pens versus styluses for students with emotional behavioral disorders. Their results found that overall words per minute written with styluses was higher than with regular pens. With results like these, it is clear that there is room for further research into how the technology that brings the feeling of writing with pencil (or pen) and paper to electronics can help make the case for why eWriter notetaking could be beneficial.

Recently, Morehead *et al.* (2019) extended a previous established paper by Oppenheimer and Mueller (2014) that explored the difference between laptop notetaking and handwritten notetaking. Morehead *et al.*'s paper extended previous research to also look into a delay of testing to see if this would be a factor in the results of retention for basic recall and conceptual understanding. Interestingly, the results from Morehead *et al.*'s paper contradicted Oppenheimer and Mueller in that notetaking on the laptop vs handwritten did not show a significant difference. Taking a look at the designs of both of these studies, it is useful to see what the pitfalls were for each one that caused the results to be different so that we can avoid them in our own study.

Researching more into our second independent variable, we found that previous research has produced ambiguous findings on the effect of color on memory. Huchendorf (2007) did not find a noticeable difference for percent recall among different kinds of color, which is inconsistent with previous studies observed with print media (McConnohie, 1999; Spence *et al.*, 2006). One possibility of this outcome could be that participants were not exposed to colors long enough throughout the experiment. These results show exactly what to avoid during our experiment as time of exposure to color is directly related to the amount of arousal which causes an increase in memory. Also, we will be using bright colors such as red, yellow and green because brightness of color leads to the arousing effect.

When thinking about notetaking it is also important to consider what type of context surrounds the notetaking to see if any external factors could affect the process or the resulting understanding from the notes. Steimle (2007) dives into the contextual factors of notetaking that affect the understanding of the notes and how much review is required of the notes before an exam. An important note to consider when designing our method is how the type of content

presented to the participant will factor in the type of notes the participant will take. For example, if math content was presented, notes could involve more graphs and drawing as opposed to another subject. Steimle (2007) also brings up that a student's preference for notetaking is an important factor in how the student studies and performs. This is important to consider in light of our study because a participant's preference could affect their performance based on which group of our study they are placed in.

Our Study

With previous studies having not found substantial evidence for which notetaking medium is better than the other, with our study, we plan to keep the downfalls and benefits of previous studies in mind to build and improve upon what has already been done. In our study, subjects will be randomly assigned to our first independent variable with two levels: method of notetaking - iPad notetaking or handwritten notetaking. Within each group, we will measure if participants use color-coding or not - our second independent variable. Those in the iPad group will be instructed on how to use the eWriter as well as how to access color-coding options, and those in the handwritten group will be provided different colored pencils. Participants will then sit through a video lecture and take notes with their respective medium. Afterwards, an exam will be administered immediately on the content of the lecture, which will test subjects on questions falling under two main criteria: basic recall and conceptual understanding. Finally, the scores of the exams will be collected, analyzed and averaged, giving us our dependent variable: average basic recall and conceptual understanding exam performance.

Given the results of past studies and our concurrent research on this matter, we present the following hypotheses:

Hypothesis 1. Individuals who take notes on an iPad will have a significantly higher average score of basic recall and conceptual understanding exams compared to those who take handwritten notes on paper.

Hypothesis 2. Individuals who take notes using different colors will have a significantly higher average score of basic recall and conceptual understanding exams when compared to those who only take notes in one color.

Hypothesis 3. The effect of notetaking medium depends on whether you use color-coding. Particularly, taking notes on an eWriter with use of color-coding will score significantly higher than all other participants (i.e., significantly higher than using an eWriter without color-coding, and handwritten notes regardless of the use of color-coding).

While past research has shown the benefits of handwritten notes over laptop notes, there has been a lack of literature verifying if eWriter devices could similarly improve learning. This topic is only more pertinent given the growth in usage, advancement in technology, and capabilities of applications surrounding eWriting systems. With eWriters solidifying their place in the modern classroom it becomes important to verify if these devices are statistically better for notetaking compared to traditional handwriting.

Methods

Participants

The participants for this study consisted of 194 undergraduate students at the Georgia Institute of Technology ($M_{age} = 18.89$, $SD = 1.03$). Each participant was enrolled in a psychology course, with an incentive of being awarded course credit for participating in the study. All of our participants were first and second-years, and all of them wrote with paper and pencil regularly. This was not a random sample as these students were provided to us by our course instructor for the purpose of conducting this study. If students were blind or possessed vision impairments they were excluded from the study. The location of data sampling was in lecture hall G011 in the Molecular Science and Engineering building at the Georgia Institute of Technology.

Design

In this experimental study, multiple sessions were held where participants were assigned to take notes using either paper and pencil or iPad with Apple Pencil while viewing a short YouTube video created by Kurzgesagt on the immune system (See Appendix D). All participants were given the option to use color, either with colored pencils for the handwritten group or digital color options on the iPad. After the experiment, we divided the participant data into two further groups: participants who used color and participants who did not. In an effort to determine if notetaking medium and color-coding had an effect on understanding, participants' conceptual understanding and basic recall of the video lecture were measured through a two-section, post-lecture exam (See Appendix B and Appendix C).

Conceptual understanding of the material shown in the lecture is defined as the extent to which the participants are able to not only understand, but apply the knowledge they learned to

new scenarios and situations. We measured conceptual understanding based on how well each participant did on the conceptual portion of the post-lecture exam (See Appendix B). Basic recall of the material is defined as the extent to which the participants are able to remember basic information that was shown or stated in the lecture (See Appendix C). Similarly to the conceptual understanding exam, this was measured based on how well each participant did on the basic recall portion of the post-lecture exam. These two exams averaged together create our dependent variable.

Materials

Our materials for the eWriter notetaking group are as follows: any generation of Apple iPad with Apple Pencil capabilities, as provided by the researchers. An Apple Pencil for each participant, either the first or the second generation depending on the iPad used. The Microsoft OneNote application, which includes black, red, green, and blue colored pen settings. Materials for the pencil and paper notetaking group are as follows: “Five-Star” college ruled loose leaf papers, simple #2 Bic Mechanical pencils with .7mm lead, and three Crayola colored pencils in red, green and blue for each participant. As for the lecture material each participant was shown a short Kurzgesagt YouTube video on the immune system to take notes on. For our dependent variable - the average conceptual understanding and basic recall exam score - each participant was assessed through a 10 multiple choice question exam, with 5 questions testing basic recall, and 5 questions testing conceptual understanding, based on the content of the video upon completion.

Procedure

First, all participants were briefed on the general idea, motive, and possible risks of the study and were asked for their consent to participate and given a simple demographics survey (See Appendix A). Participants were then either given an iPad with Apple Pencil or paper and a mechanical pencil and three colored pencils. For each session, we asked participants with an iPad if any of them needed help using the iPad and Apple Pencil and gave them brief instructions on how to use them. Participants were then informed that they would watch a short educational Youtube video lecture, take notes accordingly, and immediately be given an exam with multiple choice questions on the content of the video they just watched. The video was then played, and each participant was allowed to begin taking notes. Upon completion of the video, notetaking materials and notes were removed from all participants, and the post-lecture exam was administered. The exam contained 5 basic recall multiple choice questions and 5 conceptual understanding multiple choice questions based on the content of the video and was administered for 15 minutes (See Appendix B and Appendix C). Once all participants completed the exam, they were debriefed on the purpose of the study, allowed to ask any questions, and thanked for their time.

Results

Data Analysis

This study tested three hypotheses pertaining to notetaking medium, use of color-coding and overall exam performance. Our first hypothesis was that eWriters would perform better than handwritten notetaking on the post-lecture exam. Our second hypothesis was that participants taking notes with color-coding would perform better on a post-lecture exam than participants

taking notes without color-coding. Our third hypothesis was that the effect of notetaking medium depends on whether color-coding was used. Specifically, we hypothesized that participants using an eWriter and color-coding would score significantly higher than all other participants (i.e., significantly higher than using an eWriter without color-coding, and handwritten notes regardless of the use of color-coding).

In order to test these three hypotheses, we conducted a 2 (Notetaking method: eWriter, handwritten) x 2 (use of color-coding: No Colors Used, Colors Used) between-subjects factorial analysis of variance (ANOVA) because we had two categorical between-subjects independent variables and one continuous dependent variable (i.e., averaged basic recall and conceptual understanding post-lecture score). This test allowed us to examine the main effect of notetaking medium on averaged basic recall and conceptual understanding (See Hypothesis 1), the main effect of the use of color-coding on averaged basic recall and conceptual understanding (See Hypothesis 2), and the interaction between color-coding and notetaking medium on averaged basic recall and conceptual understanding (See Hypothesis 3).

Hypothesis 1. The first hypothesis was that eWriter users would perform better than handwritten users on the combined conceptual and basic recall exam. There was a significant main effect of the method of notetaking on exam performance, $F(1, 190) = 932.5, p < .001, \eta_p^2 = .831$. As predicted, the eWriter users ($M = .75, SE = .005$) scored significantly higher than the handwritten users ($M = .54, SE = .005$). Thus, we were able to reject the null hypothesis.

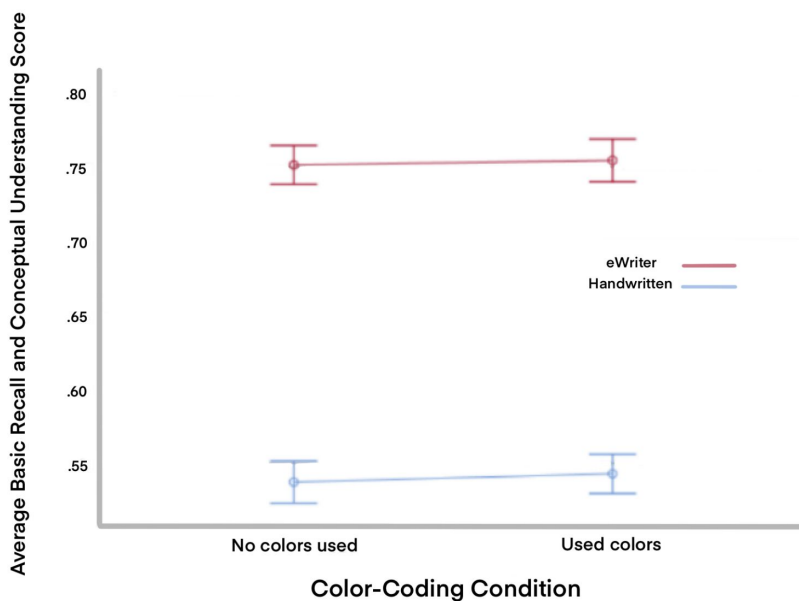
Hypothesis 2. The second hypothesis was that participants taking notes with color-coding would perform better on the combined conceptual and basic recall exam than participants taking notes without color-coding. There was not a significant main effect of color

coding on exam performance, $F(1, 190) = 0.386$, $p = .535$, $\eta_p^2 = .002$. We failed to reject the null hypothesis.

Hypothesis 3. The third hypothesis was that the effect of notetaking medium depends on whether you use color-coding. Specifically, we hypothesized that taking notes on an eWriter with use of color-coding would score significantly higher than all other participants (i.e., significantly higher than using an eWriter without color-coding, and handwritten notes regardless of the use of color-coding). There was not a significant notetaking Style x Color-Coding interaction, $F(1, 190) = 0.033$, $p = .856$, $\eta_p^2 = .000$. We failed to reject the null hypothesis.

Figure 1

A Look At Average Test Performance Across Color-Coding and Writing Conditions



Note. This Figure shows the main effects of Notetaking method, Use of colors and the interaction between the two. The x-axis shows the Independent Variable, Colors_used with levels No colors used and Used colors and the y-axis shows the Dependent Variable, which

is the averaged scores of the conceptual understanding and basic recall exams. From this figure, we can observe that there is a main effect on Experimental Notetaking Method Type and there is no observable main effect on the Colors_used. We can also observe that there is no interaction effect between the two independent variables.

Discussion

Looking back at the initial research question, this study wanted to address the ever-growing use of technology in the classroom and determine if this growth could lead to significantly better achievement by students. More specifically, it looked at how eWriters, devices that combine familiar writing mechanics with electronics, could affect students' performance. What was found was that students who took notes using the eWriters did perform better than their handwritten counterparts. A significant main effect of color on performance was not found and performance using either eWriter or handwriting was not found to be dependent on the use of color.

As mentioned earlier, past research tends to show favor towards handwritten notes when compared to laptop notes (Mueller & Oppenheimer, 2014). Even studies that looked at the iPad specifically such as Bennet's (2017) study showed that there was not a notable difference between students' performance on pencil and paper versus the iPad. The present study hoped to expand upon this research and not count out computer aided note-taking entirely, but focus on a specific technology, one that combined both handwriting and computer aid. The results of the study supported our theory that when working with technology that bridged these two areas, users would have a better notetaking experience and, consequently, better performance. Despite

theorizing that color use would also be a factor in better performance, this was not supported from the results.

If we take a look at our first hypothesis which stated that eWriter users would perform significantly better than handwritten users we see that this was in fact that case here. Across both exams, conceptual understanding and basic recall, the eWriter users outperformed the longhand participants. Our second hypothesis though, stating that the color users would perform better than the non color users, was not supported. There was not a significant main effect of color use on exam performance. This could be attributed to the fact that participants being able to choose using color or not likely went with what worked best for them. In this case, it would be hard to attribute color-use to better performance. This leads to our third and final hypothesis stating that the effect of notetaking medium depends on color-use. The experiment showed that no interaction effect was present and that regardless of note-taking medium, color use was shown to have no effect.

Strengths

It is important to note that our study, while by no means perfect, did excel in some areas. The advancements in technology found in devices like the iPad directly contributes to their growing adoption amongst college populations (Singer, 2015). Students forgo laptops, pencils, and paper in favor of eWriters like the iPad. Regardless, there has been a limited amount of research done on these topics. As aforementioned, a 2019 study did compare eWriters to not only laptops, but handwritten notes as well (Morehead *et al.*, 2019). Fittingly, these researchers stated a need for further exploration on the topic. As one of the first studies to ever examine the impact of eWriter's on learning and retention, we are broadening the necessary body of knowledge on a

now-prevalent set of devices. The findings of this study directly open up the door to more research being conducted in this field. We thoroughly believe that further research on this topic will lead to a shift in the general understanding of notetaking platforms in the classroom, much like Mueller & Oppenheimer's 2014 study did.

Furthermore, our study was created with ease-of-replicability in mind. Our exam was written by ourselves, the Kurzgesagt video we used is free to watch, and iPads can be replaced with budget eWriters costing less than \$30. Subsequently, it follows that this study can be replicated, at least conceptually, and scaled easily. This allows for future research to expound on our findings and elaborate the effects of eWriters.

Limitations and Future Research Directions

During the course of the current study, several limitations and corresponding future research directions were identified; the first is related to how the research was conducted. In this study, the handwritten notetaking group and the eWriter notetaking group experimented in the same space. This detail meant the experiment was more efficient with respect to time, and many participants were able to partake in the experiment at once. However, it later came to our attention that the iPad group may have figured out the true purpose of study and exerted more effort than handwritten groups in order to fall in line with intended results. For this reason, it would have been better for the eWriter and handwritten groups to perform separately from each other rather than in conjunction.

A second limitation pertains to the consistency of the eWriting device used in the experiment. For the sake of financial and temporal reasons, not all participants in the iPad group were able to use the exact same iPad; they differed in size and model. Since the same version of

eWriting software, Microsoft OneNote, was used, the model differences among the devices did not cause differences in conducting the experiment, but the variances in the sizes of the devices was a factor that could have altered the participants' performances.

In the future, as this area of research is explored further, we hope to see our initial theories supported. More research could go into the ease of color-coding notes with eWriters and how this could affect how student's feel about their notes and their performance in the classroom. Further research could also compare eWriters to laptops for notetaking just as pencil and paper has been. Our study made do with the resources provided to us as far as participants go and the time constraints and we believe this study can generalize to a broader audience of college aged kids as that is the population our participants came from. To help with further generalizing these findings though, future studies could replicate this study with various age groups and modify the study to reflect the classroom experience more closely. Potentially a longitudinal study that allows students to sit through actual lectures and use eWriters for an extended period of time.

As a whole, our finding's show that eWriters provide a benefit in terms of performance on our basic recall and conceptual understanding exams, while use of color-coding proved to have no significant effect. We attribute the better performance of those using eWriters to the fact that eWriters provide the best of benefits from both laptops and traditional pencil and paper. While recent research on the use of laptops has shown their inferiority to handwritten notes, we find no such inferiority in the case of eWriters (Mueller & Oppenheimer, 2014). Accordingly, the use of eWriters in modern-day classrooms and lecture halls should be welcomed with open arms, though more research on this nascent topic is necessary.

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Appendix A

Demographics Survey

1. What is your name?
2. What is your email address?
3. What is your age?
4. What is your college major?
5. What is your current year?
6. How do you usually take notes in class?
7. Have you ever taken notes with a stylus and eWriter (like the iPad and Apple Pencil)?

Appendix B

Basic Recall Exam

1. What is the first barrier of the skin?
 - a. Hair
 - b. Skin
 - c. Fat Cells
 - d. Regenerative Cells

2. Which of these doubles every 20 or so minutes?
 - a. Enzymes
 - b. Viruses
 - c. Bacteria
 - d. Immune System Cells

3. Which step of the immune response do macrophages start fighting bacteria?
 - a. 1st
 - b. 2nd
 - c. 3rd
 - d. 4th

4. How have neutrophils evolved to stop from harming the body excessively?
 - a. They are only released in small numbers
 - b. They only appear every other time the body has to fight bacterial intruders
 - c. They are small enough that they can only harm bacterial cells

- d. They commit suicide every 5 days
5. What do B cells produce?
- a. Antibodies
 - b. Memory T Cells
 - c. Bacteriophages
 - d. Viral Cells

Answer Key:

- 1: B
- 2: C
- 3: A
- 4: D
- 5: A

Appendix C

Conceptual Understanding Exam

1. What are two ways macrophages help fight bacteria harming the body? (Select two)
 - a. They break bacteria down with enzymes
 - b. They suffocate bacteria by removing oxygen from bacteria-infested blood
 - c. They call for backup using messenger proteins
 - d. They trigger allergic reactions that cause you to become unconscious

2. Imagine bacteria begins harming the body. Macrophages enter the system to help fight back, and for assistance, they call on Neutrophils to assist. Why might having too many neutrophils actually be harmful for the body?
 - a. Neutrophils are large cells that take up a lot of cells. Having too many of them means other helpful cells can't attack bacteria.
 - b. Neutrophils are so deadly they kill even healthy cells. Having too many might kill a lot of healthy cells.
 - c. Neutrophils deliver small pockets of poison to kill invaders. Having too many could lead to blood poisoning.
 - d. The body has a limited number of neutrophils. If too many are supplied, the body is more susceptible to future attacks.

3. How do helper T cells protect the body from future bacterial intruders?
 - a. Some helper T cells become memory T cells that stay in the body and make you immune to further interactions with this bacterial.
 - b. When helper T cells die, they leave behind traces of the "antidote" to immediately kill the bacteria they fought against.
 - c. Helper T cells deliver antibodies that make your immune system stronger.
 - d. Helper T cells do not protect the body from future bacterial intruders in any way.

4. After a week long bacterial sickness, your body has lost millions of healthy cells, but your immune system has rid your body of the bacteria. Why isn't this a big deal?
 - a. Your body has trillions of cells. Losing a few million is not a big deal in the grand scheme of things.
 - b. The lost cells were damaged and needed to be discarded as they no longer properly functioned.
 - c. The lost cells are slowly repaired by helper T cells.
 - d. The lost cells are quickly replenished without any harm occurring to your body.

5. Continuing from the previous scenario in question 4, your body now has many immune cells that are no longer serving a purpose. What happens to the now useless immune cells and what will happen next time your body encounters the same bacteria? (Select two)
 - a. The immune cells commit suicide so they don't waste any resources.

- b. The immune cells reactivate the next time the body encounters a bacterial invasion.
- c. Memory cells immediately kill the bacteria the next time they are encountered.
- d. The body can never be attacked by the same bacteria twice.

Answer Key:

- 1: A, D
- 2: B
- 3: A
- 4: D
- 5: A, C

Appendix D

Kurzgesagt YouTube Video On the Immune System

<https://youtu.be/zQGOcOUBi6s>