Paper Notebooks vs. Digital Notebooks: Recognition and Recall

W241 Final Project

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Abstract

Does hand-writing digital notes improve recognition and recall compared to paper note-taking? In the last decade, research has been conducted comparing typed notes to handwritten notes, finding that recall was better among computer users but recognition was better among handwriters. To find out whether or not digitally handwritten notes bridge this gap, we conducted a controlled study. Our intervention was to randomly assign college students who were familiar with both note-taking methods to take notes using pen and paper or digital handwritten notes on a subject, after which the students took recognition and recall tests. We found that recall was slightly improved in the tablet and stylus group but recognition was slightly worse; however, both outcomes were not significantly significant, thus we cannot conclude if these results are truly accurate.

Background

Our team was interested in investigating if there is a difference in recognition and recall between those who handwrite their notes on paper and those who handwrite their notes on digital devices. Previous academic research had analyzed a similar concept with handwritten notes and typed notes. A study conducted by Mueller and Oppenheimer found that while students can more easily transcribe lectures through typing, they are actually processing less information, thus performing worse on conceptual questions. On the other hand, Bui, Myerson, and Hale found in

their study that those who typed notes had better recall immediately after a lecture. These two studies both brought up the concept that alternative note-taking can impact recognition and recall in learning. A study conducted at the University of Tokyo found that “the unique, complex, spatial and tactile information associated with writing by hand on physical paper is likely what leads to improved memory.” In consideration of their results, we wanted to replicate similar experiments but study the differences between notes written on pen and paper and notes written on a tablet and stylus. We found only one study that had tried to examine these differences, in which Japanese graduate students measured brain activation in memory recall with participants who used a notebook, a tablet, or a phone to memorize appointment times. The researchers found that those who used a notebook had higher accuracy and activation, thus maintaining better retention of encoding and spatial information. These results were insightful to our experiment in terms of a more technical standpoint of brain activation. We wanted to extend this study and investigate the recognition and recall between digitally and physically handwritten notes by measuring memory performance on lecture-style material.

Research Question

Our study aimed to answer the question: “Does handwriting digital notes improve recognition and recall compared to paper note-taking?” Many experiments have been conducted in the past to compare recall and recognition in handwritten versus typed notes. These experiments showed that there is higher recognition among those who handwrite and higher recall among those who type their notes. In consideration of these results, we wanted to explore if digitally handwritten notes bridge this gap between recall and recognition. We believe our experiment is necessary to understand this and further help students understand which

note-taking method is best for them and will allow them to perform better.

Hypothesis

We hypothesized that taking digitally handwritten notes with a tablet and stylus versus taking handwritten notes with paper and pen would show a difference in recall and recognition. We expected recognition to improve as some actions of digital note-taking such as highlighting, bolding, changing colors, and other markups are faster than doing the same tasks on paper, thus making digital note-taking more efficient. The previously mentioned study from the University of Tokyo looked at all three methods of note-taking – typed, digital handwritten, and paper – and found paper to be the best for taking down appointments due to spatial memory. For our study, we examined memory in a different way by experimenting on taking lecture notes for long-term memory. Therefore, we believe digital handwritten notes would be better in terms of recognition. All previous studies between typed and paper handwritten notes found paper worked best in terms of the recall because the act of writing encodes information most efficiently. In our experiment, we thought that with the added functions of tablet writing while maintaining the action of writing by hand, would imply that recall levels stay the same while recognition levels improve when compared to paper writing.

Experiment Design

Experiment Overview

To test our hypothesis and our research question, the experiment followed a between-subjects design. Interested participants filled out an interest form, and were then hand picked to proceed with the experiment. Selected participants were split into control and treatment

groups based on the section they signed up for, with treatment participants using a stylus and tablet and control participants using paper and pen. They then watched a short lecture on Zoom, which was proctored, and afterwards were given a short inference task. This was followed by a short memory assessment consisting of multiple choice and short answer questions, which were generated by us. We used these questions to measure recognition and recall of information from the lecture. In total, the experiment duration was around one hour. Below is the project timeline we followed along with details of our enrollment and recruitment process, randomization, and a more thorough explanation of our experiment design.

Project Timeline

Begin Recruitment	**Randomization**	**Release Sign-Ups**	**Pre-Experiment Survey**	**Experiment Conducting**	**Post-Experiment Survey**
March 7	March 11	March 12	Prior to sign up slot time	March 14 - March 31	Immediately after experiment

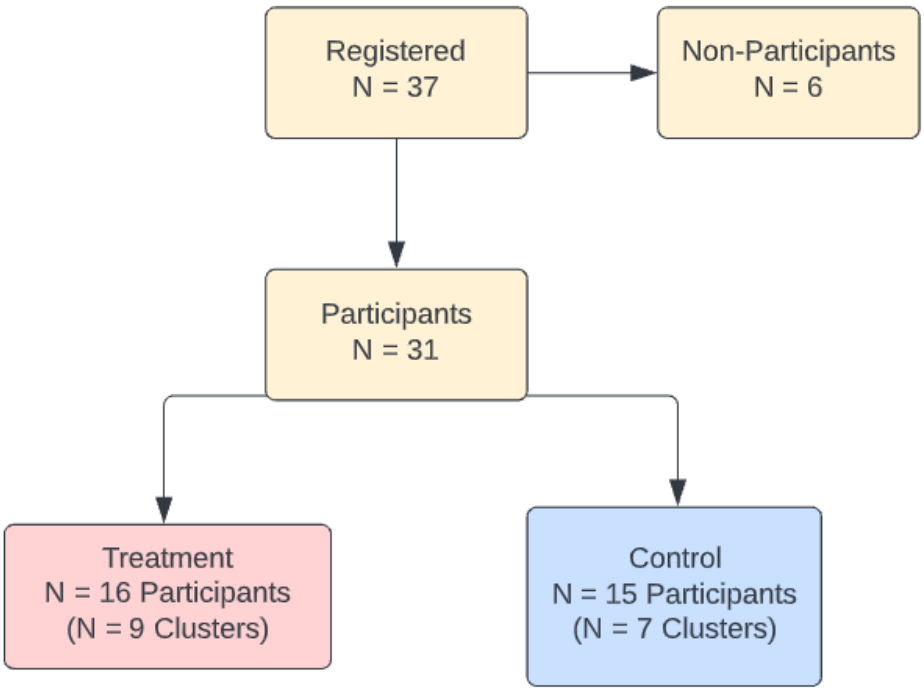
Enrollment and Recruitment Process

We recruited UC Berkeley students and graduates who owned a tablet and stylus from the well-known Berkeley Facebook group, Free and For Sale, to participate in the experiment with an incentive of $15 upon completion of the experiment. Potential participants filled out an interest form attached to our post where we could ensure the participants owned a tablet and stylus. We created this requirement to ensure participants could be randomly assigned to treatment or control as well as have participants who had experience with both note-taking forms for comparable results. This idea also removed the potential learning curve for taking notes on a tablet if a participant had never done so before. The interest form recorded the name, email, and

access to a digital note-taking device and stylus, access to pen and paper (and any other note-taking tools they'd like to use), and access to materials that would allow for an uninterrupted and focused learning environment. Qualifying participants were then contacted through email to schedule a time slot for the experiment.

Randomization

Figure 1: Treatment v. Control Flow Diagram



After verifying that our participants qualify for our research, we asked participants to sign up for a scheduled time slot which was, unknown to them, assigned to treatment or control prior to the experiment. By using block randomization of splitting subjects into groups by time slot, we were able to conduct the experiment in a reasonable time frame and achieve relatively equal sample sizes between treatment and control. This design choice also allowed the experiment to mimic a discussion section, similar to what students would experience in the real world. This

clustering also reduces any confusion during each time slot so that every participant is using the correct note-taking option during their chosen section time. To find the optimal sample size needed so we do not falsely reject nor accept the null hypothesis, we performed a power calculation. Assuming a significance level of α= 0.05 and a treatment effect size of 7, our power calculation showed that we require a minimum of 31 participants to have significant results of 90% power. The flow diagram (Figure 1) illustrates our process of splitting the 31 participants.

Experiment design

When sending out sign-ups for time slots to participants who filled our interest form, we also attached a pre-experiment survey. Data about a participant's graduate status, major, and hand-dominant-ness were collected. We sent a reminder email one day prior to a scheduled time-slot along with the pre-experiment survey again. Then we conducted our experiment online through Zoom where we first asked all participants to hold up their note-taking device to ensure they were using the correct note-taking method corresponding to treatment or control. The participants watched a twenty minute TED Talk we selected called "The Surprising Science of Happiness." We chose this topic hoping it was obscure enough so that no one person was extremely familiar with it to have any advantage that would skew our results. Following the lecture, participants then had five minutes to review their notes. Afterwards, participants completed an inference task for five minutes to take their mind away from the lecture and ensure the information was encoded into their long term memory. The inference task was Wordle, a word game where a player has six attempts to correctly guess a five-letter word. The game will indicate if a letter is in the correct position, in the word but in the wrong position, or if the letter is not in the word at all. After the five minutes, participants had fifteen minutes to finish the quiz

composed of eleven multiple choice questions and eleven short answer questions. The multiple choice was used to measure recognition while the short answer is used to measure recall - this design was inspired by the California Verbal Learning Test, a common way to test memory. At the end of the experiment, we sent the participants a link to the post-experiment survey, as well as in an email following the end of the Zoom meeting. This survey asked for a copy of the participant's notes, their comfortability with the assigned note-taking style, familiarity with the lecture, interest in the lecture, any disruptions that occurred during the experiment, as well as their preferred compensation method for distribution later.

Figure 2: ROXO Diagram

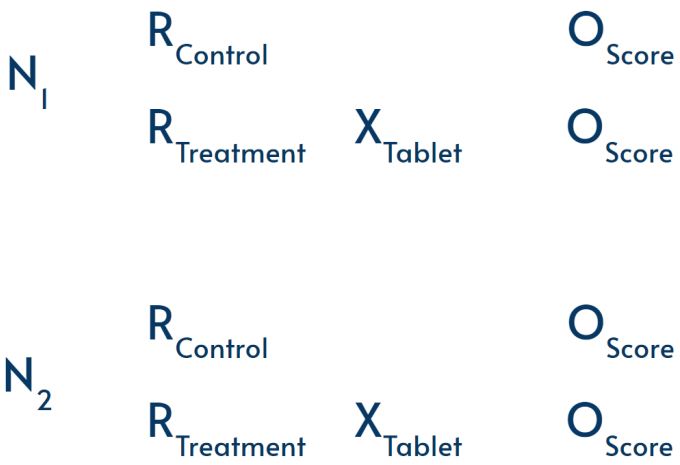


Figure 2 shows our experiment in ROXO grammar. Since we do not have an observation prior to treatment, the experiment is a posttest only randomized experiment. An individual could be assigned to control or treatment, with treatment being the use of tablet and stylus. We would then observe the outcome which is the score on the quiz.

Results

Figure 3: Percent Correct Responses

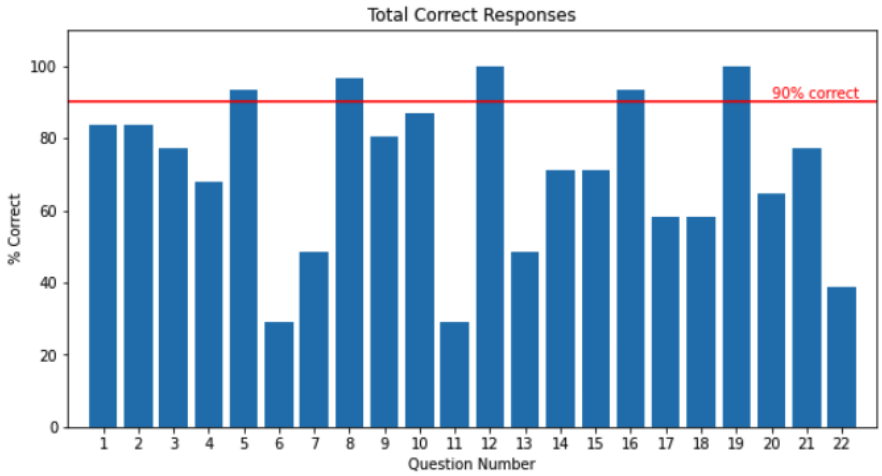


Figure 4: Percent Correct Responses per Group

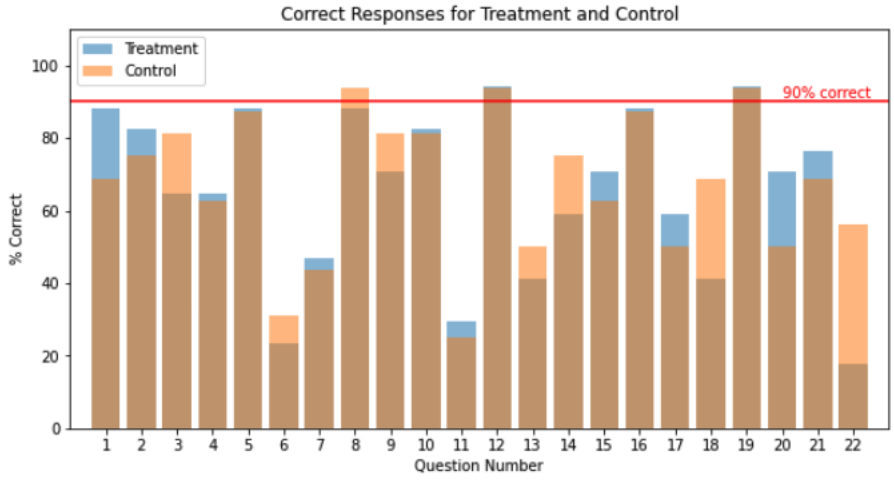


Figure 3 is a bar chart of the overall distribution of correct responses to each question. Two of the multiple choice and three of the short answer questions had total correct response rates of over ninety percent, indicating that those questions were perhaps too easy. From Figure 4 we saw that the difference between treatment and control for most questions is minimal, except for question 18 and question 22.

Figure 5: Histogram of Familiarity With Lecture Material

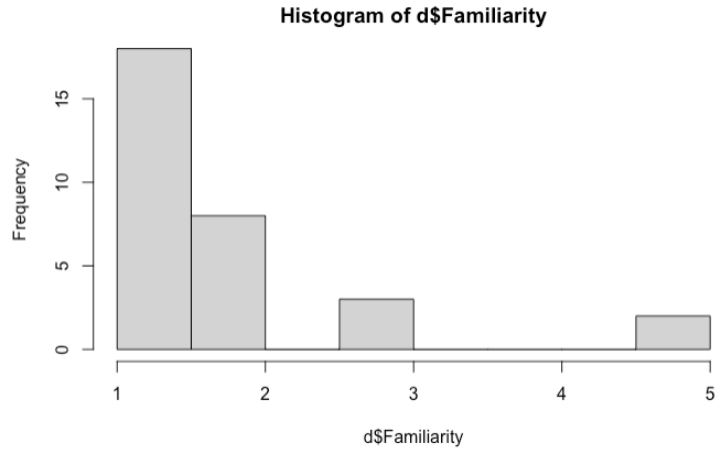


Figure 6: Histogram of Undergraduate Students

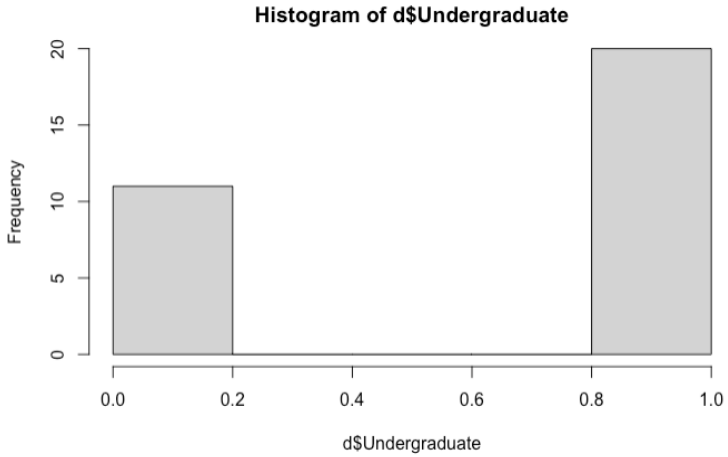
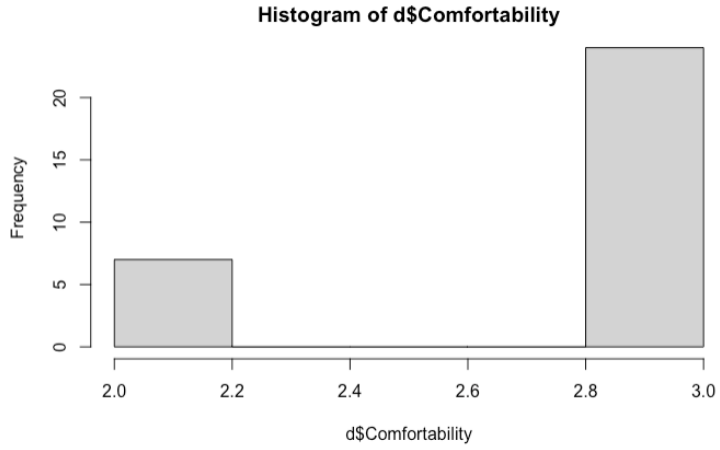


Figure 7: Histogram of Comfortability With Digital Note-taking



About two-thirds of participants were undergraduate students, with one-third post-graduates. Comfortability of participants with writing notes digitally was about the same -- all answered two or three on a scale of five, five being most comfortable. Due to this there was not much difference in writing styles. Some use of highlighting or underlining was present in four digital notes and two paper notes. Two-thirds of participants were completely unfamiliar with the material, two participants were extremely familiar, and the rest were neutral or moderately unfamiliar. Participants answered roughly evenly in interest levels, between three to five on a scale of five, five being most interested. Participants came from a variety of different backgrounds, including Biology, Computer Science, and Economics. Participants finished the quiz with an average of 9 minutes, the fastest finishing at four minutes and the slowest at fifteen minutes.

Regressions and models

	Dependent variable:					
	Recognition (1)	Recall (2)	Recognition (3)	Recall (4)	Recognition (5)	Recall (6)
Treatment	-0.500	0.204	-0.352	0.139	-0.723	0.142
	(0.593)	(0.631)	(0.609)	(0.716)	(0.643)	(0.454)
"Section Leader"Shanie			-1.151*	-1.795***		
			(0.633)	(0.504)		
"Section Leader"Simran			-0.807	-1.614*		
			(0.695)	(0.835)		
Undergraduate			-1.233**	0.309		
			(0.501)	(0.602)		
Familiarity					-0.210	0.027
					(0.215)	(0.242)
Interest3 - Neutral					1.405	4.237***
					(1.946)	(0.977)
Interest4 - Interesting					2.872	4.236***
					(1.788)	(1.015)
Interest5 - Very Interesting					2.985*	5.081***
					(1.801)	(0.968)
Constant	8.000***	7.733***	9.477***	8.887***	6.072***	3.402***
	(0.416)	(0.446)	(0.644)	(0.690)	(1.768)	(0.935)
Observations	31	31	31	31	31	31
R2	0.025	0.004	0.271	0.193	0.320	0.544
Adjusted R2	-0.008	-0.031	0.159	0.069	0.184	0.453
Residual Std. Error	1.597 (df = 29)	1.701 (df = 29)	1.459 (df = 26)	1.617 (df = 26)	1.437 (df = 25)	1.239 (df = 25)
F Statistic	0.759 (df = 1; 29)	0.112 (df = 1; 29)	2.413* (df = 4; 26)	1.554 (df = 4; 26)	2.352* (df = 5; 25)	5.971*** (df = 5; 25)
Note:						*p<0.1; **p<0.05; ***p<0.01

We regressed treatment and covariates on the multiple choice score and short answer score with robust standard errors. Across all models, the treatment group had slightly worse recognition and slightly better recall than the handwritten group, but these changes were not statistically significant. Undergraduate students performed slightly worse than graduates at recognition. When comparing perceived interest in the topic, students who expressed high interest did significantly better than those less interested. We also looked for differences between section leaders, and found interestingly that it supposedly affected recall scores.

Conclusion

With the widespread adoption of digital note-taking devices and proliferation in the classroom, we were interested in exploring the effects of these new devices compared to traditional note-taking methods. Due to increased efficiency when using new technology and the fact these new devices maintained the action of writing, we hypothesized that digital handwritten note-taking would surpass paper note-taking in recognition levels while maintaining recall levels. Thirty-seven participants showed interest in our experiment, from which thirty-one participants watched a short lecture, completed a game, and took a memory quiz. We found that the difference between these two note-taking methods had no significant effect on memory performance, but rather interest in the topic affected the outcome greatly.

Limitations and future research

After conducting this experiment in full, we gathered a list of limitations and things to improve upon in the future. We received a flood of interest from the initial advertisement on Facebook, but were unable to recruit all 31 participants in a short time frame in order to

randomize all participants at the same time leading to unequal cluster size, though we did not expect this to greatly affect results. Next, when analyzing submitted notes from participants, it was clear some participants utilized more features and tools of the treatment, such as highlighting and bolding, than others. Underutilization of these tools may have suppressed any improvements from the treatment group. In the future, we hope to find a better way of standardizing the note-taking for each method to limit this problem. We were also limited by time and thus the lecture was only twenty minutes long. Perhaps participants were able to memorize aspects of the lecture without any form of note-taking at all, which would obscure any effects of note-taking entirely. Our intention was to show the effects of note-taking of students, who often sit through hours of lectures. Due to time and financial limitations, we were unable to conduct a within-subjects design by collecting observations before and after treatment, which we thought would be more informative of the average treatment effect. Nevertheless, our experiment paved the way for future studies that hope to capture effects of these widely spreading novel technologies on learning.

Works Cited

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Keita, Umejima et al. “Paper Notebooks vs. Mobile Devices: Brain Activation Differences During Memory Retrieval.” Frontiers in Behavioral Neuroscience, vol. 15, 2021.

Mueller, Pam A., and Daniel M. Oppenheimer. “The Pen Is Mightier Than the Keyboard: Advantages of Longhand Over Laptop Note Taking.” Psychological Science, vol. 25, no. 6, June 2014, pp. 1159–1168, doi:10.1177/0956797614524581.

Stephens, Abby. "The Benefits of Hand-written Versus Digital Notetaking in College Lectures," *Lexia: Undergraduate Journal in Writing, Rhetoric & Technical Communication*: Vol. 5 , Article 2, 201

University of Tokyo. "Study shows stronger brain activity after writing on paper than on tablet or smartphone: Unique, complex information in analog methods likely gives brain more details to trigger memory." ScienceDaily. ScienceDaily, 19 March 2021. <www.sciencedaily.com/releases/2021/03/210319080820.htm>.

Appendix

Appendix A - Messages to Participants

1. Initial Recruitment Post

Hi Bears! Would you like to make a quick $15 in an hour and contribute to research?

If so, please fill out this short interest form: https://forms.gle/SnDUa8kamxYFdg5c8

Duration: 1 hour

Compensation: $15

Requirements: access to tablet and stylus

About the experiment: Participants will watch a 20 minute video and take notes on it. Afterwards, participants will play a short game. Then participants will take a short quiz related to the video. Everything will be conducted online through Zoom. Compensation will be given after completion of the above tasks and can be sent through Paypal or Venmo.

Contact: jyeung2@berkeley.edu and shhsieh99@berkeley.edu
OR dm Jeremy Yeung , Shanie Hsieh , and Simran Sachdev

If you have any questions, feel free to send us an email at the contact listed above with "[Notetaking Experiment] Question" in the subject line please!

2. Initial Sign-Up Email

Hello,

*Thank you so much for taking the time to fill out our Interest Form for our Notetaking Experiment. Please fill out our Pre-Experiment Survey (<5 mins) as well as select a time slot that works best for you. We'd like to remind you that sessions are ~1 hour long and they are conducted on Zoom which means participants require access to webcams, headphones, stable internet connection, and a quiet, non-distracting environment. Per our experiment, we also require all participants to have access to a desk as well as a tablet, stylus, notebook, and note-taking tools. For ease of scheduling, please sign up for **ONE** open slot at your earliest convenience!*

Pre-Experiment Survey: https://forms.gle/2QtRRp2tXHE9RMVR9
Sign-ups: https://www.signupgenius.com/go/60b0e49a5aa2fa1fc1-notetaking

Feel free to respond with any questions you may have!

3. Control Pre-Experiment Reminder

Hello,

*A reminder that you have a slot time for our notetaking research tomorrow, **DATE**, at **TIME**. You will only need to bring your **paper notebook and note taking tools**. Please join this zoom at your section time: **ZOOM**.*
Also please remember to fill out the Pre-Experiment survey before your section tomorrow if you haven't done so already! See you tomorrow!

Pre-Experiment survey: https://forms.gle/AWz5eYwwrUfDWTXLA

4. Treatment Pre-Experiment Reminder

Hello,

*A reminder that you have a slot time for our notetaking research tomorrow, **DATE**, at **TIME**. You will only need to bring your **digital note taking device**. Please join this zoom at your section time: **ZOOM**.*
Also please remember to fill out the Pre-Experiment survey before your section tomorrow if you haven't done so already! See you tomorrow!

Pre-Experiment survey: https://forms.gle/AWz5eYwwrUfDWTXLA

5. Post-Experiment Reminder

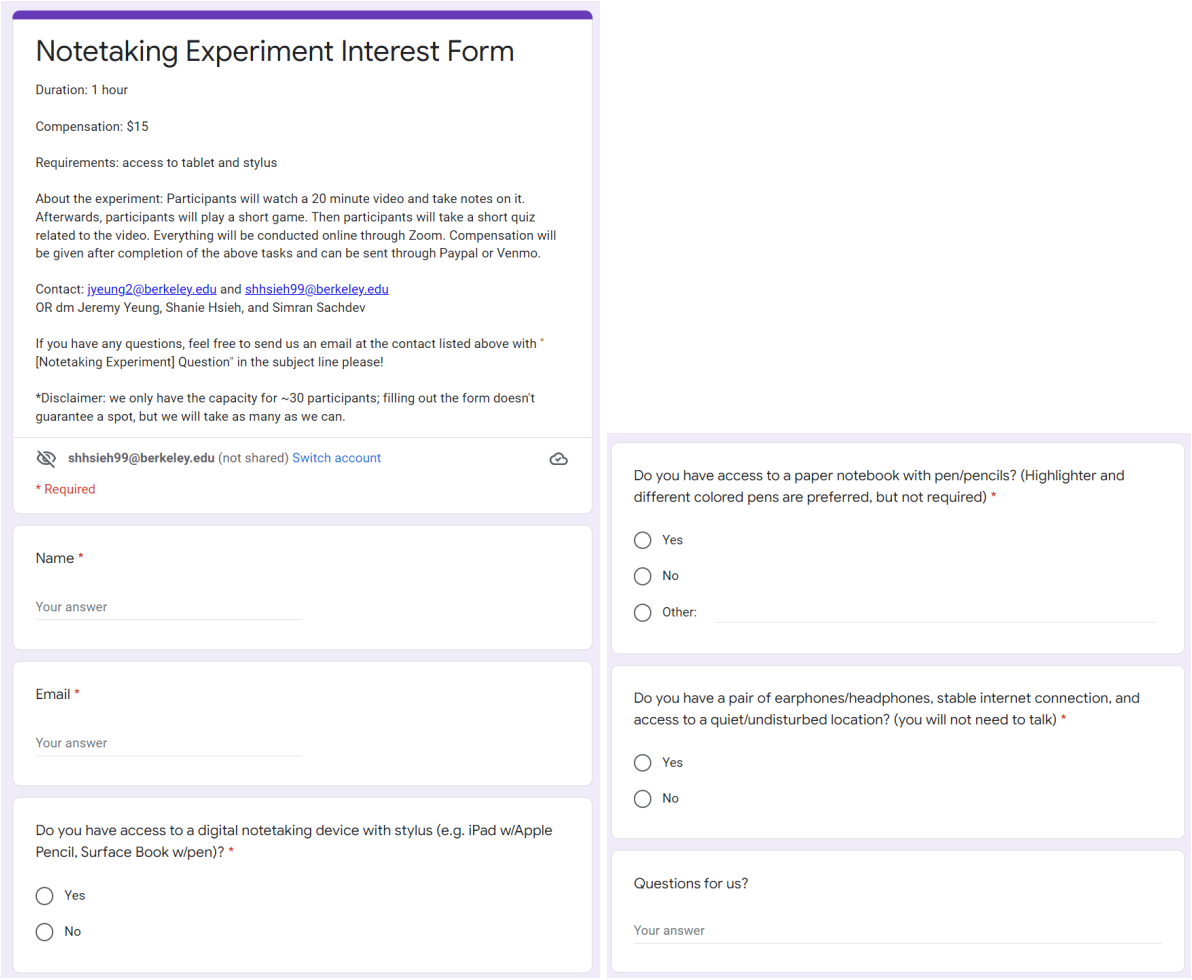
Hello,

Thank you so much for participating in our experiment. If you haven't already done so, please fill out our post-experiment survey, which also asks for your preferred compensation information. Compensations will be sent out at the completion of the experiment, within 3-4 weeks. Feel free to reach out if you have any questions at all. Thank you for your time!

Post-Experiment survey: https://forms.gle/xAqvyqsLXk2qCehk6

Appendix B - Surveys

1. Initial Recruitment Interest Form



Notetaking Experiment Interest Form

Duration: 1 hour

Compensation: $15

Requirements: access to tablet and stylus

About the experiment: Participants will watch a 20 minute video and take notes on it. Afterwards, participants will play a short game. Then participants will take a short quiz related to the video. Everything will be conducted online through Zoom. Compensation will be given after completion of the above tasks and can be sent through Paypal or Venmo.

Contact: jyeung2@berkeley.edu and shhsieh99@berkeley.edu
OR dm Jeremy Yeung, Shanie Hsieh, and Simran Sachdev

If you have any questions, feel free to send us an email at the contact listed above with "[Notetaking Experiment] Question" in the subject line please!

*Disclaimer: we only have the capacity for ~30 participants; filling out the form doesn't guarantee a spot, but we will take as many as we can.

shhsieh99@berkeley.edu (not shared) Switch account

* Required

Name *

Your answer

Email *

Your answer

Do you have access to a digital notetaking device with stylus (e.g. iPad w/Apple Pencil, Surface Book w/pen)? *

Yes

No

Do you have access to a paper notebook with pen/pencils? (Highlighter and different colored pens are preferred, but not required) *

Yes

No

Other:

Do you have a pair of earphones/headphones, stable internet connection, and access to a quiet/undisturbed location? (you will not need to talk) *

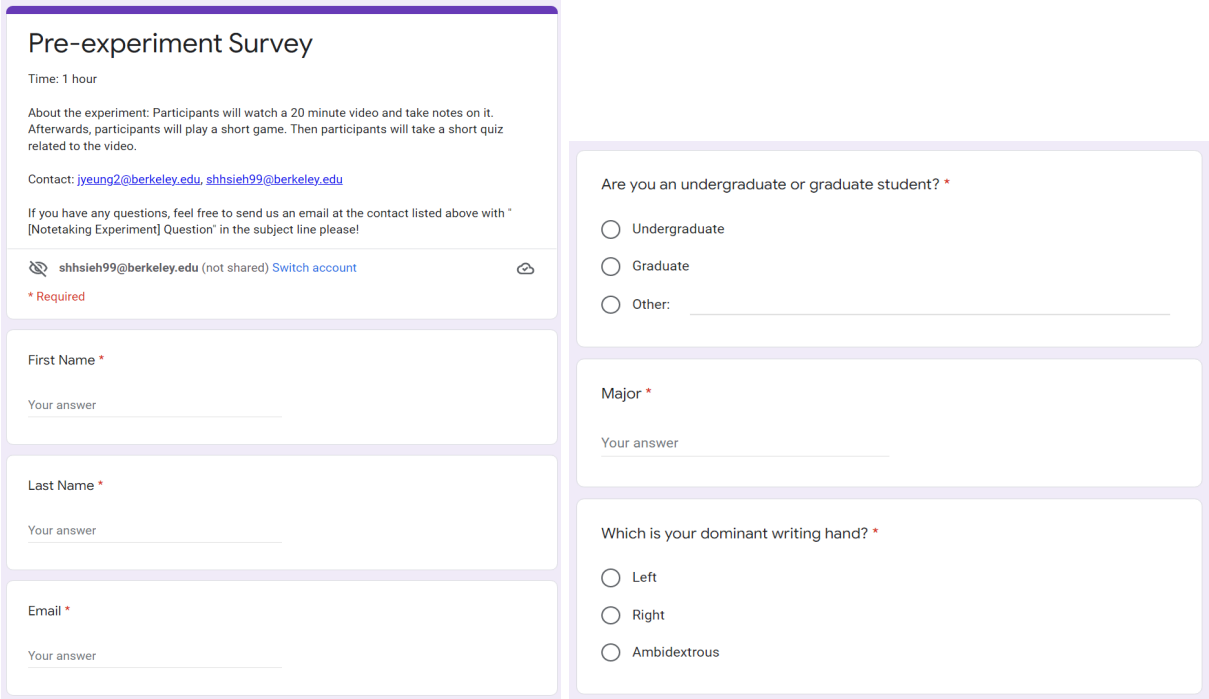
Yes

No

Questions for us?

Your answer

2. Pre-Experiment Survey



Pre-experiment Survey

Time: 1 hour

About the experiment: Participants will watch a 20 minute video and take notes on it. Afterwards, participants will play a short game. Then participants will take a short quiz related to the video.

Contact: jyeung2@berkeley.edu, shhsieh99@berkeley.edu

If you have any questions, feel free to send us an email at the contact listed above with " [Notetaking Experiment] Question" in the subject line please!

shhsieh99@berkeley.edu (not shared) Switch account

* Required

First Name *

Your answer

Last Name *

Your answer

Email *

Your answer

Are you an undergraduate or graduate student? *

- Undergraduate
- Graduate
- Other:

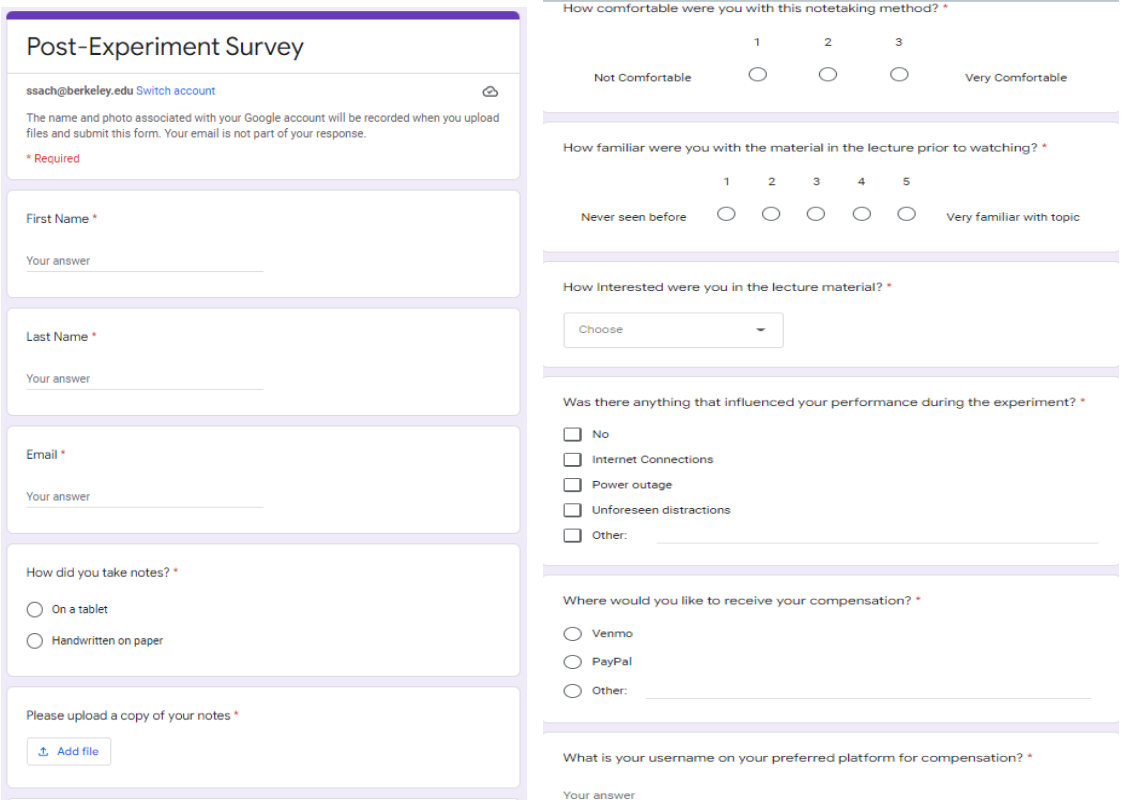
Major *

Your answer

Which is your dominant writing hand? *

- Left
- Right
- Ambidextrous

3. Post-Experiment Survey



Post-Experiment Survey

ssach@berkeley.edu Switch account

The name and photo associated with your Google account will be recorded when you upload files and submit this form. Your email is not part of your response.

* Required

First Name *

Your answer

Last Name *

Your answer

Email *

Your answer

How did you take notes? *

- On a tablet
- Handwritten on paper

Please upload a copy of your notes *

Add file

How comfortable were you with this notetaking method? *

	1	2	3	
Not Comfortable	○	○	○	Very Comfortable

How familiar were you with the material in the lecture prior to watching? *

	1	2	3	4	5	
Never seen before	○	○	○	○	○	Very familiar with topic

How interested were you in the lecture material? *

Choose

Was there anything that influenced your performance during the experiment? *

- No
- Internet Connections
- Power outage
- Unforeseen distractions
- Other:

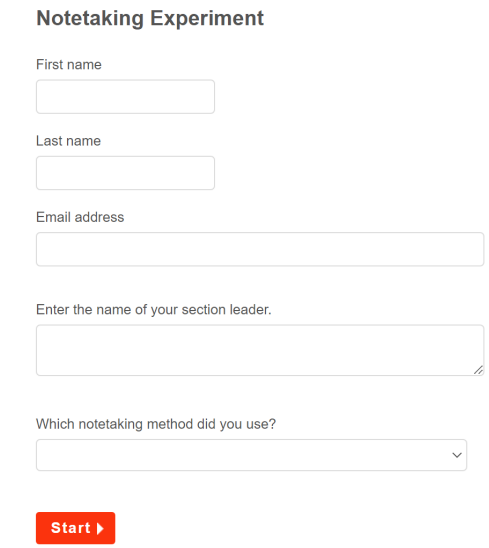
Where would you like to receive your compensation? *

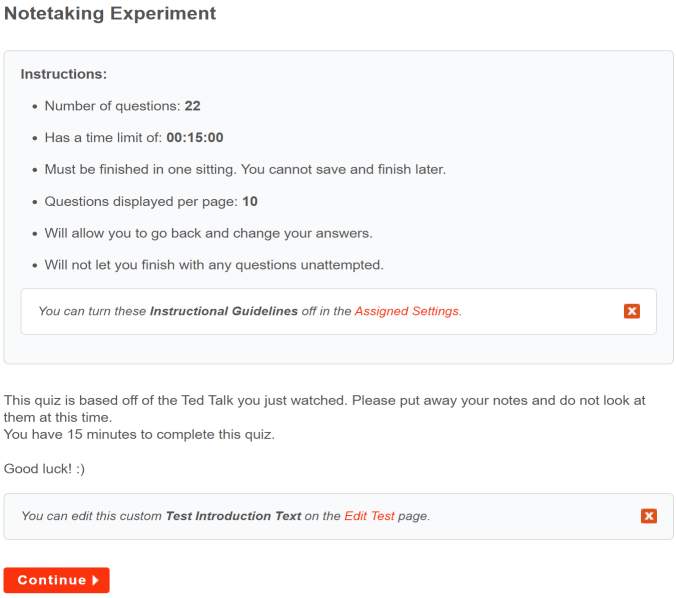
- Venmo
- PayPal
- Other:

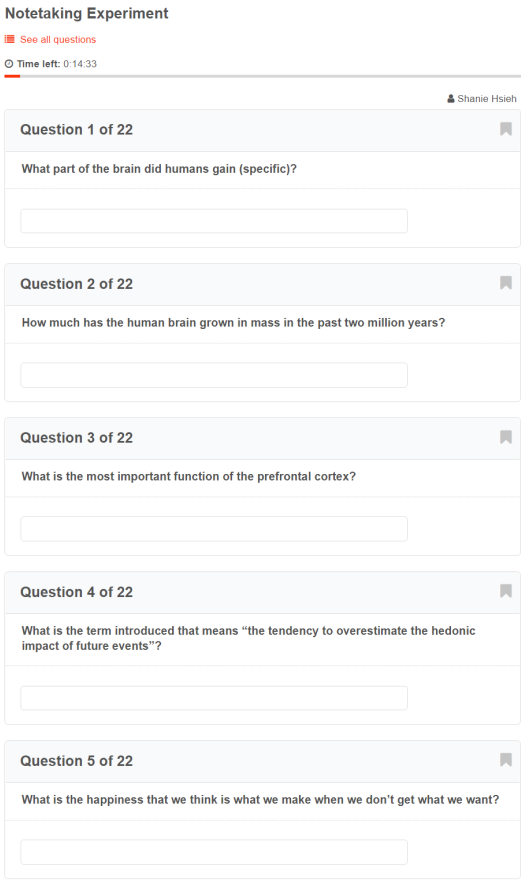
What is your username on your preferred platform for compensation? *

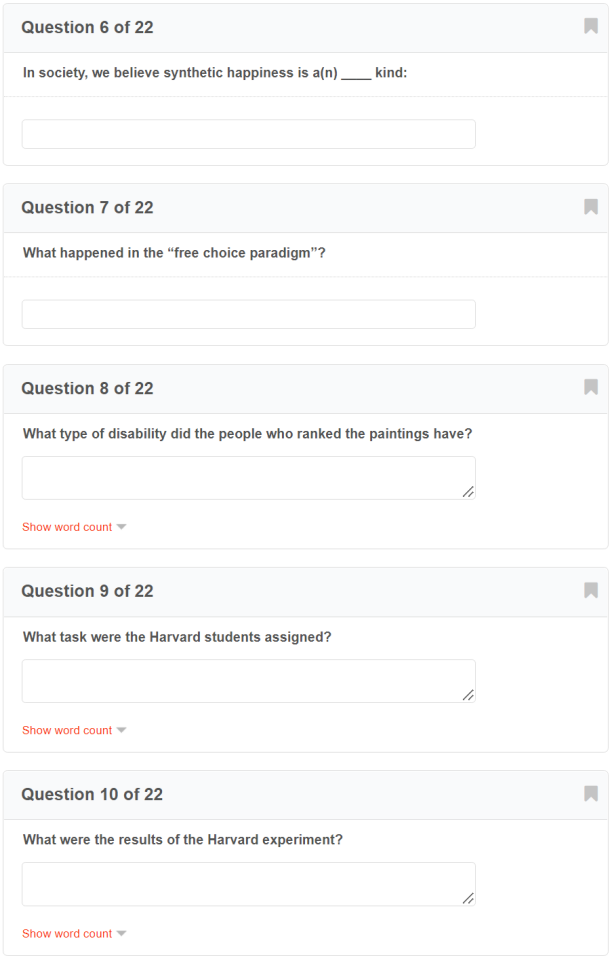
Your answer

Appendix C - Experiment Quiz









Question 11 of 22

When our ___ are bounded, we're careful and prudent

Question 12 of 22

What is the psychological immune system?

- A. A physical system that protects organisms from diseases
- B. A system of cognitive processes that help change one's views of the world so they can feel better about the world around them
- C. System that makes us fear the people around us
- D. A system of cognitive processes that keeps one's views of the world the same so they feel afraid of those around them

Question 13 of 22

Which is the secret of happiness according to the speaker:

- A. Accrue wealth, power, and prestige. Then lose it
- B. Spend as much of your life in prison as you possibly can
- C. Make someone else really, really rich
- D. All of the above
- E. None of the above

Question 14 of 22

How does the speaker compare Synthetic Happiness and Natural Happiness?

- A. Synthetic happiness is not real like natural happiness
- B. Synthetic happiness and natural happiness are created from having the freedom of choice
- C. Synthetic happiness is every bit as real and enduring as natural happiness
- D. None of the above

Question 15 of 22

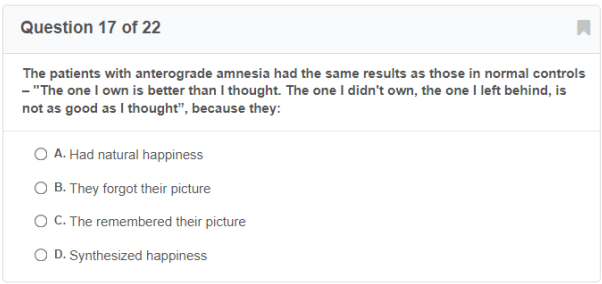
What is freedom to natural and synthetic happiness?

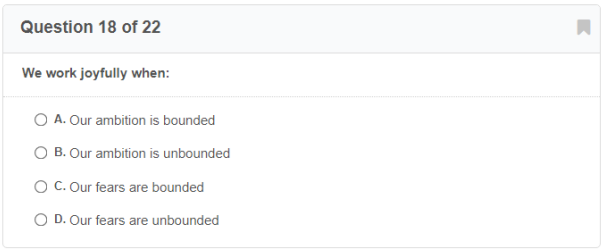
- A. A “friend” of natural happiness and an “enemy” of synthetic happiness
- B. A “friend” of synthetic happiness and an “enemy” of natural happiness
- C. A "friend" to both synthetic happiness and natural happiness
- D. An "enemy" to both synthetic happiness and natural happiness

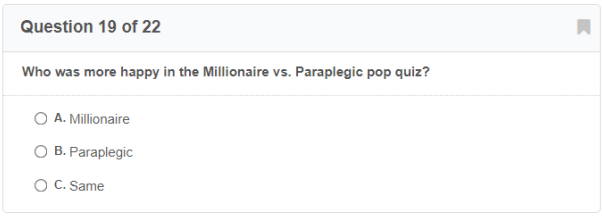
Question 16 of 22

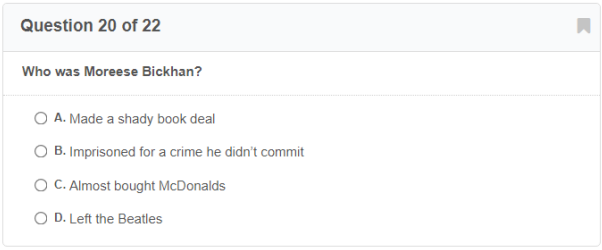
When does the psychological immune system work best?

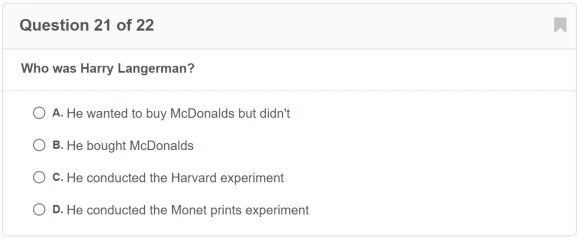
- A. When we are stuck
- B. When we are free
- C. When we are mad
- D. When we are sad

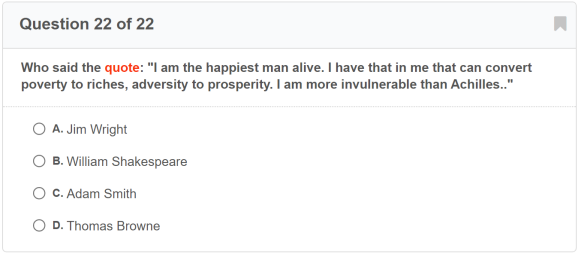












Appendix D - Additional Participant Materials

Ted Talk

https://www.ted.com/talks/dan_gilbert_the_surprising_science_of_happiness?referrer=playlist-the_most_popular_talks_of_all&autoplay=true

Wordle - Inference Task

https://www.devangthakkar.com/wordle_archive/?124