Department of Psychological Science

Note-Taking Method and Recall Performance: Effects of Computer-Based Versus Handwritten Note-Taking

Honors in Psychology Project

2016-17

Clair Tischner

Northern Kentucky University

Dr. Kalif Vaughn, Faculty Mentor

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Clair Tischner

Northern Kentucky University

Author Note

Clair Tischner, Department of Psychological Science, Northern Kentucky University.

Correspondence concerning this proposal should be addressed to Clair Tischner, Department of Psychological Science, MEP 301, Northern Kentucky University, Highland Heights, KY 41099

E-mail: tischnerc1@nku.edu

Honors in Psychology Program

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Student: Clair Tischner

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Signatures below signify that the student has successfully completed the requirements of the Honors in Psychology Project.

Kaliff Vaughn 04/26/17

Project Mentor: *Date*

04/26/17

Committee Member: *Date*

Penelope Goddard 04/26/17

Committee Member: *Date*

Abstract

The role of note-taking method (computer-based vs. handwritten) on recall performance was investigated. A total of 129 participants listened to an academic lecture video and were randomized to take notes or not take notes during the lecture. Participants assigned to take notes either handwrote notes with pen and paper or typed notes on a computer. Participants not assigned to take notes did not take notes and/or were given access to review the video lecture. Participants were assessed immediately after taking notes through a recall test comprising multiple choice, short answer, and fill-in-the-blank questions. I predicted that the handwritten condition would have improved recall performance compared to the computerized condition. Results found that taking notes is generally better than not taking notes and that reviewing the video is not better than not taking notes. Overall, note-taking method does not seem to affect recall performance. Implications and applications for the real world are discussed.

Keywords: note-taking, study habits, laptop use, academic achievement

Note-Taking Method and Recall Performance: Effects of Computer-Based Versus Handwritten Note-Taking

Student-learning strategies in the classroom are an interest of study, including the impact of note-taking on learning and recall. Note-taking techniques require various cognitive processes, such as language comprehension, working memory (Peverly et al., 2012), encoding, and retrieval (Kiewra et al., 1991). With increasing technology, researchers are interested in how digital advancements can enhance classroom learning. College students now integrate laptops in the classroom to take notes. Whether laptops aid in student learning has been debated (Fried, 2008). With this debate in consideration, comparisons between traditional-learning strategies and technological-learning strategies have been investigated. Specifically, researchers have compared handwritten note-taking to computer-based note-taking (Beck, 2014; Bui, Myerson, & Hale, 2013; Mueller & Oppenheimer, 2014). The results of the studies will be discussed in further detail.

As previously mentioned, taking notes requires several processes, such as encoding (studying information), retrieval (accessing information from long-term memory), and working memory (processing and storing information to be learned and remembered). While taking notes, individuals pay attention to multiple factors such as distinguishing the speaker's central ideas and organizing the ideas into information that can be understood later (Piolat, 2007). Peverly et al. (2007) suggest that computer-based note taking is faster than paper-based note taking, allowing for more information to be gathered compared to handwriting notes.

Access to computers is sometimes allowed in college classrooms by professors. Computers offer several learning advantages to students while in the classroom. Efaw, Hampton, Martinez, and Smith (2003) examined learning in students who used laptops to take notes in the

classroom. Instructors' course sections were assigned to integrate technology in the classroom, allowing students to use laptops to take notes, or use traditional teaching methods. Students assigned to the integrated technology sections received higher scores on all exams throughout the course compared to those assigned to traditional teaching sections. Students in the technology condition reported higher motivation and interest in the course and found note taking to be more beneficial. Students in the technology section claimed to take more notes in a shorter time frame and have more organized and legible notes compared to students taking notes with pen and paper.

Although some research supports students using computers in the classroom, other studies do not. For example, Fried (2008) conducted research concerning student use of laptops in classes; however, laptop use was not required. For 20 weeks of the course, students completed weekly surveys that assessed classroom laptop use, classroom attendance, and classroom experiences. Approximately 64% of students reported using their laptop in at least one class period. Laptop use in the classroom negatively correlated with student learning. Participants using laptops during class reported paying less attention and having poorer understanding of class content. Students reported being distracted by neighboring laptop use, which resulted in less concentration during lecture. Students also reported using their laptops during class for non-class related activities, such as checking email, for approximately 17 minutes of the 75-minute class. These findings contradict the belief that laptop use in the classroom is helpful to student learning.

To further investigate the effectiveness of laptops in the classroom, researchers compared computer based note-taking to handwritten note-taking with respect to recall performance. In a study conducted by Bui, Myerson, and Hale (2013), participants listened to an 11-minute passage

from a nonfiction book about a 1930s popular film. Participants were assigned to take notes in one of four possible conditions: handwritten and organize, handwritten and transcribe, computer-based and organize, and computer-based and transcribe. In both handwritten conditions, participants took notes with a notepad and pen. In the computer-based condition, participants typed their notes in a word processor on the computer. In the organize condition, participants paraphrased the material learned and organized their notes. In the transcribe condition, participants documented the lecture verbatim. Free recall and short answer tests (e.g. "What was the political idea that Light Brigade was intended to promote?") measured participants' recall performance over the material. Participants could not view their notes during the final test. On the immediate recall test, the transcribe-computer condition performed better than the transcribe-hand condition. On the delayed recall test with note review, the transcribe note-taking with note review condition displayed better delayed recall performance than organized note-taking with note review condition. Overall, results suggested that computerized note-taking produces better recall performance than handwritten note-taking. Also, when brief study time is allowed, verbatim note-taking is more beneficial for delayed recall. One limitation of this research was the lack of multiple-choice questions, which is one of the most common forms of academic assessment due to the ease with which they can be graded by instructors (Smith & Karpicke, 2014). Therefore, it is not clear if similar results would extend with a more common academic approach.

Contrary to previous research indicating better recall performance among laptop note-takers, Mueller and Oppenheimer (2014) found that handwritten notes are more beneficial in recall performance. Each of the three studies revealed superior performance for the handwritten group. Participants took notes while listening to a TED talk for approximately 15 minutes.

Participants assigned to the laptop condition typed notes on the laptop provided and participants assigned to the handwritten notes condition wrote their notes by hand in a notebook. After engaging in two 5-minute working memory distractor tasks, participants were assessed on the TED talk through questions covering either conceptual (e.g., "How do Japan and Sweden differ in their approaches to equality within their societies?") or factual information (e.g., "Approximately how many years ago did the Indus civilization exist?"). Participants in the handwritten condition performed significantly better on conceptual information. Computer-based notes were often verbatim from the lecture and contained more words compared to the handwritten condition. After a one-week delay, participants were randomly assigned to review their notes and were assessed on recall performance. Participants who handwrote and reviewed their notes performed significantly better on the recall assessment than those who typed and reviewed their notes.

In a similarly designed study, Beck (2014) found no difference in recall performance when comparing handwritten note-taking versus typed note-taking. Twenty-one participants listened to a 9-minute video lecture discussing the Standard of Ur while either taking notes with a laptop or with pen and paper. The Standard of UR is a large box made of limestone that depicts scenes of war and peace from the city of Ur, what is now current day Iraq. Immediately after the lecture, a test composed of 20 multiple-choice questions (e.g. "How old is the Standard of Ur?") measured participants' memory on the video content. One week later, participants took the same test to assess recall performance. No significant differences were found between handwritten note-taking and typed note-taking in immediate or delayed recall performance, even though participants who typed their notes took significantly more notes than participants who handwrote them.

As indicated above, research findings are mixed based on the effectiveness of computerized note-taking. Laptop note-taking is occasionally more successful in recall performance, sometimes handwritten note-taking is more successful, and occasionally there is no difference. In addition to mixed results, prior research is limited based on small sample sizes, and inaccurate representations of academic settings through the use of poor recall performance assessments and impractical lecture content. The purpose of this study was to investigate the relationship between note-taking method and recall performance in realistic academic context by using more practical recall assessments and more academically-based lecture content. In order to address previous limitations related to academic representation, participants watched a video-lecture discussing cellular respiration. In order to address previous limitations related to recall performance, learning was assessed using multiple-choice, fill-in-the-blank, and short answer questions.

I predicted that students in the handwritten note-taking condition would have higher recall performance on the immediate test. Handwritten notes would seemingly require more effort, which should result in more learning according to desirable difficulties (Bjork, 1994). Desirable difficulties is a learning construct that states learning conditions that require more effortful encoding result in more successful learning. Previous research has found support for desirable difficulties. Rohrer and Taylor (2009) had students learn to solve math problems and found that interleaving problems (abcbcacab) resulted in worse performance than blocking problems (aaabbbccc) during initial learning practice performance; however, final test performance favored participants who had learned with interleaved problems. Interleaving practice required more effort during practice, and this improved their ability to solve novel problems on the final test. Pyc and Rawson (2009) manipulated interstimulus intervals, the

number of items between practice trials with any given item. In Pyc and Rawson (2009), the long ISI consisted of 34 intervening items and the short ISI consisted of 6 intervening items. On a final test, recall performance favored the long versus short ISI items. Presumably, more effort is needed to retrieve information when there is a greater time interval and more intervening information between presentations, which results in more learning. The evidence of desirable difficulties corresponds to the prediction that, if handwritten notes require more effort to take, then the increased effort should improve final performance relative to the computer-based note taking condition.

Method

Participants

Students at Northern Kentucky University were recruited to participate in the study through the SONA program. Students received course credit for participation. One hundred twenty-nine undergraduate students participated in the study. Participants were excluded from the study if they indicated "exclude me" during the short post-experiment questionnaire, did not complete all of the experiment, indicated that they had previously completed the study, did not take notes, and/or did not submit a picture of their notes. After exclusions, a total of 110 students completed the experiment. These participants were divided approximately equally into the no notes with review group (n=25), the no-notes group (n=36), the computer-based group (n=32), and the handwritten group (n=17).

Design

A between-participants design was used. Students were randomly assigned to one of four conditions: handwritten note-taking, computer-based note-taking, no-note-taking, or no-note-

taking with video review. The no-note taking group served as the control condition. Immediate recall performance was the dependent measure.

Materials

All participants viewed a video about cellular respiration that was approximately 10 minutes in length (https://www.youtube.com/watch?v=P27djgzRL8c). After watching the video, all participants took a final recall test. The recall test included questions in multiple-choice format, consisting of one correct answer and three incorrect possible alternatives, in addition to fill-in–the-blank and short-answer questions based on information presented during the lecture (see Appendix A). At the completion of the session, participants answered questions in a short survey assessing demographic information and note-taking behavior (see Appendix B).

Procedure

The study was conducted online. Participants watched a 10-minute video lecture. The handwritten note-taking group took notes with paper and pen and the computer-based note-taking group typed their notes in a web browser computer program on the computer during the lecture. The computer program consisted of a divided computer screen, one side for viewing the lecture video and one for taking notes. Participants in the paper and pen note-taking condition submitted a photo of their paper-based notes for verification purposes (computer-based notes were stored electronically automatically). For 2 minutes, students in both note-taking groups reviewed their notes after the lecture was finished and the no-note-taking with review group had access to the original lecture content. Notes were removed from view once the review time had elapsed. A 2-minute distractor task was given during which participants played Tetris. After playing Tetris, participants immediately took the recall test, which was the same across all conditions. Immediately following the recall test, a short survey collected demographic

information, including participants' age, gender, ethnicity, year of study, GPA, and information about note-taking (e.g. "How do you typically take notes?").

Results

Final Performance

A one-way ANOVA was used to compare the four note-taking groups for total recall performance. Means and standard errors are plotted for each group as a function of total recall performance in Figure 1. The ANOVA indicated a significant difference in note taking groups and total recall performance, $F(3, 109) = 6.30$, $p = .001$. Follow-up Tukey t-tests were used to make post-hoc comparisons. Results do not support the hypothesis that handwriting notes compared to typing notes results in greater recall performance. Results indicate no significant difference between handwritten note-taking and computer-based note-taking in terms of total recall performance. However, on average, participants in the handwritten and computer-based note-taking conditions had greater recall performance than the no-note-taking and no-note-taking with review conditions. Also, there was no significant difference in total recall performance in the no-notes with video review and no-notes condition ($p = .954$); however, recall performance was greater in the no-notes condition ($M = .47$, $SE = .04$) compared to the no-notes with video review condition ($M = .45$, $SE = .04$). Results from the post-hoc Tukey t-tests suggest that taking notes (either computer-based or handwritten) is more effective for recalling information than not taking notes (either no notes or no notes with review) (all p-values $< .032$). Although not significant, on average the overall recall performance was higher in the handwritten condition ($M = .65$, $SE = .04$) compared to the computer condition ($M = .61$, $SE = .03$), $p = .870$.

Additionally, a multivariate ANOVA examined recall performance as a function of question type (multiple-choice, fill-in-the-blank, and short answer) and note-taking group (no

notes, no notes with review, handwritten notes, and computer-based notes). Means and standard errors are plotted for each group as a function of question type in Figure 2. Results revealed a significant difference in group performance based on multiple-choice questions $F(3, 106) = 3.90$; $p = .011$; $\eta^2 = .10$, short answer questions $F(3, 106) = 5.55$; $p = .001$; $\eta^2 = .14$, and fill-in-the-blank questions, $F(3, 109) = 2.56$; $p = .035$; $\eta^2 = .08$. Post-hoc Tukey t-tests were used to make post-hoc comparisons; results are reported in Table 1. Results indicate no significant difference between handwritten note-taking and computer-based note-taking in terms of recall performance by question type. Although not significant, recall performance in fill-in-the-blank questions, multiple choice questions, and short answer questions was on average greater in the handwritten group compared to the computer-based group.

Survey Results

The survey on note-taking behavior examined which note-taking method (computer, handwritten or no notes) students typically use in class and which note-taking method (computer or handwritten) they think is superior. Results of the survey are reported in Table 2. The overwhelming majority of participants indicated that they typically take notes with pen and paper. Furthermore, results showed that the majority of participants think that handwritten notes are more beneficial than computer-based notes.

Discussion

With an increase in technology included in the classroom for note-taking purposes, researchers have debated if computer-based or handwritten note-taking is more superior for memory recall (Beck, 2014; Bui, Myerson, & Hale 2013; Mueller & Oppenheimer, 2014). Evidence shows mixed results in whether computer-based or handwritten note-taking produces better memory performance. The present study found no significant difference between the two methods, although the handwritten condition recalled slightly more information. The hypothesis

that handwritten notes would produce superior recall performance was not supported. Results indicate that reviewing the video is not better than not taking notes. Also, taking notes is generally better than not taking notes, consistent with previous research (Weiland & Kingsbury, 1979). Findings reveal that note-taking method does not seem to matter in terms of recall performance. These results suggest that instructors not limit students to note-taking method (e.g., not allowing laptops to be used in classrooms), as long as students are taking notes.

It is unclear if the research findings may produce similar effects to a more diverse group, such as younger or older participants. The sample of participants consisted only of college students. Therefore, it is not clear if similar results would extend to other age ranges and settings (e.g., middle or high school, taking notes during a business meeting). Results may not be a true indication of note-taking effect on memory performance. Participants, specifically biology majors, may have been familiar with the lecture content before taking part in the experiment. If students were familiar with lecture content before participating in the study, results may have only represented knowledge of the material and not the effect of note-taking on memory.

Another limitation is that the current study may not portray a real learning environment. The lecture video used was approximately 10 minutes in length, whereas a typical classroom lecture is longer. Therefore, the lecture used may have been easier to pay attention to and allow for fewer distractions compared to a typical lecture, causing increased recall performance. Also, participants were immediately tested on the material. In a typical learning setting, students are tested on material at a later time point, which typically results in worse performance. Therefore, if a delayed retention interval was used, differences between computer-based and handwritten note-taking may have been enhanced.

Future studies should examine the extent to which the results can be attributed to real classroom environments, accommodating for the limitations produced by lecture content and duration. Students using laptops in the classroom generate possible internet distractions, such as using social media. Research has found that internet use for nonacademic relations (e.g., social media) is negatively correlated with final exam scores (Ravizza, Uitvlugt, & Fenn, 2016). Present results produce uncertainty on the influence of distraction by note-taking method corresponding to recall performance. Effective note-taking method may vary based on individual differences, such as typing speed, note-taking preference, and ability to disregard distractions. Further research is necessary to examine individual differences in note-taking method, so that students can determine the best individual way to learn academic material and allow for a decrease in distraction.

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Table 1

Results from Post-Hoc Tukey T-Tests Comparing Group Performance by Question Type

	p-value
No notes with review versus No notes	
Fill in the blank	1.000
Multiple-choice	.920
Short answer	.971
No notes with review versus Computer-based notes	
Fill in the blank	.300
Multiple choice	.040
Short answer	.043
No notes with review versus Handwritten notes	
Fill in the blank	.143
Multiple-choice	.069
Short answer	.008
No notes versus Computer-based notes	
Fill in the blank	.182
Multiple choice	.108
Short answer	.073
No notes versus Handwritten notes	
Fill in the blank	.085
Multiple choice	.165
Short answer	.014
Computer-based versus Handwritten notes	
Fill in the blank	.899
Multiple choice	.997
Short answer	.727

Table 2

Results from the Survey on Note-Taking Behavior

	Pen and Paper	Computer-based	I do not really take notes
Which type of notes do you think are most beneficial?	85.0%	15.0%	N/A
Which type of notes do you typical take?	76.6%	16.8%	6.5%

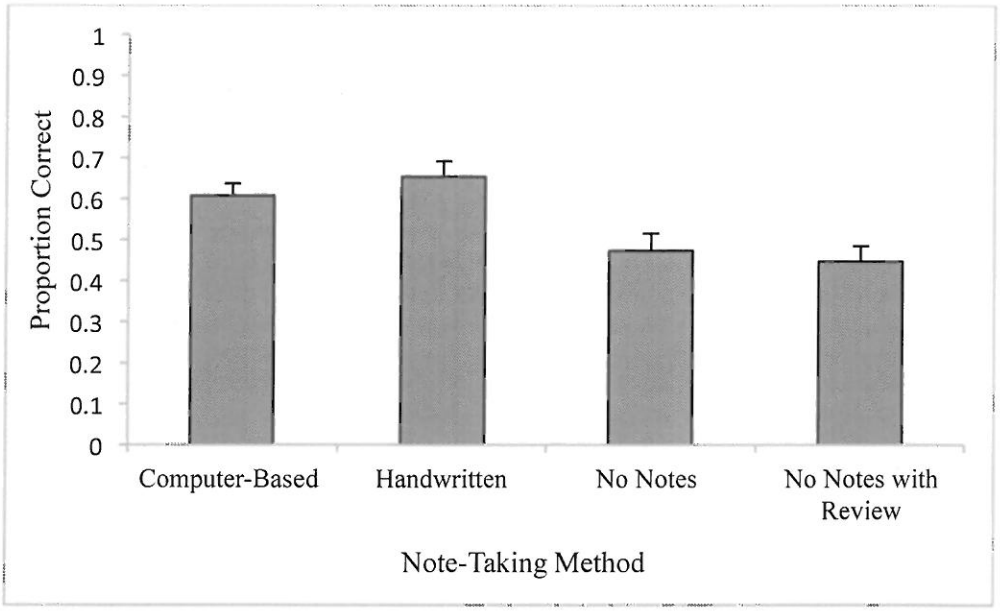

Figure 1. Final recall performance as a function of note-taking group.

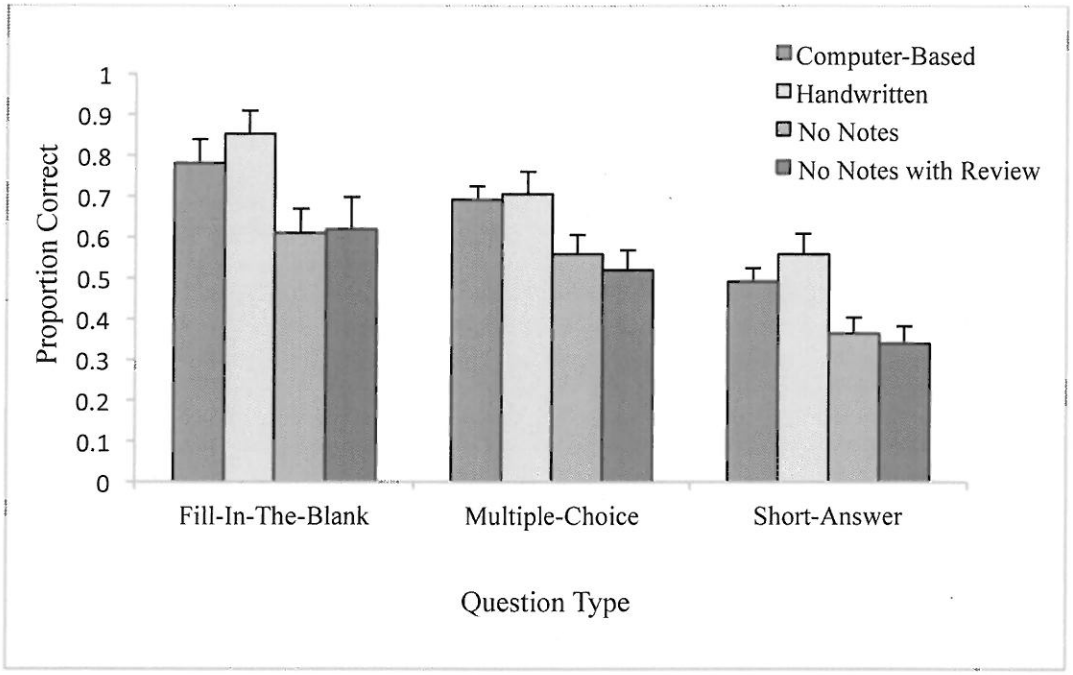

Figure 2. Final recall performance as a function of question type and note-taking group.

Appendix A

The recall assessment participants were given immediately after the distractor task.

Carefully read each statement below and select the best answer from the choices provided or write the correct answer in the space provided.

1. What is the purpose of cellular respiration?

Answer: Cellular respiration breaks down food, turns food into energy, and provides energy to the cell to do work.

2. During conversion pyruvate is made into

a. ATP
b. $FADH_2$
c. **Acetyl CoA**
d. NADH

3. Which of the following is a result of fermentation?

a. pyruvate is made
b. **muscle fatigue**
c. glucose is broken down
d. cellular respiration occurs

4. Which of the following is gained from the Citric Acid Cycle?

a. 2 ATP, CO_2
b. 2 ATP and 2 NADH
c. 34 ATP
d. **2 ATP, 2 NADH, 2 $FADH_2$, CO_2**

5. If not enough oxygen is available _____ respiration takes place and ATP is made in the _____ of the cell.

a. aerobic; cytoplasm
b. anaerobic; cytoplasm
c. aerobic; mitochondria
d. anaerobic; mitochondria

6. Which of the following steps takes place during anaerobic respiration?

a. glycolysis and fermentation

b. conversion and fermentation
c. Krebs cycle and conversion
d. glycolysis and Krebs cycle

7. During which step of aerobic respiration is the most ATP gained?

a. fermentation
b. pyruvate
c. conversion
d. electron transport chain

8. What occurs during glycolysis?

a. glucose is broken down
b. glucose is broken down into 6 pyruvate molecules
c. glucose is converted into Acetyl CoA
d. glucose is removed from the cell

9. List and describe the types of respiration.

Answer: In anaerobic respiration oxygen is not required and less ATP is made.

In aerobic respiration oxygen is required and more ATP is made.

10. The type of respiration that occurs depends on the amount of **oxygen** available.

11. List the 4 steps of cellular respiration as they occur

1. **glycolysis**
2. **conversion**
3. **citric acid cycle (krebs cycle)**
4. **electron transport chain**

12. How much ATP is made during aerobic respiration?

Answer: 38 ATP is made during aerobic respiration

13. Which type of respiration results in the more ATP?

Answer: Aerobic respiration results in more ATP made

14. The video uses the analogy of NADH and $FADH_2$ acting as **shopping carts** during cellular respiration.

15. What is the conversion rate during Electron Transport Chain?

Answer: The conversion rate is 1 NADH = 3 ATP and 1 FADH = 2 ATP

16. If you were to be in a small, non-ventilated, freshly painted room what effect might this have on cellular respiration?

Answer: Less oxygen will be available which can result in anaerobic respiration and muscle fatigue

17. If 3 FADH2, 8 NADH, and 2 ATP were generated during the Krebs cycle how would this affect the electron transport chain?

Answer: The result will be that more ATP (46 total ATP) will be generated

Appendix B

The short post-experiment survey participants were given about note-taking behavior.

1. How do you typically take notes during class? Describe the method you use (pen and paper, computer, nothing).

2. What do you find beneficial about the method you use to take notes?

3. What do you find to be a negative aspect in the way you take notes?

4. In the research experiment that you just participated in, how did you take notes?

5. Did you find this method beneficial to learning the lecture material? Please explain.

6. What note-taking method do you think is more superior, pen and paper or computer-based?

7. I pay more attention in class when I am not taking notes.

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

8. Taking notes during class helps me remember class material.

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