What's More Notable: Typing or Handwriting? An Exploration of Student Preference on Cognitive Load in Note-Taking Strategies

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Abstract

The present study investigated the impact of student preference for notetaking methods (handwriting or typing) on notetaking performance due to cognitive demand. Participants (N=12) were undergraduate students enrolled at a university in Western Canada. Using two TED Talk lectures, notetaking performance was assessed by analyzing the quality of taken notes and recall ability. Cognitive demand was measured by assessing working memory through a digit span task. To address the research questions, a series of Mann-Whitney U tests and profiling of descriptive data was performed. Results indicated that notetaking preference had little impact on notetaking performance or working memory. These findings suggest that choosing notetaking methods according to preference may not necessarily result in better performance. Rather it is possible that factors such as individual cognitive ability or contextual demands would be more important to consider. Future research is needed to further explore the complex relationship between student preference, individual cognitive ability and notetaking tasks to better inform educational practices.

Key Words: Notetaking, handwriting, typing, cognitive demand, student preference

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Dedication

To begin, I would like to thank my research supervisor, Dr. Mariel Miller for supporting me, taking me under her wing for this project and spending long hours assisting me through the process. I am very grateful for the support from my co-supervisor, Dr. Lucinda Brown. Her care and consideration for her students is something I can say I have been lucky to experience through my degree and is something I will always cherish. I would also like to thank my committee member Dr. Gina Harrison. Her feedback, encouragement and knowledge shared with me is something I am thankful for and will always value. Finally, thank you to my friends and family who were always there to bounce ideas off, or give me support and kindness when needed. The people in my life during this time have been nothing short of extraordinary.

This paper is dedicated to my little dog, Belinda. The countless early mornings and late nights with you draped across my lap while I wrote will never be forgotten or underappreciated. This accomplishment belongs to both of us.

Introduction

The use of technology in education has been steadily increasing over the last few decades, with digital devices beginning to replace traditional writing in academic settings (Ose Askvik et al., 2020). In schools, young children are beginning to learn to type on computers instead of engaging in classic handwritten printing and writing (Longcamp et al., 2006; Mangen et al., 2015), while post-secondary students increasingly use technology to access content, lectures, textbooks, and assignments. In particular, students have increasingly turned to mobile devices, such as laptops for notetaking in their classes rather than taking notes by hand. However, as notetaking plays a critical role in reviewing materials and preparing for examinations, the impact of this trend on student learning is unclear.

One of the main concerns of using computers for notetaking is the reduced level of cognitive processing that may come with the action. Laptop use has been found to increase word-for-word verbatim in notes as students can type much faster than they can write (Brown, 1988; Mueller & Oppenheimer, 2018). Verbatim notetaking, which is the action of recording lecture information word-for-word, has been found to result in shallow cognitive processing, impairing the encoding process of the information being received (Kiewra, 1985a; Meter et al., 1994; Mueller & Oppenheimer, 2014). Taking notes by hand (also known as longhand writing) has been attributed to being more cognitively engaging than typing. Due to the visual and kinesthetic processes that are involved, longhand writing requires greater cognitive processes in order to print words and letters (Mangen et al., 2015; Morehead et al., 2019), and has been considered to be more effective for conceptual comprehension purposes (Osugi et al., 2019).

The current evidence regarding the benefits of typewritten vs. longhand notetaking is mixed. Multiple studies indicate individuals have better recall of word lists when using longhand rather than typing (see: Bouriga & Olive, 2021, Mangen et al., 2021; Smoker et al., 2009), supporting an argument for longhand superiority. However, other studies have found that regardless of whether notes are hand- or type-written, the action of notetaking itself improves recall and retention due to the accessibility of reviewing these notes (Kiewra, 1989; Meter et al., 1994). Furthermore, much of the literature supporting longhand superiority over type-written notes is limited to the examination of word recall and not large bodies of information, such as lecture notes. Students in higher education are required to recall large amounts of information, especially when examinations are cumulative. Overall, there is little consensus regarding which medium is more effective.

Using a lens of cognitive-demand theory, the purpose of the present study is to determine if differences in the cognitive demand of notetaking methods may help explain the conflicting literature. It has been proposed by one group of researchers that allowing students to use their preferred method of notetaking results in higher academic performance (Shell et al., 2020). Using a method that is familiar can help lessen cognitive load, as the automatic process that comes with the known process can allow the individual to dedicate their cognition towards other imperative inputs, such as lecture content. The importance of notetaking as a learning strategy has long been emphasized (Di Vesta & Gray, 1972), therefore, it is critical to provide clarity in the debate between longhand and laptop notetaking. With lucidity in this body of literature, individuals will be better informed on the most effective notetaking method and, in turn, may have the opportunity to improve their academic performance.

In the following section, the cognitive psychology of working memory and the cognitive functions that are active with notetaking are discussed. This is followed by an overview of the current literature involving both longhand notetaking and laptop notetaking. The inconsistencies of these studies will be discussed, as well as influential external factors that may affect notetaking strategies prior to discussing the present study.

Theoretical Framework

Exploring notetaking, memory is what drives the ability to for writers to effectively take notes. Due to various taxing cognitive processes that influence writing ability, it is vital that notetakers not only have a strong, fundamental knowledge basis of the skills needed to write accurate bodies of text but can transcribe incoming verbal information down into a condensed piece of work that is coherent when recall is needed. Therefore, writers must have strong working memory abilities as well as strong writing skills learned from previous years of education.

Working Memory Model

According to the working memory model proposed by Baddeley and Hitch (1994), the process of working memory involves three components: the central executive, the phonological loop, and the visuospatial sketchpad. The central executive is the core component, acting as a control center for both phonological and visuospatial functions, and is responsible for overall cognitive processing (Baddeley & Hitch, 1974). During the progression of learning, the central executive controls the ability to retain as well as recall information. More specifically regarding notetaking, it has been theorized that two different executive processes are at work throughout the learning activity: the encoding function and the external storage function.

Encoding Function

The encoding function suggests that the action of taking notes encourages cognitive processing which in turn, results in higher amounts of learning and retention of the information. As the material is being reprocessed and "self-generated" by the individual, the information is more deeply processed, resulting in higher recall levels (Benton et al., 1993). Studies have shown that those who took notes by handwriting performed better without review than those who did not take notes regarding problem-solving tasks and the number of main ideas recalled (see: Einstein et al., 1985; Kiewra, 1989; Shrager & Mayer, 1989).

External Storage Function

The second function of taking notes, the storage function, states that having notes in a written form improves student ability to review and recall the material (DiVesta & Gray, 1972; Kiewra, 1989). Students often forget a large amount of information learned in lectures as time passes, so having an external source to go back to can provide students with a refresher of the content and reduces memory loads as the students are not under demand to keep the learned information in their working memory (Kellogg, 1988). Research has shown that using notes has been more effective on student performance in comparison to those who do not use notes (Kiewra, 1989). Kiewra (1989) proposed that notetaking uses both external storage and encoding functions in tandem as the process usually involves both recording and review of the notes.

Writing to Learn – The Cognitive Process Theory of Writing

Another important process required for academic success in students is the ability of writing to learn. As children age and continue through their education, the shift of learning how to write gradually turns into using writing as a tool to learn new information. New cognitive processes are needed to allow students to use writing in order to process information and generate new ideas. Hayes and Flower (1981) examined the cognitive processes required for writing and proposed a theory that consists of four key points. Although Hayes and Flower’s 1981 model is most often used in the context of classic writing, it can be reflected on notetaking as it is a form of complex writing. Like writing large bodies of text, notetaking requires the writer to be cognitively engaged with the process, have formal training on writing, have goals for their output, and is reliant on the individual's working memory capacity.

Point 1: Writing is best understood as a set of distinctive writing processes.

Hayes and Flower (1981) proposed that the major units of analysis are mental processes that have hierarchal structure and can occur at any time in the composing process. In their model, three main units make up the writing process: the task environment, long-term memory, and the overall writing process (planning, translating, and reviewing) (Flower & Hayes, 1981). Writers must have strong task understanding and writing skills to begin their writing process, as otherwise, a misunderstanding of the task or the inability to compose coherent text can hinder a successful output. Next, the writer must be able to use their long-term memory to identify cues from similar previous experiences and be able to apply these to the situation at hand. Finally, the writer can begin the overall writing process, beginning with planning. For writers, planning consists of generating ideas, organizing thought processes and text layout, and setting goals to help provide structure for the writer. Writers then move on to the translation process, which consists of them putting their planned processes down into written, visible language (Flower & Hayes, 1981). Lastly, the writer enters the reviewing process, which consists of two separate sub-processes: evaluating and revising. Writers must review their work and from there, can decide to revise points as needed.

Point 2: Processes of writing are hierarchically organized.

As mentioned, Flower and Hayes (1981) believed that the cognitive processes that create the ability to write work together as a large system that is dependent on all of its moving parts. The three main elements and their supporting subsections can be used at any time, are interchangeable and are not set in a specific order of occurrence. This ability that allows the individual to switch between the cognitive processes during writing allows for flexibility.

Point 3: Writing is a goal directed process.

To be able to output a strong body of written work, writers must be able to formulate goals that help guide the creation of text. Typically, writers create process goals and content goals. Process goals provide instruction about how to carry out the process, while content goals represent all of the things that the writer wants to say/convey to the audience (Flower & Hayes, 1981). Goals often change as the writer continues as new knowledge can influence the output of work as the writer continues, however, this interaction allows for collaboration and flexibility and develops purposefulness in writing (Flower & Hayes, 1981).

Point 4: Writers create their own goals based on new ideas and regenerating old ideas.

The final key point that encompasses this cognitive process theory is writing allows for the development of new knowledge. As a product of goal setting, writers explore both previous knowledge and formulate new knowledge as they compose their body of text. This occurs in three typical patterns: explore and consolidate, state and develop, and lastly write and regenerate. First, working usually under a high-level goal, the writer will explore previous knowledge and other sources on this topic and then connect this back to their original high-level goal, creating complex ideas and creating new concepts. Then, in the state and develop stage, the writer moves on from high-level goals and begins to formulate smaller level goals that help create a network that satisfies the requirements/needed information to complete the higher-level goal. Finally, similar to the first stage of explore and consolidate, the writer will begin to write, allowing their ideas formulated from their goal setting to flow onto the page.

Notetaking and the Cognitive Process Theory of Writing

Without the ability to engage in the mental processes required for writing, individuals will be unsuccessful in their output. Relating this theory back to notetaking, students taking notes in class must already contain the fundamental skills needed in order to compose text that can be used as a means for recall. Setting goals prior to the creation of the notes, having the ability to revise text throughout the transcription process, and being able to return back to long-term memory stores of similar information are all vital tools for notetakers in order to create successful notes that allow for the encoding process to be engaged and allow for the storage function to be used successfully at the time of recall. Writers are subjected to the limits of their working memory, meaning they must be intentional when writing in order to have a successful output (Kellogg, 1988), regardless of the style of writing.

Literature Review

Benefits of Longhand Notetaking

Although the influence of notetaking has been studied long before the introduction of technology in the classroom, the recent study that influenced a new wave of literature and movement towards favouring longhand notetaking was conducted by Mueller and Oppenheimer (2014). The authors conducted three separate studies to test whether longhand or typing resulted in better information processing, with their hypotheses favouring longhand writing. Results found that individuals who handwrote their notes performed better on conceptual questions in all studies and although they wrote fewer words in their notes in total, they had less word-for-word verbatim overlap, increasing their performance (Mueller & Oppenheimer, 2014, Experiment 1).

Regarding recall, Mueller and Oppenheimer (2014) found that participants taking longhand notes who were able to review and study them prior to examination outperformed those who used laptops, as well as those who used either notetaking medium (longhand or typing) but did not have the opportunity to review (Experiment 3). Results also showed a positive correlation between the number of words in the notes taken and the performance of the participants, as well as a negative correlation between verbatim and performance (Mueller & Oppenheimer, 2014, Experiment 1). Despite both correlational findings, emphasis was placed on the latter as longhand notetakers had less verbatim in their notes, increasing their level of performance. These findings together solidified the authors' argument for longhand notetaking superiority.

Mueller and Oppenheimer's 2014 results influenced numerous media reports (see Doubek, 2016, May, 2014; Meyer, 2014) creating an interest favouring longhand notetaking in the academic and psychology community, prompting numerous replication studies. For example, Morehead et al., (2019, Experiment 1) found similar results to Mueller and Oppenheimer (2014) with word count and verbatim being higher for laptop note-takers; however, they found that longhand notetakers performed better on factual questions rather than conceptual questions on a delayed test.

In another example, Mitchell and Zheng (2019) found similar results to Morehead et al. (2019) with longhand notetakers performing better on factual recall questions. However, results showed that there was only a significant correlation between word count and test performance on factual recall questions, creating disparity between results of replication studies (Mitchell & Zheng, 2019). Regardless, these findings still supported the longhand superiority argument made by Mueller and Oppenheimer (2014).

A meta-analysis conducted by Allen et al. (2020) consisting of 14 different studies also found longhand-favouring results, with students' grades drastically decreasing when changing to notetaking on a computer versus by hand. Other studies that included a third style of notetaking (the use of a digital stylus) too found superiority for longhand notes for overall course grades for both pen and stylus writers (Shell et al., 2021). This finding seems logical since longhand and digital stylus use the same kinesthetic processes, resulting in deeper cognition.

In summary, longhand notetaking was favoured over laptop notetaking in several studies (Allen et al., 2020; Mitchell & Zheng, 2019; Morehead et al., 2019; Mueller & Oppenheimer, 2014; Shell et al., 2021) as it showed to result in better performance in recall tests, both with and without the opportunity to review, and deeper cognitive processing of the information.

Benefits of Laptop Notetaking

Conversely, some studies in this field have demonstrated the superiority of laptop notetaking (Bui et al., 2013; Fiorella & Mayer, 2017; Schoen, 2012). For example, Bui et al., (2013) conducted a study aimed to measure which type of notetaking strategy was more effective and if different styles of note-taking instruction (such as transcribing the lecture or creating paraphrased-organized notes) also had an influence on retention and recall in both immediate and delayed tests. Results of this study showed that after a delay of 24 hours, individuals who took organized notes on their computers who did not have the opportunity to study had greater recall on both free recall and short-answer tests, yet, when there was an opportunity to review and study their notes, participants who transcribed the lectures on computers had better recall during both tests (Bui et al., 2013, Experiment 3). The authors also found that individuals who took notes on a computer and were instructed to transcribe the lecture outperformed those who took longhand notes as well as those who took structured and organized notes on a computer when the tests were given immediately after the lecture (Bui et al., 2013, Experiment 1). The authors hypothesized that this result was due to the translation hypothesis which explains that directly transcribing what is heard during a lecture can benefit memory (Bui et al., 2013; Conway &

Gathercole, 1990). Working memory in participants was assessed in its relation to transcribed vs. organized notes, and the authors concluded that working memory was significantly correlated to organized notes, as taking notes in this manner requires deeper processing of the information due to the orthographic and cognitive processes that are required to record and transform incoming information (Benton et al., 1993; Bui et al., 2013). In conclusion, the authors decipher their results as being dependent on the working memory skill of the individual, claiming that both transcribed and organized notes typed on a computer are beneficial over longhand writing but are subjectively effective depending on the individual's cognitive ability.

A study conducted by Fiorella and Mayer (2017, Experiment 2) also found results favouring laptop notetaking. The main objective of the study was to examine if different notetaking strategies influenced spatial strategy usage (creating concept maps and diagrams) and performance. It was hypothesized that taking notes by hand encourages the usage of spatial strategies which in turn, allows the student to conceptualize and process information more deeply, while notetaking on a laptop may inhibit this process. Results were opposite to what was hypothesized: laptop notetakers had greater scores than the longhand notetakers in both retention and transfer tests, despite a lower usage of spatial learning strategies (Fiorella & Mayer, 2017, Experiment 2). It was speculated that laptop users possibly found other techniques to create comprehensive notes due to a lack of ability to use spatial strategies on a laptop. This study supports the notion that the use of laptops for notetaking can also be relevant in domains where higher levels of cognitive processing are required, combating the argument for pen-and-paper longhand superiority.

Schoen (2012) also found a laptop-superiority effect, with participants having higher scores of retention than those who handwrote their notes after being exposed to three separate distracting tasks immediately after they finished completing their notes. This study offers an interesting viewpoint, as participants were subjected to distractors to eliminate recency effects and were not allowed to review their notes, supporting the notion that typing on laptops has a superior encoding function (Schoen, 2012). In conclusion, based on the findings of the above studies, typing notes has also been seen as an effective medium, with laptop users outperforming those handwriting notes in recall and retention measures. As handwriting is more cognitively taxing process (Mangen et al., 2015; Morehead et al., 2019; Ose Askvik et al., 2020; Osugi et al., 2019), laptop users may be experiencing less of a cognitive load than their handwriting peers, resulting in higher performance as they have access to a fuller extent of their working memory.

Inconsistencies of the Literature

Although the studies discussed appear to paint a polarized picture of the literature, there are many inconsistencies that fall within the murky middle. Across the literature, there is inconsistency amongst the replication studies, leading the different authors to struggle with making a definitive decision about the most superior note-taking process. For example, despite their Experiment 1 results being supportive of the original Mueller and Oppenheimer (2014) study, Morehead et al., (2019) conducted a second experiment that included a control group of individuals who did not take notes. The goal of Experiment 2 was to examine if typing or handwriting notes resulted in greater encoding and storage benefits, and the authors found that with a delayed test that allowed studying, there was no significant difference in overall performance between the groups (longhand, laptop, no notes), suggesting that there are no specific encoding or storage benefits for any group.

Another inconsistency that is interesting to note that laptop notetakers performed slightly better than longhand notetakers on specifically the conceptual questions in this second experiment, showing opposite results from the Muller and Oppenheimer study (Morehead et al., 2019). The findings from this study add to the complexity of this topic, as despite previous research claiming that handwriting results in deeper processing of the information, Morehead et al. (2019) found none of the notetaking strategies to be superior for encoding functions. On the contrary, Luo et al., (2018) found that typing on a laptop benefited the encoding function, and longhand writing promoted the storage function, while Mueller and Oppenheimer (2014, Experiment 3) found longhand to be superior for both encoding and storage functions.

Incongruous results have also caused other authors to be unsure of their replication results, as found in Mitchell and Zheng's (2019) replication study. Although their study did result in similar findings to Mueller and Oppenheimer (2014), further analysis showed a non-significant indirect interaction between verbatim overlap and performance, leading them to find difficulty in their interpretation of the results. Due to the positive correlation between word count and performance as well as the finding that longhand notetakers did have superior performance on factual recall tests, Mitchell and Zheng (2019) were inconclusive in their discussion, supporting both laptop usage and handwriting.

As seen in the meta-analysis conducted by Allen et al. (2020), results were supportive of longhand notetaking, but the effect size found was small (r = - .12), indicative of low practical significance. One influence that was discussed and not controlled among the studies that Allen et al. (2020) examined were computer distractions, which may have influenced the results to favour longhand notetaking as individuals who use laptops have been found to be more vulnerable to distractions (such as unlimited internet access) than those who handwrite (Allen et al., 2020; Voyer et al., 2022). Other studies have shown multiple insignificant findings with very small interaction effects (see: Artz, et al., 2020; Urry et al., 2021, Study 1), and other meta-analyses of the literature have also failed to provide significant findings supporting either notetaking method (Urry et al., 2021; Voyer et al., 2022).

Readers should also be cognizant of using Bui et al., (2013) as a direct comparison to longhand-favouring studies, as although this study provides a basis for the argument of laptop superiority, longhand notetakers were only compared to laptop notetakers in Experiment 1. Participants in both Experiments 2 & 3 solely used laptops, disregarding the potential outcomes of longhand notetaking entirely. Experiment 1 also only involved an immediate test, not a delayed test, completely ignoring the concept of examining deeper encoding functions between laptop notetaking and longhand notetaking.

Another critique may be made on the difficulty of the lecture material used in the different studies. Although both Bui et al., (2013) and Mueller and Oppenheimer (2014) used recorded video lectures for their experiments, Mueller and Oppenheimer opted to use TED talk videos, which can be argued to be basic in their content (Jansen et al., 2017). Bui et al. (2013) used a more complex video lecture that has been previously used in studies and involved a scoring system that measured main ideas, important details as well as unimportant details. This scoring system was used to measure the organization and detail of participants' notes while Mueller and Oppenheimer did not aim to measure the quality of notes. One may also argue that the literature base that supports laptop superiority in direct comparison to longhand notetaking is much smaller than the latter and therefore needs more research before authors can argue in favour of laptop usage.

Overall, many authors (Artz et al., 2020; Bui et al., 2013; Mitchell & Zheng, 2019; Morehead et al., 2019; Urry et al., 2021; Voyer et al., 2022) call for the continuation of further studies in this field as across the literature, readers have not been provided clear explanation of which notetaking method is most beneficial for academic success. As such, it is important to consider the external variables that are possibly influencing the results.

Cognitive Load

One possible contributing factor to the inconsistencies in research involving notetaking is cognitive load. While taking notes, individuals are subjected to numerous cognitive demands, such as retention of the information being verbally communicated and the ability to translate that into a written piece. According to the Cognitive Load Theory (Sweller, 2010), individuals have a specific amount of working memory that is available for use. As more factors are introduced (such as noise, information, visuals, etc.) the limit of their load ability is reached. The more strained individuals' load is, the more it will negatively influence their performance on tasks (Jansen et al., 2017) as the individual's working memory is overwhelmed, impairing the ability to self-generate and process the incoming information (Benton et al., 1993).

Students often use techniques to reduce information such as abbreviating words (e.g., *"poss.*" for the word "*possible"*) or shortening syntax using symbols (e.g., using an arrow or a dashed line to further a sentence) (Piolat et al., 2005) to lessen cognitive load. These techniques are used to reduce the level of verbal information being processed cognitively and allow the individual to translate it into a piece of work that contains core ideas. Due to this balance of comprehension and writing, multiple cognitive processes must occur, subjecting the individual to the limit of their working memory (Baddeley, 1996).

Different learning environments can also require different cognitive concentration from students. This can influence how much attention students need to pay in order to learn difficult concepts and can influence what types of notes are required (Fiorella & Mayer, 2017). For example, a course in math may require students to perform formulaic calculations, which would most likely require them to handwrite and transform their notes. On the other hand, psychology students who are being lectured on theory may prefer to type their notes as the concepts are not as cognitively demanding and do not require spatial strategies to be used to comprehend ideas. Therefore, different types of lectures may place differing amounts of cognitive demand on students.

To counteract this limitation of working memory, individuals often engage in two different strategies: choosing to focus on comprehending the material by only listening to the lecture and therefore reducing their amount of notetaking, or by focusing on transcription only, resulting in lower cognitive processes of the information (Piolat et al., 2005). However, engaging in these strategies can result in poor retention and recall of the information by impacting cognitive encoding and storage functions.

Student Preference

One possibility that may be influencing the differences found in notetaking literature is that allowing students to use their preferred method of notetaking style can result in higher performance levels, as using a familiar method may lower cognitive demand. A study conducted by Shell et al. (2020) explored whether students who were allowed to choose their preferred method (either using a stylus, laptop, or handwriting) had a difference in recall in comparison to those who did not use their method of choice. Students were subjected to three mini-lectures (social comparison, autism, and ADHD), and data was analyzed separately for each. Results showed that students who used their preferred notetaking method had higher recall test results in each lecture; social comparison ($d = .12$), autism ($d = .45$), and ADHD ($d = .31$).

Shell et al. (2020) speculated that this finding was due to the familiarity the individual had with their method of choice and the automatic processes that came with prolonged practice with the chosen method. Therefore, it was considered that students who use a preferred method may experience less cognitive demand because using their preferred method allows them to dedicate their inputs towards understanding lecture information. Individuals using an unpreferred method during a lecture may experience more difficulty because using an unfamiliar method would require more attention paid to the actual process of using that medium, and less on translating and understanding the incoming information. Cognitive load, alongside working memory, has been explored in the literature of notetaking (Benton et al., 1993; Di Vesta & Gray, 1972a; Jansen et al., 2017; Kiewra, 1985, 1989; Piolat et al., 2005; Schoen, 2012; Smoker et al., 2009), however, few studies have explored the influence of cognitive demand on individual notetakers and how to mitigate an excess of cognitive load, leading into the present study.

The Present Study

The purpose of this study is to investigate the impact of student preference for notetaking methods (handwriting or typing) on notetaking performance due to cognitive demand. According to the cognitive load theory, when the capacity of working memory is exceeded, learning is impeded, and individuals begin to perform poorly on their tasks (De Jong, 2010). As individuals may be subjected to less cognitive demand when using a notetaking method that is familiar, they can focus more on comprehension of the incoming information of the lecture and less on the transcription of that information. However, to date, few studies have examined this possibility. As such, the main research question for this study is: does the use of a preferred method lessen cognitive demand in notetakers? To address this question, cognitive load theory was used to formulate four hypotheses:

1. Individuals who have access to their preferred notetaking method will have greater recall in the difficult lecture condition than those who use an unpreferred method.

According to cognitive load theory, students using a preferred notetaking method are likely more comfortable and efficient, thereby reducing cognitive load and enhancing their ability to focus on and recall lecture content. In contrast, an unpreferred method may increase cognitive strain, making it harder to remember information, especially when the lecture material is difficult.

2. Individuals who use their preferred method of notetaking will produce more complete notes in the difficult lecture than those using an unpreferred method.

Using a preferred method may facilitate a more efficient allocation of cognitive resources, allowing for better processing and documentation of complex information, thereby, in the hard lecture, producing notes that include a higher proportion of relevant idea units. In contrast, an unpreferred method may increase cognitive strain, making it harder to capture relevant ideas.

3. Individuals who have access to their preferred notetaking method will have lower cognitive load at the end of the difficult lecture than those who use an unpreferred method.

When exploring cognitive demand, students subjected to a more cognitively taxing (difficult) lecture who are using their preferred method of choice will have access to more of their working memory to due to lower cognitive demand present and familiarity with their method of choice.

4. Both preferred and unpreferred method users will have similar recall, complete idea units, and cognitive load after the easy lecture due to a lessened amount of cognitive demand.

In line with theory when the cognitive demand of the lecture is low, we expect the advantage of using a preferred notetaking method will be negligible. This is because the cognitive load is sufficiently manageable regardless of the notetaking method used.

Taking effective notes in lectures and tutorials is an essential skill for studying for students. This study aims to provide insight into how students can effectively take notes in ways that meet their individual needs while maximizing their working memory. Findings have significance for informing future educational practices, allowing students to efficiently utilize both the encoding and storage functions and can potentially allow for an increase in academic performance.

Methods

Participants

In this study, 12 undergraduate students, aged 18-25 ($M = 21$), were recruited from the University of Victoria. Participants included 8 females (66.7%) and 4 males (33.33%) from varying degrees and years of study ($M = 2.6$). Students from all academic, cultural, and linguistic backgrounds were encouraged to participate in the study. The only inclusion criteria required was that students were actively completing an undergraduate degree. Graduate students were not invited to participate. Recruitment posters were placed in various buildings across the University of Victoria and the researcher presented the posters in multiple large, undergraduate courses to further interest in participation. Two $50 gift cards, either to the University of Victoria Bookstore or Starbucks (chosen by the participant), were used as incentives for participation in the study. These were awarded based on a random draw composed of all participants in the study. The draw occurred at the end of data collection, and winners were individually notified of their prize wins.

Table 1
Participant Demographics

	n	%
Age		
18-21	8	67
22-25	4	33
Gender		
Female	8	67
Male	4	33
Year of Study		
1	1	8
2	5	42
3	3	25
4	3	25
GPA*		
2-3.5	2	17
3.6-5.5	4	33
5.6-7.5	3	25
7.6-9	3	25
Preferred Notetaking Method		
Handwriting	10	83
Laptop	2	17

Note. On a 9.0-point grade scale*

Ethics Statement

This study was reviewed and approved by the University of Victoria affiliated Human Research Ethics Board (HREB). Participation in this study was voluntary and participants were informed they could withdraw at any time. Participant information was kept confidential and adhered to the guidelines set with the HREB.

Materials and Procedure

The study occurred in a private study room at the University of Victoria. Each session took approximately 1 hour to complete with one participant at a time. Upon arrival, participants completed a consent form and provided demographic information. The demographic information form asked for details such as academic level (e.g., year of study and GPA), gender, and age. It also included questions that highlighted the individual's preferred notetaking method and their experience with taking notes. Nondescript questions, such as "what is your favorite course at the University of Victoria," were included to prevent the participant from determining the experimental purposes of the study and engaging in detection bias. A masked approach, a form of deception, was used to reduce the risk of participants recognizing the intervention they would be subjected to, thus protecting the outcome of the results. Participants were instructed that the study's purpose was to simply explore students' note-taking strategies in post-secondary education. Finally, participants were appointed to a notetaking method (longhand or typing on a laptop).

Lectures

Two separate TED Talks were selected to use as lectures: (a) an “easy” lecture TEDTalk, *A Rosetta Stone for a Lost Language* (Rao, 2011), and (b) a “difficult” lecture, *Is Our Universe the Only Universe?* (Greene, 2012). The TED Talks chosen were defined by difficulty to subject participants to differing levels of lecture complexity to measure cognitive load. The easy lecture was taken from Mueller and Oppenheimer’s 2014 study to maintain consistency and similarity across the literature, while the difficult lecture was selected from the TED website.

Participants were instructed to watch lectures and take notes. Laptops or paper with pens were provided for notetaking usage. Use of personal laptops was prohibited to minimize the risk of distraction, and participants were only allowed to review the lecture once, with no pausing or rewinding the video permitted. Participants were counterbalanced, with half beginning with the easy lecture and then moving on to the difficult lecture, while the other half began with the difficult lecture and progressed to the easy lecture (see Figure 1 for procedure sequence). After the completion of each lecture, notes were taken away from the participant by the researcher.

The linguistic complexity of each was measured to determine the level of difficulty of each lecture. Each TED Talk is transcribed and can be found alongside the original video. The written passages for both lectures were used to measure semantic properties such as sentence length, common nouns, jargon, as well as idea units. Although one may note that listening and reading comprehension are two separate language processes, tests that measure listening comprehension skills use text complexity measures to rate item difficulty for the examination (Ilc & Stopar, 2016; Loukina et al., 2016; Nissan et al., 1995), allowing us to appropriately use the transcribed versions of the lectures to measure content difficulty. Listening comprehension has been found to have a strong influence on reading comprehension based on skills learned in early education, such as word recognition, decoding, and inference-making (Hogan et al., 2014).

As used in a previous study conducted by Loukina et al. (2016), the online program *TextEvaluator* (Sheehan et al., 2014) was used to analyze the complexity of each lecture. This program is designed to assess text complexity for both English native and non-native speakers and has been used to measure item difficulty for English Language Proficiency Tests (Chen & Sheehan, 2015). Four dimensions of text complexity are measured by this program: syntax, vocabulary, cohesion, and discourse. The transcripts of both lectures were run through the program to determine their difficulty. According to TextEvaluator text complexity expectations, which are based on the US Common Core State Standards (CCSS), it is anticipated that students in Grade 12 can comfortably read pieces with a median lexical score of 1130. College students typically excel at comprehending texts with a lexical score of 1300, while post-college students exhibit competence with texts reaching a lexical score of 2000 (Sheehan, 2015). These scores were calculated by lexically analysing multiple texts such as textbooks and novels for different grade levels approved by the CCSS, and other bodies of text such as newspapers and first year assigned textbooks (Sheehan, 2015). Due to the limitations of the amount of body text that is enterable in TextEvaluator, each transcript was divided into three parts and separately entered to receive an overall score. The three scores then were used to create an average final score. The easy lecture average score fell at 900 (see Table 2), while the difficult lecture's average score fell at 1060 (see Table 3). Although both scores fall below the limit of the average college-level reading ability, it is evident that the easy lecture is less cognitively demanding than the difficult lecture. The difficult lecture was found to have higher scores of syntactic complexity, argumentation, academic vocabulary, and degree of narrativity.

Distractor Tasks

After each lecture, a distractor task was administered to participants to diminish recency effects (Schoen, 2012), allow for the encoding function and measure working memory (Luo et al., 2018; Morehead et al., 2019; Mueller & Oppenheimer, 2014; Schoen, 2012; Smoker et al., 2009). After the easy lecture, participants completed an online typing speed test to reduce recency effects (Morehead et al., 2019) sourced from the website Ratatype (https://www.ratatype.com/typing-test/test/). After the difficult lecture, participants completed the Digit Span Task (DSB) from the Wechsler Adult Intelligence Scale, 3rd Edition (WAIS-III, Wechsler, 1997). Each distractor task lasted for approximately 3-5 minutes each.

Recall Performance Task

Following the distractor task for each lecture, participants completed a recall test asking them to summarize the important concepts learned in the lecture. Participants were not able to review their notes before the recall test and all participants were required to handwrite their summaries to adhere to the ecological validity of university testing environments. Recall tests were administered within 5 minutes. After the recall task, participants were allowed to take a 5-minute break before continuing. At the end of the session, participants were debriefed and had an opportunity to learn the full purpose of the experiment and discuss any details or questions pertaining to the research.

Figure 1
Procedure Sequence

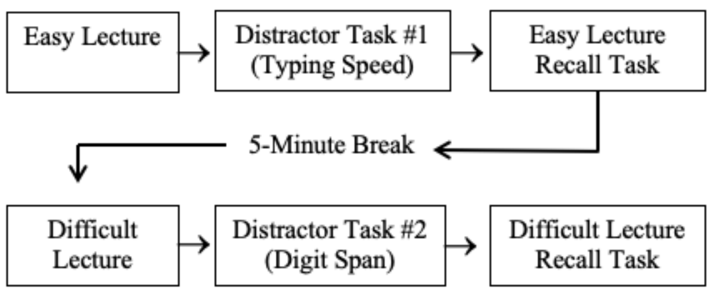

Table 2
Easy Lecture – Difficulty Relative to Target Grade

Component	Score
Sentence Structure	
Syntactic Complexity (Higher values indicate lower complexity)	60
Vocabulary Difficulty	
Academic Vocabulary (Higher values indicate lower complexity)	57
Word Unfamiliarity (Higher values indicate lower complexity)	67
Concreteness (Lower values indicate lower complexity)	32
Connections Across Ideas	
Lexical Cohesion (Lower values indicate lower complexity)	49
Interactive/Conversational Style (Lower values indicate lower complexity)	65

Level of Argumentation (Higher values indicate lower complexity)	61
Organization Degree of Narrativity (Lower values indicate lower complexity)	52
Overall Text Complexity **TextEvaluator Complexity Score**	**900**

Note. Component scores fall on a scale of 1-100, while Overall Text Complexity Scores fall on an alternate scale ranging from 100-2000 (Sheehan, 2015).

Table 3
Difficult Lecture – Difficulty Relative to Target Grade
Component Score

Sentence Structure Syntactic Complexity (Higher values indicate lower complexity)	68
Vocabulary Difficulty Academic Vocabulary (Higher values indicate lower complexity) Word Unfamiliarity (Higher values indicate lower complexity) Concreteness (Lower values indicate lower complexity)	67 68 28
Connections Across Ideas Lexical Cohesion (Lower values indicate lower complexity) Interactive/Conversational Style (Lower values indicate lower complexity) Level of Argumentation (Higher values indicate lower complexity)	53 56 74
Organization Degree of Narrativity (Lower values indicate lower complexity)	45

Overall Text Complexity **TextEvaluator Complexity Score**	**1060**

Note. Component scores fall on a scale of 1-100, while Overall Text Complexity Scores fall on an alternate scale ranging from 100-2000 (Sheehan, 2015).

Measures

Recall and Completeness of Notes

Idea Units. Idea units in students' notes and responses to the recall test were used to measure the quality of notes and recall test performance. First, idea units were identified in the easy and the difficult TED Talk lectures through keywords (such as "cause," "purpose," and "effect") that signal important information, definitions and key terminology that help portray the relevance/importance of the lecture and supportive details (examples, dates, etc.,) that help support main ideas (Wong, 2009, pp. 302–304). Second, idea units for each participant were identified in both the easy and difficult lectures' notes to measure quality and recall task to measure encoding and recall ability. Each correct idea unit identified by the participant was scored 1 point. The easy lecture was scored out of 35, while the difficult lecture was scored out of 33 (see Appendix A for scoring guide). The number of correct idea units identified in raw scores acted as an indicator of completeness of notes and represented how well the lecture information was encoded and recalled (see Appendix B for example of scored notes). For interrater reliability measures, Cohen's kappa was calculated to assess the level of agreement in scores for both the easy and difficult lecture conditions (notes and recall). A strong agreement was found, $\kappa = 0.81$ in the easy lecture condition, and $\kappa = 0.90$ in the difficult lecture condition, between raters.

Cognitive Load

Verbal Working Memory Task. The Digit Span Task from the Wechsler Adult Intelligence Scale, 3rd Edition (WAIS-III, Wechsler, 1997), a verbal working memory measure, was used as an indicator of cognitive demand. As per the requirements of the WAIS-III administration guide, both the *Digits Forward* and the *Digits Backward* subtests were administered, with an average raw score combining the two subtests calculated. The digit span backward task (DSB) test is frequently used in clinical psychology to measure verbal working memory ability in children and adults (Hilbert et al., 2015), however, both Digits Forwards and Digits Backwards were administered to adhere to the standards and scaling of the WAIS-III. Participants were required to listen to increasing lists of digits and then repeat them back to the investigator in both regular and reverse order. Raw scores were converted to scaled scores based on WAIS-III normative sample. Scaled scores of 8-12 (M = 10, SD = 3) are considered to be within average range (Weschler, 1997). The internal consistency reliability alpha coefficient ranged from 0.91-0.92 for this age demographic in this study (18-25).

Results

Analysis

A 2 (notetaking method: preferred or unpreferred method) x 2 (lecture difficulty: easy or hard) mixed factorial analysis was planned to investigate the impact of student preference and lecture difficulty on the idea units correctly identified in notes and recall test performance with the expectation that preferred method would engender less cognitive demand, thereby resulting in a higher completeness of notes and encoding of lecture information. Lecture difficulty was to be considered the within-subjects factor, while participants were assigned randomly to a notetaking method (preferred or non-preferred), acting as a between-subject factor. Therefore, participants would have acted as their own baseline for lecture difficulty, while student preference was directly measured.

To calculate the minimum sample size required to test the study's hypothesis, a priori power analysis was conducted using G*Power version 3.1.9.6 (Faul et al., 2007). To achieve 80% power for detecting an overall medium effect size 0.25 at a significance of a = 0.05, results signified that a sample size of N = 36 was necessary for conducting a 2x2 mixed-design ANOVA that is statistically significant.

However, a limited sample size was collected (N = 12). Participants were randomly assigned to two separate groups: preferred (n = 8) vs non-preferred (n = 4). Descriptive statistics (mean and standard deviation (SD)) and data visualization (histograms) were computed to provide information about the data and to measure assumptions. Histograms displayed non-normality, bringing suspicion to the accuracy of the assumption tests. Due to a small sample size and the risk of Type II errors occurring due to a lack of power, nonparametric measures were used for analysis.

As such, a series of Mann-Whitney U tests were used to address the research question. This non-parametric measure was used to accommodate the small sample size and non-normal distributions found across the data and acted as the alternative of parametric independent t-tests.

To address Hypothesis 1 (individuals who have access to their preferred notetaking method will have greater recall in the difficult lecture condition than those who use an unpreferred method), a Mann-Whitney U test was performed to compare whether access to a preferred or unpreferred method (dependent variable) influenced recall performance in the difficult lecture (independent variable). For Hypothesis 2, (individuals who use their preferred method of notetaking will produce more complete notes in the difficult lecture than those using an unpreferred method), a Mann-Whitney U test was conducted to analyze the completeness of notes in both preferred vs. unpreferred method users in the difficult lecture. The quality of notes (idea units measured) in the difficult lecture condition was the dependent variable, while the use of a preferred or unpreferred method acted as the independent variable. Hypothesis 3 aimed to examine cognitive demand and working memory of participants (individuals who have access to their preferred notetaking method will have lower cognitive load at the end of the difficult lecture than those who use an unpreferred method), therefore, another Mann-Whitney U test was conducted to measure digit span scores (dependent variable) for individuals using a preferred or unpreferred method (independent variable). Finally, Hypothesis 4 (both preferred and unpreferred method users will have similar recall, complete idea units, and cognitive load after the easy lecture due to a lessened amount of cognitive demand) was explored with two separate Mann-Whitney U tests to compare the impact of preferred vs unpreferred method on the completeness of notes and recall performance in the easy lecture. The method used (preferred vs. unpreferred) was the independent variable, while completeness of notes and recall performance acted as the dependent variable.

Results

Descriptive Statistics

Descriptive statistics are summarized in Table 4. In the easy lecture task, the mean score for preferred users in the notes was 14.12 (*SD* = 3.44) with a range of 8-17, with recall scores falling within *M* = 6.75 (*SD* = 2.19). Unpreferred notetakers in the easy lecture condition had scores of *M* = 19.50 (*SD* = 6.56) with a range of 12-28 in notes, indicating a large amount of variability between participants, and a mean score of 7.75 (*SD* = 2.50) in recall.

Participants using a preferred method in the difficult lecture condition for notes had a mean score of 12.15 (*SD* = 6.52) and a range from 2-21, also indicating large variability amongst scores. Scores for preferred users in the difficult condition recall had a mean score of 5.75 (*SD* = 3.41). Unpreferred method users in the difficult conditions scores of *M* = 15.5 (*SD* = 4.36) for notes, and *M* = 8.25 (*SD* = 2.87) in recall. It is interesting to note that individuals using an unpreferred method of choice in both the difficult and easy lectures had higher mean scores, however, it is evident that there is variability amongst participants' scores.

Regarding digit span, all participants scored within the average range for working memory (8-12), however, unpreferred method users had a higher mean score (*M* = 11.75, *SD* = 3.86) than those using a preferred method (*M* = 9.62, *SD* = 2.72). However, similarly to scores found for the lecture conditions, more variability was seen amongst unpreferred method users in the digit span task (*SD* = 3.86) with a range of 8-17.

Table 4

Descriptive Statistics Across All Measures

			n	*M*	*SD*	Median	IQR	Range
Easy Lecture								
	Preferred							
		Notes*	6	14.12	3.44	15	5	8-17
		Recall**	6	6.75	2.19	7	4.75	3-10
	Unpreferred							
		Notes	4	19.50	6.56	19	4.0	12-28
		Recall	4	7.75	2.50	7.5	2.25	5-11
	All							
		Notes	12	15.92	5.12	16.5	4.0	8-28
		Recall	12	7.08	2.71	7.5	4.25	3-11
Difficult Lecture								
	Preferred							
		Notes	6	12.75	6.52	14.0	7.25	2-21
		Recall	6	5.75	3.41	16.5	5.75	2-10
	Unpreferred							
		Notes	4	15.50	4.36	5.5	6.00	14-19

	Recall	4	8.25	2.87	7.5	3.75	6-12
All							
	Notes	12	13.67	5.84	14	9.0	2-21
	Recall	12	6.58	3.34	6.5	5.5	2-12
Digit Span							
Preferred		6	9.62	2.72	10	2.25	6-14
Unpreferred		4	11.75	3.86	11	3.75	8-17
All		12	10.33	3.14	10	3.25	6-17

Note. *Scored out of 35 (raw scores), **Scored out of 33 (raw scores). Digit span task is presented in scaled scores (WAIS-III norm-referenced standardized scores).

Recall Performance Task

Two Mann-Whitney U tests were conducted to examine the impact of the use of a preferred vs. unpreferred method on recall. Results revealed no significant difference in idea unit recall between preferred or non-preferred in the easy lecture recall test (U = 13, p = > 0.05), with a small effect size found (r = 0.12). Similar results were found for the difficult lecture condition, with no significant difference found in recall between preferred and unpreferred method users (U = 10, p = > 0.05), also reporting a small effect size (r = 0.27). Results showed that neither preferred or unpreferred method users had higher recall test performance, indicating no difference in regard to the encoding of the lecture information.

Completeness of Notes

Two Mann-Whitney U Tests were performed to measure the completeness of notes through correct idea units identified in both easy and difficult lecture conditions. Results showed no significant difference in idea unit scores between preferred or non-preferred notetakers in the easy notes (U = 6, p = > 0.05), with an effect size showing a medium difference between groups (r = 0.43). Similar results were found for the difficult lecture condition, with no significant difference found in difficult notes (U = 13.5, p = > 0.05) with an extremely small effect size reported (*r* = 0.099). Therefore, no difference was identified in the quality of notes found between either preferred or unpreferred method users in both lecture conditions.

Cognitive Load

Another Mann-Whitney U test was conducted to analyze verbal working memory through digit span scores. Results of this test showed that there was no significant difference in digit span scores between the mean ranks of preferred and unpreferred groups (U = 11, $p = > 0.05$). An effect size of $r = 0.23$ was reported, meaning that there was a small magnitude of differences between groups. These results indicate that there was no evident difference found between working memory in participants, representing that neither preferred or unpreferred method users faced an increased load of cognitive demand.

Notetaking Performance Profiles

To shed further light on these results, descriptive data was closely examined and two profiles of participants were identified: (a) Group 1: high performance notetakers, and (b) Group 2: low performance notetakers. Regarding performance standards, individuals who fell below the mean in both completeness of notes (easy lecture: M = 15.92, difficult lecture: M =13.67) and recall performance (easy lecture: M = 7.08, difficult lecture: M = 6.58) were deemed as low performers. Similarly, scores that fell below the mean for the digit span task (M = 10.33) were also labeled as individuals with low performance. It is important to note that according to the WAIS-III, scaled scores between 8-12 are considered within average range, however, for the purpose of this study the mean of scores was used as a cut-off for performance. Trends were only found within the performances of seven participants, with the remaining participants having extremely variable performances.

Group 1 – High Performance Notetakers. Group 1 included participants who demonstrates scores on digit span task, note completeness, as well as recall performance that fell within the higher end of the distribution. Specifically, three participants were identified as high performers: Participants A, B, and C. These participants demonstrated potential low cognitive demand as seen in their higher digit span scores, with participants A and C using a preferred method and participant B using an unpreferred method. Performing above average, these individuals were able to have more completeness in their notes and recall as they were able to correctly identify correct idea units, signifying proper encoding of the lecture information in both the easy and difficult lecture.

Table 5
Profile Scores of Group 1

Participant	Preferred (y/n)	Laptop/Handwriting	Easy Lecture Notes (Max score = 35) (M = 15.92)	Difficult Lecture Notes (Max score = 33) (M = 13.67)	Easy Lecture Recall (Max score = 35) (M = 7.08)	Difficult Lecture Recall (Max score = 33) (M = 6.58)	Digit Span Task (M = 10.33)
A	Yes	Handwriting	16	15	8	10	14
B	No	Laptop	28	19	11	12	17
C	Yes	Laptop	17	21	9	8	12

Note. Participant profiles are listed under pseudonyms. Lecture notes and recall are presented as raw scores. Digit span scores are presented as scaled scores.

Group 2 – Low Performance Notetakers. Group 2 identified four participants (D, E, F, and G) who had low notetaking performance across all scores. Despite all participants in this group using a preferred method, these individuals had low digit span scores, potentially indicating high amounts of cognitive demand, and correctly identified idea units in both easy and difficult note conditions fell towards the low end of the distribution of the data. The individuals struggled particularly with recall performance, struggling to identify and recall correct idea units in both the easy and difficult lecture conditions.

Table 6

Profile Scores of Group 2

Participant #	Preferred (y/n)	Laptop/Handwriting	Easy Lecture Notes (Max score = 35) (M = 15.92)	Difficult Lecture Notes (Max score = 33) (M = 13.67)	Easy Lecture Recall (Max score = 35) (M = 7.08)	Difficult Lecture Recall (Max score = 33) (M = 6.58)	Digit Span Task (M = 10.33)
D	Yes	Handwriting	17	14	6	3	10
E	Yes	Handwriting	14	10	5	4	6
F	Yes	Handwriting	8	2	3	2	6
G	Yes	Laptop	14	6	3	2	9

Note. Participant profiles are listed under pseudonyms. Lecture notes and recall are presented as raw scores. Digit span scores are presented as scaled scores.

Discussion

The purpose of this study was to investigate whether student preference for notetaking methods (handwriting or typing) influences notetaking performance due to cognitive demand. Specifically, the research question "does the use of a preferred method lessen cognitive demand in notetakers?" was posed, with four hypotheses guiding the exploration of this question. Hypothesis 1 predicted that individuals who had access to their preferred method would have greater recall in a difficult lecture, while Hypothesis 2 estimated that preferred method users would have more complete notes in the difficult lecture condition. To explore cognitive demand, Hypothesis 3 predicted that preferred method users would experience less cognitive demand than their unpreferred method peers, while Hypothesis 4 estimated that all notetaker users would perform similarly in all measures (digit span, note completeness and recall) in the easy lecture condition. This next section will discuss the results for each.

Notetaking Preference and Lecture Recall

When exploring performance through recall, it was hypothesized that when learners used a preferred method to take notes, they would have higher recall scores about difficult lecture material compared to learners using a unpreferred method due experiencing less cognitive load. However, results did not support this hypothesis. Individuals using a preferred method did not outperform those using an unpreferred method, suggesting that method had little impact on the participants' ability to encode the information learned in the difficult lecture (Benton et al., 1993; Kiewra, 1989).

This finding aligns with previous similar findings, with Mueller and Oppenheimer (2014, Experiment 1) reporting no significant difference between handwriting or laptop notetakers with factual-recall questions. Bui et al (2013) also found no significant result found in laptop notetakers instructed to take organized notes in immediate free recall, however, individuals instructed to transcribe the lecture directly performed better on free recall on immediate tests. One possibility is that individuals did not experience a large difference of cognitive load between the easy and difficult lecture, resulting in the use of a preferred or unpreferred method rendering unimportant. Furthermore, in the present study, participants were not instructed on how notes should be taken and had free choice in how they wanted to record lecture information with the method they were assigned to. An area for future research to explore would be to look at the style of notetaking each participant used, and to see if preferred method users differed in their notetaking strategies than those using an unpreferred method.

Notetaking Preference and Completeness of Notes

Examining the influence of student preference on the completeness of notes, no significant results were found in the difficult-notes condition, meaning that preferred method users did not identify more correct idea units in their note than those using a unpreferred method. This showed that student preference in notetaking settings was not influential, regardless of the lecture difficulty and the load of cognitive demand the student was placed under. This did not support the hypothesis that students using a preferred method would have more complete idea units, as they would be able to focus more on comprehending and translating the lecture and less on using the notetaking medium itself.

Notetaking Preference and Cognitive Demand

Examining cognitive demand directly through working memory limits, it was hypothesized that students who have access to their preferred notetaking method will have higher digit span scores due to lower cognitive demand experienced. However, results showed no significant interaction between preferred vs. unpreferred notetakers and their digit span scores, indicating no significant difference between working memory performance in notetakers. Based on previous literature, it was estimated that due to the familiarity and automatic processes of using a preferred notetaking method (Shell et al., 2021), the load of cognitive demand that the individual was placed under in lecture settings would be minimized, though this was not the case in the present study. However, it is important to note that working memory was not directly controlled for in relation to task performance in this study. Therefore, this makes it difficult to attribute the observed differences in task performance to working memory performance due potentially differing cognitive function skills of each participant.

Examination of the descriptive statistics revealed that students using a non-preferred method had a higher mean digit span scores (M = 11.75) than those using a preferred method (M = 9.62), although no statistically significant result was found in non-parametric measures. This result conflicts with findings in the previous literature, with Shell et al. (2021) reporting that students using a preferred method had higher scores on recall.

One possible explanation may be due to the typing skill level of all students in the 21st century. In this study, data was collected on the type of notetaking method students were randomly assigned to (handwriting vs laptop), however, no data was collected on individuals using handwriting as an unpreferred method. Therefore, all students in the unpreferred condition used laptops. With the increase of the use of technology in schools, students are often taught how to type on computers at a very early age (Mangen et al., 2015), and universities rely on computers to allow students to showcase performance and achievement levels. Based on the increased use of technology, typing has become an automatic process for many individuals and has been reported to be less cognitively engaging than handwriting (Kiewra, 1985a; Meter et al., 1994; Mueller & Oppenheimer, 2014). As a result, non-preferred laptop notetakers may have experienced less of a cognitive load during the lecture conditions, as although they are using a "unpreferred" method, they still are extremely experienced with laptop use.

Another reason that may have influenced the results of this finding may have been the level of difficulty of the lecture conditions. Although two topics were chosen that were estimated to be more "novel" concepts and were analyzed for lexical complexity, participants may not have experienced a cognitively demanding environment influential enough to affect their notetaking performance. As mentioned previously, TED Talks can be argued to be more basic in content in comparison to lectures that previous research has used (Jansen et al., 2017). TED Talks are aimed for global education, differing from specific, complex, and lengthier lectures that would be found in university settings. Therefore, the concepts from the difficult lecture (Greene, 2012) video may have not influenced as much cognitive load as estimated. Although the TED Talks were chosen based on their specialized content, familiarity of the lecture content in participants was unable to be controlled for. Specifically, one participant mentioned that they enjoyed the difficult lecture, claiming that they had interest in similar topics. Biases as such may have influenced their performance, as the goal of subjecting participants to an increase of cognitively demanding lectures may not have been relevant.

Notetaking Preference in Low Demand Settings

Comparing participant performance in preferred vs. unpreferred methods in the easy lecture condition was also explored to understand how all students performed in a less cognitively taxing environment. It was hypothesized that all participants would perform similarly in both the completeness of notes and recall performance task. Supporting this estimation, results showed no significant difference between preferred vs. non-preferred method users in either completeness of notes or in their recall scores in the easy lecture, indicating no large difference in performance. Therefore, it can be assumed that the easy lecture (Rao, 2011) did not influence any extreme cognitive demand in participants, however, examining the descriptive data provides interesting results.

Despite no statistical difference being found between preferred vs. unpreferred notetakers, it is interesting to note that in the easy lecture condition, participants using an unpreferred method had higher mean scores of completeness of notes ($M = 19.50$) and recall performance ($M = 7.75$) than those using a preferred method for notes ($M = 14.12$) and recall ($M = 6.75$). This finding may be a result based on the specific notetaking method being used. Although laptop vs.

handwriting use was not directly measured in this study, previous research has found laptop users to have higher word count than their handwriting peers (Mitchell & Zheng, 2019; Mueller & Oppenheimer, 2014). Therefore, individuals who used a laptop to type their notes may have had higher word counts, allowing them to capture more idea units than those handwriting. Future research should explore the relationship between notetaking medium (handwriting vs. typing) and its influence on student preference and performance.

Participant Profiles

Finally, upon examination of the raw data, two profiles identified within the data showed those who had trends of high performance and those who had low performance. Group 1 consisted of three participants who showed evidence of high scores in their completeness of notes, recall performance scores and digit span task in both the easy and difficult lecture conditions. Out of these 3 individuals, two participants used their preferred method, and one used an unpreferred method, showing interesting results. As hypothesized, Participants A and C, who used a preferred method, performed within the high end of the distribution on their completeness of notes and recall performance, and had above average digit span scores, indicating a lowered amount of cognitive load. On the other hand, although Participant B's scores fell well into the higher end of the distribution, they used an unpreferred method. Specifically, this individual used a laptop, and although it was identified as not their preferred method, they were still able to identify a high number of correct idea units in both easy and difficult lectures and score the highest out of all participants on the digit span task. As discussed above, this individual may have been proficient with using a laptop despite their preference to handwrite, as university students have become reliant on the use of computers (Dontre, 2021). Therefore, it may be possible that student preference may not have as much relevance on the outcome of performance as students in the 21st century have become proficient in both their handwriting and typing skills.

A second profile of low performing notetakers were also identified in the data. Specifically, Group 2 consisted of four individuals who all used their preferred method of choice and had low scores in all measures. Participants D, E, F, and G fell towards the lower end of the distribution in identifying correct idea units in their notes, had poor recall performance, and scored lower on the digit span task in comparison to peers. All four participants scored low in the easy lecture notes and recall as well, indicating a lack of encoding and ability even when exposed to low cognitively demanding environments. Overall, no other profiles were identified in the data, with participant performance being highly variable, across scores.

One explanation to consider would be subjective individual differences among participants. As seen with Group 2, individuals who had low easy lecture condition score were low performers overall. On the contrary, those in Group 1 had high performance in the easy lecture conditions, leading into high scores across all measures. This showed that individuals who started off strong ended strong, while those already struggling with less complex environments had difficulty with the rest of the tasks as well.

It is important to recognize that individuals are subjected to their own working memory, cognitive strengths and weaknesses, and other personal factors that may be influencing their performance. While exploring working memory in their study, Bui et al. (2013) concluded their results by stating that participant performance was dependent on the working memory skill of the individual. In the present study, the variability amongst participants where no trends were found provides foundation for a similar explanation. As it has been found that different notetaking strategies place different demands on working memory (Piolat et al., 2005), recommendations based on the findings of the present study would suggest that notetakers continue to use which ever medium they find less cognitively taxing based on their own personal needs. When notetaking, students should be cognizant of a multitude of factors that could influence the outcome of their notes, including different academic environments, the style of notes required for the course they are taking (Fiorella & Mayer, 2017), distractions that come with use of computers (Dontre, 2021; Fried, 2008; Glass & Kang, 2019; Junco & Cotten, 2012), and personal working memory limits (Jansen et al., 2017; Sweller, 2010). Therefore, based on the findings of this study, it can be concluded that there was no interaction found between student preference and notetaking performance. It is essential to acknowledge individual differences in working memory and cognitive ability when examining notetaking, and students should remain mindful of their personal needs when selecting notetaking mediums in order to promote academic success.

Limitations and Future Directions

The main limitation of this research study was the small sample size collected (n = 12), and an unequal size of groups (preferred, n = 8; unpreferred, n = 4). This had a large influence on the statistical analysis of the data, as small sample sizes can result in a lack of power in analysis. Small sample sizes also reduce the ability to see patterns and trends throughout the data, hindering the ability to make conclusions based on the results. Future research should include a larger sample size in order to reduce the risk of Type II errors and potentially allow for better generalization of the results found.

Another limitation was the number of tasks used to measure the encoding process through recall. In the literature, previous studies used multiple tasks to measure performance, including factual recall, conceptual quiz questions short answer, and overall course grades (Bui et al., 2013; Fiorella & Mayer, 2017; Mitchell & Zheng, 2019; Mueller & Oppenheimer, 2014; Shell et al., 2021). These studies also included both immediate and delayed testing, providing more insight to the encoding and storage functions (Benton et al., 1993; Kiewra, 1989). As this study only used free recall and immediate testing as a means to measure the encoding of information, future research should consider using other forms of testing to allow for closer examination of performance. Working memory was also not directly controlled for in relation to task performance. Therefore, future studies should consider controlling for this variable to better understand the relationship between cognitive demand and notetaking task performance.

Other limitations to consider involve exploring student disabilities and other barriers, such as differences in first languages. During debriefing, one student reported difficulty with participation because English was their second language, however, limitations such as linguistic restrictions, learning disabilities, medical conditions or other potentially influential barriers were not recorded. Another limitation to study that may explain variation between participant performance would be to consider student effort and motivation. Research has shown that students show performance decline in low stakes assessments (List et al., 2017; Wise & Kong, 2005): their performance effort is not as high in a low-stake assessment as it would be in an assessment where the results would be impactful on their personal lives. It is also important to note that this experiment did not represent authentic notetaking activities that would occur in a classroom, which could also lead to a potential lack of motivation. Variations in keyboard preferences were also not considered, which may have potentially influenced performance, as keyboards can differ between brands of computers and laptops. Therefore, in this study, it should be considered if performance bias was evident as the students recognized the lack of consequences participation entailed, as well as the lack of generalizability to regular classroom tasks and personal electronic preferences. Finally, future research should consider focus on the rapid evolution of notetaking technology and its impact on accessibility. Students are able to access assistive technologies such as speech-to-text programs, electronic smart pens, various education-supportive applications and browser extensions on tablets and computers, and the affordances of digital text (e.g., editing, collaboration, text-to-audio, multimedia, etc.), influencing their notetaking activities (Belle et al., 2024; Fichten et al., 2023; Newton & Dell, 2011). Therefore, it is important to explore technology's influence on notetaking further in order to guide recommendations to all learnings, including those with accessibility needs.

Conclusion

In conclusion, no evidence was found to support that student preference (handwriting vs. typing) has an impact on performance in notetakers. This goal of this study was to examine and clarify if student preference for notetaking methods influences performance (notes completeness, recall performance and working memory measures), based on the level of cognitive load they are experiencing. However, results showed varying performances across participants, leading to the conclusion that other factors, such as individual cognitive differences, may be more influential in the outcome of notetakers performance.

Future examination of this research should focus on exploring individual cognitive differences further, as well as on having a larger sample size in order to be able to identify potential trends in the data. Overall, there are many influences that may impact a notetakers performance, including external distractions, the type of information they are learning, as well as personal capabilities. However, until further research is able to identify external and personal factors that influence notetaking strategies, it is recommended that students remain cognizant of discipline, motivation and the type of task they are presented with when deciding to handwrite or type their notes.

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Appendix A

Coding Guide for TED Talk Lectures

Easy lecture scoring guide. The symbol of (1) represents a single point for a key idea found within the lecture. This lecture was scored out of 35.

A Rosetta Stone for a Lost Language (Easy Lecture)

Idus Valley civilization

- Existed 4,000 years ago (1)
- Larger than Egyptian and Mesopotamian civilizations (1)
- Covered what is now Pakistan, Northwestern India and parts of Afghanistan and Iran (1)

Artifacts

- Don't know whom the artifacts represent (1)
- Stone seals, copper seals and tablets, pottery and sign boards were all found with writing on them (1)
    - Don't know what any of these objects say because the Indus script is undeciphered. (1)
    - Symbols most commonly found on seals (1)
        - Seals are very small – one inch by one inch (1)
        - Seals were used for stamping clay tags attached to bundles of goods (1)

Script

- Question of deciphering the script has become a political battle between 3 different types of people (1)
    - 1. Group of people who believe that the script does not represent a language at all (1)
        - Think the symbols are like traffic symbols (1)
    - 2. Group of people who believe that the Indus script represents an Indo-European language (1)
        - Like Sanskrit
    - 3. Group of people believing that the Indus people were ancestors of people living in South India today (1)
        - The Indus script represents what is now known as the Dravidian Language (1)
- Don't know which hypothesis is true (1)
- No software to help decipher the script (No "rosetta stone") (1)
- Most of these symbol texts are very short, making it difficult to decipher (1)
- Last major undeciphered script in the world (1)

3 Steps to attempt deciphering the writing

- Some Indian scientists using computer models to try to decipher it (1)
    - 1. Figure out the direction of writing (1)
        - Looks like the Indus text is written right to left (1)

- 2. Patterns in Language (1)
    - Has patterns in the text – often followed by similar symbols, end-of-text symbols, frequently occurring symbols (1)
    - Used a computer to learn these patterns (1)
- 3. Entropy (1)
    - Language has intermediate levels of entropy (1)
        - High entropy ex. Ahfghjsdjhfjdfdg
        - Low entropy ex. Aaaaaaaaaaaaaaa
    - Idus script falls within intermediate levels of entropy – shows that the Indus script shares an important property of language (1)

- Linguistic scripts can encode multiple languages
    - Found that Indus script has been used to write multiple languages depending on regions and who they were trading with (1)
- Conclusions = indus script does represent language (1)

Reading the symbols

- Rebus Principle – using pictures to represent words (1)
    - However, difficult to determine the meaning/sounds of each of these symbols (1)
    - Using Dravidian language to determine meaning of the script (1)
        - Not proved, however
        - Still working on deciphering the language (1)

Difficult lecture scoring guide. The symbol of (1) represents a single point for a key idea found within the lecture. This lecture was scored out of 33.

<u>Is Our Universe the Only Universe? (Difficult Lecture)</u>

Multiverse

- 1929 (1), Edwin Hubble realized that distant galaxies were morning away from us – meaning that space was expanding (1)
    - Revolutionary result
    - There was certainty that the expansion was slowing down – the gravitational pull of each galaxy slows down the overall expansion of space (based this off of earths gravity) (1)
- In the 1990s (1) two teams of astronomers were inspired to measure the rate at which the expansion was slowing (1)
    - Did this by painstaking observations of the galaxies over time (1)
    - Found that the expansion was actually speeding up, not slowing down (1)
    - Posed the question – what is causing the galaxies to rush away at a fast speed?
        - Einstein's theory (1) – gravity can also be repulsive = pushing things away (1)

        - Repulsive energy = dark energy (1)
            - Found that only a small number of dark gravity is needed to cause this expansion (1)
                - Why? String Theory

String Theory

- String theory: unified theory of physics – describes all the forces at work in the universe. (1)
    - If you examine any piece of matter closely, if you can probe smaller you'd find vibrating filament of energy inside particles or also considered little strings (1)
        - These "strings" produce elections, quarks, neutrinos, photos and all other particles. (1)
    - In string theory, vibration determines everything (1)
    - However, years of research shows that the math of string theory does not quite work (1)
        - String theory suggests that on incredibly small scales, there are additional dimensions crumpled into a tiny size so small that we have not detected them. (1)
        - The shape of the extra dimensions would determine particle masses, strengths of forces, and amounts of dark energy. (1)
            - If we knew the shape, we should be able to calculate these features/amount of dark energy (1)
            - But we don't know shape of these extra dimensions (1)
                - There are candidate shapes that are allowed by math but as time has gone on, this list has grown from 10-500 (1)
                - Due to this, some have suggested a multiverse (1)
                    - Different shapes can = different universes with different levels of dark energy (1)
                    - In this context, the laws of physics cant explain one number for the dark energy because there are actually many numbers (1)
                - We've been able to measure dark energy here because we are here, and it created hospitable life for us specifically. (1)
                    - Other planets are in their specific locations based on the conditions that they need – this is relevant to universes and the amount of dark energy that they need. (1)

The Big Bang

- Big Bang – image of a cosmic explosion that created our universe and sent space rushing outwards (1)
- No explanation to what actually caused the bang other than:
    - Inflationary Cosmology – identifies a particular type of fuel that naturally generates and outward rush of space (1)
    - This fuel cannot be used all up = the big bang was not a one off event (1)
        - Other universes would've been created. (1)

- Can we detect other universes?
  - Possibly – if they collide – this would create temperature variations across space which we could identify (1)
- Although we cannot see into deep space yet (due to the laws of our physics) (1), we are hoping that astronomers will continue to look through and explore. (1)

Appendix B

Example of Scored Notes

This appendix demonstrates a participant's scored notes from both the easy and the difficult lecture conditions. Each symbol (1) represents 1 point received. The coding guide found in Appendix A was used to score these notes.

Easy Lecture (EXAMPLE)

What could present day artifacts (credit cards, coins, writing, etc.) say about our society/civilization?

How would objects and their meaning to the civilization

Indus society's artifacts:
Seals, copper tablets, signboards, pottery (1)

Interpreting meaning can be done by understanding meaning of script/symbols.

Scripture identified, but meaning not clear:

3 hypotheses exist in regards to the origins of the scripture
1. Script does not rep. lang. (1)
2. Script encodes ancient Indo-European script (1)
3. Script encodes a Dravidian language family (1)

Indus script: last major undefined scripture (1)
How to assess if a script is a language

3 characteristics to observe:
1. Direction of writing (1)
    a. Left right, right left.
    b. Indus script: cramping of signs on the upper left corner suggests right-left direction (1)
2. Patterns in language (1)
    a. Morphological rules in terms of what symbol can follow the other. (1)
    b. Some signs cannot follow others
3. Entropy – level of random sequencing of symbols (1)
    a. Uniformly random: neither high nor low. Linguistic scripts are within middle range.
    b.

What can the computer model do?

c. Computer model can be used to assess the possible combinations of symbols. (1)
d. Computer model can detect atypical patterns (according to standard linguistic entropy norms)

Rebus principle:

- Represent a concept with symbols (logography) (1)
- Many ancient scriptures are logographic.

Sequences of Indus scripture associated with Dravidian names based on planets and constellations.
If we decipher scripture, we can decipher meaning of artifacts and better understand history of ancestors.

SCORE = 12/35

Difficult Lecture (EXAMPLE)

Theory describing the nature of the universe and putting it into a wider context.

Multi-verse: contains multiple universes/ realms which may be fundamentally different from our universe.

1. Hubble:
    a. Distant galaxies getting continuously further.
    b. Universe is static. (1)
    c. Expansion of space is speeding up (1)
        i. Measures of expansion rate showed this
        ii. What force is driving the quickening speed?
            1. Einstein's theory of general relativity: If space is uniformly filled with some force > repulsive gravity would cause each universe to push against one another. (1)(1)
2. String theory:
    1. What: approach to realize a unified framework of the forces of physics. (1)
    2. Fundamental vibrating strings at the core of every particle in the universe. (1)
    3. The math has internal inconsistencies, unless we alter our view of universe dimensions. If we know to features of these alternate/extra dimensions, then we can do the math.
    4. Problem: Too many candidate shapes of alternate dimensions. (1)
    5. Solution: theorized that there isn't just one shape for strings in each universe (1)

6. Dark matter:
3. Inflation
    a. Inflationary cosmology:
    b. Improved big bang.

The big bang giving rise to our universe is likely not a one time occurance, but rather a chain of big bangs resulting in different universes with different characteristics per big bang. (1)

Can we count # of universes?

Subtle temperature difference in the universe cause by collisions of universes could be measured to assess # (?) (1)

SCORE = 10/33