1-1-2011

Individual Differences and Notetaking: Exploring Alternative Strategies for Improved Test Performance

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INDIVIDUAL DIFFERENCES AND NOTETAKING:

EXPLORING ALTERNATIVE STRATEGIES FOR IMPROVED TEST PERFORMANCE

by

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A thesis presented to the
Graduate School of Arts and Sciences
of the Washington University in
partial fulfillment of the
requirements for the
degree of Master of Arts

May 2011

Saint Louis, Missouri

Abstract

Three experiments examined notetaking strategies and their relation to test performance. In Experiment 1, participants handwrote or typed lecture notes, and were instructed to organize their notes or to transcribe the lecture. Notetaking with computers led to better test performance than taking handwritten notes. Moreover, transcribing with computers resulted in better test performance compared to those who took organized notes with computers. Because computers resulted in the best test performance, the subsequent experiments focused on notetaking using computers. Experiment 2 showed that organized notes produced the best recall after a delay, consistent with the levels-of-processing framework. However, when participants restudied their notes in Experiment 3, typing transcribed notes produced the best recall. Our results suggest that both the translation effect (Gathercole & Conway, 1988) and the levels-of-processing effect (Craik & Lockhart, 1972) improve test performance, but optimal learning results from a combination of the two. Correlational analyses of data from all three experiments revealed that for those who took organized notes, working memory predicted note-quantity, which predicted recall on both immediate and delayed tests. For those who took transcribed notes, in contrast, only note-quantity was a significant predictor. These results suggest that individuals with poor working memory (a skill traditionally thought to be needed for notetaking) can take effective notes, essentially "leveling the playing field" for individuals across the range of working memory abilities. Taken together, the study introduces a notetaking strategy (transcribing) that can be effective given the proper notetaking method (computers) for students of diverse cognitive abilities.

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The process of note-taking is familiar to just about everyone and may occur in a variety of situations, both academic and nonacademic. However, nowhere is the negative consequence of poor notetaking more evident than in classrooms, where students are evaluated on the basis of how much information they can retain from lectures, and where the idea of "notetaking" is often virtually synonymous with "class." Indeed, notetaking has long been linked to positive test performance (e.g. Crawford, 1925b; Armbruster, 2000). This relationship is not lost on students, who acknowledge lecture notetaking as a crucial component of the educational experience (Dunkel & Davy, 1989). In fact, lecturing constitutes nearly 83% of university instructors teaching methods (Wirt et al., 2001), and it should not be surprising that nearly all college students take notes in class (Palmatier & Bennett, 1974), even when they are not explicitly told to do so by the instructor (Williams & Eggert, 2002).

Recent advancements in technology have led to more and more computers being introduced into the classrooms and incorporated into students learning experiences. In addition, the availability of portable computers has resulted in a steady increase in the number of college students who own one (89%; Smith & Caruso, 2010). The combination of portability, flexibility, and affordability of laptops has made them ideal for students to use even when they are not at home. With more universities providing wireless internet throughout campus, students are able to do on campus what they could do at home with their computers. And though many students still prefer to take notes via handwriting, it should come as no surprise that many students also prefer to take notes using a computer (Efaw, Hampton, Martinez, & Smith, 2004) Research has compared typing speed to writing speed, and found evidence indicating that proficient typists type faster than they can handwrite (Brown, 1988), and that this pattern emerges in children as young as sixth-grade (Rogers & Case-Smith, 2002). Thus, in addition to the conveniences that laptops provide for students, it seems as though for many students, portable computers can also increase transcription speed during notetaking of lectures.

The Dual Benefits of Notetaking

Research has identified two primary ways in which classroom notetaking is beneficial: encoding and external storage (DiVesta & Gray, 1972). The encoding benefit (sometimes referred to as the process benefit) refers to the learning that results from the act of taking notes, and suggests that when students take notes, they are processing the information on a meaningful level (e.g., Peper & Mayer, 1978; Bretzing & Kulhavy, 1979). The external storage benefit (sometimes referred to as the product benefit) refers to the benefit that comes from restudying the notes. In other words, notetaking facilitates learning not only when we restudy our notes, but also when we actually take them.

Several studies have focused on determining to what extent each of the two aspects of notetaking plays a role in learning. Whereas some studies indicate that the encoding function is more beneficial (e.g., Annis & Davis, 1975; Barnett, DiVesta, & Rogozinski, 1981), others have provided data suggesting that the external storage component is more important for students (e.g., Howe, 1970a; Carter & Van Matre, 1975). But as Kiewra (1985) argues, there is evidence pointing to *both* aspects of notetaking being utilized in conjunction as being a more potent learning tool than any of those aspects on its own (e.g., Fisher & Harris, 1973; Kiewra, DuBois, Christensen, Kim, & Lindberg, 1989), and that it serves little purpose for advancing educational instruction to focus solely on each component s relative contributions.

The Relation Between Working Memory and Notetaking

Taking notes on a lecture is quite different than taking notes on what to buy from a grocery store. Despite its benefits, lecture notetaking can be cognitively demanding. Typically, such notetaking requires holding information in short-term memory, organizing it, then writing it down before it is forgotten, all while attending to an ongoing lecture. As a result, students develop various strategies for notetaking, almost all for the purpose of maximizing their note quality. However, students notes can vary greatly for a number of other reasons, among them being individual differences in ability.

For example, some students are able to organize lecture ideas better than others. For some students, the language of the lecture may not be that student s primary language, therefore hindering their ability to comprehend the lecture at the necessary speed (Dunkel, Mishra, & Berliner, 1989). Some students may suffer from dyslexia, and often report experiencing difficulties taking notes (Mortimore & Crozier, 2006). In short, the degree of efficiency with which certain cognitive operations are performed can vary from one individual to another, which in turn creates variability in how well people can perform more complex tasks. Those who are fluent in lower-order cognitive abilities are able to execute more complex tasks (in this case, notetaking) with more ease than those whose lower order abilities may not operate at such a high level. Indeed, ample evidence suggests that if basic skills are not autotomized, the ability to execute other higher order abilities that rely on those basic skills are compromised (e.g., Baddeley, 2000; Ericsson & Kintsch, 1995; Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977).

One cognitive ability hypothesized to be important in notetaking is working memory: our ability to temporarily hold and manipulate a limited amount of information

(Baddeley, 1986). If notetaking requires an ability to effectively take what the instructor is saying and organize that information into something more succinct and meaningful, then it may be reasonable to expect that working memory plays a role in such a skill. In fact, results from a study by Olive and Piolat (2002) show that reaction time to a secondary task was much slower for people who were composing (which, according to the authors, required retrieval of information from long-term memory, organization of the content, and goal planning) text compared to those who were simply copying down a text, suggesting that the composition of text requires executive control (which has been thought to be critical in the performance of working memory tasks; Engle, Tuholski, Laughlin, & Conway, 1999). To date, there have been relatively few empirical studies examining the link between working memory and notetaking (see Piolat, Olive, & Kellogg, 2005, for a more recent work examining the relationship). While some studies have demonstrated a correlation between working memory and notetaking (e.g., Kiewra & Benton, 1988; Kiewra, Benton, & Lewis, 1987; McIntyre, 1992), other studies have not been able to conclude that relationship (e.g., Cohn, Cohn, & Bradley, 1995; Peverly et al., 2007).

As Peverly et al. points out, the differences in these findings can be partly attributed to what tasks were used to assess working memory. In the three studies that did show a significant correlation, working memory was assessed using tasks not typically used by cognitive psychologists. Conversely, Cohn et al. (1995) and Peverly et al. (2007) assessed working memory with more traditional complex span tasks that were first introduced by Turner and Engle (1989; operation span) and Daneman and Carpenter (1980; reading span). However, in the two studies that did not find a significant correlation (or even in the three studies that did show a correlation), it is unclear as to whether participants were told to explicitly organize and paraphrase their notes. In fact, Cohn et al. s data was collected in the context of a classroom environment, making it unlikely that students were given instructions as to how to take notes.

Although the effect of specific notetaking instructions was not of interest in these studies, the lack of explicit instructions as to how to take lecture notes in all the studies described examining the link between working memory and notetaking raises an interesting point: it is possible that mixed findings regarding the relation between working memory and notetaking is due to the variability in notetaking strategies that students naturally engage in. Without explicit instructions as to how to take notes, there is no guarantee that a given sample of participants will all organize and paraphrase their notes (and thus have to rely on working memory); instead, some may choose strategies that rely less on working memory. The resulting variability in notetaking strategies can potentially mask a correlation between working memory and notetaking that would have otherwise been there if all participants attempted to take organized notes.

It should also be pointed out that the qualitative relation between working memory and notetaking may be different when the notetaking is done using computers, and that no study to date has examined the cognitive demands of notetaking with computers. Olive and Piolat (2002) have argued that handwriting notes places cognitive demands on the notetaker to not execute motor movements and with their hands to write down information, but to monitor the spatial position of their hand relative to the paper (making sure letters and words are appropriately spaced apart, or making sure the words fit on the current line of the paper). But since computer word processors often automatically maintain consistent spatial alignment, it is possible that some of the cognitive demands of physically handwriting notes do not exist when notes are being typed. Given that, it would not be unreasonable to believe that the role of working memory in notetaking is different for when notes are taken by hand than when it is taken by computer.

Currently, it is unclear whether certain components of working memory play a vital role in notetaking, or whether working memory is important only for select notetaking strategies. Nonetheless, if notetaking, like other cognitive skills, relies on our basic processing abilities, then it would not be too surprising that individual differences in such abilities might account for much of the variance in notetaking quality as it relates to test performance. And if taking notes in and of itself serves as a learning event, then we would expect to see individual differences predict test performance in similar ways even when individuals are not allowed to restudy their notes.

The Relation between Note-Quantity and Test Performance

As mentioned previously, the act of notetaking is beneficial in of itself, independent of restudying. One possible consequence of this encoding benefit of notetaking is that taking more notes will lead to better learning, because taking more notes means that students are encoding a greater quantity of information. Is more really better   The answer seems to be "yes": studies have shown a significant relation between note-quantity and test performance when students are allowed to restudy their notes (e.g., Crawford, 1925a; Nye, Crooks, Powley, & Tripp, 1984; Kiewra & Benton, 1988; Kiewra, Benton, Kim, Risch, & Christensen, 1995), as well as when students are not allowed to restudy their notes (e.g., Howe, 1970b; Fisher & Harris, 1973; Aiken, Thomas, &

Shennum, 1975). Findings from a study done by Peverly et al. (2007) found that transcription fluency (how fast one can take notes) predicted notetaking, which in turn predicted test performance. In the context of the Peverly et al. study, what seemed to matter most is how fast students can take notes, and that students who can take notes faster take more notes than those who cannot take notes quite as fast.

The idea that more notes leads to better test performance is most certainly intuitive on the external storage level: a student with more notes has more material to restudy, and therefore receives additional learning on more of the information that is likely to be tested. However, the notion that more notes leads to better test performance even without restudying them highlights the encoding nature of notetaking. As mentioned earlier, the encoding benefit arises in part because information conveyed in the lecture is processed on a meaningful level and at times is integrated the student s previous knowledge, such that as students record a greater quantity of notes, they are also processing more of the lecture information.

The benefit that is gained from simply writing down what is said in lecture can also be explained by the "translation hypothesis" (Conway & Gathercole, 1990), which suggests that memory benefits when input activities require translation between specialized processing domains because memory representations becomes more distinct compared to one another, leading to higher levels of learning. For example, listening to a lecture requires phonological processing, whereas writing down what was said in that lecture invokes orthographical processing. To the extent that a notetaker has to translate information from one modality to a different one (in this case, translating phonological information to orthographical information), notetaking will benefit from the hypothesized translation effect. In fact, an earlier study by Gathercole and Conway (1988) showed that writing printed words did not provide a memory advantage over reading the printed words. Presumably, writing down a printed word does not require translation between domains as both the input and output are orthographic. The translation hypothesis provides an intriguing explanation as to why quantity of notes is positively correlated with test performance: Writing down more of what was said in lecture leads to translation of more material across modalities, resulting in more, and better memory representations.

Notetaking Quality and the Encoding Benefits of Notetaking

It is not uncommon for instructors to emphasize notetaking quality to their students. In general, notetaking quality can be thought of as reflecting how deeply the lecture information is processed when the notes are actually taken, and it is assumed that to the extent that students engage in deeper semantic processing of the lecture information, the quality of notetaking will be high and the information will be better learned by the student (Einstein, Morris, & Smith, 1985). In other words, notetaking quality reflects the depth at which students engage in the encoding process of notetaking. Not surprisingly, this is what instructors often want from their students, and it is precisely why instructors often times do not want their students to write down word for word what the instructor says. When taking transcribed notes, it is believed that the lecture information is not processed as deeply (e.g., Peper & Mayer, 1978; Bretzing & Kulhavy, 1979), which is consistent with the levels-of-processing framework which predicts that deeper encoding of information leads to better long term retention of information than shallow encoding (Craik & Lockhart, 1972).

Empirical studies that attempt to manipulate levels of notetaking are relatively scarce, and most of those studies did not actually examine note content to assess differences in notetaking quality. Of the few studies that did examine note content as a manipulation check, it was found that quality of notetaking can be influenced to some degree through test expectancy (Rickards & Friedman, 1978) or direct instruction (Kiewra & Fletcher, 1984). The conclusion drawn by Kiewra (1985) was that although students may have preferred notetaking strategies that may be difficult to alter, quality of notetaking can in fact be experimentally manipulated.

Current Study

If note-quantity is such a strong predictor of test performance, will instructing students to take as much notes as possible be beneficial for learning? The established relation between note-quantity and test performance can be interpreted in at least two different, although not necessarily mutually exclusive, ways: one possibility is that people with better cognitive abilities are able to take notes faster, and that this leads to better test performance. In other words, note-quantity mediates the relation between cognitive ability and test performance. An alternative explanation is that greater note-quantity leads to better test performance independent of cognitive abilities, and that taking down more notes is potentially beneficial to everyone. If the latter case is true, then instructing individuals to take down as many notes as possible (through the instruction to take transcribed notes) should be directly beneficial for test performance. Although some have suggested that transcribing does not lead to any encoding benefits (Bretzing & Kulhavy, 1979), it seems more likely that the information recorded by students is encoded to some degree, even if minimally. Additionally, the benefit of translating information across modalities should be greater for those who take down more information, and should be independent of notetaking quality.

Moreover, if note-quantity is important in and of itself, can computers provide a means by which students can take notes down faster? With the relatively widespread availability of computers, we are introduced with the prospect of increasing transcription speed via this technology. If transcription speed plays such a major role in notetaking as suggested by Peverly et al. (2007), and if typing with a computer is so much faster than writing by hand (Brown, 1988), then computers would appear to provide an opportunity to increase note-quantity for virtually all students, which in turn would improve test performance.

Finally, if individual differences play an influential role in notetaking, then a third question that naturally arises from this is "How can we help individuals with lower cognitive abilities improve their notetaking ability so that they can improve test performance " If notetaking relies on working memory when students are trying to organize lecture information on the fly, then instructing students to not try and mentally organize their notes should reduce or eliminate any reliance on working memory. In fact, telling students to write down everything the instructor says should utilize minimal working memory, since students are simply transcribing word for word what is said during lecture.

In short, one aim of this study is to examine the relative efficacy of taking notes by hand versus using a computer, and to see if learning benefits differ when people take organized notes or transcribed notes. The other aim of this study is to examine the role of working memory in notetaking when students are either trying to take organized notes or trying to take transcribed notes. Unlike some other cognitive skills, it is not the case that the only way to help people improve their notetaking skills would be to try and make them faster (through lots of practice) or develop their working memory (through adaptive training procedures). As mentioned, there is now a technological advance that allows everyone to become faster. Therefore, almost everyone could benefit from taking faster (and thus, more) notes. And though it is natural to assume that the keyboard will increase note quantity for all students, it may very well be the case that the benefits of using a keyboard are greater for students who do not have the efficient working memory skills needed for notetaking than for those who are already adept at taking notes.

Experiment 1 examines the relation between different notetaking instructions (organizing or transcribing) and notetaking methods (hand or computer) in the context of an immediate test when people are not allowed to restudy their notes. Experiment 2 examines how the variables of interest in Experiment 1 influence performance on a delayed test. Finally, Experiment 3 examines the effects of restudying notes on delayed test performance.

Experiment 1

Method

Participants

Eighty undergraduate students (53 females and 27 males; mean age = 19.2 years, SD = 1.2) at Washington University, all of whom were proficient English speakers, participated for course credit.

Materials

Participants were tested individually in a private testing room equipped with a PC and a 15-inch monitor that was used for stimulus presentation on all tasks. Notetaking was done using either pen and paper or computer and keyboard, depending on the condition. On the free-recall and short-answer tests, all participants responded using the computer keyboard.

Complex Span Task. A reading span task was used to assess working memory capacity (Daneman & Carpenter, 1980). In this task, participants were shown a series of sentences and digits. A green fixation cross was presented prior to each series, and participants then pressed the spacebar key to begin the series. After reading each sentence aloud (e.g., "She is listening to music", "She is smelling music"), participants used a mouse click to report whether or not the sentence was sensible at which time the sentence disappeared and a digit (e.g., "7", "3") appeared on the screen for 1.5 seconds, and participants read the digit aloud. At the end of each series, participants were cued to recall the digits aloud in the order of presentation. Following recall, participants pressed the spacebar to begin the next series. Following five practice series, participants were administered twelve series, each of which consisted of from two to seven sentences and digits.

Lexical Decision Task. Processing speed was measured using a lexical decision task in which participants were shown strings of letters (e.g., bin , mun) that were presented one by one on a computer monitor. For each string of letters, participants made a decision as to whether or not it was a real English word. To report their decision, participants used a keyboard with the labels “yes” and “no” assigned to the “z” and “ ” keys, respectively. Participants were told to report their decisions as quickly and accurately as possible. The task consisted of ten practice trials followed by forty experimental trials.

Lecture. All participants listened to an 11-min lecture that discussed the inaccuracy of Hollywood s films portraying historical events, and the ways in which movies can distort our knowledge of history. The lecture consisted of a passage from a nonfiction book (Carnes, 1995) in which a popular film from the 1930 s (*The Charge of the Light Brigade*) is compared with the event it depicted (the Crimean War). None of the participants in any of the three experiments in the present study had ever seen the film, nor knew anything about the Crimean War.

The 1541-word passage was read aloud and recorded in a sound-proof room. The recording was then presented to participants through the computer speakers. This particular passage had been used previously by Rawson and Kintsch (2005) who modified the passage and developed a scoring system in which select idea units represented main points, important details, or unimportant details of the passage. Out of the 125 total idea units, eight of the idea units were classified as representing main points, fifteen as representing important details, and sixteen as representing unimportant details (for further details, see Rawson & Kintsch, 2005, Exp. 2).

Tests. Two types of test, free recall and short answer, were used to assess memory for the passage. The short answer test was taken from Rawson and Kintsch (2005) and consisted of eighteen questions, of which eight were about important details in the passage, and the other ten were about unimportant details.

Design and Procedure

A 2 (instruction: organize, transcribe) x 2 (method: hand, computer) between-subjects design was used. Following collection of demographic information, participants performed the tasks in the following order: complex span task, lexical decision task, lecture notetaking, free-recall test, and then short-answer test.

Participants were told that they would be listening to the lecture just once and were instructed to take notes for an upcoming test. Further instructions were given as to how the notes should be taken. For those in the "organize" condition, participants were told to paraphrase and organize their notes as much as possible. Those in the "transcribe" condition were told to write down as much of the lecture as possible. In addition, participants in the "hand" condition were provided a notepad and a pen, and participants in the "computer" condition were told to type their notes onto a computer word processor. After these instructions, the experimenter started the audio file and left the room.

When participants finished listening to the lecture, the experimenter made the notes unavailable to the participants and told them that they would now be taking a test on the passage they had just listened to. The free-recall test was given first, in which participants were told that they had ten minutes to recall as much information as they could remember from the lecture. All participants were given the full ten minutes, regardless of how much information they were able to recall. Following the free-recall test, participants were told that they would take a short-answer test. Before they started, participants were asked to estimate what percentage of the short answer questions they thought that they would answer correctly. They then were told that they would have ten minutes to complete the short answer test. As was the case with the free-recall test, all participants were given the full ten minutes to complete the short-answer test.

Results

The groups assigned to the four conditions did not differ in either working memory, $F(1, 76) = 1.63$, $p = .19$; or processing speed, $F(1, 76) = 0.10$, $p = .96$. Correlation analyses involving these variables with test performance will be discussed in a later section. Two independent raters, blind with respect to the conditions, scored all of the notes and the free-recall responses; inter-rater reliability was .85 and .82 for notes and free-recall responses, respectively. Participants were given either a full point for recall of an entire idea unit, half a point for partial recall of that idea unit, or zero for no recall. Discrepancies in scoring were resolved by taking the average of the two scores given by each rater. Scores in each category (overall recall, main points, and recall of important and unimportant details) were then converted into reflected proportion of the maximum number of points possible (125, 8, 15, and 16, respectively). The proportions of total idea units, main idea units, important details, and unimportant details were each analyzed using a separate 2 (instruction: organize vs. transcribe) x 2 (method: hand vs. computer) analysis of variance (ANOVA).

Table 1
Exp. 1: Proportion of idea units in notes (standard deviations in parentheses)

Group	Overall	Main	Important Details	Unimportant Details
Hand				
Organize	.28 (.12)	.54 (.15)	.41 (.08)	.20 (.16)
Transcribe	.28 (.10)	.46 (.16)	.33 (.12)	.24 (.12)
Computer				
Organize	.34 (.13)	.50 (.16)	.48 (.10)	.26 (.17)
Transcribe	.44 (.12)	.59 (.15)	.53 (.13)	.41 (.14)

Note. Numbers indicate the mean proportions of the total of 125 idea units, 8 main points, 15 important details, and 16 unimportant details in the passage.

Notetaking. The mean proportions of idea units in participants notes are provided in Table 1. With respect to the overall quantity of notes taken, there was an effect of instruction (organize vs. transcribe), $F(1, 76) = 4.18$, $p < .05$, as well as an effect of method (hand vs. computer), $F(1, 76) = 17.68$, $p < .001$, indicating that on average, computerized notes contained more total idea units than handwritten notes and transcribed notes contained more idea units than organized notes. There was an interaction between notetaking instruction and method, $F(1, 76) = 4.07$, $p < .05$, reflecting the fact that when using a computer, transcribing led to more notes than organizing, $t(38) = 2.71$, $p < .05$, whereas there was no difference between notetaking instructions when notes were taken by hand, $t(38) < 1.0$. With respect to the main idea units found in participants notes, there was no main effect of instruction, $F(1, 76) = 0.29$, $p = .87$; or method, $F(1, 76) = 1.76$, $p = .19$. There was an interaction, however, between the two factors, $F(1, 76) = 6.12$, $p < .05$. Independent t-test indicated that when taking organized notes, there was no difference between taking notes by hand or using a computer, *t*(38) = 0.82, *p* = .42; whereas when taking transcribed notes, using a computer led to the recording of more main idea units than taking notes by hand, *t*(38) = 2.68, $p < .05$. There was an effect of method on the amount important details was recorded in participants notes, *F*(1, 76) = 28.32, $p < .001$, reflecting the greater quantity of important details in computerized notes, but there was no main effect of instruction, *F*(1, 76) = 0.26, *p* = .61. An interaction between the factors was found, *F(1*, 76) = 6.04, $p < .05$, indicating that when using a computer, transcribing did not lead to more recording of important details notes than organizing, *t*(38) = 1.28, *p* = .21, although taking organized notes led to more important details than transcribed notes when it was done by hand, *t*(38) = 2.30, $p < .05$. Finally, when analyzing notes for unimportant details, there were effects of both instruction, *F*(1, 76) = 7.96, $p < .01$, and method, *F*(1, 76) =11.71, $p < .01$, indicating that notes taken with a computer contained more unimportant details than notes taken by hand, and that transcribed notes contained more unimportant details than organized notes. However, the interaction between instruction and method was only marginally significant, *F(1*, 76) = 2.90, *p* = .09.

Table 2
Exp. 1: Proportion of idea units recalled on the free recall test (standard deviations in parentheses)

Group	Overall	Main	Important Details	Unimportant Details
Hand				
Organize	.12 (.05)	.17 (.10)	.18 (.09)	.10 (.08)
Transcribe	.12 (.04)	.17 (.12)	.21 (.10)	.08 (.07)
Computer				
Organize	.12 (.05)	.21 (.14)	.16 (.10)	.10 (.10)
Transcribe	.18 (.06)	.25 (.13)	.24 (.12)	.12 (.08)

Free Recall. Table 2 provides the mean proportions of idea units recalled by each group. In regards to overall recall, there was an effect of method, $F(1, 76) = 7.62$, $p < .01$, that indicated better free-recall performance for those who took computerized notes than for those who took handwritten notes. In addition, an effect of instruction showed that transcribed notes led to better free-recall performance than organized notes, $F(1, 76) = 7.82$, $p < .01$. There was also an interaction between the two factors, $F(1, 76) = 6.41$, $p < .05$, with *t*-tests confirming that taking transcribed notes led to higher overall free recall performance than taking organized notes when it done on computer, $t(38) = 3.36$, $p < .05$, whereas there was no difference between instruction in overall free recall when notes were taken by hand, $t(38) = 0.22$, $p = .83$.

Analyses of main idea units recalled indicated that there was an effect of method, $F(1, 76) = 4.73$, $p < .05$, in that the who had taken computerized notes recalled more main idea units than those who had taken handwritten notes. No main effect of instruction was found, $F(1, 76) = 0.47$, $p = .49$, nor an interaction between method and instruction, $F(1, 76) = 0.74$, $p = .39$. Recall of important details was affected by instruction, $F(1, 76) = 5.61$, $p < .05$, in that those who transcribed their notes recalled more important details than those who took organized notes, but there was no main effect of method, $F(1, 76) < .001$, $p = .99$, and no interaction between the factors, $F(1, 76) = 1.01$, $p = .30$. There were no main effects of method or instruction on unimportant details, $F(1, 76) = .73$, $p = .40$, and $F(1, 76) = 0.01$, $p = .93$, respectively, nor was there an interaction between instruction and method, $F(1, 76) = 1.41$, $p = .24$.

Table 3
Exp. 1: Proportion correct on short answer test (standard deviations in parentheses)

Group	Overall	Important Details	Unimportant Details
Hand			
Organize	.47 (.19)	.52 (.16)	.42 (.26)
Transcribe	.46 (.15)	.45 (.17)	.47 (.18)
Computer			
Organize	.50 (.20)	.53 (.20)	.46 (.25)
Transcribe	.64 (.12)	.72 (.16)	.58 (.13)

Short Answer. Table 3 shows performance on the short answer test questions. There was an effect of method on overall short answer performance, $F(1, 76) = 7.69$, $p < .01$, but only a marginal main effect of instruction, $F(1, 76) = 3.42$, $p = .07$, as well as an interaction between notetaking instruction and method, $F(1, 76) = 3.97$, $p < .05$. Independent t-tests confirmed that transcribing led to better short answer performance than organizing when notes were taken on computer, $t(38) = 2.76$, $p < .01$, whereas there was no difference in short answer performance when notes were taken by hand, $t(38) = 0.10$, $p = .92$. Analyses of important details did not reveal a main effect of instruction, $F(1, 76) = 1.99$, $p = .16$. However, there was an effect of method, $F(1, 76) = 12.85$, $p < .01$, as well an interaction between instruction and method, $F(1, 76) = 10.64$, $p < .01$. Test to localize the interaction revealed that after taking notes by computer, people who transcribed their notes performed better on short answer questions addressing important details compared to those who organized their notes, $t(38) = 3.15$, $p < .01$, but there were no differences found between the two instructions of notetaking when notes were taken by hand, $t(38) = 1.38$, $p = .18$. As for unimportant details, the main effect of instruction was at the trend level, $F(1, 76) = 3.14$, $p = .08$; there was no main effect of method, $F(1, 76) = 2.78$, $p = .10$, and no interaction between the two variables, $F(1, 76) = 0.58$, $p = .45$.

Discussion

The instruction to take transcribed notes led to greater note-quantity if people used a computer to take the notes, but not if they took notes by hand. Moreover, computer transcription was associated with the greatest quantity of notes regardless of what measure was used (overall number of idea units, main points, important details or unimportant details), with note-quantity not only exceeding that of organized computer notes but also that of both hand-written note strategies. Similar patterns emerged when examining test performance: Taking transcribed notes using a computer led to better free recall and short answer performance than taking organized notes. Most importantly, as was the case with notetaking, taking transcribed notes with a computer was associated with the best performance on both the free recall and short-answer tests, regardless of what measure was used (recall of overall number of idea units, main points, important details or unimportant details), with performance not only exceeding that of those taking organized computer notes but also that of those who used either hand-written note strategy. Working memory and processing speed did not differ significantly among the groups assigned to the four conditions, precluding the possibility that the observed differences in notetaking and test performance were due to differences in cognitive abilities.

Interestingly, for people taking notes by hand, telling them to write down as much as possible from the lecture did not result in more notes compared to telling them to paraphrase and organize the lecture. One possible explanation as to why transcribing by hand did not lead to more notetaking than organizing is simply because of the physical limitations imposed by handwriting. In other words, it is possible that an individual transcribing notes by hand cannot physically write fast enough or for a long enough period of time to establish more notes than someone who is organizing by hand. Moreover, those who took organized notes by hand did not do better on either the free-recall or short-answer tests, consistent with the view that note-quantity, and not note-quality, is what is important for test performance. This places an emphasis on the potential impact that computers can have on notetaking in classroom settings, as keyboards allow for faster notetaking for a longer period of time.

The ability to take more notes, of course, provides clear benefits for students from an external storage standpoint, since it means there is more information to restudy. However, participants in Experiment 1 were not allowed to restudy their notes, and thus differences in external storage cannot explain any of the differences in test performance among the four groups. Instead, it would seem more likely that any differences between groups were driven by the encoding benefit that comes with notetaking. Given that those who transcribed using a computer took the most notes and that the other three groups did not differ in quantity of notes, the encoding benefit would be strongest for people transcribing using a computer. Our results on both the free-recall and short-answer tests are consistent with what would be predicted based on encoding benefits   transcribing with a computer led to more notes and thus superior memory performance. Taken together, the results of Experiment 1 indicate that transcribing lecture notes using a computer not only yields a greater quantity of notes, but results in a benefit on both free-recall and short-answer tests.

One potential criticism/concern of taking transcribed notes is that students may do so at the expense of understanding and recording the important points of lecture. Our results suggest that this does not seem to be the case for those who took notes by computer: although people who transcribed their notes recorded more unimportant details than those who organized, there was no difference between those two groups in regards to the amount of main ideas or important details recorded in their notes. On the free recall test, the lack of differences on main ideas and important details between the two groups indicate that the greater quantity of notes for those who transcribed using a computer did not require the sacrificing of note quality. And because there were no differences in the amount of main ideas and important details recorded in each group s notes, it was not surprising to see that there were also no differences in the number of main ideas and important details recalled on a free recall test.

It is likely, however, that there is a difference in the quality of the information processing that takes place when people organize their notes versus when people transcribe their notes. Those in the organize condition were perhaps more likely to deeply process the lecture material into meaningful ideas than those in the transcribe condition, who were probably more likely to simply write down whatever they heard at the moment. If it is the case that there are differences in levels of processing between the two notetaking instructions, then clear-cut predictions can be drawn about long-term retention of the lecture material presented in this study. Specifically, it would be expected that the advantage of taking transcribed notes using a computer over taking organized notes with a computer would change over time, such that taking organized notes would lead to better long term learning compared to taking transcribed notes. This is consistent with the levels-of-processing framework, which predicts that deeper encoding of information will lead to better long term retention of the information than shallow encoding (Craik & Lockhart, 1972).

Experiment 2

Of primary interest in Experiment 1 was the finding that taking transcribed notes using a computer led to better immediate test performance than taking organized notes. For the reasons just given, however, that advantage may not hold when the test is delayed. Because differences in notetaking instruction were only found for those who used computers to take notes in Experiment 1 (which, in fact, led to the best performance overall), the two conditions in where participants took handwritten notes were not included in Experiment 2, and. all participants took notes using a computer. Experiment 2 was designed to test the clear predictions following from the levels-of-processing framework by examining how notetaking instructions affect performance on both an immediate test (a partial replication of Experiment 1) and a 24-hour delayed test.

Method

Participants

Seventy-six undergraduate students (37 females and 39 males; mean age = 19.4 years, SD = 1.3) at Washington University, all of whom were proficient English speakers, participated for course credit.

Materials

The materials used were identical to that used in Experiment 1.

Design and Procedures

A 2 (instruction: organize, transcribe) x 2 (test time: immediate, delay) between-subjects design was used. The procedures were also very similar to Experiment 1, except that there was no “hand” condition that is, all participants in Experiment 2 took organized or transcribed notes by computer only. After doing the complex span task, lexical decision task, and lecture notetaking, half the participants immediately were administered the free recall test followed by the short answer test, whereas the other half were tested after a twenty-four hour delay. Thus, the participants tested immediately (immediate condition) provided a replication of the conditions of interest in Experiment 1 (taking organized and transcribed notes with a computer).

Results

The groups assigned to the four conditions did not differ in either working memory, $F(1, 72) = 1.70$, $p = .17$; or processing speed, $F(1, 72) = 0.30$, $p = .83$. Both the notes and free recall were scored by two independent raters blind with respect to the conditions. Inter-reliability for notes and free recall were .84 and .91, respectively. Discrepancies in scoring were resolved by taking the average of the two scores given by each rater. A 2 x 2 ANOVA was performed on free recall performance for each of the four different types of recall.

Table 4
Exp. 2: Proportion of idea units recalled on free recall test (standard deviations in parentheses)

Group	Overall	Main	Important Details	Unimportant Details
Immediate				
Organize	.12 (.05)	.29 (.12)	.14 (.09)	.12 (.10)
Transcribe	.16 (.06)	.30 (.18)	.23 (.12)	.14 (.11)
Delay				
Organize	.11 (.04)	.30 (.10)	.17 (.11)	.06 (.07)
Transcribe	.07 (.05)	.19 (.09)	.12 (.11)	.05 (.05)

Note. Numbers indicate the mean proportions of the total of 125 idea units, 8 main points, 15 important details, and 16 unimportant details in the passage.

Free Recall. The mean proportion of total idea units recalled by each group is shown in Table 4. There was no effect of instruction on overall free recall, $F(1,72) = 0.07$, $p = .79$, but there was an effect of delay, $F(1,72) = 23.29$, $p < .001$, indicating that in general, free recall was higher when tested immediately as opposed to after a delay. There was also a delay by instruction interaction, $F(1,72) = 11.58$, $p < .001$, and pairwise comparisons indicated that taking transcribed notes led to better free recall performance on an immediate test than taking organized notes, $t(36) = 2.38$, $p < .05$, replicating Experiment 1. When testing took place after a delay, however, taking organized notes yielded better free recall performance, $t(36) = 2.47$, $p < .05$.

With regard to recall of main ideas, there was no effect of either instruction, $F(1, 72) = 2.93$, $p = .09$, or delay, $F(1, 72) = 3.13$, $p = .08$, but there was an interaction between instruction and delay, $F(1, 72) = 5.19$, $p < .05$. Independent t-tests revealed no effect of instruction on an immediate test, $t(36) = 0.34$, $p = .74$, but that taking organized notes led to more recall of main ideas than taking transcribed notes when testing took place after a delay, $t(36) = 3.71$, $p < .01$.

With regard to important idea units, again there was no effect of instruction, $F(1, 72) = 0.40$, $p = .53$, nor was there an effect of delay, $F(1, 72) = 2.80$, $p = .10$, but there was an interaction between instruction and delay, $F(1, 72) = 8.16$, $p < .01$. Follow-up tests revealed that taking transcribed notes led to better recall of important idea units compared to taking organized notes when testing was immediate, $t(36) = 2.59$, $p < .05$, but that when testing was done after a delay, there was no effect of instruction, $t(36) = 1.51$, $p = .14$. With regards to unimportant idea units recalled, there was an effect of delay, $F(1, 72) = 12.73$, $p < .01$, but no effect of instruction on recall of unimportant

Table 5
Exp. 2: Proportion correct on short answer test (standard deviations in parentheses)

Group	Overall	Important Details	Unimportant Details
Immediate			
Organize	.50 (.19)	.51 (.21)	.44 (.19)
Transcribe	.64 (.15)	.73 (.19)	.51 (.18)
Delay			
Organize	.48 (.19)	.51 (.20)	.37 (.19)
Transcribe	.37 (.15)	.40 (.18)	.27 (.14)

details, $F(1, 72) = 0.03$, $p = .87$, nor an interaction, $F(1, 72) = 0.39$, $p = .54$.

Short Answer. Table 5 shows performance on the short answer questions as proportion correct, with the scoring procedure identical to that used in Experiment 1. There was no main effect of instruction on overall recall, $F(1, 72) = .15$, $p = .70$, but there was an effect of delay, $F(1, 72) = 13.63$, $p < .01$, indicating that performance on immediate tests was better than performance on delayed tests. There also was an interaction between the two factors, $F(1, 72) = 10.34$, $p < .001$, and post hoc analysis replicated the finding in Experiment 1 that taking transcribed notes led to better short answer test performance compared to taking organized notes, $t(36) = 2.53$, $p < .05$. As hypothesized, when testing was done after a 24-hour delay, taking organized notes with a computer led to better short answer test performance than taking transcribed notes with a computer, $t(36) = 2.02$, $p < .05$.

Analyses of performance on short answer questions regarding important details revealed no main effect of instruction, $F(1, 72) = 1.60$, $p = .21$. There was an effect of delay, however, $F(1, 72) = 14.12$, $p < .001$, as well as an interaction between instruction and delay, $F(1, 72) = 14.20$, $p < .001$. Independent t-tests again replicated the finding from Experiment 1 that taking transcribed notes with a computer led to better performance on questions addressing important details compared to taking organized notes with a computer, $t(36) = 3.50$, $p < .01$. In the delay conditions, the finding that taking organized notes yielded better performance than taking transcribed notes was found to be marginally significant, $t(36) = 1.81$, $p = .08$.

Finally, there was no main effect of instruction on recall of unimportant details, $F(1, 72) = 0.10$, $p = .75$, although there was an effect of delay was found, $F(1, 72) = 14.75$, $p < .01$, as well as an instruction by delay interaction, $F(1, 72) = 4.09$, $p < .05$. Follow-up tests revealed that although there was no effect of instruction when testing was immediate, $t(36) = 1.15$, $p = .26$, the pattern indicating that taking organized notes resulted in higher performance on questions regarding unimportant details compared to taking transcribed note were marginally significant, $t(36) = 1.74$, $p = .09$.

Discussion

The results of Experiment 2 replicate the findings in Experiment 1 that transcribing using a computer leads to better performance on both immediate free recall and immediate short answer tests than taking organized notes with a computer. Of importance to this second study, however, was how these patterns changed over a delay. Whereas transcribing led to better performance than organizing on immediate tests , the pattern reversed over a 24-hour delay, such that taking organized notes yielded better test performance on both free recall and short answer tests compared to taking transcribed notes. This is consistent with a levels-of-processing account, which would predict better retention of the lecture material for the organize group than the transcribe group. Presumably, taking organized notes involved deeper and more thorough processing of the lecture information, whereas taking transcribed notes required only a shallow encoding of the information.

This reversal in pattern between immediate and delayed tests was not due simply to the fact that the participants who transcribed forgot at a faster rate than those who organized. In the instance of both the free recall and short answer tests, it was only the transcribe groups that showed evidence of substantial forgetting over a 24-hour delay, whereas the amount of forgetting seen in the organize groups was minimal. These results suggest that although transcribing with a computer may be an effective way to take notes, the benefits of such a strategy is very short-term. Indeed, if one s aim is for optimal long-term retention of information without having to restudy notes, then perhaps not surprisingly, taking organized notes seems to yield better results than transcribing. Of course, it is uncommon for students to take lecture notes and then to never restudy them before an exam. Although the goal of Experiment 2 was to examine how notetaking instructions affect retention over a delay, it is clear that in order to model more realistic educational scenarios, a third experiment is needed in which whether or not participants restudy their notes is manipulated.

Experiment 3

As established in Experiment 1, transcribing with a computer led to more notetaking and better immediate test performance than organizing, and the benefits in performance stemmed from an encoding benefit. In the present experiment, however, by having participants restudy their notes, we allow the external storage function of notetaking to influence test performance. Because we expect the transcribe group to take significantly more notes than the organize group, we expect the former group to have a distinct advantage from an external storage standpoint.

In Experiment 3, we test the hypothesis that people who take transcribed notes will benefit more from restudying compared to those who take organized notes. We do so by replicating the delayed test conditions in Experiment 2, and adding two novel restudy conditions. If external storage plays a critical factor in performance, we should expect to reverse the pattern in Experiment 2 (or put another way, to maintain the advantage of transcribing over organizing notes seen in Experiment 1). Again in Experiment 3, all notetaking is done by computer, and all testing is done after a 24-hour delay so that we can compare the long-term effects of restudying notes as a function of notetaking instruction.

Method

Participants

Seventy-two undergraduate students (47 females and 25 males; mean age = 19.0 years, SD = 0.9) at Washington University, all of whom were proficient English speakers, participated for course credit.

Materials

The materials used were identical to that used in Experiment 1 and 2.

Design and Procedure

A 2 (instruction: organize, transcribe) x 2 (study: restudy, no restudy) between-subjects design was used. Participants were told to either organize or transcribe their lecture notes using a computer keyboard. Although the tasks used in Experiment 3 did not differ from the first two experiments, the order in which those tasks were given was different in Experiment 3. Following the lecture, participants completed the complex span task and lexical decision task. When these two tasks were finished, half of the participants were given access to their notes again to restudy. By reordering the procedures and placing the complex span and lexical decision task between the lecture and restudying of notes, we created approximately fifteen minutes of delay between initial encoding of the lecture (through notetaking) and restudying of the notes. Participants in the restudy conditions were given five minutes to reread their notes, during which they were told to not alter their notes in any way. Participants in the no restudy conditions left the first experimental session without their notes again, which served as a replication of the conditions of interest in Experiment 2 (Transcribing and organizing with computers at a 24-hour delay). All participants returned twenty-four hours later to complete the testing portion of the experiment.

Results

As was the case in Experiment 1 and 2, there were no group differences in working memory, $F(1, 68) = 1.31, p = .28$; or processing speed, $F(1, 68) = 0.22, p = .89$. Both the notes and free recall were scored by two independent raters blind with respect to the conditions. Inter-reliability for notes and free recall were .90 and .82, respectively. Discrepancies in scoring were resolved by taking the average of the two scores given by each rater. A 2 x 2 ANOVA was performed on free recall performance for each of the four different types of recall.

Table 6
Exp. 3: Proportion of idea units recalled on free recall test (standard deviations in parentheses)

Group	Overall	Main	Important Details	Unimportant Details
No restudy				
Organize	.12 (.04)	.29 (.15)	.19 (.07)	.07 (.04)
Transcribe	.09 (.03)	.16 (.06)	.12 (.05)	.07 (.04)
Restudy				
Organize	.13 (.04)	.25 (.10)	.20 (.07)	.09 (.06)
Transcribe	.16 (.06)	.28 (.12)	.18 (.07)	.14 (.07)

Note. Numbers indicate the mean proportions of the total of 125 idea units, 8 main points, 15 important details, and 16 unimportant details in the passage.

Free Recall. Table 6 displays the mean proportion of total idea units recalled by each group. Results did not reveal a main effect of instruction, $F(1,68) = 0.27, p = .64$, but did indicate an effect of re-exposure, $F(1,68) = 16.50, p < .001$, along with an interaction between the two factors, $F(1,68) = 9.13, p < .001$. Independent t-tests replicated the finding in Experiment 2 that taking organized notes led to a higher proportion of total idea units recalled than taking transcribed notes, $t(34) = 2.28$, $p < .05$. However, when participants were allowed to restudy their notes, taking transcribed notes led to higher free recall performance compared to taking organized notes, $t(34) = 2.11$, $p < .05$, showing a reverse pattern of test performance from when participants are not allowed to restudy their notes.

There was a marginal main effect of instruction on recall of main idea units, $F(1,68) = 3.29$, $p = .07$, but no main effect of re-exposure, $F(1,68) = 2.03$, $p = .16$. However, there was an interaction between instruction and re-exposure, $F(1,68) = 8.48$, $p < .001$, where follow-up tests revealed that organizing resulted in more main idea units recalled than transcribing, $t(34) = 3.36$, $p < .05$, which again replicated the simple main effect found in Experiment 2. However, instruction of notetaking did not have an effect on performance when participants were allowed to restudy their notes, $t(34) = 0.78$, $p = .44$. There was an effect of instruction on recall of important ideas, $F(1, 68) = 6.51$, $p < .05$; as well as an effect of re-exposure, $F(1, 68) = 4.55$, $p < .05$. An interaction between instruction and re-exposure on recall of important ideas was marginally significant, $F(1, 68) = 3.13$, $p = .08$. The effect of instruction on recall of unimportant details was marginally significant, $F(1, 68) = 3.14$, $p = .08$, though an effect of re-exposure was found, $F(1, 68) = 10.87$, $p < .01$, as well as a marginally significant interaction, $F(1, 68) = 2.85$ $p = .10$.

Table 7
Exp. 3: Proportion correct on short answer test (standard deviations in parentheses)

Group	Overall	Important Details	Unimportant Details
No restudy			
Organize	.52 (.18)	.58 (.20)	.43 (.19)
Transcribe	.41 (.11)	.41 (.15)	.37 (.15)
Restudy			
Organize	.49 (.15)	.59 (.14)	.37 (.18)
Transcribe	.67 (.16)	.81 (.16)	.50 (.19)

Short Answer. Table 7 displays performance on the short answers questions as a proportion of questions answered correctly, with the scoring identical to that used in the previous studies. A main effect of instruction on overall short answer performance was not found, $F(1, 68) = .76$, $p = .39$, but there was an effect of re-exposure, $F(1, 68) = 9.46$, $p < .01$. In addition, an interaction between instruction and re-exposure was found, $F(1, 68) = 16.07$, $p < .001$. Independent t-tests replicated the finding in Experiment 2 that organizing led to better short answer performance compared to transcribing when testing was delayed and participants were not allowed to restudy their notes, $t(34) = 2.27$, $p < .05$. As hypothesized, the relation between taking organized notes and transcribed notes changed when a restudy period was allowed, such that those who took transcribed notes recalled a higher proportion of short answers than those who took organized notes, $t(34) = 3.38$, $p < .01$.

Analyses for recall of questions regarding important details did not reveal a main effect of instruction, $F(1, 68) = 0.41$, $p = .52$, although an effect of re-exposure was found, $F(1, 68) = 30.19$, $p < .001$. An interaction between instruction and re-exposure was also revealed, $F(1, 68) = 27.25$, $p < .001$. Again, independent t-tests replicated the finding from Experiment 2 that when testing was administer at a delay and participants were not allowed to restudy their notes, taking organized notes led to better performance on short answer questions addressing important details compared to taking transcribed notes, $t(34) = 2.99$, $p < .01$. In the re-study conditions, the pattern reversed, such that taking transcribed notes led to better performance compared to taking organized notes, $t(34) = 1.81$, $p < .001$.

Lastly, there was no main effect of instruction on recall of questions about unimportant details, $F(1, 68) = 0.64$, $p = .43$; no main effect of re-exposure was found, $F(1, 68) = 0.55$, $p = .46$; but there was an interaction between the two factors, $F(1, 68) = 4.96$, $p < .05$. Follow-up tests revealed that when participants were not allowed to restudy their notes, performance on short answer questions addressing unimportant details did not differ between those who took organized notes and those who took transcribed notes, $t(34) = 1.04$, $p = .31$. When participants were allowed to restudy, the transcribe group performed better compared to the organize group, $t(34) = 2.08$, $p < .05$.

Discussion

The findings from Experiment 3 replicated the general patterns of interest found in Experiment 2 mainly, taking organized notes yields superior test performance compared to taking transcribed notes when the test is given after a 24-hour delay. However, Experiment 3 also demonstrates that the benefit of transcribing over organizing can be maintained if people are given a brief restudy period shortly after taking their notes, and that this benefit persists for at least 24-hours for both free recall and short answer tests. Thus, it seems that although encoding benefits for those who transcribe are relatively brief, the external storage function of notetaking is able to compensate for it.

One curious finding in Experiment 3 is that restudying seems to not affect performance for those who took organized notes. Whereas the transcribe conditions benefited greatly from a five minute restudy period, the organize conditions do not benefit. This, of course, is contrary to the external storage benefit account of notetaking, and is not consistent with previous findings suggesting that even brief restudy periods can yield external storage benefits (Annis & Davis, 1975; Carter & Van Matre, 1975). There are no studies to date that can directly explain why people who take organized notes might not benefit from a restudy period, but a few plausible explanations can be thought of. First, it seems as though restudying can only be beneficial to the degree that people have something to study from. That is, people will benefit from restudying if they have a large quantity of notes, whereas someone with a few sentences of brief notes may not benefit from restudying, simply because they are exposed to less information to relearn.

Secondly, restudying notes would not seem to help much for an individual who was unlikely to forget the information over that same time period anyways. Bjork and Bjork (1992) describe memory by two indexes: storage strength and retrieval strength. According to the theory, the probability of recalling a target memory only depends on the retrieval strength of the item, and that retrieval strength decreases over time. The storage strength of an item is critical in that it mediates retrieval strength, such that items with high storage strength will show less rapid decreases in retrieval strength than items with low storage strength. When a target item is retrieved or relearned, storage strength for that item increases, but the degree of increase is in turn mediated by the retrieval strength of the item when it was retrieved or restudied. Items with high retrieval strength will gain little additional storage strength when the item is retrieved or relearned, whereas an item with low retrieval strength will receive a relatively larger boost in storage strength.

With respect to notetaking, data from Experiment 2 showing that those who took organized notes suffer little from forgetting over a 24-hour delay can be interpreted as showing that students who take organized notes having high retrieval strength for that information. Conversely, students who transcribed forgot nearly half the information over the delay, suggesting low retrieval strength for the lecture information. If students who organized their notes have high retrieval strength for the information they learned and students who transcribed their notes have low retrieval strength for the lecture information, then Bjork and Bjork (1992) would predict that when both groups are allowed to restudy their notes, only those who take transcribed notes should see a significant boost in storage strength. Because those who took organized notes have high retrieval strength for the information, they receive little storage strength benefit. Indeed, results from Experiment 3 show exactly this: students who did not restudy their organized notes did as well on a final test as students who did restudy their organized notes.

Experiment 3 provides evidence for an external storage benefit, although only for those who took transcribed notes. More important, however, is the fact that the transcribed notes group showed higher test performance than those who took organized notes when everyone was allowed to restudy. This reestablishment of transcribing as an effective way of taking notes can only persist over a delay if students restudy their notes. As shown in Experiment 2, taking organized notes resulted in superior test performance compared to taking transcribed notes. The results from Experiment 3 showed that taking transcribed notes was only beneficial if students took the necessary steps to reinforce their initial learning by restudying their notes. When students were allowed to restudy their transcribed notes, they not only benefited compared to those who had not restudied their notes, but their test performance was better compared to those who did restudy their organized notes.

Individual Differences

The group level differences observed across the three experiments provide insight as to whether certain notetaking strategies can indeed improve test performance. Of additional interest in this study was not only what strategies work best for notetaking, but also who benefits from these strategies. To supplement those findings, we conducted correlational analyses to examine which particular individuals were benefiting from these notetaking strategies. As mentioned in the introduction, one goal of this study was to examine whether taking transcribed notes would reduce dependence on working memory. If typical notetaking (i.e., taking organized notes) relies on working memory to hold and manipulate lecture information, one consequence may be that students with poor working memory are unable to take notes effectively. As a result, their notes will provide little benefit during restudy, which then leads to a decrement in test performance.

However, taking transcribed notes should not require working memory to the same degree compared to taking organized notes (Olive & Piolat, 2002), because people are simply writing down what they are hearing. As such, our primary interest in examining individual differences is the relations among working memory, note-quantity, and free recall. Although short answer tests were also used to assess learning in this study, we focused on the free recall measure in our correlational analyses because it was administered before the short answer portion. Because free recall was the first memory test given to participants in the study, it provided a better index of learning compared to the short answer test, where performance could have been influenced by the free recall test given right before it. Specifically, we wanted to see how the relations among working memory, note-quantity, and free recall differed between participants who took organized notes and participants who took transcribed notes, and to see how these relations changed when a delayed test or a restudy period was introduced.

To maximize statistical power, our correlations pooled similar groups across the three experiments. Because Experiment 2 and Experiment 3 both included conditions that replicated the previous experiments (Experiment 1 and Experiment 2, respectively), it allowed us to collapse those similar conditions across experiments. Doing so yielded four groups: two of which who were tested immediately (half the participants in Exp. 1 and half from Exp. 2), and the other two who were tested after a delay (half the participants in Exp. 2 and half from Exp. 3).

Table 8
Correlations between processing speed, working memory, notetaking, and free-recall.

	1	2	3	4
	Transcribe/immediate condition (n = 38)			
1. Processing speed	1.00			
2. Working memory	**-.33***	1.00		
3. Note-quantity	.17	-.05	1.00	
4. Free-recall	.24	-.15	**.35***	1.00
	Organize/immediate condition (n = 39)			
1. Processing speed	1.00			
2. Working memory	**-.39***	1.00		
3. Note-quantity	-.14	**.45***	1.00	
4. Free-recall	-.25	**.33***	**.47***	1.00

* $p < .05$.

Immediate Testing. Table 8 provides the correlations for those who used a computer to take transcribed notes and those who took organized notes when testing was immediate. In both the transcribe and organize groups, processing speed was a significant predictor of working memory, consistent with previous research examining this relation (e.g. Fry & Hale, 1996). In addition, note-quantity predicted free recall performance in both the transcribe and organize groups. That is, those who took more notes tended to recall more idea units on the free recall test, even without restudying the notes, and regardless of whether they attempted to transcribe or organize their notes. This replicates findings that have established the link between these note-quantity and test performance without restudying (e.g., Howe, 1970b; Fisher & Harris, 1973; Aiken, Thomas, & Shennum, 1975).

Consistent with previous findings (e.g., Kiewra & Benton, 1988; Kiewra et al., 1987; McIntyre, 1992), working memory predicted notetaking as well as free recall performance in the organize group. A hierarchical regression with free recall as the dependent measure was conducted with note-quantity entered in first, followed by working memory in the next block. Only note-quantity predicted free recall performance, $\beta = .40$, $t(36) = 2.45$, $p < .05$; working memory did not contribute any unique variance above and beyond what note-quantity provided, $\beta = 0.15$, $t(36) = 0.95$, $p = .35$.

In the transcribe group, working memory was not a significant predictor of note-quantity. This lack of correlation is novel in the notetaking literature, yet expected given our hypothesis that taking transcribed notes does not involved mental organization of information. The lack of correlation introduces an interesting aspect of taking transcribed notes: students with poor working memory who may have struggled to take organized notes now have a new notetaking strategy that does not rely on working memory, but rather on how fast they can take down their notes. Given our earlier finding that transcribing only leads to more notes (and better test performance) than organizing when using a computer and not by hand, our results suggest not only that transcribing using a computer can lead to superior immediate test performance, but also that working memory does not have to play a role in taking those notes.

Table 9
Correlations between processing speed, working memory, note-taking, and free-recall.

	1	2	3	4
	Transcribe/delay condition (n = 37)			
1. Processing speed	1.00			
2. Working memory	**-.33***	1.00		
3. Note-quantity	-.16	.05	1.00	
4. Free-recall	-.16	**.35***	**.37***	1.00
	Organize/delay condition (n = 37)			
1. Processing speed	1.00			
2. Working memory	**-.37***	1.00		
3. Note-quantity	.03	**.41***	1.00	
4. Free-recall	-.12	**.36***	**.40***	1.00

* $p < .05$.

Delayed Testing. Table 9 provides the correlation between the two methods of notetaking along the measures of interest when testing was administered after a 24-hour delay. Consistent with the correlations in the immediate testing sample, processing speed was correlated with working memory. For both instructions of notetaking, note-quantity again predicted free recall, consistent with the immediate testing sample. It is important to point out that the relation found between these two variables remained significant even after a 24-hour delay. In other words, note-quantity not only predicted immediate learning, but long-term learning as well.

When examining working memory for those who took organized notes, we found again that working memory predicted note-quantity as well as free recall. A hierarchical regression showed that when note-quantity was entered into the model to predict free recall performance, note-quantity was a marginally significant predictor, $\beta = .31$, $t(34) = 1.83$, $p = .07$. Working memory was entered into the model at the next step, and did not contribute any unique variance after accounting for note-quantity, $\beta = 0.24$, $t(36) = 1.41$, $p = .17$. This suggested that the influences of working memory and note-quantity on delayed free recall are redundant, and that each measure in and of itself may not explain a significant amount of unique variance in free recall.

Not surprisingly, working memory did not predict note-quantity for participants who took transcribed notes. However, working memory did predict delayed free recall, a relation that was not found when testing was immediate. In a hierarchical regression where note-quantity was entered into the first step, note-quantity explained a unique amount of variance in free recall scores, $\beta = .35$, $t(34) = 2.36$, $p < .05$, as did working memory when it was entered into the model afterwards, $\beta = 0.33$, $t(36) = 2.20$, $p < .05$.

In the context of this study, there are a number of possible reasons as to why low working memory individuals in the transcribe group forgot a lot of what they learned from the lecture when testing was delayed. One possible reason is that low working memory individuals do not encode the lecture information as well as high working memory individuals, and that although performance on an immediate test did not differ between working memory groups, the better encoding of information by high working memory individuals led to better free recall performance after a delay. In essence, what previously was a null correlation between working memory and free recall now became a positive correlation when free recall was delayed 24-hours.

From the perspective of finding an effective note-taking strategy for those with lower working memory ability, these correlational results for delayed tests are problematic. It should be noted, however, that they come from participants who were not allowed to restudy their notes. As we will show, these problems are alleviated when restudying is allowed.

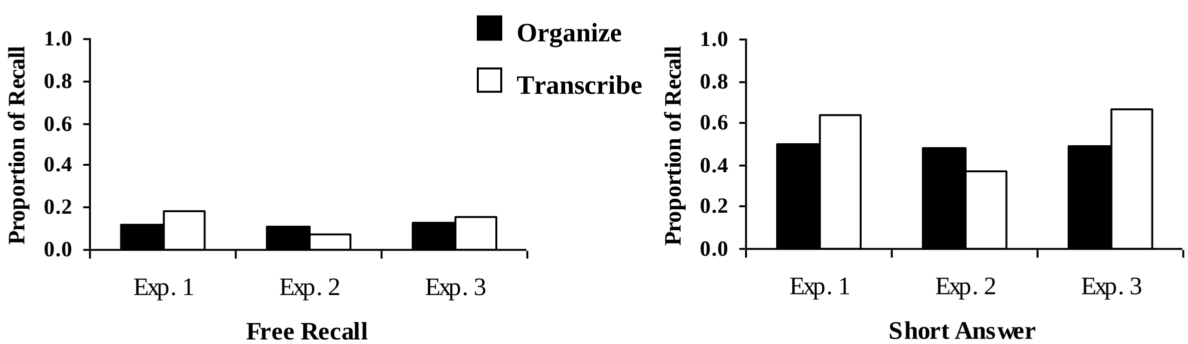
Delayed Testing with Restudying. Experiment 3 demonstrated that taking transcribed notes and then restudying them led to the best long-term learning compared to taking organized notes. One consideration is that although taking transcribed notes with restudying resulted in the best test performance, it may be possible that certain individuals benefited more from restudying those notes than others. Specifically, the possibility that higher working memory individuals benefited more from restudying their notes in this study cannot be completely ruled out. If individual differences in working memory predicted delayed test performance for those who restudied transcribed notes, then we would be faced with the same issue introduced at the beginning of the study: that notetaking benefits being driven by differences in inherent cognitive abilities.

In the transcribe group (n=18), the correlation between working memory and free recall (n=18) was not significant, r = -.01, whereas the correlation between note-quantity and free recall was r = .63. Surprisingly, even with a small sample size, the correlation between note-quantity and free recall was significant, $p < .01$. The correlation between working memory and free recall in the transcribe group does not definitively preclude a relation, as the sample may be too small to draw firm conclusions. It seems unlikely, however, that increasing the number of observations would change the results, especially given that the correlation is virtually non-existent.

Additionally, the presence of a significant correlation between note-quantity and free recall suggests that strong predictors of free recall performance can be detected despite the small sample size. For those who took organized notes the relationship between working memory and free recall, the correlation for those who organized their notes was r = .30, whereas the correlation between note-quantity and free recall was r = .28. Although these moderate sized correlations in the organize group would suggest that the sample size needs to be increased, the primary purpose of examining individual differences in the restudy/delayed test individuals was to examine whether the benefits of restudying transcribed notes were reserved for only those with high working memory.

General Discussion

Figure 1
Performance at final test across all three experiments.



Note. Figure includes computer conditions only. "Exp. 1" represents immediate testing without restudy, "Exp. 2" represents delayed testing without restudy, and "Exp. 3" represents delayed testing with restudying.

Transcribing as an Effective Notetaking Strategy

This study provides insight into the effectiveness of certain notetaking strategies, and how the impact of these strategies is affected when students are allowed to restudy their notes. Figure 1 compares the mean performance on free recall and short answer tests between the two conditions of notetaking instruction across all three experiments. As may be seen, Experiment 1 suggests that when students take notes by hand, notetaking instruction does not produce a difference in immediate test performance. However, when students take notes using a computer, test performance for those who transcribe is better compared to those who organize.

The results of Experiment 2 suggest that if students do not restudy their notes after taking it, however, the benefit of taking transcribed notes disappears, such that taking organized notes results in better information retention. This is not surprising, given a levels-of-processing account (Craik & Lockhart, 1972), which would predict better long-term retention of information that is deeply encoded compared to information that is only shallowly encoded. Finally, Experiment 3 suggests that when students are given an opportunity to review their notes, even a brief five minute restudy period is sufficient for those who take transcribed notes, whose boost in test performance provides evidence of an external storage benefit. It is important to mention that the benefit of taking transcribed notes is not just due to restudying. As our results suggest, students who take transcribed notes do in fact can recall more information on an immediate test without restudying compared to those who take organized notes. Because this benefit is temporary when the notes are not restudied, restudying regains the benefit of transcribing over organizing.

Interestingly, it is only those who take transcribed notes that seem to benefit from restudying. One potential explanation as to why those who take organized notes do not benefit from restudying was provided earlier: the information recorded in the notes by those who take organized notes is learned well enough so that restudying does not help them learn the information any better. This is consistent with B ork and B ork s (1992) theory, which suggests that information that is highly retrievable does not benefit as much from a relearning phase compared to information that is less retrievable. Indeed, even without being allowed to restudy, students who organize their notes suffer from virtually no forgetting over a 24-hour delay, indicating that the learned information remains highly retrievable throughout that period. To be clear, this is not to say that those who take organized notes would never benefit from restudying their notes. Rather, students who take organized notes may benefit more from restudying their notes at a later period in time, when the lecture information may not be as accessible in memory.

Transcribing as a Practical Notetaking Strategy

Our results suggest that using computers to take transcribed notes is not only beneficial for test performance when combined with restudying, but is a practical strategy that students can use regardless of cognitive ability. Because previous literature has pegged working memory as a critical component for notetaking (Piolat et al., 2005), the implications were rather dire for individuals with lower working memory ability. The implication, of course, was that they would be unable to take effective notes, which would then result in poor test performance. Our results confirmed the relation between working memory and notetaking for participants who take organized notes with computers. On the other hand, when participants took transcribed notes with computers, working memory did not predict notetaking. Although the advantage of transcribing over organizing highlights the value of taking transcribed notes, another equally important aspect of this method of notetaking is that transcribing does not rely on working memory. In short, taking transcribed notes means that even students with poor working memory are introduced to a way to take effective notes. This in essence “levels the playing field” for individuals across all ranges of working memory.

Reducing working memory as a predictor of test performance is particularly important because whereas certain skills can be improved through a reasonable amount of training, there is no clear consensus as to whether general working memory is a skill that can improved. Even with the extensive amount of training thought to be needed to improve working memory, only some studies have been able to show that the gains transfer to higher order abilities (e.g. Jaeggi, Buschkuehl, Jonides, & Perrig, 2008; Dahlin, Neely, Larsson, Bäckman, & Nyberg, 2008), and it is still unclear what aspect(s) of working memory the training needs to focus on. Given the lack of consensus in the working memory training literature, the potential to take notes without relying on this cognitive skill further highlights the potential impact of using computers to take transcribed notes.

To date, there is not a known study that has established the relation between working memory and note-quantity using a more traditional working memory measure. This study is the first to show a correlation between working memory and note-quantity using a complex span task (Daneman & Carpenter, 1980), and is also the first study to demonstrate the link between working memory and note-quantity when notes are taken with computers. Studies that have found a correlation between working memory and note-quantity did not use traditional complex span tasks (e.g., Kiewra & Benton, 1988; Kiewra et al., 1987; McIntyre, 1992), and studies that did use more traditional working memory tasks were not able to find a correlation (e.g., Cohn et al., 1995; Peverly et al., 2007). One possible reason suggested earlier as to why performance on traditional working memory tasks did not predict note-quantity was because of variability in notetaking strategies. If explicit instructions on how to take notes are not provided, participants may select strategies that do not rely as much on working memory, and this variability in turn can mask a positive correlation between working memory and note-quantity. Our study not only included explicit instructions on how to take notes, but provided evidence that certain notetaking instructions in fact do not rely on working memory.

Beyond the contribution of working memory towards note-quantity and test performance, our results suggested that note-quantity predicted test performance for those who took organized notes as well as those who took transcribed notes. This finding replicates several studies that have established this correlation when students are not allowed to restudy their notes (e.g., Howe, 1970b; Fisher & Harris, 1973; Aiken, Thomas, & Shennum, 1975), and reiterates an important point: students do better on tests when they write down more notes. This in fact may go against what many instructors preach to their students that students do not have to write down everything the instructor says. While this may be true to the extent that instructors know what students will and will not be tested on later, students themselves often cannot predict what will be on the test. To this end, students are better served writing down information that may possibly be important for a later test.

In addition to the information benefiting from the encoding aspect of notetaking, the information in a student s notes is also available to restudy later. In our study, we provided results suggesting that for those who took transcribed notes, the only thing that predicted immediate and delayed (with restudying) test performance was note-quantity.

When testing was delayed and participants were not allowed to restudy their notes, note-quantity still predicted test performance, although we found working memory to be a predictor as well. In short, the faster a student can take down their notes, the better they will perform on a test. The reason why a student may benefit changes depending on when the test is administered: when testing is immediate, students who take transcribed notes may do better because of an encoding benefit, whereas the external storage benefit seems to be what drives the advantage of taking transcribed notes when testing is given after a 24-hour delay.

Computers as a Notetaking Tool

Our study also examined the question of whether computers should be used to take notes. Because taking notes using a computer increased note-quantity for students that used them to take transcribed notes, we are introduced with the prospect of improving the degree to which students can benefit from restudying. Of possibly greater value, because it is the case that introducing computers to less efficient note-takers creates greater benefits compared to those who are already efficient note-takers, our findings present researchers and educators alike the opportunity to minimize the influence of individual differences on notetaking, and gives more students a better chance to maximize their learning experience.

It would be myopic to discuss the potential contribution of computers in classrooms without acknowledging its drawbacks. At its best, laptop computers can provide technology that potentially creates a more interactive learning experience for students, as well as confer an effective way of taking notes: more note-quantity with less cognitive load on a skill traditionally needed to take notes (working memory).

Furthermore, technology corporations such as Microsoft have developed software (OneNote) to help students take notes by providing a simplified interface that makes it easier for students to format and structure their notes. As a result, students can take more notes in an efficient manner, and with more notes, students should benefit more from an external storage standpoint of notetaking.

However, laptops are also capable of introducing distractions during a lecture. In large classroom settings where the instructor is often facing the student, it is relatively easy for students with laptops to engage in extracurricular activities with little concern about repercussion from the instructor. Even a student doing school work for another course, however admirable (or not) the effort, can be disruptive to paying sufficient attention to the information being presented during class. In short, any computer-related activity that can lead to diverting attention away from the current lecture at hand can create negative consequences for student learning.

Instructors are not oblivious to this potential Catch-22. Whereas many instructors embrace the laptop s ability to technologically enhance a student s learning experience, there are just as many that completely ban laptops from their classrooms altogether (one professor at the University of Oklahoma even went as far as pouring liquid nitrogen over a laptop and then shattering it on the floor to serve as a warning to students distracted by their laptops). To the extent that laptops facilitate distractions in the classrooms, the debate will continue as to whether to allow them in classrooms in the first place. Independent of that dispute, this study provides evidence that laptops can serve as powerful tools in helping students take better notes, which in turn improves test performance. Perhaps more importantly, students are now given a means by which they can take these notes while relying less on traditional cognitive abilities needed to carry out this task.

Concluding Remarks

University instructors spend a large majority of their class time lecturing (Wirt et al., 2001), meaning that effective notetaking skills are needed in order for students to do well on exams. The idea of what constitutes effective notetaking skills vary among students because of differences in lower yet inherent cognitive abilities. As such, studies should not only seek to understand how these cognitive abilities interact with various notetaking strategies, but to find ways to help students to either take notes using cognitive abilities that they are stronger in, or to take notes without having to rely on abilities they are weaker in.

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