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Note-Taking With Computers: Exploring Alternative Strategies for Improved Recall

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Three experiments examined note-taking strategies and their relation to recall. In Experiment 1, participants were instructed either to take organized lecture notes or to try and transcribe the lecture, and they either took their notes by hand or typed them into a computer. Those instructed to transcribe the lecture using a computer showed the best recall on immediate tests, and the subsequent experiments focused on note-taking using computers. Experiment 2 showed that taking organized notes produced the best recall on delayed tests. In Experiment 3, however, when participants were given the opportunity to study their notes, those who had tried to transcribe the lecture showed better recall on delayed tests than those who had taken organized notes. Correlational analyses of data from all 3 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 tried to transcribe the lecture, in contrast, only note-quantity was a consistent predictor of recall. These results suggest that individuals who have poor working memory (an ability traditionally thought to be important for note-taking) can still take effective notes if they use a note-taking strategy (transcribing using a computer) that can help level the playing field for students of diverse cognitive abilities.

Keywords: note-taking, note quantity and quality, computers, individual differences, working memory

Note-taking has long been linked to positive test performance (e.g., Armbruster, 2000; Crawford, 1925b), and this relationship is not lost on students, who acknowledge that lecture note-taking is a crucial component of the educational experience (Dunkel & Davy, 1989). In fact, lecturing constitutes nearly 83% of college instructors' teaching methods (Wirt et al., 2001), and 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). Researchers have identified two primary ways in which classroom note-taking is beneficial: *Encoding* and *external storage* (Di Vesta & Gray, 1972). The encoding benefit (also termed the process benefit) refers to the learning that results from the act of taking notes, whereas the external storage benefit (also termed the product benefit) refers to the benefit that comes from studying the notes. Furthermore, Kiewra (1985) pointed out that utilizing *both* aspects of note-taking in conjunction provides a more potent learning tool than either aspect on its own (e.g., Fisher & Harris, 1973; Kiewra, DuBois, Christensen, Kim, & Lindberg, 1989).

Recent advancements in technology have led to more computers being introduced into the classroom and incorporated into students' learning experiences, and the availability of portable computers has resulted in a steady increase in the percentage of college students who own one (89%; Smith & Caruso, 2010). Research has compared typing speed to writing speed and found evidence that proficient typists can type faster than they can handwrite (e.g., Brown, 1988), and that this pattern emerges in children as young as sixth grade (Rogers & Case-Smith, 2002). Thus, it would appear that for many students, portable computers can increase their transcription speed when they take lecture notes.

The Relation Between Working Memory and Note-Taking

Despite its benefits, lecture note-taking is a complex and cognitively demanding skill that requires comprehending what the instructor is saying, holding that information in memory, organizing and paraphrasing it, and then writing it down before it is forgotten, all while attending to the ongoing lecture. When note-taking skill is framed as a composition of more basic cognitive abilities, it is clear that one reason why students' notes vary among one another is likely because of individual differences in these lower-order abilities.

One ability hypothesized to be important in note-taking is *working memory* (e.g., Olive & Piolat, 2002), the ability to temporarily hold and manipulate a limited amount of information (Baddeley, 1986). While some studies report a correlation between working memory and note-taking (e.g., Kiewra & Benton, 1988; Kiewra, Benton, & Lewis, 1987), other studies do not (e.g., Cohn, Cohn, & Bradley, 1995; Peverly et al., 2007). It is possible that these mixed results are due to variability in the note-taking strategies that students naturally use. Without explicit instructions, students may choose strategies that vary in the extent to which they rely on working memory, potentially masking a correlation between working memory and note-taking.

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Currently, it is unclear whether working memory always plays a vital role in note-taking, or whether working memory is important only for select note-taking strategies. Nonetheless, if note-taking, like other cognitive skills, relies on basic processing abilities, then it would not be too surprising if individual differences in such abilities account for much of the variance in note-taking as it relates to test performance. And if taking notes in and of itself provides an encoding benefit, then individual differences in working memory may predict test performance even when individuals do not get to study their notes.

The Relation Between Note-Quantity and Recall

As mentioned previously, note-taking is beneficial in and of itself, independent of studying. One consequence of this is that taking more notes may lead to better learning, as more information has been encoded. Indeed, studies have shown a significant relation between note-quantity and test performance, both when students study their notes (e.g., Crawford, 1925a; Kiewra & Benton, 1988), as well as when they are not allowed to study their notes (e.g., Fisher & Harris, 1973). Moreover, Peverly et al. (2007) found that measures of transcription fluency (how fast one can take notes) predicted note-taking, which in turn predicted performance on writing tasks measuring recall, raising the possibility that increasing transcription fluency may be one way to increase recall.

The benefit of simply writing down what is said in lecture may be explained by the *generation effect* (e.g., Rabinowitz & Craik, 1986): the finding that information is better remembered when it is generated, compared to when it is simply read or heard. One interpretation of this effect is that the act of generation is itself really an act of recall, and that the opportunity for recall benefits memory for that information (Slamecka & Graf, 1978). Similarly, Scardamalia and Bereiter (1986) suggested that note-taking forces students to generate (recall) information just heard during the lecture, which benefits memory more than merely hearing the information. Faber, Morris, and Lieberman (2000) found that note-taking without an opportunity to study the notes facilitated comprehension for students as young as ninth grade, providing further support for the role of generation in lecture note-taking (see Kobayashi, 2005, for a meta-analysis focusing on the factors that influence the encoding benefits of note-taking).

Conway and Gathercole's (1990) *translation hypothesis* provides another account of why writing down what is said in lecture can benefit memory. According to their hypothesis, when input activities require translation between specialized processing domains, this leads to the formation of more distinctive memory representations. Because listening to a lecture requires phonological processing, whereas writing down what was said invokes orthographical processing, the translation effect should benefit memory. Moreover, 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 a lecture leads to more information being encoded, as well as more distinctive memory representations.

Alternatively, the quality of one's notes may be much more important than the quantity. This view is consistent with the *levels of processing framework* in that taking organized notes would appear to involve the kind of semantic processing that leads to better retention of verbal information (Craik & Lockhart, 1972). Taking organized notes may also enhance retention because it involves the kind of "desirable difficulty" highlighted by Bjork (1994). Although there is an extensive literature that examines the contributions of the quantity and quality of students' notes to learning and test performance, perhaps not surprisingly, previous studies have been focused almost exclusively on taking handwritten notes (for a meta-analytic review, see Kobayashi, 2005). It is possible, however, that taking notes with a computer may change the balance between note quality and quantity, and the current study is the first to directly examine this emerging issue.

The Current Study

If transcription speed plays an important role in note-taking (e.g., Peverly et al., 2007) and typing is faster than writing by hand (e.g., Brown, 1988), then computers would appear to provide an opportunity to increase note-quantity for virtually all students, thereby improving their test performance. Moreover, given that note-quantity predicts test performance, it is possible that instructing students to take as much notes as possible will prove more beneficial for learning than the usual practice of taking organized notes.

This study has three aims. One aim is to compare taking notes by hand with taking notes using a computer in terms of their effects on test performance. The second aim is to compare the effects of taking organized notes with the effects of trying to transcribe a lecture. The third aim is to examine the role of working memory in these two note-taking strategies. Experiment 1 compares the effects of different note-taking methods (hand or computer) and note-taking instructions (organizing or transcribing) on an immediate test. Experiments 2 and 3 examine how these same two note-taking strategies influence performance on delayed tests when people are not allowed to study their notes (Experiment 2), and when they are given an opportunity to study (Experiment 3). Finally, we examine the role of individual differences in working memory in determining who benefits from different note-taking strategies.

Experiment 1

Method

Participants. Eighty undergraduate students (53 females and 27 males; mean age = 19.2 years, $SD = 1.2$), all proficient English speakers, participated for course credit.

Materials. Participants were tested individually in a private testing room equipped with a PC and a 15-in. (38.1-cm) monitor that was used for stimulus presentation on all tasks. Note-taking 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.

Reading span task. A reading span task (Daneman & Carpenter, 1980) was used to assess working memory ability. Participants were shown a series of sentences and digits. After reading each sentence aloud, participants reported whether or not the sentence was sensible, at which time the sentence disappeared and a digit appeared on the screen, 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. The total score was calculated by summing the series lengths of the correct trials.

Lexical decision task. Processing speed was measured using a lexical decision task in which participants were shown strings of letters (e.g., "bin," "mun"). For each letter string, participants made a decision as to whether or not it was a real English word. Each individual's measure of processing speed was based on correct responses to both words and nonwords.

Lecture. Participants listened to an 11-min lecture that consisted of a passage from a nonfiction book (Carnes, 1995) in which a popular film from the 1930s (*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, and they did not know anything about the Crimean War. This passage was used previously by Rawson and Kintsch (2005), who developed a scoring system in which select idea units represented main points, important details, or unimportant details of the passage. Of the 125 total idea units, eight were classified as representing main points, 15 represented important details, and 16 represented unimportant details (Rawson & Kintsch, 2005). The 1,541-word lecture was read aloud and recorded in a sound-proof room at an average rate of 140 words per minute. The recording was subsequently presented to participants through the computer speakers.

Tests. Two types of test, free recall and short answer, were used to assess memory for the passage. The short answer test (Rawson & Kintsch, 2005) consisted of 18 questions (e.g., "What was the political idea that *Light Brigade* was intended to promote?"), of which eight were about important details, and 10 were about unimportant details.

Design and procedure. A 2 (instruction: organize, transcribe) $\times$ 2 (method: hand, computer) between-subjects design was used. For this and all subsequent experiments, analyses of variance (ANOVAs) were performed on the notes, free recall performance, and short answer performance, and planned comparisons with Bonferroni corrections were conducted for all significant interactions.

Following collection of demographic information, participants performed the tasks in the following order: Reading span task, lexical decision task, lecture note-taking, free recall test, and short answer test. Participants were told that they would be listening to the lecture 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 to organize their notes as much as possible. Those in the *transcribe* condition were told to record as much of the lecture as possible. Finally, participants in the *hand* condition were provided a notepad and a pen, and participants in the *computer* condition were told to type their notes into a computer file using a word processor.

When participants finished listening to the lecture, the experimenter made the notes unavailable to the participants and administered the two tests. For the free recall test, participants were told that they had 10 min to recall as much information as they could remember from the lecture. This was followed by the short answer test, which participants also had 10 min to complete. Two independent raters, blind with respect to the conditions, scored all of the notes and free recall responses. Participants were given either a full point for recall of an entire idea unit, half of a point for partial recall of the idea unit, or zero for no recall. Inter-rater reliability was .85 and .82 for notes and free recall responses, respectively. Discrepancies in scoring were resolved by taking the average of the scores given by the raters.

Results

The groups assigned to the four conditions did not differ in either working memory or processing speed, both Fs < 1.63, precluding the possibility that any group differences in note-taking and test performance could be due to differences in these cognitive abilities.

Note-taking. For each participant, note-quantity was measured as the proportion of the idea units from the lecture that were recorded in the participant's notes (see Table 1). There was an effect of method on note-quantity, $F(1, 76) = 17.68$, $p < .001$, $\eta^2 = .19$, as well as an effect of instruction, $F(1, 76) = 4.07$, $p < .05$, $\eta^2 = .05$, indicating that, on average, notes taken with a computer contained a larger proportion of idea units than handwritten notes and transcribed notes contained a larger proportion of idea units than organized notes. There was also an interaction between note-taking method and instruction, $F(1, 76) = 4.07$, $p < .05$, $\eta^2 = .04$, reflecting the fact that when using a computer, the instruction to try and transcribe the lecture was associated with a larger proportion of idea units than the instruction to try and take organized notes, $t(38) = 2.71$, $p < .05$, whereas there was no effect of note-taking instructions on the proportion of idea units when notes were taken by hand, $t < 1.00$.

Free recall. Table 1 displays the overall proportion of idea units, as well as the proportions of main points, important details, and unimportant details recalled by each group. Those who took

Table 1
Experiment 1: Proportions of Idea Units Recalled (Standard Deviations in Parentheses)

Group	Note-taking overall	Free recall: Overall	Free recall: Main ideas	Free recall: Important details	Free recall: Unimportant details	Short answer: Overall	Short answer: Important details	Short answer: Unimportant details
Hand								
Organize	.28 (.12)	.12 (.05)	.17 (.10)	.18 (.09)	.10 (.08)	.47 (.19)	.52 (.16)	.42 (.26)
Transcribe	.28 (.10)	.12 (.03)	.17 (.12)	.21 (.10)	.08 (.07)	.46 (.15)	.45 (.17)	.47 (.18)
Computer								
Organize	.34 (.13)	.12 (.05)	.21 (.14)	.16 (.10)	.10 (.10)	.50 (.20)	.53 (.20)	.46 (.25)
Transcribe	.44 (.12)	.18 (.06)	.25 (.13)	.24 (.12)	.12 (.08)	.64 (.12)	.72 (.16)	.58 (.13)

notes using a computer recalled more idea units than those who took handwritten notes, $F(1, 76) = 7.62$, $p < .01$, $\eta^2 = .08$, and those who took transcribed notes recalled more than those who took organized notes, $F(1, 76) = 7.82$, $p < .01$, $\eta^2 = .08$. There was an interaction between method and instruction, $F(1, 76) = 6.41$, $p < .05$, $\eta^2 = .06$: Transcribing led to better overall free recall performance than taking organized notes when notes were taken using a computer, $t(38) = 3.36$, $p < .05$, whereas there was no effect of instruction when notes were taken by hand, $t < 1.00$. Analysis of free recall of main idea units indicated an effect of method: Taking notes using a computer led to greater recall of main idea units compared to taking notes by hand, $F(1, 76) = 4.73$, $p < .05$, $\eta^2 = .06$. However, there was no effect of instruction and no interaction between the two factors, Fs < 1.00. Recall of important details was better for those who transcribed, $F(1, 76) = 5.61$, $p < .05$, but did not differ by method, and there was not an instruction by method interaction, Fs < 1.00. Finally there were no effects of method or instruction on unimportant details and no interaction, Fs < 1.00.

Short answer. Table 1 shows overall performance, as well as performance on short answer questions addressing important and unimportant details. Taking notes using a computer led to better overall test performance compared to taking notes by hand, $F(1, 76) = 7.69$, $p < .01$, and taking transcribed notes led to better performance compared to taking organized notes, $F(1, 76) = 3.46$, $p < .05$. An interaction between method and instruction was found, $F(1, 76) = 3.97$, $p < .05$, reflecting a difference in performance between the two note-taking instructions when notes were taken with a computer, $t(38) = 2.76$, $p < .01$, but not when notes were taken by hand, $t < 1.00$. Analysis of recall of important details revealed an effect of method, $F(1, 76) = 12.85$, $p < .01$, $\eta^2 = .13$, indicating that using computers led to better performance than taking notes by hand, but no effect of instruction, $F < 2.00$. A significant interaction between method and instruction was found, $F(1, 76) = 10.64$, $p < .01$, $\eta^2 = .10$, reflecting the fact that when taking notes by computer, transcribing led to better performance than taking organized notes on questions addressing important details, $t(38) = 3.15$, $p < .01$, whereas when taking notes by hand, there was no difference between the two note-taking strategies, $t < 1.50$. With respect to recall of unimportant details, there were no significant main effects and no interaction between the two factors, Fs < 3.0.

Discussion

When people used a computer to take notes, they took more notes and recalled more of the lecture than when they took notes by hand. Moreover, when they used a computer and were instructed to try and transcribe the lecture, this strategy was associated with the most notes and the best performance on both the free recall and short answer tests, with performance not only exceeding that of those who took organized notes with a computer but also that of those who used either handwritten note strategy. And because the benefits of transcribing with a computer extended to recall of both the main idea units and the important details, it is clear that the superior overall performance of those using this strategy was not simply due to their including more unimportant information in their notes or in their free recall. The present results are consistent with the generation effect (Slamecka & Graf, 1978) as well as the translation hypothesis (Conway & Gathercole, 1990), both of which would predict that memory should be better for information that is written down compared to information that is simply heard.

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 to organize their notes. One possible explanation is that this 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 produce more notes than someone who is organizing by hand. This highlights the potential impact that computers can have on note-taking in classroom settings, as keyboards allow for faster note-taking for a longer period of time.

The ability to take more notes, of course, provides clear benefits for students from an external storage standpoint because it means there is more information to study. However, participants in Experiment 1 were not allowed to study their notes, and thus differences in external storage cannot explain any of the observed differences in test performance. Instead, it would seem more likely that the differences between groups were driven by the encoding benefit that comes from note-taking. Our results for 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 to 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 also results in a benefit on both free recall and short answer tests.

One potential concern about recommending to students, based on this finding, that they try transcribing lectures (rather than taking organized notes) is that students might do so at the expense of failing to highlight important details (i.e., note quality could suffer). Our results suggest that this does not seem to be the case, at least for those who took notes using a computer: Indeed, the fact that the transcription strategy, when combined with using a computer, resulted in not only the most notes but also recall of the most main ideas and important details of any of the four groups in the experiment indicates that the resulting greater quantity of information did not come at the expense of the quality of the information.

Nevertheless, people may process the information more deeply when they organize their notes. If it is the case that there are differences in the level of processing produced by the two note-taking instructions, then clear-cut predictions can be made about long-term retention of the lecture material. Specifically, it would be expected that any advantage of the transcription strategy over taking organized notes would change over time, such that taking organized notes would lead to better long-term learning. This would be consistent with the levels-of-processing framework, which predicts that deeper encoding of information will lead to better long-term retention 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. As just noted, however, transcription likely involves shallower processing than taking organized notes, and thus according to the levels-of-processing framework, the results of Experiment 1 should not generalize to situations in which the test is delayed. Accordingly, Experiment 2 was designed to test the predictions of the levels-of-processing framework by examining how note-taking instructions affect performance on both an immediate test (a partial replication of Experiment 1) and a test administered 24 hr after the lecture. If taking organized notes is associated with deeper processing, then a significant delay by instruction interaction would be expected, reflecting greater forgetting by those who were instructed to try and transcribe the lecture. Because effects of note-taking instruction were only found for those who used computers, and because computer use led to the best performance overall, all of the participants in Experiment 2 took notes using a computer.

Method

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

Materials. The materials used were identical to those in Experiment 1.

Design and procedure. A 2 (instruction: organize, transcribe) × 2 (test delay: immediate, delay) between-subjects design was used. The procedures were very similar to Experiment 1 except that in Experiment 2, all of the participants took their notes using a computer and were randomly assigned to the delay groups. After doing the complex span task, the lexical decision task, and lecture note-taking, half of the participants immediately were administered the free recall test followed by the short answer test, whereas the other half were tested 24 hr later. Thus, the participants tested immediately provided a replication of the conditions of current interest from Experiment 1 (i.e., using a computer either to try and transcribe the lecture or to take organized notes).

As in Experiment 1, two independent raters, blind with respect to the conditions, scored all of the notes as well as the free recall responses. Inter-rater reliability was .84 and .91 for notes and free recall responses, respectively, and discrepancies in scoring were resolved by taking the average of the scores given by the two raters.

Results

The groups assigned to the four conditions did not differ in either working memory or processing speed, both Fs < 1.70, precluding the possibility that any group differences in note-taking and test performance could be due to differences in these cognitive abilities.

Note-taking. Note-quantity was greater for those who transcribed compared to those who took organized notes, $F(1, 72) = 24.60$, $p < .001$, $\eta^2 = .26$ (see Table 2). There was no effect of delay and no interaction between the two factors, Fs < 1.60.

Free recall. Table 2 presents the mean proportion of total idea units recalled by each group, as well as a breakdown by types of information. There was no effect of instruction on overall free recall, $F < 1.00$, but there was an effect of delay, $F(1, 72) = 23.29$, $p < .001$, $\eta^2 = .22$, indicating that recall was higher when tested immediately as opposed to after a delay. As predicted, there was a delay by instruction interaction, $F(1, 72) = 11.58$, $p < .001$, $\eta^2 = .11$, such that for those instructed to try and transcribe the lecture, performance on the delayed test was significantly poorer than that on the immediate test, $t(36) = 5.20$, $p < .05$, whereas for those instructed to take organized notes, performance did not differ between the immediate and delayed tests, $t < 1.50$. Performance after a delay was better for those who organized compared to those who transcribed, $t(36) = 2.47$, $p < .05$. With respect to main idea units, there was no effect of either instruction or delay, Fs < 3.13, but as predicted, there was an interaction, $F(1, 72) = 5.19$, $p < .05$, $\eta^2 = .07$. Although there was no effect of delay for those taking organized notes, $t < 1.00$, those instructed to transcribe recalled less main idea units on the delayed test than on the immediate test, $t(36) = 2.54$, $p < .05$, and their performance was lower than those who organized and were tested at a delay, $t(36) = 3.71$, $p < .01$. With regard to important idea units, there was no effect of instruction or delay, Fs < 2.80, but there was an interaction, $F(1, 72) = 8.16$, $p < .01$: There was no effect of delay for those taking organized notes, $t < 1.00$, but those instructed to transcribe showed poorer recall after a delay than when tested immediately, $t(36) = 3.03$, $p < .01$. For unimportant idea units, there was an effect of delay, $F(1, 72) = 12.73$, $p < .01$, but no effect of instruction or an interaction, Fs < 1.00.

Short answer. Table 2 shows overall performance on the short answer test by the four groups, as well as a break down into recall of important and unimportant details. There was no main effect of instruction on overall recall, $F < 1.00$, but there was an effect of delay, $F(1, 72) = 13.63$, $p < .01$, indicating that performance on the immediate test was better than performance on the delayed test. There also was an interaction, $F(1, 72) = 10.34$, $p < .001$, such that those who organized did not show a decrement in performance across the delay, $t < 1.00$, whereas those who took transcribed notes did, $t(36) = 5.64$, $p < .01$. As was the case with

Table 2
Experiment 2: Proportions of Idea Units Recalled (Standard Deviations in Parentheses)

		Free recall				Short answer		
Group	Note-taking overall	Overall	Main ideas	Important details	Unimportant details	Overall	Important details	Unimportant details
Immediate								
Organize	.25 (.10)	.12 (.05)	.29 (.12)	.14 (.09)	.12 (.10)	.50 (.19)	.51 (.21)	.44 (.19)
Transcribe	.42 (.15)	.16 (.06)	.30 (.18)	.23 (.12)	.14 (.11)	.64 (.15)	.74 (.19)	.51 (.18)
Delay								
Organize	.25 (.09)	.11 (.04)	.30 (.10)	.17 (.11)	.06 (.07)	.48 (.19)	.51 (.21)	.37 (.19)
Transcribe	.36 (.14)	.07 (.05)	.19 (.09)	.12 (.11)	.05 (.05)	.37 (.15)	.40 (.18)	.28 (.14)

free recall, those who organized showed performance on the delayed test superior to the performance of those who transcribed, $t(36) = 2.02$, $p < .05$. On questions regarding important details, there was no effect of instruction, $F < 2.00$, but there was an effect of delay, $F(1, 72) = 14.12$, $p < .001$, $\eta^2 = .18$, as well as the predicted interaction, $F(1, 72) = 14.20$, $p < .001$, $\eta^2 = .18$. When testing was immediate, transcribing led to better performance on an immediate test than on a delayed test, $t(36) = 5.71$, $p < .05$, but for those instructed to take organized notes, there was no effect of delay, $t < 1.0$. Finally, there was no effect of instruction on recall of unimportant details, $F < 1.00$, but there was an effect of delay, $F(1, 72) = 14.75$, $p < .01$, $\eta^2 = .12$, as well as an interaction, $F(1, 72) = 4.09$, $p < .05$, $\eta^2 = .03$: There was no effect of delay for those taking organized notes, $t < 1.50$, but those instructed to transcribe showed poorer performance on a delayed test than on an immediate test, $t(36) = 4.58$, $p < .05$.

Replication. The results for the immediate free recall and short answer tests in Experiment 2 replicated those in Experiment 1: Those who transcribed using a computer had better immediate performance than those who took organized notes on both the free recall and short answer tests, $t(36) = 2.38$, $p < .05$, and $t(36) = 2.53$, $p < .05$, respectively.

Discussion

The results of Experiment 2 replicate the finding in Experiment 1 that when notes are taken with a computer, the instruction to transcribe a lecture leads to better immediate test performance than the instruction to take organized notes. However, the pattern of performance reversed after a 24-hr delay. Whereas trying to transcribe led to better performance on immediate tests than taking organized notes, having taken organized notes yielded better performance on delayed tests. This finding is consistent with a levels-of-processing account (Craik & Lockhart, 1972), which predicts better retention of the lecture material for the organize group than the transcribe group because taking organized notes presumably involves deeper and more thorough processing of the lecture information, whereas transcribing requires only a shallow encoding of the information.

The findings of the current experiment may also be conceptualized in terms of Bjork and Bjork's (1992) distinction between storage strength and retrieval strength. This theory assumes that the probability of recalling a target memory depends only on the item's retrieval strength, and that retrieval strength decreases over time. The retrieval strength of an item is mediated by its storage strength, such that items with high storage strength will show less rapid decreases in retrieval strength than items with low storage strength. In Experiment 2, taking organized notes may have resulted in items with higher storage strength than trying to transcribe the lecture, so that these items showed little decline in retrieval strength over the 24-hr delay. Conversely, trying to transcribe the lecture resulted in items with low storage strength that therefore showed a substantial decrease in retrieval strength and considerable forgetting after 24 hr. Further, the finding that, compared to trying to transcribe the lecture, taking organized notes led to poorer immediate learning but superior long-term retention is consistent with the idea of desirable difficulties (Bjork, 1994): Seemingly difficult learning conditions can actually lead to more durable learning. In the present context, it may be assumed that taking organized notes is more difficult than transcribing what is said, and that this is actually beneficial for long-term retention.

These results suggest that although trying to transcribe a lecture using a computer may be an immediately effective way to take notes, the benefits of such a strategy can be very short-lived. It is relatively uncommon, of course, for students to take lecture notes and then not have an opportunity to study them, as was the case in the first two experiments. It is clear that in order to model more realistic educational scenarios, a third experiment is needed in which the opportunity for students to study their notes is manipulated.

Experiment 3

The preceding experiments establish that transcribing a lecture using a computer can result in better performance on immediate tests than taking organized notes. Presumably, this reflects the benefit of greater note-quantity, although this advantage maybe relatively short-lived. But what about the external storage benefit from note-taking that comes when one studies one's notes? It is unclear which note-taking strategy should lead to a greater external storage benefit because although taking organized notes presumably results in better note quality, trying to transcribe leads to greater note quantity. Experiment 3 pitted note quantity against quality to determine which strategy leads to better learning when, as is typical outside the laboratory, students have the opportunity to study their notes. In Experiment 3, half of the participants were given an opportunity to study their notes and the other half were not. At issue was whether providing a study opportunity would alter the outcome observed in the previous experiment, in which taking organized notes resulted in better performance on delayed tests.

Method

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

Materials. The materials used were identical to those used in Experiments 1 and 2.

Design and procedure. A 2 (instruction: organize, transcribe) $\times$ 2 (study: study, no study) design was used. After the lecture, all participants completed the reading span and lexical decision tasks, after which half of the participants were told to study their notes for 5 min. Participants returned 24 hr later for testing. Notes and free recall were scored by two raters blind with respect to the conditions, and discrepancies were resolved by taking the average of the scores. Inter-rater reliability for notes and free recall were .90 and .82, respectively.

Results

As was the case in Experiments 1 and 2, there were no group differences in either working memory or processing speed, both $F\text{s} < 1.31$.

Note-taking. Consistent with the previous experiments, note-quantity was again greater for those who transcribed than for those who took organized notes, $F(1, 68) = 27.48$, $p < .001$, $\eta^2 = .29$

(see Table 3). There was no effect of study on note-quantity and no interaction between the two factors, $F\text{s} < 1.00$.

Free recall. Table 3 displays the mean proportion of total idea units recalled by each group, as well as the break down by types of information. There was no effect of instruction on overall recall, $F < 1.00$, but the opportunity to study one's notes did have an effect, $F(1, 68) = 16.50$, $p < .001$, $\eta^2 = .12$, which interacted with the note-taking instructions, $F(1, 68) = 9.13$, $p < .001$, $\eta^2 = .06$. As in Experiment 2, when participants were not given an opportunity to study, taking organized notes resulted in delayed recall of a higher proportion of total idea units, $t(34) = 2.28$, $p < .05$. However, when participants were allowed to study, the opposite pattern was observed: Those instructed to transcribe showed better performance than those who took organized notes, $t(34) = 2.11$, $p < .05$. With respect to main idea units, there was no effect of instruction, nor an effect of study, $F\text{s} < 3.28$. There was an interaction between the two factors, $F(1, 68) = 8.48$, $p < .001$, $\eta^2 = .11$: When participants had no opportunity to study their notes, taking organized notes resulted in greater recall than transcribing the lecture, $t(34) = 3.36$, $p < .05$. However, when participants were allowed to study, there was no effect of note-taking strategy, $t < 1.00$. An effect of instruction on recall of important details was found, $F(1, 68) = 6.51$, $p < .05$, as well as an effect of study, $F(1, 68) = 4.55$, $p < .05$, but there was no interaction, $F < 3.13$. Finally, studying led to greater recall of unimportant idea units than not studying, $F(1, 68) = 10.87$, $p < .01$, but there was no effect of instruction, nor an interaction, $F\text{s} < 2.85$.

Short answer. Table 3 presents performance on the short answer questions. There was no effect of study or instruction on overall recall, $F\text{s} < 3.29$, although there was an interaction, $F(1, 68) = 16.07$, $p < .001$, $\eta^2 = .19$: When participants were not allowed to study their notes, performance was better for those who organized compared to those who transcribed, $t(34) = 2.27$, $p < .05$, whereas when a study period was provided, those instructed to transcribe performed better than those who took organized notes, $t(34) = 3.38$, $p < .01$. There was no effect of instruction on recall of important details, $F < 1.00$, but the opportunity to study had an effect, $F(1, 68) = 30.19$, $p < .001$, $\eta^2 = .26$, which interacted with the instructions, $F(1, 68) = 27.25$, $p < .001$, $\eta^2 = .23$. As in Experiment 2, when participants were not allowed to study their notes, taking organized notes led to better performance on a delayed test than transcribing, $t(34) = 2.99$, $p < .05$. When an opportunity to study one's notes was provided, however, the opposite pattern was observed: Those who tried to transcribe the lecture showed greater recall of important details, $t(34) = 1.81$, $p < .05$. Finally, there was no effect of either instruction or study opportunity on recall of unimportant details, $F\text{s} < 1.0$, but there was an interaction, $F(1, 68) = 4.96$, $p < .05$, $\eta^2 = .04$: When participants were not allowed to study, there was no difference in recall between those who took organized notes and those who transcribed the lecture, $t < 1.00$, but when participants were allowed to study, those who tried to transcribe the lecture performed better, $t(34) = 2.08$, $p < .05$.

Discussion

As in Experiment 2, taking organized notes yielded better test performance than trying to transcribe the lecture when tests were given after a 24-hr delay and participants had no opportunity to study their notes. When participants were allowed to study, however, those who had tried to transcribe the lecture were the ones who showed superior delayed recall. These results demonstrate that the benefits of the transcription strategy, which were observed on immediate tests in Experiment 1, can be maintained for at least 24 hr if students are given a brief opportunity to study their notes shortly after the end of a lecture.

Individual differences. The results reported so far provide information regarding the advantages and disadvantages of different note-taking methods and strategies at the group level. A further aim of this study was to examine the role of working memory in note-taking in order to determine what kinds of individuals benefit from these different strategies. If typical note-taking (i.e., taking organized notes) relies on working memory to hold and manipulate lecture information, as Olive and Piolat (2002) hypothesized, then one consequence may be that students with poor working memory are unable to take notes effectively, and thus for these students, studying their notes will provide relatively little benefit. We hypothesize further that simply trying to transcribe a lecture should not require working memory to the same degree as taking organized notes, and therefore students with poor working memory may be able to use this strategy as effectively as those whose working memory ability is much better.

To evaluate these hypotheses, we examined individual differences in working memory and their relation to note-quantity and free recall using data from all three experiments in the present study. To maximize statistical power, we pooled data from similar groups across the three experiments, which yielded four groups of participants who all took notes using a computer. One group took organized notes and was tested immediately, and another group

Table 3
Experiment 3: Proportions of Idea Units Recalled (Standard Deviations in Parentheses)

Group	Note-taking overall	Free recall: Overall	Free recall: Main ideas	Free recall: Important details	Free recall: Unimportant details	Short answer: Overall	Short answer: Important details	Short answer: Unimportant details
No study								
Organize	.26 (.11)	.12 (.04)	.29 (.15)	.19 (.07)	.07 (.04)	.52 (.18)	.58 (.20)	.43 (.19)
Transcribe	.42 (.14)	.09 (.02)	.16 (.06)	.12 (.06)	.07 (.04)	.41 (.11)	.41 (.15)	.37 (.15)
Study								
Organize	.28 (.12)	.13 (.04)	.25 (.10)	.20 (.07)	.09 (.06)	.49 (.15)	.59 (.14)	.37 (.18)
Transcribe	.45 (.17)	.16 (.06)	.28 (.12)	.18 (.07)	.14 (.07)	.67 (.16)	.81 (.16)	.50 (.19)

took transcribed notes and was also tested immediately; each of these two groups consisted of participants in Experiment 1 and Experiment 2. The other two groups used these same two note-taking strategies but were tested after a 24-hr delay; each of these groups consisted of participants in Experiment 2 and Experiment 3. Finally, we looked at data from Experiment 3, where participants were allowed to study their notes and then were tested 24 hr later.

Immediate testing. Descriptive statistics of the measures used in the individual differences analyses of data from those tested immediately after the lecture are provided in Table 4, with the intercorrelations among these measures presented in Table 5. For both groups, processing speed was a significant predictor of working memory, and note-quantity predicted free recall. Of particular interest, however, are the differences between the two groups. Whereas working memory predicted both note-taking quantity and free recall in the organized note-taking group, working memory was not a significant predictor of either note-quantity or free recall for those who were told to transcribe the lecture.

This absence of a correlation between working memory and either note-quantity or recall of the lecture is unusual in the literature, yet was expected here given our hypothesis that transcribing minimizes the need to hold and manipulate lecture information. Although recall performance did not correlate with working memory, it did correlate with note-quantity, suggesting that students with poor working memory could use the transcription strategy precisely because it relies simply on how fast they can take notes. This is especially important because the results for those taking organized notes indicate that with this latter strategy, those with poor working memory are at a disadvantage when they are given tests that assess their recall of the lecture material. Taken together, our findings suggest not only that transcribing using a computer can lead to superior immediate recall, but also that working memory does not have to play a role in this process.

Delayed testing. Tables 6 and 7 provide descriptive statistics and intercorrelations, respectively, when testing was delayed with no opportunity for participants to study their notes. As expected, processing speed again correlated with working memory regardless of note-taking strategy. More importantly, note-quantity again predicted free recall regardless of note-taking strategy, attesting to the powerful role of sheer note-quantity as a predictor of test performance, regardless of whether testing is immediate or delayed. With respect to the two note-taking strategies, working memory predicted note-quantity only for those who took organized notes, replicating the results for those tested immediately. The one difference between the results for those tested immediately and those tested after a delay was that in the latter case, working memory and free recall were significantly correlated for both note-taking strategies: Those with higher working memory ability showed less forgetting over the delay. With respect to finding an effective note-taking strategy for those with lower working memory ability, these results may appear problematic. However, they come from participants who were not allowed to study their notes, and as we will show, the situation appears to be different when studying is allowed.

Delayed testing after studying. Experiment 3 demonstrated that although taking organized notes led to better delayed test performance than the transcription strategy when there was no study opportunity, the opposite was true when participants had the opportunity to study their notes—in this case, those using the transcription strategy did better on the delayed tests. For those taking organized notes, both working memory and note-quantity were moderately correlated with free recall after a 24-hr delay (r = .30 and r = .28, respectively). For those using the transcription strategy, however, note-quantity was strongly correlated with free recall, r = .63, but working memory was not, r = –.01. Although the sample is obviously too small to draw firm conclusions (n =

Table 5
Correlations Between Processing Speed, Working Memory, Note-Taking, and Immediate Free Recall

Measure	1	2	3	4
	Transcribe 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 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

* $p < .05$.

Table 4
Descriptive Statistics for Processing Speed, Working Memory, Note-Quantity, and Immediate Free Recall

Measure	*M*	*SD*	Range
	Transcribe condition (n = 38)		
Processing speed	602.3	91.3	448.0
Working memory	35.5	9.0	38.0
Note-quantity	52.7	17.0	69.3
Free recall	20.5	6.9	26.7
	Organize condition (n = 39)		
Processing speed	599.6	59.5	242.0
Working memory	35.6	7.4	30.0
Note-quantity	36.5	15.1	69.8
Free recall	14.9	5.9	26.5

Table 6
Descriptive Statistics for Processing Speed, Working Memory, Note-Quantity, and Delayed Free Recall

Measure	*M*	*SD*	Range
	Transcribe condition (n = 37)		
Processing speed	594.6	73.8	311.0
Working memory	34.5	7.5	32.0
Note-quantity	52.0	18.1	67.0
Free recall	10.7	4.6	23.0
	Organize condition (n = 37)		
Processing speed	605.6	87.6	387.6
Working memory	36.8	9.5	39.0
Note-quantity	32.7	32.7	48.0
Free recall	14.2	5.3	22.8

Table 7
Correlations Between Processing Speed, Working Memory, Note-Taking, and Delayed Free Recall

Measure	1	2	3	4
	Transcribe 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 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

* $p < .05$.

18), given these results it seems unlikely that increasing the number of observations would lead to a significant correlation between working memory and free recall for those using a transcription strategy.

General Discussion

Three experiments compared the effectiveness of taking organized notes with a transcription strategy in which students try to record as much of a lecture as possible. The results of Experiment 1 revealed that when students took notes by hand and were tested immediately after the lecture, both strategies were equally effective for recall. When students took notes using a computer, however, trying to transcribe the lecture resulted in better test performance than taking organized notes—better, in fact, than using either strategy but taking notes by hand. These results are consistent with the generation effect (Slamecka & Graf, 1978) as well as the translation hypothesis (Conway & Gathercole, 1990), both of which predict that engaging in generative activity during note-taking improves memory.

The results of Experiment 2 revealed that if participants did not study their notes after taking them, the initial advantage that came from use of the transcription strategy with a computer was gone 24 hr later, and those who took organized notes did significantly better. From the perspective of a levels-of-processing framework (Craik & Lockhart, 1972) and Bjork and Bjork's (1992) distinction between storage and retrieval strength, this is not surprising if transcribing information involves shallow processing, whereas organizing information involves deeper, semantic processing, which promotes long-term retention. For participants in Experiment 3 who briefly studied their notes shortly after the lecture and who were tested 24 hr later, transcription was once again the most effective strategy. Because using this strategy with a computer resulted in greater note-quantity than an organized note-taking strategy, we attribute the superior delayed recall of those who used the transcription strategy and then reviewed their notes primarily to an external storage benefit. Taken together, our results suggest that, with respect to the issue of note quality versus quantity, which one plays a more important role for recall depends on the situation. When testing was delayed, for example, those who used the transcription strategy and took more notes did better if studying one's notes was allowed; when studying was not allowed, however, then those who took higher quality, organized notes did better.

One concern is that participants might not have followed our instructions with respect to note-taking strategy. However, this concern is reduced by examination of the types of idea units that participants recorded in their notes. We would expect to find more main ideas as a proportion of the total number of idea units in the notes of those told to organize compared to those told to transcribe. Indeed, the proportion of main idea units was greater for those told to take organized notes, $t(186) = 2.65$, $p < .001$. Conversely, if those told to try to transcribe the lecture simply typed everything they heard, we should see a greater proportion of unimportant details in their notes compared to those told to take organized notes. This expectation was also confirmed, $t(186) = 4.43$, $p < .001$. Thus, examination of both the quantity and differential selectivity of participants' notes provides no reason to doubt that participants were using the note-taking strategies they were told to.

Researchers have argued that working memory is critical for effective note-taking (e.g., Piolat et al., 2005) because working memory allows individuals to take what is said and (re)organize it into a concise outline of the lecturer's most important points. This process of creating organized notes is reminiscent of certain reading strategies whose goal is to increase comprehension for the material. In such cases, successful text comprehension has been linked to reading strategies such as self-explanation (McNamara, 2004) and generating inferences (McNamara, 2001), which have been thought to be critical for deep-level comprehension of texts (Best, Rowe, Ozuru, & McNamara, 2005). Given the similar goals of strategy use in reading and taking organized lecture notes, it should come as no surprise that there is evidence to suggest that working memory is also related to effective reading strategies (Daneman & Carpenter, 1980).

The relation between working memory and note-taking can create a dire situation for individuals with lower working memory ability who may be unable to take effective organized notes. Previous studies have been inconsistent with respect to the relation between working memory and note-taking (Kiewra & Benton, 1988; Peverly et al., 2007), and as suggested earlier, this may be because different note-taking strategies vary in their reliance on working memory. Indeed, the present results show that whereas taking organized notes depends on working memory ability, the effectiveness with which one can use a transcription strategy does not. For the participants in Experiment 3 who used a transcription strategy and then studied their notes, test performance depended only on note-quantity and not on working memory, suggesting that this strategy may help level the playing field in terms of learning outcomes.

It would be myopic, of course, to introduce the strategy of transcribing notes using computers without discussing potential boundary conditions. To begin with, the benefits of this strategy are undoubtedly limited to those who can type reasonably well. We would note, however, that in the present study, 96% of the participants said they were proficient typists, and we suspect that this is true for college students in general. Another potential boundary condition concerns the extent to which the transcription note-taking strategy improves performance on more conceptually-oriented tests (e.g., those that require reasoning, induction, or transfer). Indeed, it is possible that note-quantity, to the extent that it reflects shallow processing of the lecture material, could be inversely related to performance on conceptually-oriented tests that may require deeper levels of processing (Bretzing & Kulhavy, 1979; Kiewra, 1985; Kobayashi, 2005; Mayer, 1992). Given that educators are interested in students' grasp of information on a conceptual level, future studies are needed that address this important issue. Another potential concern is that it is unclear whether asking students to try and transcribe an entire lecture is reasonable. Because our lecture passage was only 11 min long, factors such as attention and fatigue may not have played a role, although they might have a much larger influence with longer lectures.

Future studies should explore the extent to which our results apply to e-learning environments, as these may provide a way to deal with this issue of lecture duration. Access to lectures on demand, for example, may allow students to experience a lecture in sections, rather than all at once, if they so choose. This would allow them to select how long they wanted to take notes for before reviewing the material, thereby potentially maximizing the benefits of the transcription note-taking strategy. Finally, it is not immediately clear how the current findings would apply to lectures in different disciplines, particularly those in which material is presented graphically, diagrammatically, or pictorially. Nevertheless, even as the variety of educational experiences available is expanding such that students are able to attend lectures from home via the Internet, or to develop a schedule of learning activities that best suits them, the role of note-taking is likely to remain critical for creating meaningful information from lecture material.

Instructors spend most of their class time lecturing, and students need effective note-taking skills and strategies in order to do well on exams. However, exactly what constitutes the most effective note-taking strategies may vary across students who differ in cognitive ability. As a result, research is needed on how individual differences interact with note-taking strategies so that students can be guided toward strategies that rely on cognitive abilities that they are stronger in, or toward strategies that depend less on the abilities that they are weaker in. For students who have poor working memory, at least, help may be on its way.

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