An Investigation of Cognitive Processes Associated with Notetaking and Notes-Review

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ABSTRACT

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Notetaking is a cognitively complex academic task that requires the execution of multiple cognitive processes within a limited capacity working memory (Peverly et al., 2007; Peverly & Sumowski, 2012; Piolat, Olive, & Kellogg, 2005). Several studies have investigated cognitive processes related to notetaking, but only one has looked at variables related to notes-review (Hadwin, Kirby, & Woodhouse, 1999). Also, most studies have focused on handwritten notes, and the few studies that have evaluated the effect of writing medium (handwriting or typing) on notes have been limited and equivocal (Bui, Myerson & Hale, 2013; Mueller & Oppenheimer, 2014). This study examined cognitive differences related to lecture notetaking, notes-review, and performance on a multiple-choice test that included memory and inference items. In addition, this study explored differences between handwriting and typing on notes and notes-review. Eighty undergraduate students were randomly assigned to handwrite or type notes, review them, and complete a multiple-choice test based on the lecture. They also completed a measure of letter speed consistent with their experimental condition, along with measures of language comprehension, sustained attention, background knowledge, and metacognition. MANOVAs found significant differences in letter speed between handwriting and typing groups, but no significant differences in overall notetaking or notes-review. The handwriting condition showed evidence of more transformation and organization of lecture information between notetaking and notes-review than with typing. Regression analyses found that letter speed and language comprehension predicted notetaking. Notes-review was positively and significantly related to notetaking, language comprehension, and writing medium. Typed notes were more strongly

related to notes-review than handwritten notes. A significant letter speed *x* metacognition interaction for notetaking and a significant letter speed *x* sustained attention interaction for notes-review suggest that basic cognitive processes (letter speed) need to be sufficiently automatized in order for higher cognitive processes to be applied effectively. Test performance overall and performance on inference items were predicted by notes-review and writing medium. The latter indicated that handwriting was more strongly related to test performance than typing. Findings suggest that handwriting may enable deeper processing of information compared to typing. Future studies should continue to include interactions between cognitive variables to support the theory of hierarchical processing within a limited capacity working memory. Further research on the effects of writing medium on notes and notes-review will improve understanding of the effects of handwriting and typing on these processes.

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Introduction

Notetaking is a common study process used by students at the secondary level and above (Van Meter, Yokoi, & Pressley, 1994) to capture information presented in auditory or written formats. As information increases in quantity and complexity at higher levels of learning (Thomas, Iventosch, & Rohwer, 1987), the succinct capture of verbal information through written notes serves to alleviate the burden of information processing (Peverly & Sumowski, 2012). Multiple studies have found lecture (Armbruster, 2009; Kiewra, 1989; Kobayashi, 2006; Peverly et al., 2007) and text notetaking (Peverly, Brobst, Graham, & Shaw, 2003; Peverly & Sumowski, 2012; Rickards, Fajen, Sullivan, & Gillespie, 1997; Slotte & Lonka, 1999) to be related to improved learning outcomes in comparison to not taking notes at all. If notetaking is a beneficial study strategy, then students might find it helpful to know what makes a good lecture notetaker, which cognitive processes are helpful in notes-review, how notetaking and notes-review relate to test performance, and whether it matters if notes are taken via typing or by handwriting.

In general, notetaking has been found to serve two functions: (1) encoding information through transcribing content and generating connections between new information and prior knowledge, and (2) externally storing information for later retrieval (Armbruster, 2009; Di Vesta & Gray, 1972). These functions occur within two phases of notes—notetaking and notes-review. The encoding process is cognitively complex (Kobayashi, 2005; Peverly et al., 2007; Piolat, Olive, & Kellogg, 2005). Multiple skills, such as understanding the source material, selecting salient concepts, organizing and integrating new information with current knowledge, and transcribing it in a timely manner (Makany, Kemp, & Dror, 2009), must be executed hierarchically (Peverly & Sumowski, 2012), within a limited capacity working memory (Piolat et al., 2005). Thus, as with all cognitively complex tasks, it is important to recognize which specific skills are most important to the successful execution of encoding. A series of studies have found that the quantity and quality of lecture notes is significantly related to handwriting speed (Peverly, Garner, & Vekaria, 2013; Peverly et al., 2007; Peverly, Vekaria, et al., 2013), language comprehension (Peverly et al., 2007; Peverly, Vekaria, et al., 2013), and sustained attention (Gleason, 2012; Peverly, Garner, & Vekaria, 2013; Vekaria, 2011). With text notetaking, language comprehension (as measured through reading comprehension) and handwriting speed were also found to predict quality of notes (Peverly & Sumowski, 2012).

The external storage function of notes is important in providing a physical record that allows access to information from a lecture or text for later review. Notes-review has generally been shown to be more strongly related to test performance than the encoding of notes (Kiewra, 1985a; Kobayashi, 2006). However, studies of cognitive processes related to notes-review have been limited. Only one study to date (Hadwin, Kirby, & Woodhouse, 1999) has addressed cognitive processes associated with notes-review and found that verbal ability, but not working memory or background knowledge, was significantly related to the quality of a written summary at review.

The relationship between notetaking and notes-review on learning outcomes has been studied through various measures, including essay or multiple-choice tests. In addition, outcome measures have considered the type of knowledge acquired—direct recall of information or demonstration of comprehension (Peverly, Marcelin, & Kern, 2014). Kintsch (1998) distinguished between tests of memory that assess direct recall of explicitly presented information—whether through free-recall or multiple-choice—and tests of understanding that that require inference and application of the presented information. Studies by Peverly and colleagues (Gleason, 2012; Peverly et al., 2007; Peverly & Sumowski, 2012; Vekaria 2011) found that notes were related to improved outcomes on tests of memory, but not of understanding. Studies by Kiewra and colleagues (Kiewra, Benton, Kim, Risch, & Christensen, 1995; Kiewra, DuBois, Christensen, Kim, & Lindberg, 1989; Kiewra, DuBois, et al., 1991) found that more elaborate notes such as outlines or matrices were related to performance on tests based on inferences.

Studies of notetaking and notes-review have focused primarily on notes taken via handwriting. With advances in students' use of technology in the classroom (Dahlstrom, Walker & Dziuban, 2013), it is increasingly important to investigate the impact of alternative methods of notetaking, such as typing notes on a computer. Typing, for adults, has been shown to be faster than handwriting (Brown, 1988; Novellino, Edwards, & McCallum, 1986). However, there is limited research to date on the relationship between faster transcription by typing and notes. Two studies (Bui, Myerson & Hale, 2013; Mueller & Oppenheimer, 2014) have shown that students take more notes when typing on a computer than by handwriting. However, the studies differed in their conclusions regarding the effectiveness of taking notes through keyboarding than by hand. One study showed that attempting to transcribe lecture content via typing was more effective than taking notes by hand or taking organized notes via typing (Bui et al., 2013). The other showed that handwritten notes positively impacted learning outcomes more than typed notes (Mueller & Oppenheimer, 2014). They found that typed notes are more likely to be a transcription of lecture content, thus limiting the depth of processing of information, which may negatively impact performance in comparison to notes taken via handwriting.

In this light, this dissertation had four purposes. The first was to replicate and extend findings on the relationships between individual cognitive differences and notetaking. This dissertation examined the relationship of variables studied previously—handwriting speed (Peverly et al., 2007; Peverly & Sumowski, 2012), language comprehension (Peverly et al., 2007; Peverly & Sumowski, 2012; Peverly, Vekaria, et al., 2013), and sustained attention (Gleason, 2012; Peverly, Garner, & Vekaria, 2013; Vekaria, 2011)—to notetaking. This study also included the cognitive variables of background knowledge and metacognition, to determine their relationship to notetaking. Although background knowledge has rarely been included in notetaking research (see Oefinger, 2014; Peverly et al., 2003; Peverly & Sumowski, 2012), individual differences in background knowledge have been found to be a strong determinant of text comprehension and test outcomes (Kintsch, 1998). One study of text-notetaking showed that background knowledge significantly predicted outcomes on inference measures for those who took notes, but not for those who did not (Peverly et al., 2003). Therefore, the role of background knowledge and lecture notetaking was further explored. Similarly, metacognitive ability, which per Rémond (as cited in Makany et al., 2009) refers to an individual's ability to be reflective and aware of his or her own abilities, such as to strategize, execute, evaluate, and regulate completion of a task, has rarely been studied in the context of notetaking (see for example, Peverly et al., 2003). The role of metacognition in a self-regulated learning task such as notetaking was examined in this investigation.

Second, this study sought to examine the relationship of the aforementioned cognitive variables to notes-review. The majority of studies examining individual cognitive differences have focused on notetaking, but not notes-review. As mentioned above, one previous study found verbal ability, but not working memory or background knowledge, to be significantly related to the quality of a written summary at review (Hadwin et al., 1999). The relationship between individual cognitive variables (handwriting speed, language comprehension, sustained attention, background knowledge, and metacognition), notetaking, and notes-review was examined.

Additionally, this study further examined the relationship between notetaking, notes-review and test performance. Previous research has been equivocal regarding the relationship between notetaking and performance on tests of memory (Gleason, 2012; Peverly et al., 2007; Peverly & Sumowski, 2012; Vekaria 2011) and tests of understanding (Kiewra et al., 1995; Kiewra et al., 1989; Kiewra, Dubois, et al., 1991). Therefore, the third purpose of the investigation was to examine the relationship between notetaking, notes-review, and the cognitive variables associated with them, to performance on a multiple-choice test that included both memory and inference items. This study sought to determine whether the prediction patterns found in previous studies are replicated once notes-review is included in the analyses.

Finally, in consideration of the increase in the use of technology in the classroom, and evidence that most college undergraduate students cite laptops as the most used and most important device for academic tasks (Dahlstrom et al., 2013), this study also sought to compare differences in notetaking, notes-review, and test performance based on the medium (handwriting or typing) in which notetaking is conducted.

Review of Literature

As students advance in their academic studies through secondary and postsecondary education, the amount of information they are required to understand, integrate, and recall increases significantly (Thomas, Iventosch, & Rohwer, 1987). Students identify notetaking as a strategy used to record and study information from lecture and text (Dunkel & Davy, 1989; Palmatier & Bennett, 1974; Van Meter et al. 1994), and teachers expect students to take notes during lecture (e.g. Carrier & Titus, 1979), which is the dominant mode of presenting information after elementary school. In general, research has supported the effectiveness of notetaking on outcome measures of learning (Armbruster, 2000, 2009; Kiewra, 1985a; Kobayashi, 2005; Peverly et al., 2007).

Functions of notes

The effectiveness of notes as a study strategy is attributable to its two main functions—encoding and external storage—as identified by Di Vesta and Gray (1972). Taking notes thus serves as both a process and a product to support learning (Carrier & Titus, 1979). As a process, the act of notetaking aids in the understanding and retention of information through the identification and recording of important concepts through writing. As a product, notes also serve to store information and provide an abridged record that can be referenced and reviewed at a later time (Armbruster, 2009; Carrier and Titus, 1979; Di Vesta & Gray, 1972; Kobayashi, 2006).

Notetaking. Research indicates that writing down information during a lecture results in a deeper, more meaningful processing of content than achieved by listening alone (Di Vesta & Gray, 1972; Kiewra, 1985a; Piolat et al., 2005). Thus, the very act of taking notes is seen to enhance learning, even when the notes are not later reviewed (Rickards & Friedman, 1978). In a review of 56 studies of text- and lecture-notetaking, Kiewra (1985a) found that almost three-fifths (33) of the studies identified a positive effect of notetaking on learning outcomes, and over a third (21) did not present any significant difference between those who did and did not take notes. Two studies indicated a negative effect of notetaking. In a meta-analysis of notetaking studies, Kobayashi (2005) found a moderate effect (.26) for notetakers in comparison to non-notetakers on test performance. Taking notes while reading from a text was also found to have an effect on learning outcomes even if students were not given a chance to review them (Lahtinen, Lonka & Lindblom-Ylänne, 1997; Lonka, Lindblom-Ylänne & Maury, 1994). In studies by Peverly and colleagues, notes have been found to be the best and often the only predictor of test performance (Peverly et al., 2007; Peverly & Sumowski, 2012; Peverly, Vekaria, et al., 2013; Reddington et al., 2015; Vekaria, 2011).

While the encoding function of notetaking is generally regarded as beneficial, the somewhat equivocal nature of its effectiveness may lie in the limitations of the process and resulting product. Taking notes may be seen to assist learning by increasing an individual's attention and cognitive engagement with the material (Craik & Lockhart, 1972; Frase, 1970). Conversely, the process of transcribing information may serve to distract the learner from the content of the material, resulting in a negative effect on test performance. Peters (1972) for example, compared test outcomes of undergraduate students who were randomly assigned to either take or not take notes while learning information from one of three experimental conditions: (1) lecture presented at a normal pace (130 words per minute), (2) lecture presented at a fast pace (192 words per minute), or (3) reading from text. Findings included a significant main effect for notetaking, such that those who did not take notes showed more accuracy on the criterion test than those who did take notes (Peters, 1972). This applied particularly to subjects with lower achievement scores, who showed stronger performance when information was presented at a normal reading rate, and when they were not required to take notes.

Notetaking is also limited in the amount of information that is written down. Studies of the completeness of recorded notes show that overall, college students have been found to capture approximately 10% to 60% of lecture content in notes (e.g., Armbruster, 2009; Crawford, 1925; Hartley & Cameron, 1967; Howe, 1970; Kiewra, 1985a, 1985b, 1989; Locke, 1977). Findings have ranged from 11% of information captured in notes of first year undergraduate students (Hartley & Marshall, 1974) to 60% of lecture information recorded in notes of students with high ("A") grades (Locke, 1977). Further, the amount of information captured in notes may be additionally reduced by limitations in the likelihood of recall. While research has shown that information recorded in notes is more likely to be recalled than information that was not recorded, Aiken, Thomas, and Shennum (1975) reported that the likelihood of recalling information improved from 17% to 47% when comparing information not included in notes to information that was recorded in the notes.

Rather than consider the costs and benefits of the encoding process of notetaking, Peper and Mayer (1978, 1986) suggested that notetaking serves to improve learning outcomes of specific types of information, such that notetakers are more likely to integrate new information with previously known information, whereas non-notetakers are likely to encode information only as presented. They conducted experiments in which college students were exposed to instruction and required to take or not take notes, and then tested on both fact retention (memory) and application (inference) learning outcomes (Peper & Mayer 1978, 1986). Experiments differed in (a) the presence/absence of an outline to help students organize lecture information (Peper & Mayer 1978, Experiment 1), (b) lecture versus text material (Peper & Mayer 1978, Experiment 2), (c) the addition of a review period in which subjects were asked to write down all they had learned about certain statements as if they were going to teach the information to students who were unfamiliar with it (Peper & Mayer 1978, Experiment 3), and (d) the comparison of simultaneous lecture notetaking to alternative study methods of writing summary notes, answering meaningful adjunct questions during breaks in the lecture, or not taking notes at all (Peper & Mayer 1986, Experiment 2). Results indicated that while notetakers were not found to have an advantage over non-notetakers in overall posttest performance, notetakers' and non-notetakers' performance varied by type of test problem. Notetakers showed stronger performance on interpretation-type problems and non-notetakers showed stronger performance on items that tested memory based in information presented explicitly in the lecture. Similarly, recall of lecture information also differed between notetakers and non-notetakers. Notetakers recalled more underlying concepts and additional information, whereas non-notetakers recalled more specific, technical information and more generalized connective and summary statements. These differences were found particularly for learners with lower prior knowledge of the material; those with higher knowledge were found to recall more underlying concepts and additional information, regardless of whether notes were taken or not (Peper & Mayer, 1978). Peper and Mayer thus argued for a generative theory of notetaking, in which notetaking facilitated assimilation of new information with prior knowledge, resulting in improved outcomes for applied learning.

In contrast to these findings, Peverly and colleagues have found notes to be related to outcomes on tests of memory, but not of understanding (Gleason, 2012; Peverly et al., 2007; Peverly & Sumowski, 2012; Vekaria 2011). One difference between Peverly's studies and those of Peper and Mayer (1978) may lie in the content of the material studied and recalled. Peper and

Mayer's studies used lecture and text material more technical in nature, addressing the description and application of the chi-square statistical procedure (Peper & Mayer, 1978), or on the working of car engines (Peper & Mayer, 1986). Peverly and colleagues used materials from the social sciences, such as the psychology of problem solving (Peverly et al., 2007; Vekaria, 2011), a historical event (Gleason, 2012), or a fictitious historical text (Peverly & Sumowski, 2012). Thus, differences in the type of information that was tested in measures of memory or application/understanding were likely to be very different and to impact findings. Another difference worth mentioning is that subjects in Peverly's studies were provided an opportunity to review their notes whereas those in Peper and Mayer's (1978, 1986) were not. The function of the review is discussed below.

Review. Following the notetaking process, notes serve as external storage of the information that has been captured, which is then available for review at a later time. In comparison to the encoding function, the external storage function of notes has more consistent evidence regarding its positive effect on performance outcomes. Kiewra (1985a) referenced 32 studies comparing those who did and did not review notes. He found that three-quarters (24) of the studies showed a positive effect of review, and that one quarter (8) did not find a significant difference between reviewing and not reviewing notes. Kobayashi's meta-analysis (2006) identified a medium to large effect for those who took notes and reviewed them, in comparison to control groups who only listened to or read information (.75), and to groups who listened to or read, and also mentally reviewed the information (.77). For example, in an investigation of the relationship between lecture notetaking and subsequent writing processes, Benton, Kiewra, Whitfill and Dennison (1993) had college undergraduate students listen to a lecture, take notes, and then compose an essay immediately (Experiment 1) or one week after the lecture

(Experiment 2). When composing the essay, subjects were either allowed or not allowed to utilize the notes they had taken during the lecture. Results found that the quantity and quality of notes taken were related to the length, cohesion, and coherence of the essays written about the lecture only when notes were available for reference while writing the essay. Taking notes, without the opportunity for review did not facilitate the generation or organization of writing beyond the level of listening without taking notes (Benton et al.,1993).

In addition to recognizing notes as a physical record from which information can be recalled and rehearsed during review, Carrier and Titus (1979) also found that notes-review creates an opportunity for further reconstruction and elaboration of the material. The reconstructive effect of notes-review was examined in a study of text notetaking (Rickards & Friedman, 1978), which compared students' performance on free- and cued-recall measures based on three experimental conditions for taking and reviewing notes (taking text notes and reviewing the notes before the test, taking notes and mentally reviewing the material before the test, or not taking notes and mentally reviewing the material before the test). Their findings showed that subjects who took and reviewed their notes had better performance on free- and cued recall than those who did not take notes or those who took but did not review their notes. Further analysis of the cued recall of information by its level of structural importance (high or low), showed that subjects who took and reviewed notes recalled more information of high structural importance than those who took but did not review notes. In addition, they found that compared to notetakers who did not review notes, those who took and also reviewed notes showed greater cued-recall of information of low structural importance even when not specifically contained in their notes. The latter finding led the authors to conclude that notes-review leads to enhanced recall such that reviewing notes not only results in evidence of learning of material contained in the notes, but also allows for the reconstruction of information not contained in the notes (Rickards & Friedman, 1978).

A study by Kiewra, DuBois, et al. (1991) with college undergraduates examined the relationship between notetaking functions—notetaking without review (encoding only), no notetaking with borrowed notes for review (external storage/review only), and taking and reviewing one's own notes (encoding plus review)—and the types of notes taken (conventional notes, outline notes, or matrix framework). Subjects in the encoding plus review condition were found to outperform subjects in other notetaking conditions on the outcome measure, although the authors recognized that this group had an advantage in interacting with the information twice, at both encoding and review, as opposed to just one time in the other two conditions. When they compared outcomes of the encoding and external storage conditions on a test requiring synthesis of concepts to form ideas not explicitly stated in the lecture, Kiewra, DuBois, et al. (1991) found that subjects who reviewed provided notes outperformed subjects who took notes but did not review them. The advantage of notes-review was attributed to the increased opportunity for generative processing during review compared to encoding, when the learner's attention is divided and burdened by the notetaking process (Kiewra, DuBois, et al., 1991).

Thus, while generative learning processes can occur at the encoding stage of notetaking, notes-review also allows for generative processes to occur, in which the learner can establish connections between new and previous knowledge, as well as reconstructing information not included in the notes available for review. In a study of lecture notetaking, Hadwin et al. (1999) included a review period prior to testing in which subjects were required to complete a written summary of the notes they had taken during the lecture or of lecture notes provided by the examiners. Review of the written summary was found to have a strong association with tests of both free- and probed recall of the lecture material, and the authors concluded that the process of summarization conducted at review had a generative effect that allowed for a deeper level of information encoding.

The effectiveness of lecture notes-review on test outcomes is evident. Reviewing lecture notes can help later recall of information during testing by providing a direct record of the lecture content for review, as well as to provide additional opportunity for generative processing, in which the new information can be integrated with prior knowledge.

Verbatim versus transformed notes. In considering notetaking and notes-review, it is important to also consider the types of notes that are taken during the encoding process. Notes can vary from a verbatim record of segments of the original content, to a transformation of the content through paraphrasing, summarizing, restructuring, diagramming, and/or personalizing the information (Castelló & Monereo, 2005; Slotte & Lonka, 1999; Wade & Trathen 1989).

In studies of text notetaking, Lonka and colleagues (Lahtinen et al., 1996; Lonka et al., 1994) studied the strategies used by university students who were asked to read texts while having the opportunity to make marks or notes on the document or write notes on a separate piece of paper. Different kinds of study methods were coded, such as (1) no physical records or notes, (2) underlining only, (3) whole-sentence or single-word verbatim noting on the text paper, (4) whole-sentence or single-word verbatim noting on separate paper (4) writing summary notes in their own words, and (5) concept mapping. Lonka et al. (1994) additionally obtained students' self-reports on the strategies they implemented. After the text and notes were removed, subjects were asked to write essays in response to three questions—one which required recall and definition of information, one that required synthesis and summarization of information, and one that required application of the information in the text.

Results showed that most students (88%) engaged in some type of written study strategy, with concept-mapping (diagramming) being the least common strategy (Lahtinen et al., 1996; Lonka et al., 1994). Engagement in any form of notetaking activity (verbatim notetaking or underlining, or strategies that transformed the material through summarizing or concept mapping) was related to increased coherence in essay writing, and those who neither underlined text nor took notes exhibited the lowest performance (Lahtinen et al., 1996). Within these study strategies, students who produced summary notes or concept maps scored more highly than those who took verbatim notes or only underlined, whereas the content scores of those who took no notes were the lowest. Lahtinen et al. (1996) suggested that underlining and verbatim notetaking that follows the organization of a text may improve students' textbase comprehension, and that summary notetaking requires learners to generate the relations among the ideas in a text, and may therefore enhance the construction of a situation model. Similarly, in their examination of the quality and quantity of text notes on test outcomes with high school students, Slotte and Lonka (1999) found that regardless of the review process, students who summarized text content through notetaking performed better on writing tasks involving definition, comparison, and evaluation of the text content, in comparison to students whose notes were verbatim copies of the content, or followed the organizational sequence of the text.

In generalizing text notetaking to lecture notetaking, Lahtinen et al. (1996) suggested that the simultaneous demands of listening and writing decrease the learner's ability to incorporate new ideas and organize them within the notes. In their ethnographic study of college students, Van Meter et al. (1994) found students reported taking notes verbatim when there was concern that paraphrasing the information could distort the meaning of the information, or when memory for specific information was required. In a study of students' notes collected regularly from a class taught at two different universities, Castelló and Monereo (2005) examined notes regarding (1) their organization, namely the degree to which notes followed the sequence of the class, and making idiosyncratic additions through (2) content amplification—the degree to which additional sources of information were included in notes, (3) the students' level of reflection in their notes, based on when they wrote down doubts, questions or other appropriate comments; and (4) quality of the synthesis of notes, involving the assessment of different aspects of the subject material. Students' self-reports regarding strategic knowledge, purpose of notes, and academic performance were also collected at the beginning of the study, using a four-point Likert-type scale. Results showed that students conceptualized notes halfway between verbatim capture and personalization, and that notes taken in the first sessions of the study reflected similar profiles between the notes produced by subjects and their self-ratings (Castelló & Monereo, 2005). Thus, it appears that in lecture notetaking, while it may be more difficult to incorporate additional information beyond a direct transcription of ideas in lecture notetaking, some level of transformation of lecture information does occur in notes.

Writing Medium

While the majority of studies related to notetaking have examined notes taken by hand, with advances in the use of technology in the classroom, students are increasingly equipped to take notes by computer as well as by handwriting. A 2013 study of over 100,000 undergraduates at more than 250 college/university sites across 47 states and 14 countries conducted by the EDUCAUSE Center for Analysis and Research showed that approximately 9 out of 10 students owns a laptop (Dahlstrom et al., 2013). In general, studies have shown that for adult typists, writing by keyboard is faster than by handwriting (Brown, 1988; Novellino et al., 1986). Thus, it is possible that more information may be captured in notes that are typed than are handwritten.

A limited number of studies have begun to explore the impact of notetaking medium (handwriting or typing) on notetaking, with equivocal results (Bui et al., 2013; Mueller & Oppenheimer, 2014). In a study of undergraduate students assigned to take notes by hand or computer while listening to an audio recording of a lecture, Bui et al. (2013, Experiment 1) found that participants assigned to take notes by computer took notes that contained a larger proportion of idea units from the lecture than those who took notes by hand. In addition, subjects were instructed to try to transcribe the lecture content as much as possible, or to take organized notes, in their respective writing medium. Results showed that subjects who were asked to transcribe the lecture using a computer were found to have the highest performance on free recall and a short answer test completed immediately after the lecture (Bui et al., 2013, Experiment 1). The study also showed an interaction between notetaking medium (typing or handwriting) and instructional condition (transcribe or organize), such that for those taking notes by computer, a greater proportion of idea units were captured under the transcribing condition in comparison to the organizing condition, whereas there was no difference in the proportion of ideas units for the handwriting condition.

Across three experiments conducted with undergraduates, Mueller and Oppenheimer (2014) found that when taking notes either by handwriting or by typing while watching a video recording of a lecture, participants who took notes via typing were more likely to take more notes, and more likely to transcribe the lecture content verbatim. When assessed on items of factual recall and conceptual-application questions based on the lecture, no difference was noted on performance of factual recall items between the two handwriting and typing groups. On conceptual-application items, those who handwrote notes outperformed those who took notes on a laptop, even when given an opportunity to review notes. Mueller and Oppenheimer (2014) concluded that while typing notes may allow for more content to be transcribed, handwritten notes allow for a greater depth of processing that is positively related to learning outcomes for both factual and conceptual learning.

Bui et al. (2013) also considered the issue of depth of information processing within typed notes, and conducted further studies related to kind of notes taken (transcribed or organized) and delayed performance (Bui et al., 2013, Experiment 2), as well as the impact of notes-review (Bui et al., 2013, Experiment 3). Bui et al. (2013) found that when testing was delayed by 24 hours, those who typed organized notes showed better performance than those who focused on transcribing as much of the lecture as possible (Bui et al., 2013, Experiment 2). When subjects who typed notes were given an opportunity to re-read their notes before the delayed test, those who transcribed the lecture content once again showed higher performance than those who organized and paraphrased lecture content.

These recent findings on typing notes compared to handwritten notes suggest that further examination is required to better understand differences in notetaking related to the writing medium, specifically related to the quality of information that can be captured in notetaking and the depth of information processing that occurs during notetaking and review.

Cognitive Effort in Notetaking

Almost all of the research on notetaking has compared the relative effects of the components of notes—notetaking and notes-review—on test performance. However, notetaking is a cognitively complex task (Kobayashi, 2005; Peverly et al., 2007; Piolat et al., 2005) in which multiple simultaneous cognitive processes operate within a limited working memory capacity (Piolat et al., 2005). The learner must understand the source material, select salient concepts, organize it, integrate it with current knowledge, and transcribe it before the information is forgotten and more new information is presented (Makany et al., 2009; Piolat et al., 2005). Recent studies on individual differences in cognitive processes underlying these tasks have attempted to determine why some learners take better notes than others. Studies have focused primarily on the cognitive processes needed to overcome the heavy processing demands of lecture notetaking. Research related to notes-review has been extremely limited.

As an academic skill, notetaking can be considered as similar to other complex academic tasks such as reading, writing, or mathematics in that it requires the simultaneous execution of a hierarchy of multiple cognitive processes ranging from basic domain-specific skills to higher-level processes (Peverly et al., 2007; Peverly & Sumowski, 2012; Piolat et al., 2005). Within a limited working memory capacity, basic skills must be executed with automaticity or fluency, in order for higher-level cognitive skills to be applied. For example, the academic skill of reading comprehension requires the parallel execution of the basic skill of word recognition along with more complex skills such as language ability (Perfetti, 1985, 2007). Within a limited capacity working memory, the more working memory resources are required for the execution of basic skills (e.g., word recognition), the less available they are for the access and use of higher order skills such as language ability and background knowledge. Thus, the greater the automatization and fluency of word recognition, the greater the mental capacity to apply higher cognitive processes related to comprehension. Only when word recognition is automatized do higher cognitive processes predict reading comprehension skill.

In the case of notetaking, the basic skill of handwriting speed must be sufficiently fluent in order to reduce its impact on working memory resources, allowing cognitive resources to be applied to higher-order cognitive processes (Peverly, Garner, & Vekaria, 2013; Peverly et al., 2007; Peverly & Sumowski, 2012; Peverly, Vekaria, et al., 2013). Some of the higher-order cognitive processes that have been studied in regard to notetaking have included verbal ability (Peverly et al., 2007; Peverly & Sumowski, 2012), sustained attention (Gleason, 2011; Peverly, Garner, & Vekaria, 2013; Vekaria, 2011) background knowledge (Hadwin et al., 1999; Peverly et al., 2003; Peverly & Sumowski, 2012), and metacognitive ability (Peverly et al., 2003).

Handwriting speed. Handwriting speed, which is typically measured by the number of letters a student can accurately write in order in a very limited span of time (e.g., 45 seconds), has been found to correlate positively with performance on writing tasks. Studies of handwriting speed in relation to essay writing have shown a positive correlation between the ability to write quickly and the content, quality, and length of essays in both children and adults (e.g. Berninger et al., 1997; Brown, McDonald, Brown, & Carr, 1988; Christensen, 2004; Connelly, Campbell, MacLean, & Barnes, 2006; Connelly, Dockrell, & Barnett, 2005; Graham, Berninger, Abbott, Abbott, & Whitaker, 1997; Graham, Harris, & Fink, 2000; Jones & Christensen, 1999; Olinghouse & Graham, 2009; Olive, Alves, & Castro, 2009; Olive, Favart, Beauvais, & Beauvais, 2008; Olive & Kellogg, 2002).

Within a limited capacity model, if the basic skill of physically producing letters to write words is more fluent and automatized, the burden on working memory capacity is reduced, and it becomes easier to access and use cognitive resources to attend to more complex information processing, such as the language, content, and organization of the written material (McCutchen, 1996; Peverly, 2006). However, if an individual's limited capacity working memory is consumed with the mechanics of forming letters, fewer cognitive resources are available to devote to higher level cognitive processes (McCutchen, 1996; Peverly, 2006), such as sustaining attention to the ongoing lecture, selecting the important information to be recorded, or accessing background knowledge.

Recognizing notetaking as a writing task, Peverly and colleagues (Peverly et al., 2007; Peverly & Sumowski, 2012) examined the impact of handwriting speed on the quality of notes and on test outcomes. In a study of lecture notetaking, Peverly et al. (2007, Experiments 1 and 2) found that among verbal working memory, main idea identification, spelling, speed of semantic access, and handwriting speed, only the latter was significantly related with the quality of notes, and the quality of notes was the only predictor of test outcomes. Peverly and colleagues have replicated the finding that handwriting speed is the strongest predictor of lecture (Peverly, Garner, & Vekaria, 2013; Peverly, Vekaria, et al., 2013) and text (Peverly & Sumowski, 2012) note quality.

This study sought to replicate findings regarding the relationship between handwriting speed and notetaking as well as to identify the relationship of handwriting speed to notes-review. While the relationship between handwriting speed and notetaking has been documented, its effect has yet to be explored at notes-review.

Typing speed. As a corollary to the relationship between handwriting speed and handwritten notes, there is likely to be a relationship between typing speed and typed notes. Brown (1988) found that typing speed was over five words per minute faster than handwriting for both memorized and copied passages, and that typing and writing were each about ten words per minute faster from memory than from copy. Similarly, in a study of 59 undergraduate students asked to copy text by handwriting or by keyboard, Novellino et al. (1986) found that typing was faster than handwriting. Interestingly, in an assessment of immediate recall of total words, key words, and ideas within the transcribed text, no significant main effects were found for the writing medium (Novellino et al. 1986).

This study sought to explore the relationship between typing speed and notes, to determine whether the same findings regarding the relationship between handwriting speed and the quality of lecture notes hold true when using a computer for notetaking and notes-review.

Language comprehension. Language comprehension refers to an individual's ability to understand and use spoken and written words. Within language comprehension, Kintsch (1998) identified semantics and grammar as two main components of language. Semantics refers to vocabulary knowledge and the understanding of word meanings, and grammar refers to the understanding of language based in the relationship between words and word parts, through syntax and morphology. During lectures, learners are expected to attend to orally presented verbal information, identify important elements, and remember them for later recall. The understanding of language thus presents a logical prerequisite to notetaking during lectures and subsequent performance on a test based on the lecture. However, research has shown inconsistent results regarding the relationships between language comprehension, notetaking and notes-review.

Several studies have identified significant relationships between language comprehension and the quality of notes. Language comprehension was significantly related to notes taken from text (Peverly & Sumowski, 2012), as well as notes taken from lecture (Gleason, 2012; Peverly, Vekaria, et al., 2013; Reddington, 2015; Vekaria 2011). Other studies have failed to find a correlation between language comprehension and notetaking (e.g. Peverly, Garner & Vekaria, 2013). Studies examining the relationship between scores on the English and Comprehension subtests of the American College Test and notes (Kiewra & Benton, 1988; Kiewra, Benton, & Lewis, 1987) did not show a significant relationship. Similarly, when Peverly et al. (2007) measured language comprehension as the ability to identify main ideas within a text, no significant relationship to notetaking was found. In a study by Hadwin et al. (1999) examining the relationship of working memory, verbal ability, and background knowledge to lecture notetaking, review and test outcomes, language comprehension was measured using the Similarities subtest of the Multidimensional Aptitude Battery, a 34-item, 7-minute-long multiple-choice test that provided word pairs and required subjects to select the response that best described how the words in the pair were similar. Results of this study found that language comprehension was not significantly related to the quality of notes produced. However, language comprehension was significantly related to the written summary generated at review while using notes (Hadwin et al., 1999).

It is important to note that the use of reading comprehension as a measure of language comprehension is based in the high correlation between the two constructs for college-age students (Gernsbacher, Varner & Faust, 1990; Perfetti, 1986), that allows reading comprehension and language comprehension to be a proxy for one another (Peverly, Garner, & Vekaria, 2013). Multiple studies have found a high correlation between listening and reading comprehension amongst adults (Baddeley, Logie, Nimmo-Smith, & Brereton, 1985; Daneman & Carpenter, 1980; Gernsbacher et al., 1990; Jackson & McClelland, 1979; Palmer, MacLeod, Hunt, & Davidson, 1985; Perfetti, 1986; Perfetti & Lesgold, 1977; Sticht, 1972). In turn, listening comprehension has been identified as a strong proxy for language comprehension (Stanovich, 1991). Studies have shown that once word recognition is sufficiently automatized, verbal comprehension accounts for the majority, if not all of the variance in reading comprehension (Adlof, Catts, & Little, 2006; Chen & Vellutino, 1997; Landi, 2010). For example, Gernsbacher et al. (1990) found a high correlation (.92) between comprehension of written and auditory stories among college students, and Adlof et al. (2006), found that language comprehension accounted for 100% of the variance in reading comprehension among eighth-grade students.

This study thus aimed to replicate findings supporting the positive relationship between language comprehension—as measured by reading comprehension ability—and notes. In addition, this study sought to explore the role of language comprehension in relationship to the process of notes-review, as was evident in one previous study (Hadwin et al., 1999).

Sustained Attention. As attention to the lecture is an essential element to notetaking and learning from lectures, studies have explored the relationship between different aspects of attention and notetaking speed. Per Posner and colleagues (Posner & Peterson, 1990; Posner & Rothbart, 1998), the human attention system includes selective attention, sustained attention, and executive control. Selective attention refers to the ability to orient to and receive information through sensory stimuli. In relation to notetaking and notes-review, the learner must orient to the content of the lecture in order to take in the information. Sustained attention refers to the ability to maintain an alert responsive state over long periods of time. Executive control refers to the ability to allocate cognitive resources when performing a task. Within a limited capacity processing model, notetakers are likely to be required to balance cognitive resources between the simultaneous tasks of attending to the lecture, determining the hierarchical importance of the information, recording the information in notes, and inhibiting distractions (Peverly, Garner, & Vekaria, 2013).

As the task of lecture notetaking requires individuals to simultaneously execute multiple tasks, including listening to the lecture, identifying important concepts, recording information on paper, and continuing to monitor the lecture and inhibiting distractions, executive control would seem to be logically related to notetaking. However, studies examining the relationship between executive control of attention and notetaking have failed to find a significant relationship between the two constructs (Peverly, Garner, & Vekaria, 2013; Peverly & Sumowski, 2012;

Peverly, Vekaria, et al., 2013). In these studies, executive control of attention was measured using the Stroop, a test that requires subjects to respond accurately to color vocabulary words written in a competing color (the word "red" written in green ink) by stating the color of the ink while inhibiting the impulse to read the word itself (Stroop, 1935). Studies used either a group-administered version of the Stroop (Peverly & Sumowski, 2012; Peverly, Vekaria, et al., 2013) or an individually administered version of the Stroop (Peverly, Garner, & Vekaria, 2013).

In contrast to studies of executive attention, studies have shown a significant correlation between sustained attention and notetaking, indicating that the ability to attend to a lecture for long periods of time is important to the quality of notes. Gleason (2012), Peverly, Garner, and Vekaria (2013), and Vekaria (2011) have found a significant relationship between this component of attention and notetaking. In all three studies, sustained attention was measured using The Lottery subtest of the Test of Everyday Attention (Robertson, Ward, Ridgeway, & Nimmo-Smith, 1994; TEA), a task of listening to a 10-minute series of numbers and letters of the form "BC143," to listen for a "winning number," which they were told ended with 2 specific digits (e.g., "55"). Subjects were then expected to immediately orally recall the two letters preceding the target number. This study further examined the relationship of sustained attention to the process of notes-review, with the expectation of replicating previous findings of the relationship between sustained attention and lecture notes.

Background knowledge. Prior knowledge, or domain knowledge, refers to information or skills that learners have in their long-term memory that can be used to make connections with new information in lecture and text (Jonassen & Grabowski, 1993). Anderson (1995) identified two knowledge systems: (1) declarative knowledge of a hierarchical network of concepts or facts and the relationships between them, and (2) procedural knowledge of the rules of how and when to apply this knowledge. Studies have shown that background knowledge is associated with positive learning outcomes (Chiesi, Spilich, & Voss, 1979; Dochy, Segers, & Buehl, 1999; Walker, 1987) and comprehension (Adams, Bell, & Perfetti, 1995; Schneider, Körkel, & Weinert, 1989; Walker, 1987), and that background knowledge can compensate for low ability (Schneider et al., 1996; Walker, 1987) and poor reading skills (Adams et al., 1995; Schneider et al., 1989; Recht & Leslie, 1988) when background knowledge matches the content of the material presented to the learner.

Within the context of reading, McNamara, Kintsch, Songer, and Kintsch (1996) found that when reading text of low structural coherence (i.e., text that supplied very little background information or explanations of causal relationships), background knowledge facilitated the generation of inferences not explicitly present in the text. Similarly, in text notes, background knowledge has also been found to be associated with recognizing how information is structured within a text, such that if the structure is not clear, individuals with higher background knowledge are more skilled in identifying the structure, or imposing their own structure to organize the information within the text (Annis & Davis, 1976; Bretzing & Kulhavy, 1981; Caverly, Orlando, & Mullen, 2000). This is attributed to the increased ability of individuals with higher background knowledge to develop a richer understanding of the thematic structure of text (macrostructure) than those with lower background knowledge (Kintsch, 1998), through the opportunity to make connections between and integrate new information and knowledge stored in long-term memory.

Background knowledge has also been found to have a different relationship to test outcomes based on the type of information being tested. In a study of learning from text, Haenggi and Perfetti (1992) assessed college students' knowledge of the topic of the reading (approaches to decision-making), and were then asked to take or not take notes while reading a text. Subjects responded to questions following the reading. On the following day, subjects were then asked to review the material by rereading or rewriting their notes, or rereading the text, and to respond to questions similar to the previous day. The questions at the end of both sessions included multiple-choice and true-false verification questions that were balanced between (1) text explicit items, which tested recall of information stated directly in text, (2) text-implicit items that required subjects to generate an inference of coherence by combining information from two sentences to answer the question (van Dijk & Kintsch, 1983), and (3) script-implicit items which required subjects to use prior knowledge to generate an elaborative inference (van Dijk & Kintsch, 1983). Results showed that test accuracy improved following the review phase in comparison to initial reading, and that accuracy was highest for text-explicit items, followed by text-implicit and script-implicit items. While the type of review (rereading notes, rewriting notes, or rereading text) was not significantly related to test accuracy, prior knowledge was significantly related to performance on script-implicit and text-explicit items but not to text-implicit items (Haenggi & Perfetti 1992). Relatedly, Peverly et al. (2003) found that background knowledge was significantly related to performance on inference items for notetakers, but not for non-notetakers. In another study, Peverly and Sumowski (2012) found that background knowledge was not significantly related to the quality of text notes, but was significantly related to students' performance on tests that required inferences, but not with measures of memory, which required them to recognize information stated explicitly in text.

The results of an ethnographic study based on student interviews found that students reported taking fewer notes when they had higher background knowledge of the lecture content (Van Meter et al., 1994). However, Peverly et al. (2003) found that amongst text notetakers, background knowledge was not related to the number of logical or rhetorical relationships (macropropositions) among propositions in notes, despite unlimited time to take notes, indicating that subjects with higher levels of background knowledge did not include significantly more or less information in their notes than students with less background knowledge. Given that more complete notes are typically associated with better performance (Crawford, 1925; Kiewra & Fletcher, 1984; Slotte & Lonka, 1999), further investigation of the role of background knowledge and notetaking, especially the review function of notes, may provide further insight into the role of background knowledge. Review may provide an additional opportunity to incorporate content from the lecture or text with prior knowledge.

In Hadwin et al. (1999), background knowledge was one of the variables studied in relationship to lecture notetaking, notes-review, and test outcomes. Prior knowledge was found to correlate with performance on a test of cued recall, based on two main idea and two important idea questions from the lecture, but was not found to be significantly related to the quality of notes, the quality of the written summary generated at review (students were allowed to use their notes to create the summary), or free recall. Interestingly, this study measured background knowledge using four items: three Likert-type self-rating items based on general knowledge and familiarity with the lecture topic, and one Yes/No question regarding previous knowledge of the lecturer. The validity of their assessment of background knowledge is questionable given the limited number of items and the lack of a more objective test of the subjects' prior knowledge.

While a significant relationship between background knowledge and notes has not been evident, the relationship needs to be further explored in order to gain insight into the contradictory findings of background knowledge resulting in fewer notes taken or fewer macropropositions recorded, and impact on improved test outcomes, especially on measures of inferential learning. A study including both notetaking and notes-review allows for the comparison of quality and quantity of information produced at each phase, to determine the change between phases and the possible effect of background knowledge on generative processing that may occur.

Metacognition. Metacognition refers to the self-awareness and executive control that an individual has over his or her own cognitive processes to regulate learning (C. Brown, 2005; Brown & Smiley, 1978). In any learning situation requiring information processing within a limited capacity system, metacognitive skills serve as control processes that act to compensate for limitations in information processing (Di Vesta & Moreno, 1993). Metacognition is generally thought to consist of two subcomponents—the knowledge of cognition and the regulation of cognition (Brown, 1978; Schraw & Dennison, 1994; Sperling, Howard, Miller, & Murphy, 2002).

Knowledge of cognition refers to individuals' conscious, declarative knowledge of their own and others' cognitive characteristics, including what they do and do not know, knowledge of strategies that can be used to learn and remember information, task difficulty, and how to allocate resources depending on the ease or difficulty of a task (Baker & Brown, 1984; Brown, Bransford, Ferrara & Campione, 1983; Sperling et al., 2002; Thomas & Rohwer, 1986). The regulation of cognition refers to the control and execution of cognitive skills while engaged in a task, in order to plan, monitor, and modify one's actions before as well as during a task to improve the quality of its completion (Baker & Brown, 1984; Brown et al., 1983; Thomas & Rohwer, 1986; Tobias & Everson, 1998).

In most cognitive activities, both components of metacognition can be assumed to be operating recursively. In the context of notetaking, metacognitive skills allow learners to make choices regarding the efficacy of their study habits, to manage the multiple simultaneous cognitive processes that occur during the study process, and to manage their time. Castelló and Monereo (2005) suggest that learners need more than a "technical command" of how to take notes, and also need a "strategic command" of when, how and why they take notes in different learning contexts. In their study, students received intermittent feedback from their instructors on how to improve their notes. Results showed that students' notetaking improved progressively in all of the areas in which they received guidance, reflecting changes in subjects' notes and self-reports over time in knowledge of how to take notes and when or why they take notes (Castelló & Monereo, 2005). Interestingly, actual practice reflected through the rating of notes was slightly lower than the theoretical conceptualization of notes as reflected through self-report, suggesting that declarative knowledge regarding notetaking may be stronger than procedural knowledge; subjects may know what needs to be done to improve the quality of their notes, but not necessarily reflect the same level of execution in their actual notetaking practices.

In a study of the regulation of cognition in notetaking, Kiewra, Mayer, Christensen, Kim, and Risch (1991) examined students' ability to shift their notetaking strategies with each successive presentation of a lecture. In one experiment, undergraduate college students were assigned to view an 8-minute lecture one, two, or three times, while taking cumulative notes (over trials, if applicable). Subjects then reviewed their notes for 15 minutes prior to recalling as much information as possible from the lecture. Results of the study showed that all subjects captured the majority of key, superordinate concepts of the lecture in the first trial, and an increasing number of supporting, subordinate, details in subsequent trials. An examination of the content of notes and recall showed that while all subjects prioritized the learning of main ideas, over repeated trials, subjects were assumedly able to assess their level of knowledge of main ideas metacognitively and shift their focus toward information that was not yet captured in a previous viewing of the lecture, such as supporting details (Kiewra, Mayer et al., 1991).

Some types of metacognitive judgments are a mixture of both the knowledge of and regulation of cognition. For example, judgments of learning (JOLs) involve an individual's periodic, overt, conscious self-evaluation (knowledge of cognition) of a cognitive activity in which he or she is currently engaged (e.g. studying; regulation of cognition) (Hunt & Ellis, 2004). As such, JOLs represent conscious, episodic reflections on current cognitive activity. In one study examining the relationship between JOLs and notetaking, Peverly et al. (2003) examined students' predictions of their own test performance in relation to actual test performance. At the beginning of the experiment, undergraduates were informed that they would be completing a free-recall summary and multiple-choice test based on a passage they would read and study. Subjects were assigned to either a notes or no notes group. The notes group was asked to read and study the passage while taking notes and the no notes group was asked to read and study the passage (notetaking was not mentioned). Participants were asked to predict their performance on both the essay and the multiple-choice test at three points during the study: before reading the passage (T1), after reading the passage (T2), and after completing each assessment measure (T3). The essay was scored for the number of inferences participants generated and the amount of information participants wrote down that was stated directly in the text (memory). The multiple-choice test consisted of two item types: memory and inference. Results generally showed that while notetaking was associated with higher test performance, JOLs were not significantly correlated with essay or multiple-choice test outcomes for notetakers for either inference or memory items. For non-notetakers, there was a significant relationship between JOLs and the memory test items, while there was no relationship between predictions of performance and inferences. Peverly et al. (2003) suggested that the effortful processing that occurred during notetaking might result in learners feeling less certain about what they knew and did not know, thus leading to less confidence and accuracy in their predictions of test performance.

Metacognitive skills of self-awareness and self-regulation are important to notetaking, as learners must monitor their learning, be aware of the skills and resources they have to allocate to learning, and make decisions about how to integrate the two to organize and learn new information. In general, students with well-developed metacognitive skills are thought to be able to compensate for the cognitive strains of studying by more adequately monitoring their comprehension and evaluating the relationship between study activities and task goals than students who are less metacognitively aware (Di Vesta & Moreno, 1993; Peverly, Brobst, & Morris, 2002). However, there is limited supporting evidence regarding the relationship between metacognition, notetaking, and learning outcomes. This study aimed to utilize self-ratings of both the knowledge and regulation of cognition to further explore the relationship between metacognition, notes, and test outcomes.

Measurement of Learning

According to Kintsch (1998), memory for text is the ability to recall or recognize information stated directly in a passage. Memory does not, however, imply understanding. Van Dijk and Kintsch (1983) distinguish three levels of comprehension—surface memory, textbase, and situation model. Surface memory refers to the recall of actual words and phrases. Therefore, an individual might recall words without an understanding of their meaning or significance. The textbase refers to the development of a mental representation based on the semantic understanding of the content, by understanding the organization and relationships between propositions. The situation model refers to the elaboration of information through the integration of content with current knowledge, and development of coherence through the use of bridging inferences between given pieces of information (van Dijk & Kintsch, 1983, Kintsch, 1986). Performance outcomes have been measured in various ways. Free-recall focuses on surface memory and textbase comprehension, whereas constructed-responses requiring inference, analysis, or application measure situation-model comprehension. With multiple-choice tests, items can measure recall of explicitly stated information (memory), or measure comprehension beyond the explicitly stated material (inference), which requires generating inferences from the information presented.

Results of aforementioned studies have differed in their findings regarding notetaking and performance on measures of memory and inference. Peper and Mayer (1978, 1986) concluded that notetaking supported performance on tasks of inference and that non-notetakers outperformed notetakers on memory items. In contrast, several studies suggest that notes are more strongly related to performance on measures of memory than measures of understanding (Peverly et al., 2007; Peverly & Sumowski, 2012; Vekaria 2011; Gleason, 2012). Similarly, in a study examining the relationship of lecture notetaking and notes-review, Kiewra et al. (1989, Experiment 1), assigned undergraduate college students to one of three lecture notetaking conditions: (1) taking notes twice, (2) taking notes and later reviewing them, and (3) reviewing borrowed notes two times without exposure to the original material. Results of these outcome measures showed an advantage for those who took and reviewed their own notes for items of factual recall and recognition, but not on higher-order performance items involving problem solving and inference (Kiewra et al., 1989).

Additionally, test outcomes also depend on individual differences. As mentioned previously, with text notetaking, Peverly and Sumowski (2012) concluded that background knowledge and language comprehension are related to measures of understanding and not of recall. Peper and Mayer (1986) found that lecture notetakers outperformed non-notetakers on far-transfer tasks but performed worse on near-transfer tasks if they were moderately unfamiliar with the material but not if they were highly familiar with it.

Thus, this study used a multiple-choice test that consists of text explicit (memory) and text implicit (understanding) items in order to consider the type of test outcomes when evaluating their relationships to notetaking, notes-review, and various underlying cognitive processes. Further, as previously noted, the medium in which notes are taken—handwriting or typing—has been found to show differences in the type of notes taken—verbatim or transformed, which in turn impacts performance on factual recall and conceptual application questions (Mueller & Oppenheimer, 2014). As such, this study also examined the relationship between notetaking medium and test performance.

Purpose of the Study

As previously stated, all but one (Hadwin et al., 1999) of the notetaking studies involving cognitive processes has focused solely on the encoding function of notes, and not on notes-review. This study therefore proposed that further investigation of cognitive processes related to notes-review is important to understanding the relationship between notes and test outcomes. Hadwin et al. (1999) evaluated the relationship of working memory, verbal ability and prior knowledge to both notetaking and review. In their study, undergraduates were assigned to either a notetaking or no-notetaking condition. One week later, subjects were given an opportunity to review their notes (notetakers reviewed their own notes or were given notes to review, non-notetakers were given notes to review), wherein they used the given or provided notes to generate a one-page summary of the lecture. Testing occurred one week after review, when participants were asked to write a summary of the lecture as well as to answer short questions in a probed recall task. Their findings showed that when examined together, working memory, verbal ability and prior knowledge did not show a significant relationship to notes, although when regressed separately, working memory did predict the quality of notes. In regard to review, only verbal ability was significantly related to the quality of the written summary, but not working memory or background knowledge. Prior knowledge was found to correlate with performance on the test of cued recall, but was not found to be significantly related to the quality of notes, the quality of the written summary based on notes at review, or free recall during testing.

While the Hadwin et al. (1999) study is important in its exploration of various cognitive processes as related to both notetaking and notes-review, some methodological flaws of this study are of note. First, the construct of background knowledge was measured through four self-rating items assessing familiarity with the topic and lecture, but not accuracy of knowledge, which raises questions about validity of the measurement of the construct. Second, the measurement of test outcomes through probed recall that included two "main idea" items based on broad themes of the lecture, and two "important idea" items based on explicitly stated details supporting main ideas, appear to focus on the semantic understanding of the content (textbase), but do not require any elaboration or integration of information (situation model), and are therefore limited in differentiating between memory- and inference-based learning that occurs in lecture notetaking. Finally, because only one of their experimental conditions included subjects who took lecture notes and reviewed those notes rather than notes provided by the experimenters, Hadwin et al. (1999) did not allow for the analysis of the relationship between notetaking and notes-review.

Additionally, this study explored the role of notetaking medium in relation to notetaking and notes-review. Increased opportunities to use technology in the educational setting allow for notes to be taken via typing as well as by handwriting, and the limited studies to date have had equivocal results regarding differences from the different methods of notetaking.

Summary and Hypotheses

This dissertation explored cognitive processes related to notetaking and notes-review, and the role of individual cognitive differences, notetaking, and notes-review to test performance. In addition to revisiting the cognitive processes that predict the quality of notetaking, this study extended the investigation by examining the role of notes-review in the study process—by identifying cognitive processes that predict the quality of notes-review, and considering the role of notes-review on test performance. This study also aimed to further determine differences between those who take notes via handwriting and those who take notes by keyboard.

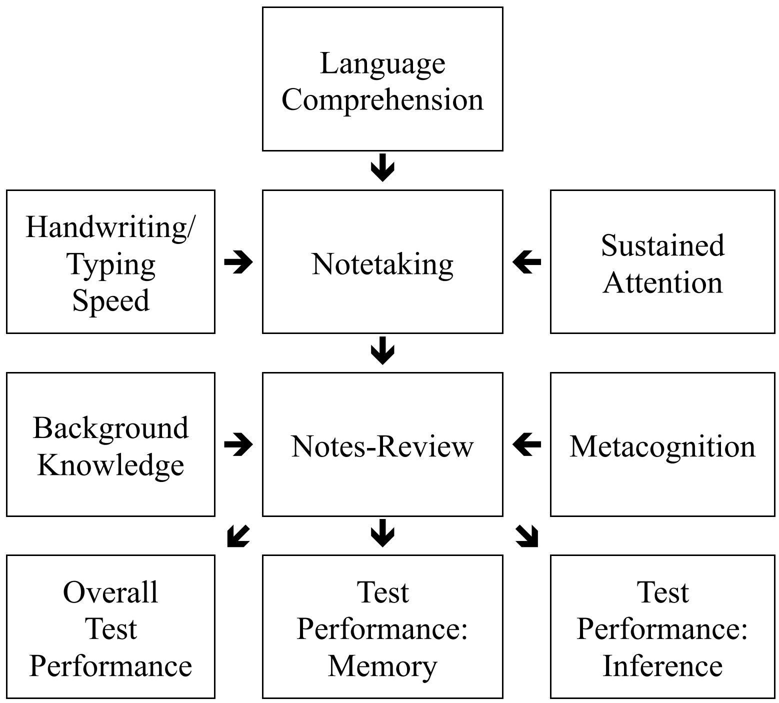
The hypotheses and research question for the study are as follows (Figure 1):

Hypothesis 1: In accordance with previous studies, only handwriting speed, language comprehension, and sustained attention will be positively and significantly related to notetaking.

Hypothesis 2: Notetaking, background knowledge, and metacognition will be positively and significantly related to the quality of summary at review. Given that notes-review is based solely on what has been recorded through notetaking, notes and notes-review should be strongly correlated. Further, given the relationship between background knowledge and generating inferences and the role of metacognition in evaluating the adequacy of notetaking and notes-review to enable good test performance, background knowledge and metacognition should also be significantly related to the quality of notes-review.

Hypothesis 3: Only quality of notes at review will be positively and significantly related to overall performance on a multiple-choice test, and separately, to performance on memory and inference items.

Figure 1.
Hypothesized Relationships of the Study



Research Question: What are the similarities and differences in the relationship between lecture notetaking, notes-review, and test performance between those who take notes by handwriting and those who take notes by typing?

Method

Participants

College students enrolled in one of two undergraduate introductory educational psychology courses at a large university in the northeastern United States were asked to take part in this study. Participants were recruited through in-class announcements offering additional class credit for their participation. A total of 90 students participated in the study; data from 10 subjects were excluded due to attrition between the first and second sessions of the data collection, or from omitted or missing responses. Of the 80 subjects in the analysis, 65 participants (81.25%) were enrolled in one course, 15 (18.75%) were enrolled in the other; the courses took place during consecutive semesters during the same academic school year.

The ages of participants ranged from 19 to 52, with an average of 19.41 years. The majority reported being in their first year of school (57.5%), followed by students in their second year (30.0%), with the remainder in their third (8.75%) or fourth year (1.25%), or beyond (2.5%). The majority (66.25%) identified their major related to education (early childhood, elementary, secondary). The gender distribution was 85% female and 15% male, and the racial/ethnic distribution was 81.25% White, 10.0% Asian, 3.75% Black/African American, 1.25% Hispanic, and 3.75% Other. The majority (90%) identified English as their first language.

Participants were randomly assigned to one of two experimental conditions: Handwriting or Typing. Subjects assigned to the Handwriting group (n = 40) were asked to complete activities including notetaking, notes-review, and measurement of handwriting speed using paper and pen. Subjects assigned to the Typing group (n = 40) were asked to complete the notetaking, notes-review and typing speed tasks using a laptop computer and to save their responses on a USB drive provided to them. All subjects completed all other measures using paper and pen.

Materials

Each participant was asked to take notes while watching a video recording of a lecture, approximately 11 minutes in length, presented via a large screen. During notes-review, participants were directed to revise their notes so that they could be used by someone who had not seen the lecture to take a test on the lecture. Later, they were asked to complete a multiple-choice test based on the content of the lecture. In addition, participants completed measures of demographic information, language comprehension, letter speed (handwriting or typing speed, consistent with their randomly assigned experimental condition), sustained attention, metacognition, and background knowledge of lecture-related information, and metacognition. All measures were group-administered.

With the exception of scoring notetaking and notes-review, inter-rater reliability was calculated for all 80 subjects by correlating scores obtained by the researcher and by an independent rater—a graduate student in school psychology who was trained by the researcher on how to score the measures. Inter-rater reliability for notetaking was established by randomly selecting 20 out of 80 protocols to be scored by the same independent rater who again received training from the researcher on how to score the measure. The same procedure was followed for notes-review with another random selection of 20 out of 80 protocols.

Lecture. The lecture used in this study is a presentation available online (Griffin, 2013), used with permission from TED.com. It is 11.5 minutes long, and identifies plans for redevelopment in the city of Detroit, Michigan. The lecture is delivered at an average rate of 170 words per minute (2.85 words per second). The lecture transcript is included in Appendix A.

Subjects were directed to take notes during the lecture. Participants assigned to the handwriting condition were provided with 3 blank sheets upon which to take notes. Participants in the typing group were provided a word-processing file on a USB drive on which to type and later save their notes. At a later time, subjects were asked to review their notes in preparation for a multiple-choice test. As part of the review process, participants were told, “You will now be given 20 minutes to review your notes for the upcoming multiple-choice test. During this time, please review your notes and create a study-sheet that you would share with a friend who had not heard the lecture, to help him/her pass the test.” Subjects in the handwriting group were provided with one blank sheet to write their review. Subjects in the typing group were provided a word-processing file on a USB drive in which to type and save their review document, with the instruction that the document should not exceed one page in length.

An analysis of the lecture transcript conducted by the researcher and two research assistants found that the lecture consists of 91 propositions, organized within 6 themes or macropropositions. Propositions refer to basic idea units in the lecture that can stand alone as a statement (Anderson, 1995). Relationships between the idea units are identified as macropropositions, and consist of general themes or main ideas contained in the lecture. In text, macropropositions describe the thematic structure of text, and are more strongly related to text understanding than are propositions (Britton & Black, 1985; Britton & Graesser, 1996; Kintsch, 1998; Lorch & Lorch, 1996; Meyer, 1985; Perfetti, Britt, & Georgi, 1995; Peverly et al., 2003; Rickards, Fajen, Sullivan, & Gillespie, 1997; van den Broek & Lorch, 1993).

The propositions and macropropositions of the lecture were identified in a process in which the primary researcher and two research assistants independently identified propositions and macropropositions within the lecture. A combined list of all propositions and macropropositions was compiled, and the researcher and two research assistants independently classified each idea unit by theme. Overall agreement ranged from 78% to 87% between each research assistant and the researcher. Disagreements were settled by consensus. The analysis of the lecture elements is presented in Appendix B.

Scoring. Notes taken during the lecture and participants revision of their notes were both scored for quality using a method similar to one developed by Brobst (1996). Each proposition was scored with a rating of 0-3. No points were given for incorrect or missing information, and one point was given if a single proposition was recorded without additional information. An additional point was given if the proposition was demonstrably connected to another proposition, and another point was scored if the proposition was demonstrably categorized within a main idea or theme of the lecture. Both verbal (e.g. "and," or "also") and visual links such as headings, subheadings, connecting lines, or arrows, were considered as acceptable evidence of a connection between ideas. With 91 total propositions that could each receive a score between 0-3, the range of scores for notes and for notes-review was 0 to 273. The Pearson correlation coefficient for inter-rater reliability for 20 out of 80 randomly selected protocols was r = .939 for notes, and r = .941 for review.

Test development. In the development of the 20-item multiple-choice test and 10-item test of background knowledge further discussed below, two research assistants were presented with all 30 items to determine inter-rater consistency for whether each item assessed memory, inference, or background knowledge related to the lecture. Agreement in classification ranged from 80% to 100% between each research assistant and the researcher, and items were modified to reduce ambiguity between the types of questions. Final agreement on each item's classification was 100% between each research assistant and the researcher.

*Multiple choice test***.** Using Kintsch's model of text comprehension (1986, 1998), C. Brown (2005) developed a test of text comprehension that divided questions equally between items that require the recall of information presented explicitly in a text, and items that require the generation of inferences from the text. Following Brown's model, a 20-item multiple-choice test was developed, consisting of an equal number of items that require recall of information stated explicitly in the lecture and questions that require inferences. Inference items required subjects to connect pieces of information provided within the lecture to generate conclusions.

All questions were randomly ordered, as were the four possible answer choices for each question. With 10 questions of each type, the possible score for each type of question ranged from 0-10, with an overall test score ranging from 0-20. During the administration of the test, subjects were directed not to refer to their notes or notes-review while completing the test. They were given 10 minutes to complete the task, and received notice when there were five minutes, two minutes, and one minute remaining to complete the test. Initial calculation of inter-rater reliability showed discrepancies in scoring due to errors in scoring and data entry. Errors were resolved and the final calculation of inter-rater reliability was $r = 1.000$. Calculation of the internal consistency of the measure produced a Cronbach's alpha of 0.315 for the complete test, showing poor reliability. Analyses involving this outcome variable should be interpreted with caution.

Test of background knowledge. Background knowledge was initially assessed using a test consisting of 10 researcher-constructed multiple-choice items. Using a method implemented by Peverly et al. (2003), the items required the application of relevant background knowledge to understand information in the lecture. All questions were randomly ordered, as were the four possible answer choices for each question. The possible score for this measure ranged from 0 to 10. The Pearson correlation coefficient for inter-rater reliability was .966. Calculation of the internal consistency of the measure produced a negative value for the Cronbach's alpha, showing poor reliability. It is likely that the types of questions included in the measure (regarding the speaker, the geographic location that is the focus of the lecture, and various other individuals and organizations mentioned in the lecture) comprised a set of unrelated and perhaps obscure facts that did not reliably measure background knowledge. For this and other reasons indicated below, this measure was ultimately removed from all analyses.

Letter speed. For subjects taking notes by hand, letter speed was measured using a modified version of a measure used by Olinghouse and Graham (2009) that asked children to copy a sentence that contained all of the letters of the alphabet, “The quick brown fox jumped over the lazy dog,” as many times as possible for 1 minute. The number of letters written correctly in one minute provided the final score for this measure. The Pearson correlation coefficient for inter-rater reliability was .831.

For subjects taking notes using a laptop, letter speed was measured using a modification of the Olinghouse and Graham (2009) task, whereby subjects were asked to access a word processing document to type “The quick brown fox jumped over the lazy dog,” as many times as possible within a 60 second time limit. The final score was the number of letters written correctly in one minute. The Pearson correlation coefficient for inter-rater reliability was .996.

Language comprehension. Language comprehension was assessed using the Comprehension section of the Nelson-Denny Reading Test, Form G (Brown, Fishco & Hanna, 1993a), a measure of academic achievement in the areas of vocabulary, reading comprehension, and reading rate in individuals in high school and above. The measure was standardized on students from 4 different populations—high school (grades 9-12), 2-year college, 4-year college, and law enforcement academy trainees. The standardization population was distributed similarly to the general population by US geographic region and by race, based on 1990 Census data.

Reliability of the test was measured via alternate-forms (comparing Form G and Form H), and Kuder–Richardson 20 (KR-20) estimates. The alternate forms method yielded a correlation of 0.81 for the Comprehension section between Form G and Form H of the test. KR-20 estimates obtained for students in their 1st through 4th years of a 4-year college ranged from .86 to .88 for the Comprehension section of Form G of the test (Brown, Fishco & Hanna, 1993b). Validity studies with Form G and Form H are not reported; the validity of the test is addressed via reports from previous forms of the test, and by correlations of scores with academic grades (Smith, 1998).

The Comprehension test contains seven reading passages and a total of 38 questions, each with five answer choices. Passages and items were selected to minimize bias between gender and ethnic groups, and questions included both literal and interpretive questions (Brown et al., 1993b, Murray-Ward, 1998). Per standard administration procedures, the measure is completed within a time limit of 20-minutes. However, for the current study, subjects were limited to 15 minutes to complete the test—a procedure used in other studies to increase the variance in participants' performance (see C. Brown, 2005; Peverly & Sumowski, 2012; Peverly, Vekaria, et al., 2013; Reddington et al., 2015).

The participants' total comprehension score was the raw total of comprehension questions answered correctly, with a possible range of 0-38. The Pearson correlation coefficient for inter-rater reliability was .988.

Sustained attention. Sustained attention, the ability to maintain attention to a relatively unchanging, rote task in the absence of external cues to attend, was measured using Version A of the Lottery subtest from the Test of Everyday Attention (TEA; Robertson, Ward, Ridgeway, & Nimmo-Smith, 1994). The TEA is one of the few tests based on an established theory of attention, demonstrating evidence of content validity and is increasingly used in clinical research on attention (Strauss, Sherman, & Spreen, 2006). It is a standardized, norm-referenced measure comprised of 8 subtests measuring different systems of attention that are classified within a four-factor model that includes sustained attention, visual selective attention/speed, attentional switching, and auditory-verbal working memory.

The normative sample is small, consisting of 154 non-clinical volunteers in England. The population ranged in age from 18 to 80, stratified between four age bands (18-34, 35-49, 50-64, 65-80) and two levels of educational attainment based (scores above or below 100 on an adult reading test). The 18- to 34-year-old and 35- to 49-year old age groups included 74 individuals; the sample included 69 males and 85 females. No information on socioeconomic status or race/ethnicity was reported; therefore, it is unclear if the norming sample was representative of an adult United States population (Strauss, et al., 2006). In addition, the test was administered to a clinical sample of 80 unilateral stroke patients seen two months post stroke.

The four factors were obtained through a principal components analysis, in which the Lottery subtest was identified as having a high loading for the sustained attention (0.70) and low loadings for the other three factors (auditory-verbal working memory $r = -.10$, attentional switching $r = .18$, visual-selective attention/speed $r =.25$). The test manual reports adequate discriminant validity for the Lottery subtest—the correlation between the Lottery subtest and estimated verbal intelligence as measured by a reading test when age is partialed out was low (.05); in addition, the Lottery subtest did not correlate highly to hearing or vision difficulties.

While a one-week test-retest reliability coefficient for the Lottery subtest for the normative sample is not reported in the manual due to a ceiling effect resulting from little variance within the normative sample, the clinical sample provided greater test-retest variability, reflecting an adequate Pearson correlation coefficient of 0.77.

Although the standardized procedures for this measure require individual administration, the task was conducted in a group format. Participants were collectively presented with the 10-minute audio recording in which they were presented with a series of numbers and letters in the form of "BC143" or "LD967", and asked to listen for target "lottery ticket numbers" ending with the digits "5-5" (Version A). Participants were asked to write down the two letters at the beginning of every target "lottery ticket." Ten items met the "lottery ticket" criteria, requiring 20 letters to be written in total. In order to increase the variation in scores, participants received one point for every correctly placed letter, for a maximum of 20 points. Raw scores were used in the data analysis instead of scaled scores since standardized administration and scoring procedures were not utilized. The Pearson correlation coefficient for inter-rater reliability was .935.

Background knowledge (self-rating). Following the multiple-choice test in the study, one additional item asked subjects to respond to the question, "*How familiar were you with the content of this lecture BEFORE today?* They rated their familiarity on a scale of 1 to 7, reflecting the range from "very unfamiliar" to "very familiar." The Pearson correlation coefficient for inter-rater reliability for this item was .995.

Metacognition. Participants' metacognition was measured via a survey based on the Metacognitive Awareness Inventory (MAI; Schraw & Dennison, 1994), a 52-item scale based on two factors of metacognition identified by Brown (1978)—knowledge of cognition and regulation of cognition. The coefficient alpha for items loading on the knowledge of cognition and regulation of cognition factors of the MAI ranged from .93 to .95 in different experiments, and ranged from .88 to .91 for each factor (Schraw & Dennison, 1994). The oblique correlations between the two factors ranged from r =.45 and r =.54 for the two experiments. In a study of various measures of metacognition, Sperling, Howard, Staley and DuBois (2004) found a high correlation between the MAI and another self-report measure of metacognition, the Motivated Strategies for Learning Questionnaire (MSLQ; Pintrich, Smith, Garcia, & McKeachie, 1991).

This study used the 18 items from the MAI that loaded most strongly on the factors of knowledge of cognition and regulation of cognition (Sperling et al., 2002). Responses are based on a 5-point Likert-type scale, ranging from "very unlike me" to "very much like me." With 18 items, the possible score for the measure ranges from 0 to 90. Calculation of the internal consistency of the measure produced a Cronbach's alpha of 0.807. The Pearson correlation coefficient for inter-rater reliability was .888.

Table 1.
Survey Results of Notetaking Practices (n=80)

	Frequency	*Percent*
Do you take notes in most of your classes?		
Yes	77	96.3
No	3	3.8
I take notes by hand with pen/pencil and paper		
Never	1	1.3
Seldom	13	16.3
Sometimes	26	32.5
Often	25	31.3
Always	15	18.8
I take notes by computer/laptop		
Never	9	11.3
Seldom	12	15.0
Sometimes	25	31.3
Often	24	30.0
Always	10	12.5
I rewrite parts of my notes when I study		
Never	7	8.8
Seldom	12	15.0
Sometimes	21	26.3
Often	24	30.0

Demographics. Participants were asked to provide information regarding their gender, age, race/ethnicity, year in school, major, and if they had a history of a reading or writing disability or Attention-Deficit/Hyperactivity Disorder (ADHD). Subjects were also asked to complete rating scales on their notetaking habits. Items are included in Appendix G. Of the 80 subjects, 77 responded that they take notes in class (96.3%). The respondents were similar in their rating of notes via handwriting or typing—most (Handwriting=63.8%; Typing=61.3%) indicated that they "Sometimes" or "Often" take notes using each of those methods (Table 1).

A multivariate analysis of variance (MANOVA) was conducted to determine whether there were significant differences between the two experimental conditions on self-reported note-taking practices. The assumption of equal covariance matrices was met (Box's M = 12.793, F(10, 29086) =1.208, p = .280). The multivariate test was not significant, Wilks' $\lambda = .926$, $F(4, 75) = 1.473$, $p \leq .219$, partial η^2=.073, observed power = .436), indicating no significant differences between the handwriting and typing groups (Table 2).

Table 2.
Results of the Multivariate ANOVA Comparing Self-Report of Notetaking Practices by Experimental Condition Group

	Handwriting Group n = 40		*Typing Group n = 40*		
	Mean	*SD*	*Mean*	*SD*	*F*
Take Class Notes	1.03	.158	1.05	.221	.339
Handwriting Notes	3.30	.966	3.70	1.043	3.168
Typing Notes	3.25	1.149	3.10	1.215	.322
Rewriting Notes	3.35	1.292	3.40	1.150	.033

$^{*}p < .05$, $^{**}p < .01$

Procedure

The study was conducted over two sessions. During the first session, participants were randomly assigned to one of two notetaking conditions: handwriting using paper and pen, or personal computer (all subjects used their own laptops). Each participant received a paper booklet of test materials constructed by the researcher that included a consent form approved by the Teachers College Institutional Review Board. Subjects assigned to the Typing group were provided a USB drive containing files corresponding to the blank pages in the paper packets for the handwritten notes group. All participants were instructed to read the consent form silently as the experimenter read it out loud. The consent form outlined the study's purpose, procedures and materials, the time commitment to complete the study, and the participants' rights, and participants were afforded the opportunity to ask questions (5 minutes).

Following consent for participation, participants were informed of the upcoming lecture and test about Detroit, Michigan. They were asked to watch the video of a lecture regarding urban redevelopment in Detroit (Griffin, 2013) while taking notes in their respective media—participants assigned to take notes by hand were provided three sheets of paper in the packet of materials, and participants assigned to type notes on a laptop accessed a corresponding blank document on a USB drive (15 minutes). Following the lecture, participants completed the test of language comprehension (20 minutes).

Participants were then given a 20-minute period to review their notes, during which they were asked to "create a one-page study-sheet summarizing as much of the information from the lecture as possible such that it could help a friend who has not heard the lecture to perform well on the test." Participants were asked to review the notes they had previously taken in order to create the study-sheet in the same medium used to take notes—participants assigned to take notes by hand were provided one sheet of paper in their packet of materials, and participants assigned to take notes by laptop accessed a corresponding blank document on a USB drive specifying a maximum of one page for the review document. Following the review phase, participants completed a measure of letter speed, again consistent with the medium in which notes were taken and reviewed—participants assigned to take notes by hand were provided a sheet on which to complete the letter speed task, and participants assigned to take notes by laptop accessed a corresponding blank document on a USB drive on which to complete the letter speed task (5 minutes). The first session concluded with the administration of a 20-item multiple-choice test based on the lecture plus one additional question regarding the participant's personal familiarity with the lecture content prior to the experiment (15 minutes).

During the second session, participants were no longer separated into experimental groups. All participants completed a demographic survey (5 minutes), a group-administered test of sustained auditory attention (15 minutes), a test of background knowledge related to the lecture content (5 minutes), and the metacognition scale (10 minutes).

Results

The current study investigated the cognitive processes related to the taking and review of lecture notes and explored differences in performance between lecture notetaking and notes-review via handwriting (pen and paper) and typing (laptop computer). The study addressed three principal questions: (1) Are the cognitive processes related to the encoding process of notetaking (hereby, "notetaking") consistent with results of previous studies? (2) What are the cognitive processes related to the quality of notes-review? and (3) What are the variables related to test performance—overall as well as separately for items measuring memory or inference?

Table 3.
Descriptive Data for Independent and Dependent Variables (n = 80)

	Mean	SE Mean	SD	Range	Variance	Skewness	Kurtosis
Writing medium	.50	.056	.503	0-1	.253	.000	-2.052
Letter speed	218.11	7.988	71.445	126-398	5104.354	.857	-.235
Language comprehension	23.41	.694	6.207	10-38	38.524	-.074	-.508
Sustained attention	16.45	.302	2.704	8-20	7.314	-1.048	.735
Bkgd. knowledge (Test)	2.68	.134	1.199	0-5	1.437	.026	-.542
Bkgd. knowledge (Rating)	1.65	.119	1.069	1-5	1.142	1.513	1.068
Metacognition	66.19	.831	7.433	47-81	55.243	-.256	-.135
Notetaking	56.45	2.393	21.401	17-119	457.997	.732	.396
Notes-review	47.28	2.235	19.994	11-118	399.772	.825	1.038
Test: Overall	11.16	.273	2.441	6-17	5.961	.015	-.464
Test: Memory items	5.65	.172	1.535	2-9	2.357	.161	-.372
Test: Inference items	5.51	.184	1.646	2-9	2.709	-.014	-.731

Notes: Standard Error Skewness = .269; Standard Error Kurtosis = .532;
Bkgd. Knowledge = Background knowledge

The experimental design consisted of one between-subjects variable (handwriting or typing) and several within-subjects variables: quality of lecture notes and notes-review, performance on a multiple-choice test of the lecture content, letter speed, language comprehension, sustained attention, background knowledge, and metacognition. The means, standard deviations, ranges and information pertaining to the distribution for each of the variables for all participants are presented in Table 3.

Table 4.
Descriptive Data for Notetaking, Notes-Review and Scores and Subscores (n = 80)

	Mean	SE Mean	SD	Range	Variance	Skewness	Kurtosis
Notetaking	56.45	2.393	21.401	17-119	457.997	.732	.396
Propositions	28.63	1.085	9.705	11-56	94.187	.605	.126
Connections	25.57	1.136	10.158	6-53	103.184	.611	-.009
Themes	2.25	.367	3.278	0-14	10.747	1.663	2.487
Notes-Review	47.28	2.235	19.994	11-118	399.772	.825	1.038
Propositions	22.65	.976	8.725	6-47	76.129	.609	.324
Connections	19.56	1.017	9.100	2-46	82.806	.571	.302
Themes	5.06	.603	5.394	0-25	29.097	1.568	3.230

Notes: Standard Error Skewness = .269; Standard Error Kurtosis = .532

Table 5.
Paired-Samples T-Test for the Square Root of Notetaking and Notes-Review Scores and Subscores, Overall and by Experimental Condition

	Notetaking		Notes-Review		Paired Differences		
	Mean	SD	Mean	SD	Mean	SD	*t*
Total (n=80)							
Overall	7.382	1.408	6.725	1.443	0.657	1.066	5.518**
Propositions	5.275	0.902	4.671	0.920	0.604	0.676	7.990**
Connections	4.958	1.004	4.293	1.071	0.665	0.781	7.617**
Themes	0.968	1.153	1.798	1.361	-0.831	1.355	-5.482**
Handwriting (n=40)							
Overall	7.319	1.532	6.440	1.511	0.878	1.262	4.402**
Propositions	5.236	0.982	4.414	0.944	0.822	0.776	6.701**
Connections	4.887	1.094	3.991	1.153	0.896	0.881	6.433**
Themes	1.046	1.179	2.139	1.260	-1.093	1.475	-4.685**
Typing (n=40)							
Overall	7.445	1.288	7.009	1.330	0.436	0.780	3.541**
Propositions	5.314	0.825	4.927	0.830	0.386	0.477	5.123**
Connections	5.029	0.913	4.595	0.899	0.434	0.591	4.643**
Themes	0.889	1.136	1.458	1.387	-0.568	1.185	-3.034**

Notes. Calculations are based on the square roots of original scores;
Bonferroni correction = .013; $^{*}p \leq .013$, $^{**}p \leq .001$

The data showed that the average notetaking score was higher than the average notes-review score, indicating that the combined number of propositions, connectedness between propositions, and identified themes was greater for notetaking than for notes-review. Additional analyses of each of the subcomponents comprising the notetaking and notes-review scores were conducted. The means, standard deviations, ranges and information pertaining to the distribution for each of the variables for all subjects are presented in Table 4.

Further comparison of means between notetaking and notes-review was conducted using a paired samples *t*-test. In consideration of the distribution of scores, values were transformed by calculating the square root. With multiple comparisons, a Bonferroni correction was used to avoid Type I errors. The significance level for all t-tests was set at $p \leq .013$. Results, presented in Table 5, showed that for both handwriting and typing groups, while the average number of propositions and connections between propositions was greater for notetaking than for notes-review, the average number of themes identified was greater at notes-review than for notetaking, suggesting more organization or summarization occurring at review.

Table 6.
Results of the post-hoc ANOVAs Comparing Predictor and Outcome Variables by Experimental Condition

	Handwriting Group n = 40		*Typing Group n = 40*		
	Mean	*SD*	*Mean*	*SD*	*F*
Letter speed	171.63	26.283	264.60	72.220	58.540^{**}
Language comprehension	24.73	6.300	22.10	5.900	3.700
Sustained attention	17.03	2.434	15.88	2.866	3.742
Bkgd. knowledge (Rating)	1.85	1.189	1.45	.904	2.869
Metacognition	65.35	6.351	67.03	8.374	1.016
Notetaking	55.85	21.920	57.05	21.131	.062
Notes-review	43.70	19.339	50.85	20.238	2.610
Test: Overall	11.80	2.534	10.53	2.195	$5.785^{\Diamond}$
Test: Memory items	6.03	1.561	5.28	1.432	$5.016^{\Diamond}$
Test: Inference items	5.78	1.672	5.25	1.597	2.062

Notes: Bonferroni correction = .005; $^{*}p \leq .005$, $^{**}p \leq .001$; $^{\Diamond}$ $p < .05$
Bkgd. Knowledge = Background knowledge

Multivariate and Univariate Tests

In order to assess the impact of writing medium on outcomes, two separate one-way multivariate analysis of variance (MANOVA) were conducted to determine whether there were significant differences between the two experimental conditions. In the comparison of independent and dependent variables between experimental conditions, the multivariate test was significant, Wilks' $\lambda = .369$, $F(9, 70) = 13.283$, $p \leq .01$, partial η^2=.631, observed power = 1.00), indicating significant differences between the handwriting and typing notetaking groups (Table 6). For post-hoc univariate analyses, a Bonferroni correction was used to avoid Type I errors; the significance level was set at $p \leq .005$. Results of the post-hoc ANOVAs revealed faster letter speed for the typing group in comparison to the handwriting group, $F(1, 78) = 58.54$, $p \leq .001$, partial η^2=.429. Significant differences were also found using the uncorrected .05 criterion for significance. The handwriting group had higher scores than the typing group on the overall test $F(1, 78) = 5.785$, $p = .019$, partial η^2=.069, and memory items $F(1, 78) = 5.016$, $p = .028$, partial η^2=.060.

Table 7.
Results of the post-hoc ANOVAs Comparing Notetaking and Notes-Review Scores and Subscores by Experimental Condition Group

	Handwriting Group n = 40		*Typing Group n = 40*		
	Mean	*SD*	*Mean*	*SD*	*F*
Notetaking	7.32	1.53	7.45	1.29	.161
Propositions	5.24	.98	5.31	.83	.149
Connections	4.89	1.09	5.03	.91	.395
Themes	1.05	1.18	.90	1.14	.367
Notes-Review	6.44	1.51	7.01	1.33	3.193
Propositions	4.41	.94	4.93	.83	6.677◊
Connections	3.99	1.15	4.59	.90	6.823◊
Themes	2.14	1.26	1.46	1.39	5.288◊

Notes. Calculations are based on the square roots of original scores;
Bonferroni correction = .006; * $p < .006$; ◊ $p < .05$

In the comparison of notetaking and notes-review scores and subscores between experimental groups (Table 7), the multivariate test was significant, Wilks' $\lambda = .769$, $F(8, 71) = 2.659$, $p = .013$, partial η^2=.231, observed power = .901). For post-hoc univariate analyses, significant differences were found using the .05 criterion for significance; no significant differences between groups were found with a Bonferroni correction set at $p = .006$. Results showed that at notes-review, the typing group on average had a greater number of propositions $F(1, 78) = 6.677$, $p = .012$, partial $\eta^2=.079$ and connections $F(1, 78) = 6.823$, $p = .011$, partial $\eta^2=.080$ than the handwriting group. The handwriting group on average had a greater number of themes than the typing group in notes-review, $F(1, 78) = 5.288$, $p = .024$, partial $\eta^2=.063$.

Intercorrelations

Intercorrelations among the independent and dependent variables overall as well as for each of the experimental conditions—handwriting and typing, are presented in Tables 8 and 9. The notes medium (typing, in reference to handwriting) was significantly correlated to letter speed ($r =.655$, $p \leq .001$), and negatively correlated to overall test performance ($r =-.263$, $p = .019$) and performance on memory items on the test ($r =-.246$, $p = .028$).

The relationship between notetaking and notes-review was significant ($r =.745$, $p \leq .001$). Letter speed ($r =.415$, $p \leq .001$), language comprehension ($r =.387$, $p \leq .001$), sustained attention ($r =.248$, $p = .026$), and self-rating of background knowledge ($r =.282$, $p = .011$) were significantly correlated to notetaking. When separated by experimental condition, the correlations were not significant for sustained attention for either writing medium, and significant only for self-rating of background knowledge for the typing medium alone ($r =.346$, $p = .029$). Correlations remained significant between notetaking and letter speed and between notetaking and language comprehension for both conditions.

Notes-review was similarly correlated with the aforementioned cognitive variables—letter speed ($r =.432$, $p \leq .001$), language comprehension ($r =.422$, $p \leq .001$), sustained attention ($r =.309$, $p = .005$), and self-rating of background knowledge ($r =.313$, $p = .005$). When separated by experimental condition, correlations remained significant.

Overall test performance ($r =.390$, $p \leq .001$), and performance on memory ($r =.237$, $p =$

.034) and inference (r =.358, p = .001) items on the test were also significantly correlated with notes-review. Interestingly, when separated by experimental condition, the correlations were significant only for the handwriting group (overall: r =.609, $p \leq .001$; memory: r =.396, p = .011; inference: r =.553, $p \leq .001$) and not for the typing group.

Language comprehension was also significantly correlated with test performance overall (r =.368, p = .001), and on memory (r =.245, p = .028) and inference (r =.317, p = .004) items. Again, when separated by experimental condition, the correlations were only significant for the handwriting group (overall: r =.530, $p \leq .001$; memory: r =.381, p = .015; inference: r =.447, p =.004) and not for the typing group.

Sustained attention was significantly correlated with test performance overall (r =.296, p = .008), and on memory (r =.252, p = .024), but not inference items. When separated by experimental condition, only the correlation between sustained attention and overall test performance was significant for the handwriting group (r =.346, p = .029); all other correlations were not significant.

Amongst the cognitive variables, sustained attention was significantly correlated with language comprehension (r =.355, p = .001) and negatively correlated with metacognition (r =-.236, p = .035). Within the handwriting group, only sustained attention and language comprehension were significantly correlated (r =.350, p = .027), and within the typing group, only sustained attention was significantly correlated with metacognition (r =-.393, p = .012). In addition, within the typing group, letter speed (typing speed) was significantly correlated with language comprehension (r =.410, p = .009) and sustained attention (r =.343, p = .030).

Between outcome measures, the overall test significantly correlated with memory (r =.748, $p \leq .001$) and inference items (r =.785, $p \leq .001$); no correlation was found between

Table 8.
Intercorrelations Among the Predictor and Outcome Variables (*n=80*)

	1	2	3	4	5	6	7	8	9	10	11
1. Writing medium	—										
2. Letter speed	.655**	—									
3. Language comprehension	-.213	.067	—								
4. Sustained attention	-.214	.052	.355**	—							
5. Background knowledge (Test)	-.168	-.023	.183	.003	—						
6. Background knowledge (Rating)	-.188	-.010	.150	.138	.127	—					
7. Metacognition	.113	.056	-.182	-.236*	-.090	.045	—				
8. Notetaking	.028	.415**	.387**	.248*	.101	.282*	.060	—			
9. Notes-review	.180	.432**	.422**	.309**	.048	.313**	.022	.745**	—		
10. Test: Overall	-.263*	-.038	.368**	.296**	.096	.158	-.023	.203	.390**	—	
11. Test: Memory items	-.246*	.017	.245*	.252*	.123	.133	.028	.154	.237*	.748**	—
12. Test: Inference items	-.161	-.073	.317**	.203	.028	.110	-.061	.158	.358**	.785**	.177

Notes. ** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed)

Table 9.

Intercorrelations Among the Predictor and Outcome Variables by Experimental Condition

	1	2	3	4	5	6	7	8	9	10
Handwriting Medium (n = 40)										
1. Handwriting speed	—									
2. Language comprehension	.063	—								
3. Sustained attention	.066	.350*	—							
4. Background knowledge (Test)	-.024	.171	-.130	—						
5. Background knowledge (Rating)	.258	.107	.081	.184	—					
6. Metacognition	.000	-.152	.053	-.139	-.119	—				
7. Notetaking	.547**	.446**	.226	.067	.256	.057	—			
8. Notes-review	.457**	.530**	.383*	.044	.314*	-.012	.652**	—		
9. Test: Overall	.124	.530**	.346*	-.084	.075	.009	.273	.609**	—	
10. Test: Memory items	.207	.381*	.236	.084	-.053	.113	.164	.396*	.766**	—
11. Test: Inference items	-.004	.447**	.304	-.206	.163	-.091	.261	.553**	.800**	.228
Typing Medium (n=40)										
1. Typing speed	—									
2. Language comprehension	.410**	—								
3. Sustained attention	.343*	.304	—							
4. Background knowledge (Test)	.187	.133	.048	—						
5. Background knowledge (Rating)	.146	.126	.131	-.013	—					
6. Metacognition	-.032	-.175	-.393*	-.022	.259	—				
7. Notetaking	.599**	.354*	.293	.150	.346*	.059	—			
8. Notes-review	.464**	.428**	.346*	.116	.425**	.012	.854**	—		
9. Test: Overall	.246	.087	.170	.219	.175	.005	.153	.302	—	
10. Test: Memory items	.301	-.003	.190	.088	.298	.014	.168	.191	.687**	—
11. Test: Inference items	.068	.122	.063	.222	-.027	-.006	.059	.245	.759**	.048

Notes. ** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed)

memory and inference items.

The measure of background knowledge based on accuracy of responses on a multiple-choice test did not present any correlations with any other variables and was eliminated from all analyses. In consideration of this as well as the poor reliability of the measure, only the measure of background knowledge based on subjects' self-rating of familiarity with the lecture was used for all subsequent analyses.

Regression Analyses

Multiple hierarchical regression analyses were conducted to evaluate which variables contributed significantly to notetaking, notes-review, and to test performance overall and on memory and inference items. Main effects were tested in the first block and interactions were tested in the second and third blocks. In order to compare regression coefficients, variables were transformed by standardizing to the overall mean and standard deviation, with the exception of letter speed, which was standardized to each respective group mean and standard deviation, in consideration of the significant difference between the two experimental conditions.

Notetaking. Total note quality was regressed first on the five cognitive variables of letter speed, language comprehension, sustained attention, background knowledge, and metacognition. The second block added interactions between writing medium and each of aforementioned five cognitive variables, and the third block added interactions between letter speed and the remaining cognitive variables. It was hypothesized that handwriting or typing speed, language comprehension, and sustained attention would all significantly predict quality of notes. The results are summarized in Table 10.

The three levels of the hierarchical regression were each significant, with tolerance and variance inflation factor values within acceptable limits. The full model (Block 3: $R = .715$, $R^2 =$

Table 10.
Summary of the Regression Analyses Predicting Notetaking

	Block 1			Block 2			Block 3		
	B	SE B	β	B	SE B	β	B	SE B	β
Writing Medium[a]	.239	.183	.120	.237	.186	.119	.187	.191	.094
Letter Speed[b]	.466**	.093	.463	.505**	.130	.502	.458**	.137	.455
Language Comprehension[c]	.276**	.096	.276	.415**	.135	.415	.373**	.138	.373
Sustained Attention[c]	.086	.097	.086	.040	.150	.040	.037	.155	.037
Background Knowledge[c]	.151	.091	.151	.089	.118	.089	.064	.122	.064
Metacognition[c]	.119	.091	.119	.154	.151	.154	.161	.156	.161
Medium[a] *x* L. Speed[b]	—	—	—	-.019	.194	-.013	-.046	.207	-.032
Medium[a] *x* L. Comp.[c]	—	—	—	-.303	.201	-.205	-.246	.211	-.166
Medium[a] *x* S. Attn.[c]	—	—	—	.042	.207	.031	.091	.213	.069
Medium[a] *x* Bkgd.[c]	—	—	—	.181	.200	.109	.172	.206	.103
Medium[a] *x* Metacog.[c]	—	—	—	-.094	.200	-.075	-.084	.200	-.067
L. Speed[b] *x* L. Comp.[c]	—	—	—	—	—	—	.082	.114	.081
L. Speed[b] *x* S. Attn.[c]	—	—	—	—	—	—	.044	.136	.038
L. Speed[b] *x* Bkgd.[c]	—	—	—	—	—	—	-.054	.081	-.071
L. Speed[b] *x* Metacog.[c]	—	—	—	—	—	—	.236*	.117	.211

Notes. [a] reference = handwriting; [b] standardized to each respective experimental condition group mean and standard deviation; [c] standardized to the overall mean and standard deviation; Medium = Writing Medium; L. Speed = Letter Speed, L. Comp. = Language Comprehension, S. Attn. = Sustained Attention, Bkgd. = Background Knowledge, Metacog. = Metacognition; Block 1: R = .668, R^2 = .446, $R^2_{adjusted}$ = .401, F (6, 73) = 9.808, $p < .001$;
Block 2: R = .685, R^2 = .470, $R^2_{adjusted}$ = .384, $R^2\Delta$= .023, F (11, 68) = 5.478, $p < .001$;
Block 3: R = .715, R^2 = .511, $R^2_{adjusted}$ = .397, $R^2\Delta$= .041, F (15, 64) = 4.462, $p < .001$;
$^{*}p \leq .05$, $^{**}p \leq .01$

.511, $R^2_{adjusted}$ = .397, F (15, 64) = 4.462, $p < .001$) accounted for over 39% of the variance in the data. All three levels showed significant main effects for both letter-writing speed (Block 3: β = .455, p = .001), and language comprehension (Block 3: β = .373, p = .009), such that those with faster letter speed produced significantly more notes, as did those with higher language comprehension.

In the full model, while metacognition alone was not significant, the letter speed *x* metacognition interaction was significant (Block 3: β = .211, p = .047). To explore this interaction more thoroughly, letter speed scores within each experimental group were divided into two equal groups—low and high, based on the median standardized letter speed z-score (standardized to each respective experimental condition mean and standard deviation). Simple scatter plots of the relationship between metacognition and notetaking by letter speed group showed a positive relationship for the high letter speed group and a negative relationship for the low letter speed group (Appendix H, Figure 2). Similar relationships were seen within each writing medium (Appendix H, Figure 3).

Notes-Review. The quality of notes-review was regressed first on the five cognitive variables of letter speed, language comprehension, sustained attention, background knowledge, and metacognition, as well as notetaking. The second block added interactions between writing medium and each of aforementioned five cognitive variables and notetaking, and the third block added interactions between letter speed and the remaining cognitive variables and notetaking. It was hypothesized that notetaking, background knowledge, and metacognition would significantly predict quality of notes-review. The results are summarized in Table 11.

The three levels of the hierarchical regression were each significant, with tolerance and variance inflation factor values within acceptable limits. The full model (Block 3: $R = .860$, $R^2 =.740$, $R^2_{adjusted} = .663$, F (18, 61) = 9.650, $p < .001$) accounted for over 66% of the variance in the data. All three models showed significant main effects for writing medium (Block 3: $\beta = .480$, $p = .002$), such that those in the typing group produced more at notes-review than those in the handwriting group. Main effects were also seen for language comprehension (Block 3 $\beta = .237$, $p = .045$), and notetaking (Block 3: $\beta = .265$, $p = .050$), such that higher language comprehension and notetaking scores were related to a higher notes-review score.

In the second block, which added interactions between writing medium and the other variables, the writing medium *x* notetaking interaction was significant (Block 2: $\beta = .519$, $p = .007$). The positive relationship between notetaking and notes-review was significantly stronger for the typing group than for the handwriting group. (Appendix H, Figure 4). There was a greater change in scores between notetaking and notes-review for the handwriting group (notetaking $\overline{x}$ = 55.85, notes-review $\overline{x}$ = 43.70; difference = 12.15) than for the typing group (notetaking $\overline{x}$ = 57.05, notes-review $\overline{x}$ = 50.85; difference = 6.20).

Table 11.
Summary of the Regression Analyses Predicting Notes-Review

	Block 1			Block 2			Block 3		
	B	SE B	β	B	SE B	B	B	SE B	β
Writing Medium[a]	.510**	.147	.257	.529**	.145	.266	.480**	.145	.242
Letter Speed[b]	.023	.086	.023	.207	.121	.206	.293*	.129	.291
Language Comprehension[c]	.181*	.081	.181	.283*	.118	.283	.237*	.116	.237
Sustained Attention[c]	.135	.078	.135	.193	.116	.193	.183	.116	.183
Background Knowledge[c]	.147	.074	.147	.114	.092	.114	.167	.092	.167
Metacognition[c]	.017	.073	.017	.023	.118	.023	.082	.128	.082
Notetaking[c]	.579**	.093	.579	.309*	.133	.309	.265*	.133	.265
Medium[a] *x* L. Speed[b]	—	—	—	-.340	.176	-.239	-.464*	.186	-.326
Medium[a] *x* L. Comp.[c]	—	—	—	-.124	.165	-.084	-.034	.168	-.023
Medium[a] *x* S. Attn.[c]	—	—	—	-.112	.160	-.085	-.092	.161	-.069
Medium[a] *x* Bkgd.[c]	—	—	—	.053	.158	.032	-.116	.161	-.070
Medium[a] *x* Metacog.[c]	—	—	—	-.038	.155	-.030	-.076	.153	-.061
Medium[a] x Notetaking	—	—	—	.519**	.187	.360	.539**	.194	.374
L. Speed[b] *x* L. Comp.[c]	—	—	—	—	—	—	-.195	.100	-.195
L. Speed[b] *x* S. Attn.[c]	—	—	—	—	—	—	.227*	.109	.197
L. Speed[b] *x* Bkgd.[c]	—	—	—	—	—	—	-.126	.064	-.167
L. Speed[b] *x* Metacog.[c]	—	—	—	—	—	—	-.017	.093	-.016
L. Speed[b] *x* Notetaking[c]	—	—	—	—	—	—	.113	.110	.130

Notes. [a] reference = handwriting; [b] standardized to each respective experimental condition group mean and standard deviation; [c] standardized to the overall mean and standard deviation;
L. Speed = Letter Speed, L. Comp. = Language Comprehension, S. Attn. = Sustained Attention, Bkgd. = Background Knowledge, Metacog. = Metacognition; Medium = Writing Medium;
Block 1: R = .808, R^2 = .652, $R^2_{adjusted}$ = .619, F (7, 72) = 19.303, $p < .001$;
Block 2: R = .833, R^2 = .694, $R^2_{adjusted}$ = .634, $R^2\Delta$= .042, F (13, 66) = 11.540, $p < .001$;
Block 3: R = .860, R^2 = .740, $R^2_{adjusted}$ = .663, $R^2\Delta$= .046, F (18, 61) = 9.650, $p < .001$;
$^{*}\ p \leq .05$, $^{**}\ p \leq .01$

In the full model, which added interactions between letter speed and the remaining independent variables, additional significant interactions were found between writing medium *x* letter speed (Block 3: β = -.464, *p* = .015) and between letter speed *x* sustained attention (Block 3: β = .227, *p* = .041). The writing medium and letter speed interaction indicated that faster letter speed was related to higher notes-review scores for the handwriting group, whereas faster letter speed was related to lower notes-review scores for the typing group, (Appendix H, Figure 5).

For the letter speed *x* sustained attention interaction, as previously mentioned, letter speed scores within each experimental group were divided into two equal groups—low and high, based on the median standardized letter speed z-score (standardized to each experimental condition mean and standard deviation). A simple scatter plot of the relationship between sustained attention and letter speed on notes-review showed a positive relationship between sustained attention and notes-review for the high letter speed group but not the low letter speed group (Appendix H, Figure 6). When separated by writing medium, a similar relationship was seen within the handwriting group; the interaction was not evident within the scatter plot for the typing group (Appendix H, Figure 7).

Test performance. Total test performance and performance on memory and inference items were separately regressed, first on letter speed, language comprehension, sustained attention, background knowledge, metacognition, notetaking and notes-review. Interactions between writing medium and each of the aforementioned variables were added in the second block. The third block added interactions between letter speed and the remaining variables. It was hypothesized that only notes-review would significantly predict overall test performance as well as performance on memory and inference items. Several of the tested models were not found to be significant (see Table 12). Block 2 regressions were significant for each of the dependent variables and are presented in Table 13.

Overall test performance. The model including interactions between writing medium and the five cognitive variables, notetaking, and notes-review was significant (Block 2: R = .641, R^2 = .411, $R^2_{adjusted}$ = .273 F (15, 64) = 2.98, p = .001; tolerance and variance inflation factor values within acceptable limits). There was a significant main effect for writing medium (β = -.690, p = .003)—the handwriting group performed significantly higher than the typing group. A main effect was also seen for notes-review (β = .670, p = .003), such that higher notes-review scores were related to higher test performance.

Performance on memory items. The model predicting performance on memory items that included interactions between writing medium and the five cognitive variables, notetaking and notes-review was significant (R = .554, R^2 = .307, $R^2_{adjusted}$ = .145, F (15, 64) = 1.89, p = .041; tolerance and variance inflation factor values within acceptable limits). There was a significant main effect for writing medium (β = -.498, p = .045)—those in the typing group performed significantly lower on memory items on the test than those in the handwriting group. A significant interaction was found between writing medium *x* language comprehension (β = -.571 p = .036), with a positive relationship between language comprehension and memory items for the handwriting group, whereas a negative relationship was seen between language comprehension and memory items for the typing group (Appendix H, Figure 8).

Performance on inference items. The model predicting performance on inference items that included interactions between writing medium and the five cognitive variables, notetaking and notes-review was significant (R = .565, R^2 = .319, $R^2_{adjusted}$ = .159, F (15, 64) = 2.00, p = .029; tolerance and variance inflation factor values within acceptable limits). There was a significant main effect for writing medium (β = -.559, p = .024)—those in the typing group performed significantly lower on inference items than those in the handwriting group. A significant main effect was seen for notes-review (β = .651, p = .007)—higher notes-review scores were related to higher test performance; no significant interactions were found.

Table 12.

Summary of the Regression Models Predicting Performance on Overall, Memory, and Inference Items on the Multiple-Choice Test

	Overall Test					Memory Items					Inference Items				
	R	R^2	$R^2_{adj.}$	$R^2\Delta$	F	R	R^2	$R^2_{adj.}$	$R^2\Delta$	F	R	R^2	$R^2_{adj.}$	$R^2\Delta$	F
1	.576	.332	.257	.332	4.42^{**}	.451	.203	.113	.203	2.26^{*}	.500	.250	.166	.250	2.96^{**}
2	.641	.411	.273	.079	2.98^{**}	.554	.307	.145	.104	1.89^{*}	.565	.319	.159	.069	2.00^{*}
3	.652	.426	.218	.014	2.05^{**}	.586	.344	.106	.036	1.45	.604	.365	.135	.046	1.59

Notes. 1: Block 1 independent variables = letter speed, language comprehension, sustained attention, background knowledge, metacognition, notetaking, notes-review; 2: Block 2 added interactions between writing medium and remaining variables; 3: Block 3 added interactions between letter speed and remaining variables

$^{*}p < .05$, $^{**}p < .01$

Table 13.
Regression Analyses Predicting Overall, Memory, and Inference items on the Multiple-Choice Test

	Overall Test			Memory Items			Inference Items		
	B	SE B	β	B	SE B	β	B	SE B	β
Writing Medium [a]	-.690**	.225	-.347	-.498*	.244	-.250	-.559*	.242	-.281
Letter Speed[b]	-.025	.176	-.025	.252	.191	.250	-.271	.189	-.270
Language Comprehension[c]	.319	.177	.319	.361	.192	.360	.137	.190	.137
Sustained Attention[c]	.069	.169	.069	.046	.183	.046	.060	.182	.060
Background Knowledge[c]	-.074	.132	-.074	-.148	.143	-.148	.028	.142	.028
Metacognition[c]	.081	.166	.081	.202	.181	.202	-.069	.179	-.069
Notetaking[c]	-.260	.199	-.260	-.335	.216	-.335	-.074	.214	-.074
Notes-Review[c]	.670**	.217	.670	.367	.236	.367	.651**	.234	.651
Medium[a] x L. Speed[b]	.329	.255	.231	.114	.277	.080	.382	.274	.268
Medium[a] x L. Comp.[c]	-.460	.245	-.311	-.571*	.266	-.386	-.149	.264	-.101
Medium[a] x S. Attn.[c]	-.036	.231	-.027	.029	.250	.022	-.081	.248	-.061
Medium[a] x Bkgd.[c]	.125	.230	.075	.459	.249	.276	-.243	.247	-.146
Medium[a] x Metacog.[c]	-.063	.219	-.050	-.233	.238	-.185	.124	.236	.098
Medium[a] x Notetaking[c]	-.333	.362	-.231	.090	.393	.063	-.579	.389	-.402
Medium[a] x Notes-Review[c]	-.020	.361	-.014	-.208	.392	-.149	.165	.388	.118

Notes. [a] reference = handwriting; [b] standardized to each respective experimental condition group mean and standard deviation; [c] standardized to the overall mean and standard deviation; L. Speed = Letter Speed, L. Comp. = Language Comprehension, S. Attn. = Sustained Attention, Bkgd. = Background Knowledge, Metacog. = Metacognition, Medium = Writing Medium; Overall Test: R = .641, R^2 = .411, $R^2_{adjusted}$ = .273, F (15, 64) = 2.98, p = .001**;
Memory Items: R = .554, R^2 = .307, $R^2_{adjusted}$ = .145, F (15, 64) = 1.89, p = .041*;
Inference Items: R = .565, R^2 = .319, $R^2_{adjusted}$ = .159, F (15, 64) = 2.00, p = .029*;
* $p < .05$, ** $p < .01$

Discussion

Notetaking and notes-review are ubiquitous study practices at the secondary and postsecondary levels that have been shown to be effective for learners. Both the encoding and storage functions of notes aid learners in their understanding and recall of lecture information. Notetaking and notes-review are also very complex academic tasks in which basic cognitive processes, such as letter speed, need to be sufficiently fluent and automatic in order to facilitate the application of higher cognitive processes within a limited capacity working memory. Several studies have examined the cognitive processes related to notetaking and good test performance. However, only one study has explored the cognitive processes associated with notes-review (Hadwin et al., 1999) and we are not aware of any study that has directly evaluated the correlational interrelationship between notes (process) and notes-review (product). In addition, most studies of notetaking have focused on handwritten notes, and have not included notes taken via other means, such as typing. This study sought to extend the research by including notes-review in an investigation of relationships among some of cognitive variables thought to be related to notes and test performance. Additionally, this study also explored differences between notes taken and reviewed via handwriting and by computer.

For this study, undergraduate students were randomly assigned to either a handwriting or typing condition. They were required to take notes while watching a video of a lecture, rewrite their notes following a delay (in the medium consistent with their original notetaking), and later take a multiple-choice test based on the lecture content. Participants also completed measures of letter speed (consistent with the medium in which notes were taken), language comprehension, sustained attention, background knowledge, and metacognition in order to understand the relationship between notetaking, notes-review, and all of the aforementioned cognitive variables.

Predictors of Notetaking

In predicting the relationship between various cognitive variables—letter speed, language comprehension, sustained attention, background knowledge, and metacognition—and notetaking, it was hypothesized that letter speed (Peverly, Garner & Vekaria, 2013; Peverly et al., 2007; Peverly, Vekaria, et al., 2013), language comprehension (Gleason, 2012; Peverly, Vekaria, et al., 2013; Reddington et al., 2015; Vekaria 2011), and sustained attention (Gleason, 2012; Peverly, Garner & Vekaria, 2013; Vekaria 2011) would be significantly related to the quality and quantity of lecture notes.

Letter speed. Consistent with previous studies that have found handwriting speed to be the strongest predictor of lecture notetaking (Peverly, Garner, & Vekaria, 2013; Peverly et al., 2007; Peverly, Vekaria, et al., 2013), results of the current study also determined that letter speed was the strongest predictor. This result suggests that the more efficiently individuals can generate letters and words, the greater the likelihood they can use their limited capacity working memory to engage more complex cognitive processes, resulting in improved notetaking (McCutchen, 1996; Peverly, 2006).

As with previous studies (Brown, 1988; Novellino et al., 1986), letter speed was significantly faster with computers than handwriting (handwriting: $\bar{x}$ = 171.63 letters per minute; typing $\bar{x}$ = 264.60 letters per minute). However, there was no significant difference between groups for lecture notetaking, despite the difference in speed (handwriting notetaking score: $\bar{x}$ = 55.85; typing notetaking score: $\bar{x}$ = 57.05). This suggests that the recorded information was similar in quality and quantity, regardless of notetaking medium and differences in letter speed. This finding differs from those of Bui et al. (2013) and Mueller and Oppenheimer (2014), who found that those who typed notes wrote more than those who took notes by hand. It is not clear why this study did not replicate the findings by Bui et al. (2013) and Mueller and Oppenheimer (2014). The studies all drew from undergraduate university students as subjects. Lecture length and presentation rate were relatively comparable and thus did not appear to impact the outcome—the current study used an 11-minute lecture presented at approximately 170 words per minute. Mueller and Oppenheimer (2014) used five TED talks, "slightly over 15 minutes in length," with presentation speeds between 150 to 186 words per minute, and Bui et al. (2013) used an 11-minute lecture with a speech rate of 140 words per minute. One noted difference was in the manner in which notes were scored—Mueller and Oppenheimer (2014) used a word count to analyze notes, resulting in a quantitative evaluation rather than a qualitative one. In their study, subjects in the typing condition were more likely to transcribe the lecture content verbatim and capture a higher quantity of information. However, it is unclear whether there was a qualitative difference in the type of information captured (as in the number of propositions or idea units) between typing and handwriting groups. However, Bui et al. (2013), similar to the current study, scored the number of idea units captured in notes.

Letter speed x metacognition. The current study found a significant interaction between letter speed and metacognition. While metacognition alone did not predict notetaking, faster letter speed and higher self-reported metacognition combined were associated with higher notetaking scores. This suggests that higher levels of reported metacognition positively influence notetaking only when accompanied by faster letter speed, or that faster letter speed may be further enhanced by higher metacognitive skills to positively influence notetaking. This supports the idea that the higher order cognitive process of metacognition, which may include monitoring of comprehension and evaluation of the effectiveness of a task strategy, positively impacts notetaking only when the process of letter speed is efficient and automatized.

Language comprehension. The current study found a significant positive relationship between language comprehension and lecture notetaking. This finding is consistent with results of previous studies that have found that higher language comprehension (as assessed via measures of reading or listening comprehension) is associated with improved lecture notetaking (Gleason, 2012; Peverly, Vekaria, et al., 2013; Reddington, 2015; Vekaria 2011) and text notetaking (Peverly & Sumowski, 2012).

Of the studies that did not find a relationship between language comprehension and notetaking, Peverly et al. (2007) identified some methodological factors (difficulty of the task, limited variation in performance, subject fatigue and one-third of subjects did not identify English as their first language) that might account for the lack of relationship. Hadwin et al. (1999), who used a word similarities identification task, may not have found a significant relationship with notetaking due to the specific nature of the task. Also, Peverly, Vekaria, et al. (2013) speculated that a lack of variance in American College Test (ACT) scores, which were used as a proxy for language comprehension by Kiewra and colleagues (Kiewra & Benton, 1988; Kiewra, et al., 1987), as a possible explanation for the lack of relationship found in their studies. As a result, Peverly, Vekaria, et al. (2013) used the Nelson-Denny Reading Test (Brown, et al., 1993a), with shortened administration time, and found significant results. Along with other studies (Peverly & Sumowski, 2012; Reddington et al., 2015), the current study used the same measure and the results support the conclusion that language comprehension is significantly related to notetaking due to an increased level of comprehension of the lecture content. It should be noted, however, that one study that also used the Nelson-Denny did not find a relationship between language comprehension and notetaking (Peverly, Garner, & Vekaria, 2013), although no explanation was provided as to why this might be the case.

Under a limited capacity working memory model in which basic processes need to be automatized to allow more complex processes to be performed with greater efficiency, it is somewhat surprising that given the interaction between letter speed and metacognition discussed above that the letter speed *x* language comprehension interaction was not significant. The latter would provide evidence for the assumption that the automatization of a basic skill (letter speed) would allow for more cognitive resources to be allocated to higher order (language) skills. It is may be that for college-age adults, letter speed is sufficiently automatized for language comprehension processes to be executed efficiently.

Sustained attention. While several studies have shown a positive relationship between sustained attention and notetaking (Gleason, 2012; Peverly, Garner & Vekaria, 2013; Vekaria 2011), contrary to prediction, the current study failed to find a relationship between the two. Although the Lottery subtest of the Test of Everyday Attention (Robertson, Ward, Ridgeway, & Nimmo-Smith, 1994; TEA) was used in all of the studies that found an effect for this variable, the relationship was not evident in the linear regressions. Although the correlation between sustained attention and notetaking was significant (r = .248, p = .026), the correlation between sustained attention and notes was not significant when the note-taking groups were analyzed separately.

A possible explanation for this finding might be attributed to differences in the lectures. The current study used an 11-minute lecture presented at approximately 170 words per minute, while the previous studies utilized a lecture that was over 20 minutes long and presented at 120 words per minute (Gleason, 2012; Peverly, Garner & Vekaria, 2013; Vekaria 2011). Increased sustained attention may have been more important over a longer lecture. In addition, attention may have been more difficult to maintain over a rapidly-paced lecture as in the current study.

Predictors of Notes-Review

In the relationship between the various cognitive variables (letter speed, language comprehension, sustained attention, background knowledge, and metacognition), notetaking, and notes-review, it was hypothesized that notetaking, background knowledge, and metacognition would be significantly related to the quality and quantity of notes-review.

Notetaking. As hypothesized, the quality of lecture notetaking was significantly related to the quality of notes-review; higher notetaking quality scores were associated with higher notes-review scores. Thus, in accordance with the storage function of notes (Armbruster, 2009; Carrier and Titus, 1979; Di Vesta & Gray, 1972; Kobayashi, 2006), higher note-taking scores led to higher notes-review scores. This finding is also consistent with those (see Johnson, 2012; Peverly et al., 2007), who found that the more idea units included in notes, the more they would be included in written summaries, even when notes were not available for review when composing the summary. This is the first study to directly evaluate the relationship between notetaking and notes-review.

Language comprehension. Language comprehension continued to show a direct relationship to notes-review, which is consistent with that of Hadwin et al. (1999). However, this was an unexpected finding. Since language comprehension was significantly related to notetaking, and notetaking was significantly related to notes-review, it was expected that notetaking would mediate the relationship between language comprehension and notes-review.

This finding suggests that language comprehension relates to notes not only in the understanding of the lecture content, as discussed above, but also relates to notes as a writing task (Kiewra & Benton, 1988; Peverly & Vekaria et al., 2013; Piolat et al., 2005; Vekaria, 2011), such that language comprehension impacts the selection of words, expression of ideas, and organization of concepts when rewriting notes (McCutchen, 1984).

Letter speed *x* sustained attention. The significant letter speed *x* sustained attention interaction suggests that for those with faster letter speed, higher sustained attention was associated with higher notes-review scores, but not for slower letter speeds. As such, it appears that overall, sustained attention has a positive effect on notes-review when letter speed is more efficient and automatized. This finding suggests that the automaticity of basic cognitive processes (letter speed) for the application of higher level processing (sustained attention), is as important to notes-review as it is to taking notes. It is possible that the process of organizing and summarizing notes at review requires greater sustained attention than during notetaking.

Surprisingly, within the typing group, a positive relationship was also seen between sustained attention and notes-review for those with low letter speed. This suggests that the hierarchical cognitive processing within a limited capacity working memory may not apply to typing in the same way as it does with handwriting. For slower typists, the ability to remain attentive over a long period of time also supported stronger notes-review. Further considerations based on writing medium are discussed below.

Writing medium. While the ANOVA did not identify any significant differences between mean notes-review scores for the handwriting and typing groups, regression analyses revealed that typing was more strongly related to notes-review than handwriting. The reason for this difference might lie in the use of word-processing tools (MacArthur, 1987) which can be used for the physical reorganization of notes without the need to re-write information (e.g. inserting/deleting text using the cursor, using a "cut-and-paste" function to move text, transforming text into lists through the use of bullet points or numbers). With the availability of word-processing tools, the notes-review study-sheet created in the computer condition is more likely to contain parts that passively replicate information from the original notes, without further processing. Since such tools are not available in the handwriting medium, the study-sheet had to be written in its entirety, providing opportunities for transformation and organization of the written information, and a deeper level of processing of the lecture material. This was evidenced in the differences in the subcomponent scores for notetaking and notes-review found between handwritten and typed notes. There were no significant differences in the average number of propositions, connections, and themes captured in notes between the handwriting and typing groups. However, in notes-review, the average number of propositions and connections was higher for those who typed, and the average number of themes identified was higher for those in the handwriting group, suggesting that more reorganization, summarization and identification of macrostructures took place in the handwriting than in the typing group.

Interactions with writing medium. The capacity of the typing medium to create and edit text faster than by handwriting also likely accounts for the writing medium *x* notetaking and the writing medium *x* letter speed interactions. In the writing medium *x* notetaking interaction, for those in the typing group, higher notetaking scores were related to higher notes-review scores and lower notetaking scores were related to lower notes-review scores in comparison to the handwriting group. Namely, there was less change in the scores between notetaking and notes-review for the typing group, while there was greater change between notetaking and notes-review for the handwriting group. This suggests that there was more variability between notetaking and notes-review for the handwriting group.

In regard to the writing medium *x* letter speed interaction, faster letter speed was related to higher notes-review scores for the handwriting group. This suggests that those with faster handwriting speed were able to include more information in notes-review than those with slower handwriting speed. For the typing group, faster letter-speed was associated with lower notes-review scores. This suggests that faster typing speed does not aid notes-review; rather, it may negatively impact the quality of notes-review. The lack of relationship between letter speed and notes-review may be due to the use of word-processing tools to create a notes-review document, where content would be rearranged via “cut-and-paste” rather than by retyping the information. It is possible that faster typing during notetaking could result in a more superficial level of information processing at notetaking that in turn negatively impacts the quality of notes-review.

Background knowledge. Contrary to the study’s hypothesis, despite finding a significant correlation between background knowledge and notes-review, background knowledge was not found to be a significant predictor of notes-review. Previous studies have found no relationship between background knowledge and notes (Peverly et al., 2003) or notes-review (Hadwin et al., 1999), and the ethnographic study of by Van Meter et al. (1994) found that students reported taking fewer, or more selective, notes when they perceived greater familiarity, or background knowledge with the lecture content. This study hypothesized that notes-review, operationalized by asking students to create a one-page study-sheet summarizing the lecture information would provide an opportunity to incorporate background knowledge and engage in generative processing to edit, organize, and elaborate on information that was captured during notetaking, thus showing a significant relationship between background knowledge and notes-review.

While Hadwin et al. (1999) did not find a relationship between the two variables, the current study critiqued their use of self-ratings to measure background knowledge, and attempted to revisit this relationship by using a more objective measure of background/prior knowledge of the lecture content—a multiple-choice test to measure subjects’ familiarity with elements related to the lecture content. Regardless, poor reliability of the measure resulted in the elimination of its use in the analyses, and a one-item likert-scale response was used in its place. This item, which asked subjects to rate, “how familiar were you with the content of this lecture BEFORE today?” was similar to one used by Hadwin, which asked subjects to “rate their familiarity with the content of the lecture before the lecture” (Hadwin et al., 1999). It is therefore not surprising that similar results were obtained, and it is hoped that future studies incorporating a reliable, objective measure of background knowledge will aid in further understanding the role of background knowledge to lecture notetaking, notes-review and test performance.

Metacognition. Also contrary to the study’s hypothesis, metacognition was also not significantly related to notes-review. While some studies have explored the relationship between notetaking, metacognition and test performance, findings have shown a limited role for metacognition (C. Brown, 2005; Peverly et al., 2003). This study sought to demonstrate that although there may be limited opportunity to plan, monitor, or organize one’s notes while taking notes, the process of reviewing notes would afford the opportunity to use metacognitive skills to enhance the organization, clarity, coherence and cohesion of what was recorded during encoding.

One explanation for the current findings is the limitation of a self-reported measure of metacognition in which declarative knowledge may not be aligned with actual metacognitive regulation (C. Brown, 2005; Kuhn, 2000; Kuhn & Pearsall, 1998). Castelló and Monereo (2005) found that the actual use of notetaking strategies observed was lower than the self-report of notetaking strategies. Similarly, other studies have found college students’ judgments of their own studying strategies and learning to be limited (C. Brown, 2005; Peverly et al., 2003; Pressley et al., 1997; Pressley & Ghatala, 1990; Pressley & Ghatala, 1998).

Also, the procedures used in the current experiment may have contributed to a limited opportunity to apply metacognitive skills. The procedure asked subjects to use their lecture notes to create a study-sheet summarizing the lecture content. In an actual studying situation, a student has the opportunity to clarify incomplete or confusing information during review, and to access other related information via class readings or other reference material to clarify any misunderstanding. In the current study, subjects were only able to rely on their notes and any other memories of the lecture.

Predictors of Test Performance

In the relationship between the various cognitive variables (letter speed, language comprehension, sustained attention, background knowledge, and metacognition), notetaking, notes-review and performance on a multiple-choice test, it was hypothesized that only notes-review would be significantly related to test performance, for both memory and inference items. However, because of the poor reliability of the multiple-choice test, the findings should be interpreted with caution.

Notes-review. As hypothesized, notes-review was a predictor of overall test performance, as well as for performance on inference items. This finding is consistent with those that found that notes-review was more strongly related to test performance than the encoding of notes (Kiewra, 1985a; Kobayashi, 2006). This is likely due to the opportunity to reorganize, summarize, and integrate information in the review phase that did not take place during the notetaking phase. Notes-review was not significantly related to performance on memory items.

While some studies (Gleason, 2012; Peverly et al., 2007; Peverly & Sumowski, 2012; Vekaria 2011) have shown that notetaking improved performance on memory but not understanding/inference items, other studies have shown that more elaborate notetaking, such as outlines or matrices, was related to performance on inference items (Kiewra et al., 1995; Kiewra, DuBois, et al., 1991). This suggests that the increased level of information processing that occurs through notes-review may serve a similar function as elaborative notetaking that transforms information from its verbatim presentation, and supports a generative function of notes-review. Thus, it may be that while the encoding process of notes may aid in supporting recall of information explicitly stated in the lecture, notes-review, in allowing further processing of the information, can support a higher level of understanding and opportunity to make connections and inferences within the lecture.

Writing medium. Results showed significant main effects for writing medium on the overall test score as well as on memory and inference items separately, with subjects in the handwriting group on average outperforming those in the typing group. This finding differs from that of Bui et al. (2013), who found that those who typed notes performed better than those who handwrote notes on a free-recall and short-answer test (Experiment 1). One possible explanation for why the two studies reached opposing conclusions is that Bui et al. (2013) did not include an opportunity for review in their comparison of handwritten and typed notes (Experiment 1). Another is that the study by Bui et al. (2013) used an audio recording of a passage read from a book rather than videos of lectures used for the current study and by Mueller and Oppenheimer (2014). Additionally, Mueller and Oppenheimer (2014) speculated that the instructions for notetaking in the study (Bui et al., 2013)—to record "as much of the lecture as possible," might have prompted notetaking practices that differ from those that might take place naturally, impacting the generalizability of the results to real-world settings. Additionally, challenges with reliability for the multiple-choice test in the current study may have also compromised results.

Findings from this study are more aligned with those of Mueller and Oppenheimer (2014), who in an experiment comparing handwriting/typing conditions and study/no-study conditions (Study 3) found a significant interaction between notetaking medium and opportunity to study, such that subjects who used handwriting to take notes and had an opportunity to study their notes before a test significantly outperformed the other groups. Mueller and Oppenheimer (2014) found that although the quantity of notes was predictive of test performance, and that those who typed took more notes than those who handwrote them, subjects in the handwriting group outperformed those in the typing group. They found that notetaking by handwriting resulted in less verbatim overlap with the lecture than typed notes, and that the transformation of lecture information in the notes resulted in greater depth of processing of the information during encoding. Further, the opportunity to study notes positively affected test performance, suggesting that the storage-function of notes was also stronger for handwritten notes than typed notes. It should be noted that the study phase for Mueller and Oppenheimer (2014) did not require a written product, and required participants to "study their notes before being tested." The notes-review process for the current study likely provided a further opportunity to engage in in-depth processing of the lecture material. Thus, the results support the generative function of notes, which may occur at both the encoding (note-taking) and external storage (review) stages of notetaking.

Additionally, Mueller and Oppenheimer (2014, Study 3) also found the interaction between notetaking medium and opportunity to study to be significant for factual, memory-based items, and to approach conventional levels of significance for conceptual, inference-based items. Current findings similarly indicated that subjects who handwrote notes and reviewed them outperformed those in the typing group for both memory and inference items.

Writing medium x language comprehension. The significant interaction between writing medium *x* language comprehension for memory items shows a positive relationship for the handwriting condition and a negative relationship for the typing condition. Those with higher language comprehension scores in the handwriting group showed stronger performance on memory items, whereas language comprehension was not related to stronger performance in the typing group. This suggests that higher language comprehension was a benefit to those in the handwriting but not the typing group on test performance for memory items.

Peverly and Sumowski (2012) suggested that for memory multiple-choice items, language comprehension might aid in the transfer of knowledge between newly acquired information via notetaking and the cues in the wording of test questions, which may not match how information was encoded. Current findings indicate that this might apply only to those in the handwriting group and not in the typing group. Verbal ability may not have aided in making connections between the questions and lecture content for the typing group due to lower depth of processing that occurred during notetaking and notes-review. Language comprehension skills may be less engaged while typing, as typing is faster, and thus linguistic resources may not need to be applied as much to make decisions about what is important and what to record. Per the generative function of notetaking and notes-review, this difference in depth of processing may have impacted outcomes in test performance for memory items.

Implications for Practice and Future Research

In examining interactions between cognitive variables, results of this study shed new light on research related to notetaking as a cognitively complex task that occurs within a limited capacity working memory. Previous studies have suggested that language comprehension, as a higher order process, is more readily and efficiently applied to understanding lecture when writing speed is efficient enough not to dominate the limited capacity resources of working memory (Gleason, 2012; Peverly & Sumowski, 2012; Peverly, Vekaria, et al., 2013; Reddington et al., 2015; Vekaria 2011). However, current findings suggest that faster letter speed does not appear to provide additional benefit to language comprehension in relation to notetaking or notes-review, and that language comprehension affects notetaking and notes-review independently of letter speed. Rather, the current study suggests that letter speed may moderate the relationship between metacognition and notetaking and between sustained attention and notes-review when letter speed is more efficient. It is recommended that future studies include interactions in their analyses to further explore the hierarchy of cognitive processes related to the complex tasks of notetaking and notes-review.

Further, the analyses in this study explained only 39% of the variance in the data for notetaking and 66% of the variance in the data for notes-review, the former of which is similar to results of related studies (Peverly & Sumowski, 2012; Reddington et al., 2015). Continued research may help account for a fuller understanding of the factors underlying notetaking and notes-review. One possibility would be to better operationalize the hypothesized constructs of the current study, for example in developing an objective and reliable measure of background knowledge. Another possibility is to incorporate additional constructs underlying notetaking and notes-review, such as goal orientation (Johnson, 2012).

The comparison of notetaking by hand and by computer in this study supported findings that handwriting for notetaking and notes-review results in better test performance than typing. It appears that handwriting may facilitate a greater depth of information processing than typing (Mueller & Oppenheimer, 2014). As such, it would be beneficial to explore how to better enhance test performance for those who choose to type for notetaking and notes-review. Thus, it may be beneficial to examine the effect of different notes-review tasks (e.g. explicit directions to organize notes) in comparison to a summary study-sheet as was done in the current study.

Additionally, a within-subjects study to compare notetaking by handwriting and by typing is likely to be helpful in further identifying and understanding differences in cognitive processes related to notetaking and notes-review by handwriting and by typing. Such a design would also allow for comparisons between individuals' preferred and non-preferred medium of notetaking and notes-review.

Limitations

The primary limitation of this study lies in the poor reliability of several measures. The multiple-choice test had poor internal consistency. In addition, as previously mentioned, the multiple-choice test for background knowledge had very poor reliability and was removed from analyses. A single-item asking participants to rate their knowledge of the content of the lecture was used as an alternative, which has obvious psychometric difficulties. Also the placement of the item in the study protocol—after completing the multiple-choice test—may have served more as a metacognitive judgment of learning (JOL) on their perceived test performance rather than as an indication of their prior familiarity with the material.

Other limitations of this study are the demographics of the subject pool, as well as the small sample size. While it is appropriate to use university students as subjects in a study about notetaking and notes-review, the subjects in this study were predominantly white (81.25%) and female (85%). In regard to the latter, studies have found significant gender differences in notetaking behaviors and related individual cognitive variables (Reddington et al., 2015). However, men are not well-represented in the current sample to adequately reflect such differences. Also, as subjects were recruited from two university courses within the same department, the majority (66.25%) also identified a common field of study—education, further limiting the generalizability of the findings. The small sample size and calculation of multiple interactions impact statistical power, and current results may underestimate the role of writing medium and individual cognitive variables on notetaking, review, and test performance. Future studies should utilize a larger sample to examine relationships between these variables.

Finally, the idiosyncratic nature of notetaking and notes-review, in which each individual may develop their own system of notetaking and notes-review, may not have aligned with the tasks of the current experiment. Those who take notes on a keyboard may not necessarily review them via typing, and those who review notes may not necessarily create a study-sheet. They may re-read, or re-write their notes for review, if they are reviewed at all.

Conclusions

This study examined the relationship between various cognitive variables and notetaking, notes-review and performance on a multiple-choice test. It also explored the impact of writing medium (handwriting or typing) on these relationships. In answer to the question of what makes a good notetaker, results showed that, consistent with previous studies, faster letter speed and higher language comprehension were important to successful lecture notetaking. Notetaking and language comprehension were identified as important to notes-review. Within the hierarchy of cognitive processes underlying the cognitively complex tasks of notetaking and notes-review, letter speed was found to be a basic cognitive skill that moderates the effects of higher order processes such as metacognition in relation to notetaking and sustained attention in relation to notes-review. In the relationship of between notetaking and notes-review to test performance, notes-review predicted performance on a multiple-choice test overall as well as for inference items.

As to the question of whether it matters if notes are taken via typing or handwriting, results appear to favor handwriting over typing. Despite faster letter speed for the typing group and a stronger relationship between typing and notes-review in comparison to the handwriting group, there were no significant differences in notetaking or notes-review between groups. However, handwritten notes-review showed evidence of more summarization and re-organization of information than the typing group, and handwriting significantly predicted test performance over typing. It appears that typing, which is faster, may result in a more superficial level of processing of lecture information compared to handwriting. Thus, while letter speed predicted notetaking, this study did not show an advantage to notes taken by computer. Rather, handwritten notes were associated with better test performance, presumably by facilitating greater depth of information processing of lecture.

Future research should focus on improving the reliability of measures used in the current study—specifically for background knowledge and test performance. Subsequent studies of cognitive processes underlying the complex tasks of notetaking and notes-review should continue to include interactions between the cognitive variables to provide evidence of hierarchical processing within a limited capacity working memory. In addition, future research should also consider within-subjects experimental designs to compare intra-individual differences related to writing medium and cognitive processes underlying notetaking and notes-review. Also, it would be beneficial to explore the effects of various notetaking and notes-review strategies to better understand differences in the generative effects of notetaking and notes-review as related to the notetaking medium.

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Appendix A

Lecture Transcript

Toni Griffin, A new vision for rebuilding Detroit

By 2010, Detroit had become the poster child for an American city in crisis. There was a housing collapse, an auto industry collapse, and the population had plummeted by 25 percent between 2000 and 2010, and many people were beginning to write it off, as it had topped the list of American shrinking cities. By 2010, I had also been asked by the Kresge Foundation and the city of Detroit to join them in leading a citywide planning process for the city to create a shared vision for its future. I come to this work as an architect and an urban planner, and I've spent my career working in other contested cities, like Chicago, my hometown; Harlem, which is my current home; Washington, D.C.; and Newark, New Jersey. All of these cities, to me, still had a number of unresolved issues related to urban justice, issues of equity, inclusion and access.

Now by 2010, as well, popular design magazines were also beginning to take a closer look at cities like Detroit, and devoting whole issues to "fixing the city." I was asked by a good friend, Fred Bernstein, to do an interview for the October issue of Architect magazine, and he and I kind of had a good chuckle when we saw the magazine released with the title, "Can This Planner Save Detroit?" So I'm smiling with a little bit of embarrassment right now, because obviously, it's completely absurd that a single person, let alone a planner, could save a city. But I'm also smiling because I thought it represented a sense of hopefulness that our profession could play a role in helping the city to think about how it would recover from its severe crisis. So I'd like to spend a little bit of time this afternoon and tell you a little bit about our process for fixing the city, a little bit about Detroit, and I want to do that through the voices of Detroiters.

So we began our process in September of 2010. It's just after a special mayoral election, and word has gotten out that there is going to be this citywide planning process, which brings a lot of anxiety and fears among Detroiters. We had planned to hold a number of community meetings in rooms like this to introduce the planning process, and people came out from all over the city, including areas that were stable neighborhoods, as well as areas that were beginning to see a lot of vacancy. And most of our audience was representative of the 82 percent African-American population in the city at that time. So obviously, we have a Q&A portion of our program, and people line up to mics to ask questions. Many of them step very firmly to the mic, put their hands across their chest, and go, "I know you people are trying to move me out of my house, right?"

So that question is really powerful, and it was certainly powerful to us in the moment, when you connect it to the stories that some Detroiters had, and actually a lot of African-Americans' families have had that are living in Midwestern cities like Detroit. Many of them told us the stories about how they came to own their home through their grandparents or great-grandparents, who were one of 1.6 million people who migrated from the rural South to the industrial North, as depicted in this painting by Jacob Lawrence, "The Great Migration." They came to Detroit for a better way of life. Many found work in the automobile industry, the Ford Motor Company, as depicted in this mural by Diego Rivera in the Detroit Institute of Art. The fruits of their labors would afford them a home, for many the first piece of property that they would ever know, and a community with other first-time African-American home buyers. The first couple of decades of their life in the North is quite well, up until about 1950, which coincides with the city's peak population at 1.8 million people. Now it's at this time that Detroit begins to see a second kind of migration, a migration to the suburbs. Between 1950 and 2000, the region grows by 30 percent. But this time, the migration leaves African-Americans in place, as families and businesses flee the city, leaving the city pretty desolate of people as well as jobs. During that same period, between 1950 and 2000, 2010, the city loses 60 percent of its population, and today it hovers at above 700,000.

The audience members who come and talk to us that night tell us the stories of what it's like to live in a city with such depleted population. Many tell us that they're one of only a few homes on their block that are occupied, and that they can see several abandoned homes from where they sit on their porches. Citywide, there are 80,000 vacant homes. They can also see vacant property. They're beginning to see illegal activities on these properties, like illegal dumping, and they know that because the city has lost so much population, their costs for water, electricity, gas are rising, because there are not enough people to pay property taxes to help support the services that they need. Citywide, there are about 100,000 vacant parcels.

Now, to quickly give you all a sense of a scale, because I know that sounds like a big number, but I don't think you quite understand until you look at the city map. So the city is 139 square miles. You can fit Boston, San Francisco, and the island of Manhattan within its footprint. So if we take all of that vacant and abandoned property and we smush it together, it looks like about 20 square miles, and that's roughly equivalent to the size of the island we're sitting on today, Manhattan, at 22 square miles. So it's a lot of vacancy.

Now some of our audience members also tell us about some of the positive things that are happening in their communities, and many of them are banding together to take control of some of the vacant lots, and they're starting community gardens, which are creating a great sense of community stewardship, but they're very, very clear to tell us that this is not enough, that they want to see their neighborhoods return to the way that their grandparents had found them.

Now there's been a lot of speculation since 2010 about what to do with the vacant property, and a lot of that speculation has been around community gardening, or what we call urban agriculture. So many people would say to us, “What if you just take all that vacant land and you could make it farmland? It can provide fresh foods, and it can put Detroiters back to work too.” When I hear that story, I always imagine the folks from the Great Migration rolling over in their graves, because you can imagine that they didn’t sacrifice moving from the South to the North to create a better life for their families, only to see their great-grandchildren return to an agrarian lifestyle, especially in a city where they came with little less than a high school education or even a grammar school education and were able to afford the basic elements of the American dream: steady work and a home that they owned.

Now, there’s a third wave of migration happening in Detroit: a new ascendant of cultural entrepreneurs. These folks see that same vacant land and those same abandoned homes as opportunity for new, entrepreneurial ideas and profit, so much so that former models can move to Detroit, buy property, start successful businesses and restaurants, and become successful community activists in their neighborhood, bringing about very positive change. Similarly, we have small manufacturing companies making conscious decisions to relocate to the city. This company, Shinola, which is a luxury watch and bicycle company, deliberately chose to relocate to Detroit, and they quote themselves by saying they were drawn to the global brand of Detroit’s innovation. And they also knew that they can tap into a workforce that was still very skilled in how to make things. Now we have community stewardship happening in neighborhoods, we have cultural entrepreneurs making decisions to move to the city and create enterprises, and we have businesses relocating, and this is all in the context of what is no secret to us all, a city that’s under the control of an emergency manager, and just this July filed for Chapter 9 bankruptcy.

So 2010, we started this process, and by 2013, we released Detroit Future City, which was our strategic plan to guide the city into a better and more prosperous and more sustainable existence -- not what it was, but what it could be, looking at new ways of economic growth, new forms of land use, more sustainable and denser neighborhoods, a reconfigured infrastructure and city service system, and a heightened capacity for civic leaders to take action and implement change. Three key imperatives were really important to our work. One was that the city itself wasn't necessarily too large, but the economy was too small. There are only 27 jobs per 100 people in Detroit, very different from a Denver or an Atlanta or a Philadelphia that are anywhere between 35 to 70 jobs per 100 people. Secondly, there had to be an acceptance that we were not going to be able to use all of this vacant land in the way that we had before and maybe for some time to come. It wasn't going to be our traditional residential neighborhoods as we had before, and urban agriculture, while a very productive and successful intervention happening in Detroit, was not the only answer, that what we had to do is look at these areas where we had significant vacancy but still had a significant number of population of what could be new, productive, innovative, and entrepreneurial uses that could stabilize those communities, where still nearly 300,000 residents lived.

So we came up with one neighborhood typology -- there are several -- called a live-make neighborhood, where folks could reappropriate abandoned structures and turn them into entrepreneurial enterprises, with a specific emphasis on looking at the, again, majority 82 percent African-American population. So they, too, could take businesses that they maybe were doing out of their home and grow them to more prosperous industries and actually acquire property so they were actually property owners as well as business owners in the communities with which they resided. Then we also wanted to look at other ways of using land in addition to growing food and transforming landscape into much more productive uses, so that it could be used for storm water management, for example, by using surface lakes and retention ponds, that created neighborhood amenities, places of recreation, and actually helped to elevate adjacent property levels. Or we could use it as research plots, where we can use it to remediate contaminated soils, or we could use it to generate energy.

So the descendants of the Great Migration could either become precision watchmakers at Shinola, like Willie H., who was featured in one of their ads last year, or they can actually grow a business that would service companies like Shinola. The good news is, there is a future for the next generation of Detroiters, both those there now and those that want to come.

So no thank you, Mayor Menino, who recently was quoted as saying, “I’d blow up the place and start over.” There are very important people, business and land assets in Detroit, and there are real opportunities there. So while Detroit might not be what it was, Detroit will not die.

Thank you.

Appendix B.

Lecture Elements for Scoring Notetaking and Notes-Review

	I. The crisis in Detroit
	a. Housing collapse
	i. 80,000 vacant homes
	ii. Living in one of only a few homes on their block that are occupied
	iii. Several abandoned homes/properties visible from where they sit on their porches
	iv. 100,000 vacant parcels city-wide
	1. Size of Detroit = 139 square miles
	a. Can fit Boston, San Francisco, and the island of Manhattan within its footprint
	2. Vacant/abandoned property smushed together = 20 square miles = Size of Manhattan
	iv. Illegal activities (e.g. Dumping)
	v. Utility costs rising due to lack of people to pay property taxes to support services
	b. Auto industry collapse
	c. Population had plummeted by 25 percent between 2000 and 2010
	d. Unemployment = 27 jobs per 100 people
	i. Different from Denver, Atlanta, Philadelphia where there is 35 to 70 jobs per 100 people
	e. Many people were beginning to write it off, as it had topped the list of American shrinking cities
	f. City under the control of an emergency manager
	g. This July filed for Chapter 9 bankruptcy
	II. The Speaker, Toni Griffin
	a. Asked by the Kresge Foundation and the city of Detroit to join in leading a citywide planning process for the city
	b. To help create a shared vision for its future.
	c. Popular design magazines were also beginning to take a closer look at cities like Detroit, "fixing the city"
	i. Speaker did an interview for the October issue of Architect magazine
	1. Asked by a good friend, Fred Bernstein
	2. They had a good chuckle over title, "Can This Planner Save Detroit?"
	a. Absurdity that a single person, let alone a planner, could save a city
	3. Sense of hopefulness that architects/urban planners could play a role in helping the city to think about how it would recover from its severe crisis
	d. Architect and an urban planner
	e. Worked in Chicago, speaker's hometown; Harlem, speaker's current home; Washington, D.C.; Newark, New Jersey

	f. Concern for unresolved issues related to urban justice, issues of equity, inclusion and access
	III. Planning Process
	a. Citywide planning process started September 2010
	a. Just after a special mayoral election
	b. Community meetings to introduce the planning process
	i. People came out from all over the city
	1. Stable neighborhoods
	2. Areas that were beginning to see a lot of vacancy
	ii. Audience was representative of the 82 percent African-American population in the city at that time.
	iii. Anxiety and fears among Detroiters evident in Q&A
	1. "I know you people are trying to move me out of my house, right?"
	2. Connects to story of African-Americans' families that are living in Midwestern cities like Detroit
	3. Fear of losing homes they have come to own through their grandparents or great-grandparents
	IV. History
	a. Great Migration (until 1950): Detroit population grew
	i. 1.6 million people migrated from the rural South to the industrial North
	1. For a better way of life
	2. Depicted in this painting by Jacob Lawrence "The Great Migration"
	3. Had little less than a high school education or even a grammar school education
	ii. Many found work in the automobile industry
	1. e.g. Ford Motor Company, as depicted in a mural by Diego Rivera in the Detroit Institute of Art
	iii. Home ownership and community building
	1. Work afford them a home, for many the first piece of property that they would ever know
	2. Building a community with other first-time African-American home buyers.
	iv. Peak population of 1.8 million in 1950
	b. 1950-2000: Second Migration: population decline
	i. Migration to the suburbs
	ii. The region grows by 30 percent 1. Migration leaves African-Americans in place 2. Families and businesses flee the city 3. City desolate of people as well as jobs
	iii. During that same period, between 1950 and 2000, 2010, the city loses 60 percent of its population, and today it hovers at above 700,000
	V. Response to Crisis
	a. Communities banding together to taking control of vacant lots
	i. Starting community gardens/urban agriculture
	1. Creating a great sense of community stewardship

	2. Benefits: provide fresh foods, provide work for Detroiters, very productive and successful intervention happening in Detroit
	3. Inadequacies: counters the purpose for which previous generations had left agrarian life to moved to Detroit
	ii. They want to see their neighborhoods return to the way that their grandparents had found them
	b. Third Wave of Migration
	i. A new ascendant of cultural entrepreneurs.
	1. Folks see vacant land and those same abandoned homes as opportunity for new, entrepreneurial ideas and profit
	2. Can move to Detroit, buy property, start successful businesses and restaurants, and become successful community activists in their neighborhood, bringing about very positive change
	ii. Small manufacturing companies making conscious decisions to relocate to the city
	1. Shinola, is a luxury watch and bicycle company
	a. Drawn to the global brand of Detroit's innovation
	b. Can tap into a workforce that was still very skilled in how to make things.
	c. Strategic plan, Detroit Future City, released in 2013
	i. Guide to a better and more prosperous and more sustainable existence
	ii. Not what it was, but what it could be
	1. Reconfigured infrastructure and city service system
	2. Heightened capacity for civic leaders to take action and implement change
	iii. Three key imperatives were really important to our work
	1. New ways of economic growth—Economy is too small
	2. Accept that we were not going to be able to use all of this vacant land in the way that we had before and maybe for some time to come
	a. Not traditional residential neighborhoods as we had before
	b. Urban agriculture productive, but not the answer
	3. Identify new, productive, innovative, and entrepreneurial uses for more sustainable and denser neighborhoods (stabilize communities with significant vacancy but population remained
	a. Neighborhood typologies, e.g. Live-make neighborhood
	i. Reappropriating abandoned structures and turn them into entrepreneurial enterprises
	ii. Opportunities for local population to own business and property within the community
	b. Alternative/new forms of land use
	i. Storm water management by using surface lakes and retention ponds, that create neighborhood amenities
	ii. Places of recreation that actually help to elevate adjacent property levels
	iii. Research plots to remediate contaminated soils, to

	generate energy
	VIII. Summary/Future outlook
	a. Opportunities for residents and those who want to move
	i. Work at companies coming in
	ii. Grow own business
	b. Important people, business and land assets in Detroit, and there are real opportunities there
	c. Detroit might not be what it was, Detroit will not die

Appendix C.

Lecture-Based Multiple-choice Test

1) Which statement about community gardens and urban farming would the speaker agree with most?

a) Urban farming will bring cultural entrepreneurs to the city of Detroit
b) Urban farming and community gardens has destroyed the Detroit economy
c) Urban farming underappreciates the history of a majority of Detroit's residents
d) Community gardens will give unemployed Detroiters a productive activity

2) When is Detroit most likely to have had the highest per capita income in the US?

a) 1880
b) 1920
c) 1960
d) 2000

3) What might best reflect the "global brand of Detroit's innovation?"

a) Press coverage in Architect magazine
b) The racial integration of popular music through the music of Motown
c) Its history as a center of worldwide automobile manufacturing
d) A company that can make both bicycles and watches

4) What is "Detroit Future City?"

a) A nickname for the city of Detroit
b) A book that was written by the speaker
c) The new manufacturing plant in development in Detroit
d) The strategic action plan for the redevelopment of the city of Detroit

5) By what percent did the population decline in Detroit between 2000 and 2010?

a) 10%
b) 25%
c) 30%
d) 60%

6) Which of the following was <u>not</u> mentioned as part of the redevelopment of Detroit?

a) Businesses relocating to Detroit
b) Community stewardship
c) Cultural entrepreneurs moving in
d) Automotive industry recovery

7) It is likely that, of the 50 largest cities in the country, Detroit has the highest

a) Organizational or corporate crime rate per capita
b) Burglary crime rates per capita
c) Unemployment rate per capita
d) Homelessness rate per capita

8) The First and Third Migration are similar because

a) both increase the population of the city
b) people are coming to work in factories
c) mostly African Americans are involved
d) people are coming from the south

9) Which of the following did not occur in Detroit in 2013?

a) The city came under the control of an emergency manager
b) The city filed for Chapter 9 bankruptcy
c) Special mayoral elections were held
d) The strategic plan to guide the city's was released

10) When coming into a new city to aid in development, the presenter is likely to recommend

a) Raising taxes
b) Investing in urban agriculture
c) Funding migration to the city
d) Talking to the residents

11) Which the geographical size of Detroit is equivalent to the combination of…

a) Los Angeles, Chicago, and Boston
b) Boston, San Francisco and Chicago
c) Boston, San Francisco and Manhattan
d) Washington, D.C., Chicago, and Manhattan

12) When did Detroit reach its peak population of 1.8 million residents?

a) 1950
b) 1970
c) 1990
d) 2010

13) Which was not listed as an issue important to the speaker?

a) Equity
b) Energy Conservation
c) Urban Justice
d) Access

The speaker, Toni Griffin, is from

a) New York, NY
b) Chicago, IL
c) Newark, NJ
d) Detroit, MI

14) Community Planning meetings were met with

a) Anxiety and concern
b) Hostility and opposition
c) A disproportionate representation of the population
d) Enthusiastic welcome

15) Per the speaker, community gardening/urban agriculture is a form of

a) Racial stereotyping through manual labor
b) Domestic labor that is dominated by women
c) Poor financial decision making
d) Responsible planning and management of available resources

16) Which statement is true about the city of Detroit?

a) There are more vacant lots than residents
b) There are more vacant lots than vacant homes
c) There are more vacant homes than vacant lots
d) There are more vacant homes than residents

17) Which of the following would <u>not</u> be a characteristic of a live-make neighborhood?

a) Abandoned structures reappropriated and turned into entrepreneurial enterprises
b) Home-based businesses grown to more prosperous industries
c) Transforming land to remediate contaminated soils, or to generate energy
d) Business owners becoming property owners

18) Which is <u>not</u> a proposed us of land in Detroit?

a) Storm water management
b) Places of recreation
c) Remediating contaminated soils
d) New housing developments

19) The Third Migration is expected to

a) Increase the racial diversity of the city
b) Improve community stewardship
c) Bring new business into the city
d) Decrease the population of Detroit

20) The Third Migration is expected to

a) Increase the racial diversity of the city
b) Improve community stewardship
c) Bring new business into the city
d) Decrease the population of Detroit

Appendix D.

Self-Rating of Background Knowledge

How familiar were you with the content of this lecture BEFORE today?

Very Unfamiliar			Neutral			Very Familiar
①	②	③	④	⑤	⑥	⑦

Appendix E.

Self-Rating of Metacognition[1]

Please read the following sentences and circle the answer that relates to you and the way you are when you are studying for a class. Please answer as honestly as possible.

1 = Never	2 = Seldom	3 = Sometimes	4 = Often	5 = Always

1. I am a good judge of how well I understand something	1	2	3	4	5
2. I can motivate myself to learn when I need to	1	2	3	4	5
3. I try to use strategies that have worked in the past	1	2	3	4	5
4. I know what the teacher expects me to learn	1	2	3	4	5
5. I learn best when I already know something about the topic	1	2	3	4	5
6. I draw pictures or diagrams to help me understand while learning	1	2	3	4	5
7. I ask myself if I learned as much as I could have once I finish a task	1	2	3	4	5
8. I ask myself if I have considered all options when solving a problem	1	2	3	4	5
9. I think about what I really need to learn before I begin a task	1	2	3	4	5
10. I ask myself questions about how well I am learning while I am learning something new	1	2	3	4	5
11. I focus on the meaning and significance of new information	1	2	3	4	5
12. I learn more when I am interested in the topic	1	2	3	4	5
13. I use my intellectual strengths to compensate for my weaknesses	1	2	3	4	5
14. I use different learning strategies depending on the situation	1	2	3	4	5
15. I ask myself periodically if I am meeting my goals	1	2	3	4	5
16. I find myself using helpful learning strategies automatically	1	2	3	4	5
17. I ask myself if there was an easier way to do things after I finish a task	1	2	3	4	5
18. I set specific goals before I begin a task	1	2	3	4	5

[1] Sperling, R. A., Howard, B. C., Miller, L. A., & Murphy, C. (2002). Measures of children's knowledge and regulation of cognition. *Contemporary educational psychology*, *27*(1), 51-79. doi:10.1006/ceps.2001.1091

Appendix F.

Background Knowledge Multiple-choice Test[2]

1) **Other than the Motor City and Motown, which is also a nickname for the city of Detroit?**
   a) The Model City
   b) The Big Easy
   c) The Paris of the Midwest
   d) City of Seven Hills

2) **Who was Antoine de la Mothe, Sieur de Cadillac**
   a) The first Governor of Michigan
   b) Founder of the city of Detroit
   c) First mayor of Detroit
   d) Founder of the Cadillac Automobile Company

3) **Who is Mayor Menino, who made the comment that that if he lived in Detroit, he'd "blow up the place and start all over"?**
   a) Current mayor of Detroit (2014)
   b) Mayor of New York in 2012
   c) Mayor of Detroit in 2011
   d) Mayor of Boston in 2013

4) **When completed in 1930, this nearly mile-long landmark became the first of its kind in the world**
   a) Detroit Windsor Tunnel
   b) Davison Freeway
   c) Detroit Boardwalk
   d) Northland Center

5) **Other than being an architect and an urban planner, Toni Griffin has also been**
   a) A university professor
   b) An Olympic athlete
   c) An industrial and organizational psychologist
   d) A member of the Council of the City of New York

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[2] *Select items taken from an online quiz: Looney, 2001, July 2. Detroit. [Quiz]. Retrieved May 3, 2014, from http://www.funtrivia.com/playquiz/quiz45276531c28*

6) **According to Crain's Communications Inc., which was the largest full-time employer in of Detroit residents in July 2013?**
   a) Michigan State Government
   b) Ford Motor Company
   c) University of Michigan
   d) Detroit Medical Center

7) **What is the tallest building in Detroit?**
   a) Guardian Building
   b) Renaissance Center
   c) Penobscot Building
   d) One Detroit Center

8) **Which of the following is <u>not true</u> about the Kresge Foundation?**
   a) One of the largest charitable foundations in the United States, second only to the Bill & Melinda Gates Foundation
   b) It is an organization that partners with organizations committed to creating opportunity for low-income people in America's cities
   c) It was established by Sebastian Kresge, of the S.S. Kresge Company, an incorporated chain of 5- and 10-cent stores that later became known as Kmart.
   d) It is a philanthropic private foundation headquartered investing Arts & Culture, Community Development, Detroit, Education, Environment, Health, and Human Services.

9) **Which professional sports team in Detroit has never won a national championship?**
   a) Tigers
   b) Pistons
   c) Lions
   d) Red Wings

10) **Geographically, Detroit is**
   a) On the border between Michigan and Wisconsin
   b) The largest city on the border between the US and Canada
   c) The state capital of Michigan
   d) The largest city on the Mississippi River

Appendix G.

Demographics Survey

1. Gender: ☐ Female ☐ Male ☐ Transgender ☐ Other

2. Date of Birth: ____________ Month ____________Day ____________Year

3. Is English your first language? ☐ Yes ☐ No

4. With which race/ethnicity do you identify?

☐ American Indian / Alaska Native	☐ Hispanic/Latino(a)
☐ Asian	☐ White
☐ Black/African-American	☐ Other (specify: _______________)

5. Which hand do you write with? ☐ Right ☐ Left ☐ Both

6. Year in school (circle one): 1 2 3 4 other: ___________

7. Have you ever been diagnosed with a reading disability? ☐ Yes ☐ No

8. Have you ever been diagnosed with a writing disability? ☐ Yes ☐ No

9. Have you ever been diagnosed with attention deficit/hyperactivity disorder? ☐ Yes ☐ No

10. What is your major? _________________

11. What is your minor? _________________

12. How many psychology courses have you taken: _______

13. Please estimate your overall academic average (select only one):

☐ A+	☐ B+	☐ C+	☐ D +	☐ F+
☐ A	☐ B	☐ C	☐ D	☐ F
☐ A-	☐ B-	☐ C-	☐ D-	☐ F-

☐ I prefer not to say

14. Do you take notes in most of your classes? ☐ Yes ☐ No

For the remaining items, please read the following sentences and circle the answer that relates to you and the way you are when you are studying for a class. Please answer as honestly as possible.

1 = Never	**2 = Seldom**	**3 = Sometimes**	**4 = Often**	**5 = Always**

15. I take notes by hand with pen/pencil and paper	1	2	3	4	5
16. I take notes by computer/laptop	1	2	3	4	5
17. I take notes by tablet	1	2	3	4	5
18. I take notes by other means *please specify*: ______________________________	1	2	3	4	5
19. I rewrite parts of my notes when I study	1	2	3	4	5

Appendix H.

Supplemental Figures

Figure 2.
Simple Scatter Plot of the Metacognition x Letter Speed Interaction for Notetaking

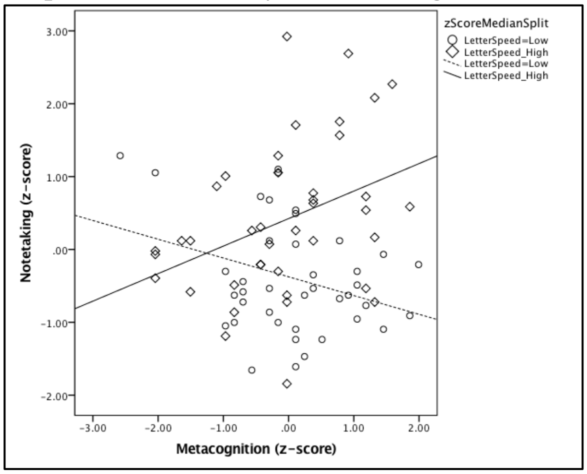

Figure 3.
Simple Scatter Plots of the Metacognition x Letter Speed Interaction for Notetaking—by Writing Medium

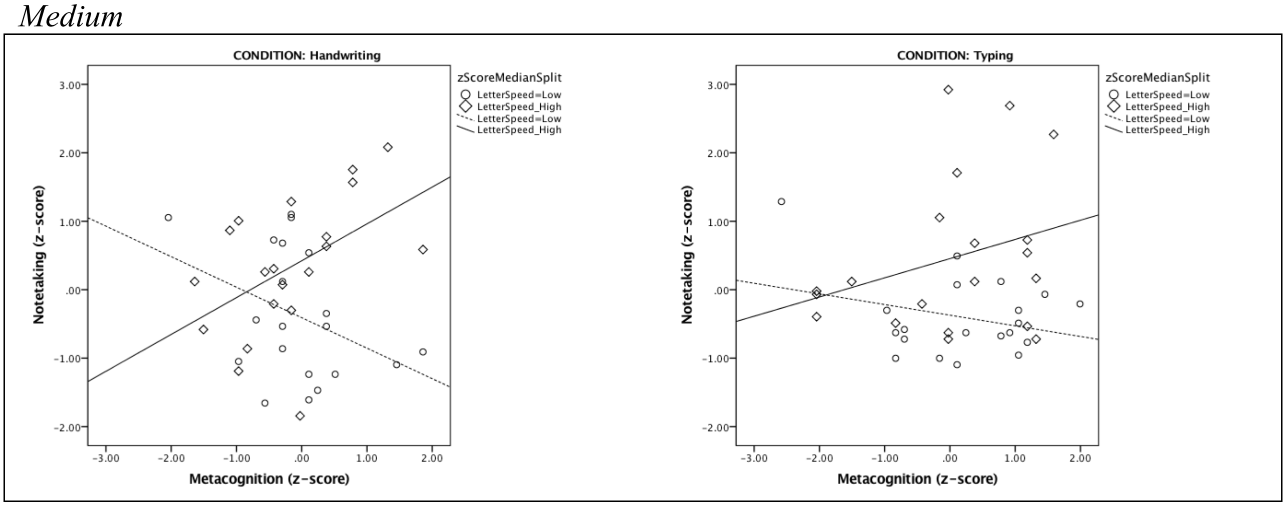

Figure 4.

Partial Regression Plots of Notetaking and Notes—by Writing Medium

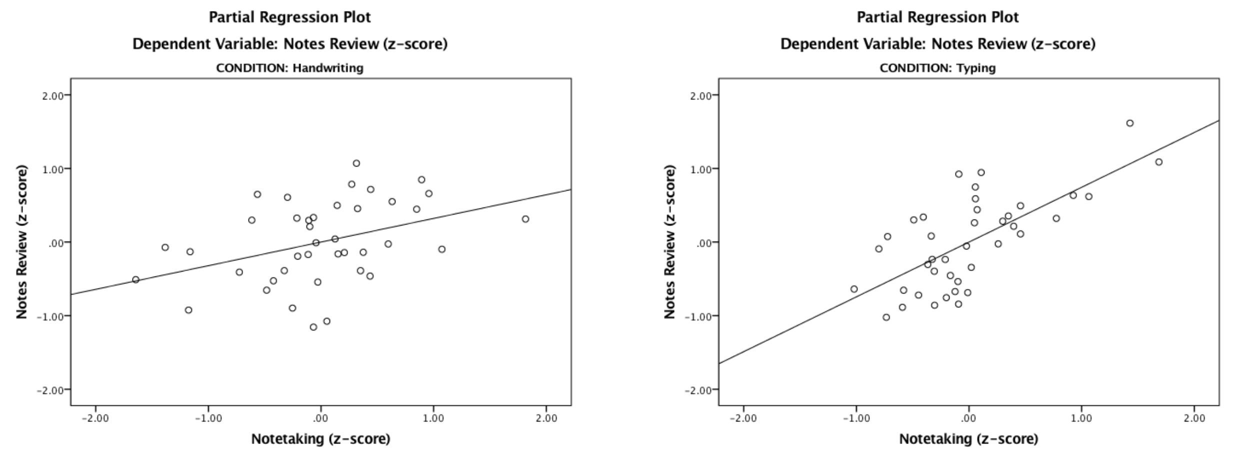

Figure 5.

Partial Regression Plots of Letter Speed and Notes-Review —by Writing Medium

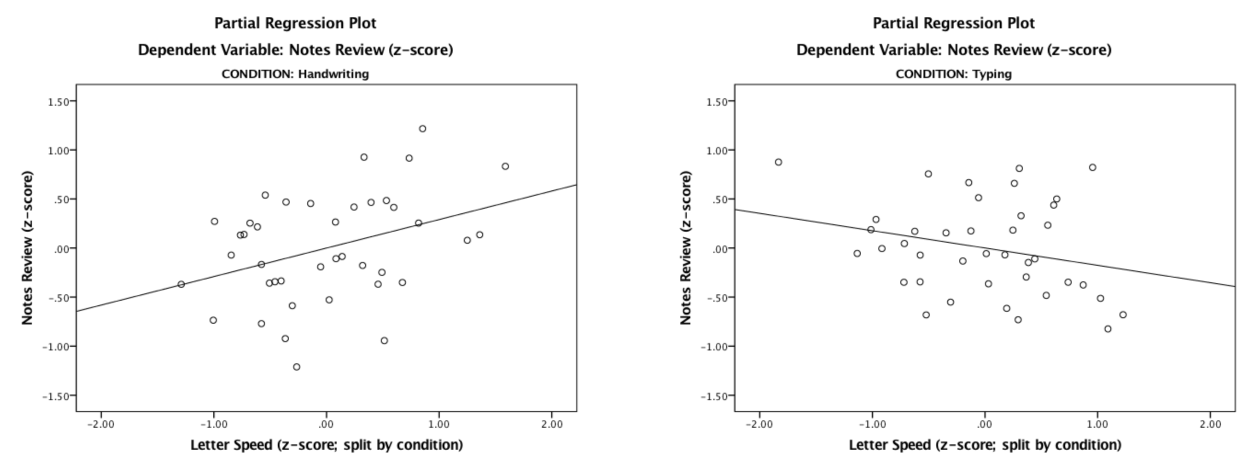

Figure 6.
Simple Scatter Plot of the Sustained Attention x Letter Speed Interaction for Notes-Review

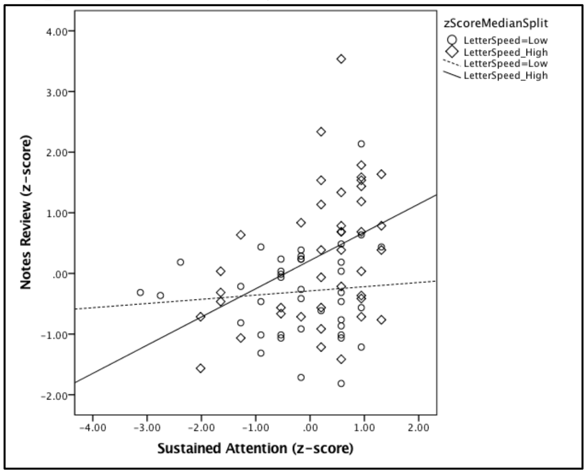

Figure 7.
Simple Scatter Plots of the Sustained Attention x Letter Speed Interaction for Notes-Review—by Writing Medium

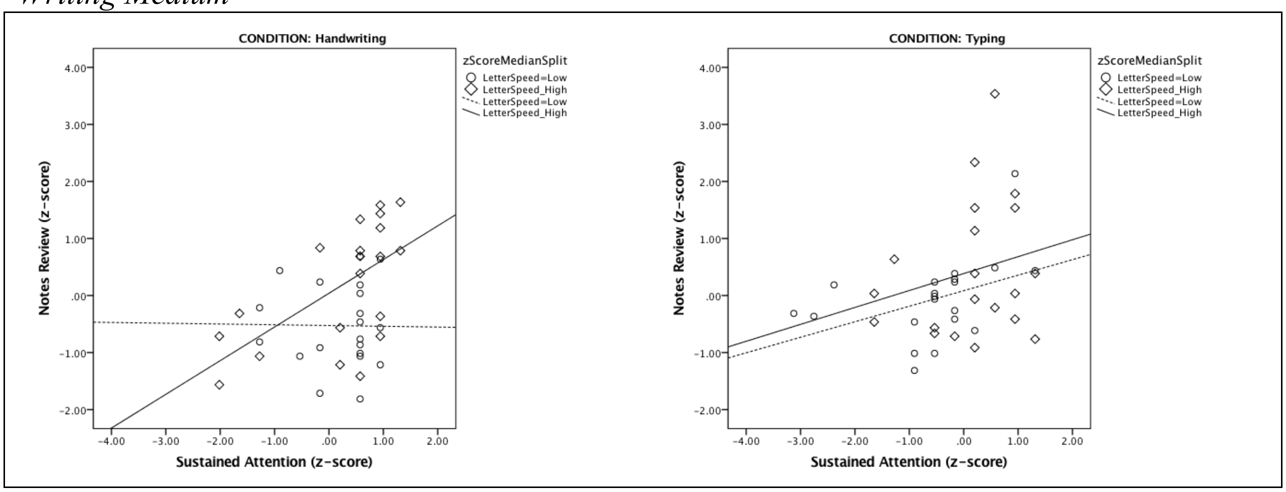

Figure 8.

Partial Regression Plots of Language Comprehension and Test Memory—by Writing Medium