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Individual Differences in Notetaking, Summarization, and Learning from Lectures

This study investigated working memory, verbal ability, and prior knowledge as predictors of the quality of: (a) students' notes taken during a lecture; (b) summaries of the lecture written during a review period; and (c) recall of the lecture content. The usefulness of taking notes was considered in terms of quality of summarization and recall of the lecture material for three groups of students who: (a) listened to the lecture, took notes, and reviewed those notes; (b) listened to the lecture and reviewed a set of provided notes; or (c) listened to the lecture, took notes, and then reviewed a set of provided notes. Results indicated that students with higher working memory benefit more from listening to the lecture than listening and taking notes. However, the quality of summaries written was a more powerful predictor of performance than the individual differences students' brought to the task. This study extends previous studies by integrating summarization and lecture learning research and providing new insight into the role of notetaking and its relationship to working memory.

La mémoire de travail, l'habileté verbale et les connaissances préalables ont été étudiées pour leur valeur prédictive de la qualité: (a) des notes que prenaient les étudiants pendant le cours; (b) des résumés de cours rédigés pendant une période de révision; et (c) du rappel du contenu de cours. L'utilité de la prise de notes a été évaluée d'après la qualité des résumés et le rappel du contenu de cours chez trois groupes d'étudiants qui: (a) écoutaient le cours, prenaient des notes et les révisaient; (b) écoutaient le cours et révisaient des notes qu'on leur fournissait; ou (c) écoutaient le cours, prenaient des notes et révisaient ensuite des notes qu'on leur fournissait. Les résultats indiquent que, pour les étudiants qui ont une plus grande mémoire de travail, il est plus profitable de tout simplement écouter le cours que d'écouter et de prendre des notes. Cependant, la qualité des résumés s'est avérée avoir une meilleure valeur prédictive de la performance que le sont les différences individuelles qui se manifestent pendant l'apprentissage. Cette étude contribue aux précédentes en intégrant la recherche sur le résumé et l'apprentissage qui a lieu pendant les cours, ainsi qu'en fournissant de nouvelles idées sur le rôle de la prise de notes et son lien avec la mémoire de travail.

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Notetaking is a common practice among university students. Although all students attending a class listen to the same lecture, the notes they take during that lecture, and the information they remember afterward, differ from student to student. Generally, students take notes because (a) they provide a written record of the lecture content for review at a later date, and (b) the process of writing information down helps them to attend to and remember that information (Hartley, 1983). Regardless of students' reasons, or research findings in the field, notetaking continues to be a prominent activity in higher education and elsewhere.

This study attempts to integrate some of the main themes in the literature to date. It addresses the usefulness of taking notes versus listening to a lecture when an alternative "written record" of the lecture is available to students. Furthermore, it considers the influence of individual differences in working memory, prior knowledge, and verbal ability to determine whether student success is primarily attributable to the abilities that students bring to the learning task, the processing activities they engage during the learning task, or a combination of abilities and processing activities. Studies have considered the contribution of each of the variables (working memory, verbal ability, and prior knowledge) to the notetaking, summarization and review processes. None, however, has attempted to consider the contribution of each of the variables in the context of each other so that any true differences can be revealed in regression analysis. Furthermore, few studies have considered the relationship of these variables to the free recall of lecture information after students have been encouraged to engage in an extensive review period (summarization). And finally, this study is the first to incorporate scoring for notetaking accuracy that accounts for the presence of ideas as well as the depth of integration into this type of model.

Comparing Learning Conditions

Studies comparing the immediate and delayed recall of students who did or did not take notes do not provide convincing support for notetaking (Kiewra, 1985a). Further, these studies support both the encoding hypothesis that notetaking helps students to encode and remember information, and the storage hypothesis that notetaking is useful because it provides a written record for review, which in turn promotes recall. This is not surprising because most students believe that writing the information down will help them to remember, and that notetaking also provides an external representation of the lecture for review (Hartley, 1983).

Typically, studies have compared an encoding condition (students took notes) to an encoding plus storage condition (students took notes and reviewed notes) and found encoding plus storage to be more effective. Kiewra et al. (1991a) suggested that two inherent difficulties in the design of these studies accounts for this finding. First, there was a generative processing effect in the encoding plus storage condition because students who engaged in a review session had opportunities actively to generate relations among ideas. Because generative processing enhances recall of information (Wittrock, Marks, & Doctorow, 1975), one would expect students who review to remember more than students who do not review. Second, there was a repetition effect in the encoding plus storage condition because students were exposed to the material twice. Repetition improves recall because each successive presentation allows the learners to add to their schema in memory and adapt learning strategies to focus on different aspects of material (Bromage & Mayer, 1986; Kiewra, Mayer, Christensen, Kim, & Risch, 1991b; Mayer, 1983).

In the present study we compared three notetaking conditions, but controlled for the repetition effect by making sure that all students had two exposures to the material. Students either reviewed their own notes or a set of instructor notes that provided a detailed account, but not a transcription, of the lecture. The impact of introducing instructor notes for review is not clear (Kiewra, 1985b). If anything, longer notes seem to be more facilitative of recall regardless of their source (Maqsud, 1980), but matrix notes are better than full transcriptions of a lecture (Kiewra, DuBois, Christian, & McShane, 1988).

We controlled for the generative processing effect by asking all students to write a summary of the lecture. King (1992) found that students trained to use summary writing as a generative review strategy outperformed students trained to use self-questioning methods on an immediate retention test. King analyzed the number of ideas in the lecture, but did not examine the content of student written summaries. Because summary quality has been shown to be a predictor of recall from text (Kirby & Woodhouse, 1994), we extended King's study by coding for idea units represented in summaries.

Individual Differences

Beyond addressing the encoding/storage paradigm, this study attempts to determine whether success in learning lecture content is primarily attributable to individual differences in ability or to the processing activities students engage during the learning task. This study considers the relationship between three individual difference variables (working memory capacity, verbal ability, and prior knowledge) and their influences on notetaking, summarizing, and learning from lectures. Primarily, working memory capacity is the focus of our hypotheses. However, the strong relationship between working memory capacity and both prior knowledge (Haenggi & Perfetti, 1992) and verbal ability (Daneman & Carpenter, 1980) indicates that the influence of working memory capacity cannot be isolated without considering the impinging contributions of verbal ability and prior knowledge. Regression analysis is employed in this study because: (a) continuous measures of individual difference variables can be used; and (b) the predictive power of working memory capacity can be considered in the context of prior knowledge and verbal ability.

Working memory capacity. Cantor, Engle, and Hamilton (1991) described working memory capacity as a "flexible computational arena, with a limited amount of attentional resources that are required for the processes" (p. 230). Recent research suggests that higher-level cognitive processes (problem-solving ability and reading comprehension) are constrained by working memory capacity (Just & Carpenter, 1992; Tirre & Pena, 1992). Notetaking during a lecture is a higher-level cognitive process that involves holding and manipulating information simultaneously; it is, therefore, a demanding activity for working memory.

Working memory capacity is a critical variable in this study for three reasons. First, working memory capacity influences the notetaking process in general. Notetaking requires students to listen, observe, integrate, process, and record information simultaneously. A student with a higher working memory capacity (able to process and hold more material simultaneously) is able to complete these simultaneous processing activities more competently than a student with limited working memory capacity (DiVesta & Gray, 1973).

Second, the usefulness of each learning condition (encoding, storage, encoding plus storage) may differ depending on a student's working memory capacity. Studies supporting the encoding function of notetaking have not examined the effectiveness of learning conditions across a range of individual differences in working memory capacity. One might expect students with lower working memory capacity to benefit from a reduction in the number of processing activities to be engaged simultaneously, thereby remembering more when required only to listen, observe, and integrate rather than record as well.

Third, differences in working memory capacity may affect the quality of student notes differently. Students with limited working memory capacity record fewer words, total ideas, and subordinate ideas than students with higher working memory capacity (Kiewra & Benton, 1988; Kiewra, Benton, & Lewis, 1987). We propose that a stronger indicator of the effect of working memory capacity on notetaking will emerge by analyzing both the number of ideas recorded and the relative importance of those ideas. Do students with lower working memory capacity just record fewer notes, or do their notes also contain less of the important information? This method of analyzing content has been implemented in the summarization literature and may provide some useful information regarding the role of working memory capacity (Kirby & Pedwell, 1991; Kirby & Woodhouse, 1994; Stein & Kirby, 1992).

Purpose

The purpose of the study was twofold. First, the effectiveness of taking notes was considered in terms of quality of review (summarization) and recall of the lecture material for three conditions: (a) Notetaking (listen + take notes + review notes), (b) Listening (listen + review provided notes), and (c) Combined (listen + take notes + review provided notes). Second, we investigated working memory capacity as a predictor of (a) the quality of notes students took during a lecture, (b) the quality of summaries students wrote during a review period, and (c) the content students recalled from the lecture. To our knowledge the influence of working memory capacity (as a continuous variable) on notetaking, summarization, and recall has never been examined in the context of other individual difference variables such as verbal ability and prior knowledge. While this approach adds significant complexity to the analysis, it provides opportunities to account for shared variance between individual difference variables as well as the linear relationships between working memory and notetaking, summarization, and recall.

Hypotheses

We hypothesized as follows.

1. Working memory capacity would predict notetaking quality such that higher working memory capacity would be associated with writing better

quality notes (i.e., notes that are more complete and contain more of both the main and important ideas of the lecture); and lower working memory capacity would be associated with writing notes of poorer quality.

2. Working memory capacity and condition would interact such that students at the lower end of the working memory measure would perform better in the Listening condition and worse in the Notetaking condition, because the demands on working memory would be reduced by having only to listen to the lecture. Furthermore, students with higher working memory capacity scores were expected to perform best in the Combined condition and worst in the Listening condition; previous literature suggests that students with higher working memory capacity benefit from notetaking, and we proposed that students in the Combined condition would have the additional benefit of reviewing good notes regardless of the quality of notes they took.
3. The quality of the summaries would predict recall in all conditions.

Method

Participants

The participants were 94 first-year university students, mean age 18.9 years, recruited through the residence system. Students volunteered to participate and represented a wide range of disciplines and faculties. A total of 12 participants were removed from analyses. One participant withdrew because he fell asleep during the lecture. One participant's data were not used because he reported feeling fatigued during the lecture. Nine participants' data were removed from the analyses because English was not their native language, and one student was unable to attend the recall session due to other time commitments. Therefore, the data from 82 participants, 48 females and 34 males, were included in the following analyses.

Lecture Materials

A videotaped lecture entitled *Stephen Jay Gould: Evolution and Human Equality* (1988) was used. The 43-minute taped lecture by Gould was chosen for three reasons: (a) it was the length of an average university lecture; (b) evolution was not a standard part of most core first-year courses, so students' prior knowledge of the lecture material was expected to be limited; and (c) the material was as challenging as, if not more challenging than, a typical university lecture.

We prepared a set of provided lecture notes, which were in point form, but were coherent enough to be understood without the lecture. These notes were intended to give students a second exposure to the lecture material and therefore closely followed the lecture content, structure, and order. They contained most of the important ideas, and all of the main ideas, and provided enough information to allow the themes to be recognized. No inferences beyond the lecture content were drawn in the provided notes.

Measures

Working memory capacity. The reading span measure was adapted from that used by Daneman and Carpenter (1983). Students were asked to read series of sentences aloud and remember the last word in every sentence. Each sentence appeared in the center of the computer screen with only one sentence per screen. The rate of presentation was controlled by the researcher and did not allow time for rehearsal. A blank screen cued the participant to report orally the last word in each sentence of the current series. There were six levels of difficulty. Sentence series consisted of a number of sentences corresponding to the difficulty level (1, 2, 3, 4, 5, or 6). Three series of sentences were presented at levels 1 (1 sentence per series) and 2 (2 sentences per series), and five sets of sentences were presented at levels 3 (3 sentences per series), 4 (4 sentences per series), 5 (5 sentences per series), and 6 (6 sentences per series). Participants continued the test until they correctly recalled the last words for one (or fewer) of the sentence series at a level. At this time the test was terminated and the participant did not attempt the next level. Participants were given credit for every series recalled correctly. At levels 1 and 2, participants were awarded .33 for one series out of three correct, .67 for two series out of three correct, and 1 for three series out of three correct. At all other sentence levels (3, 4, 5, and 6) participants were awarded .20 for one out of five series correct, .40 for two, .60 for three, .80 for four, and 1 for all five series correct. The highest possible score was 6, meaning that the student correctly remembered the last word of each sentence presented for all series presented at each of the six levels.

Verbal ability. The Similarities subtest of the Multidimensional Aptitude Battery (Jackson, 1984) was used to measure verbal ability. Students were presented with a pair of words and asked to select the multiple-choice option that best described how those words were similar. The test consisted of 34 multiple-choice questions with a maximum score of 34. The maximum time to complete this test was seven minutes.

Prior knowledge. The measure of prior knowledge consisted of four questions. The first question tapped into general knowledge about the lecture content and asked students to rate their familiarity with the content of the lecture before the lecture. The next two questions asked students to rate their familiarity prior to seeing the lecture with two pivotal concepts discussed: theories of evolution and DNA research. This method of measuring prior knowledge was implemented successfully by McGinn (1991) and was chosen because it relies on student judgments about their own familiarity with the material and avoids the problem of alerting students to lecture content through prior assessment of content knowledge. In the final question, students were asked if they had ever heard Stephen J. Gould speak (the lecturer on the videotape), and answered Yes or No. For the first three questions, students used Likert scales ranging from 1 for "completely unfamiliar" to 7 for "extremely familiar." For the fourth question a score of 1 was assigned if the answer was Yes. These four scores were summed, resulting in a maximum prior knowledge score of 22.

Content scoring of notes, summaries, and free recalls. A content scoring template was developed by transcribing the lecture and following the procedures outlined by Kirby and Pedwell (1991). The transcript was divided into idea units, which were analyzed in terms of their importance for the lecture. This was done by three researchers independently, and disagreements were resolved in confidence. Four levels of importance were employed: themes, main ideas, important ideas, and less important ideas. Each of the five themes identified was a broad statement about the lecture's intent and was generally inferred from a number of main ideas (e.g., Evolutionary theories of race center around the question "Where did humans evolve?"). These themes required students to generate connections between and beyond ideas presented explicitly in the text. The 26 main ideas were explicitly stated in the lecture and were the topics of major segments of the lecture (e.g., Theory that races are separate species). The 34 important ideas were explicitly stated details that supplied crucial support for main ideas (e.g., Humans split from chimpanzees 6-7 million years ago). The 51 less important ideas provided details that were not important for the main ideas or themes of the lecture (e.g., 147 people were the participants in a study).

The scoring template was used to score notes, summaries, and recalls. Overall scores for notes, summaries, and recalls were computed by awarding each theme 4 points, each main idea 3 points, and each important idea 1 point and adding them together (less important ideas were not scored). For example, for a free recall containing 15 important ideas, 10 main ideas, and 2 themes, the score was (15x1) + (10x3) + (2x4) or 43 points. This method of scoring has been implemented successfully in the past (Kirby & Pedwell, 1991; Kirby & Woodhouse, 1994). After completing the scoring, 10 free recalls, summaries, and notes were randomly selected and rescored by the first author without knowledge of the experimental conditions or the previous scores. The scoring was consistent with correlations of .98, .97, and .98 for recalls, summaries, and notes respectively.

Probed recall. Four probed recall questions were set based on ideas presented in the lecture. There were two important ideas questions worth 5 marks each: *Who was the Hottentot Venus and what was her relevance to Gould's lecture?* and *Gould's conclusion is that human equality is a contingent fact of history. What does he mean by this?* There were also two main idea questions worth 10 marks each: *According to the information presented in the lecture, where did humans evolve? Support with evidence; and According to the information presented in the lecture when did humans evolve? Support with evidence.* Participants were: (a) asked to provide brief written responses of approximately five lines for important ideas questions or 10 lines for main idea questions; and (b) informed that they did not have to rewrite an answer that they had just included in the free recall; instead they could mark the question with "please see free recall" and the answer would be marked from the free recall text. Probed recalls were graded according to the number of idea units represented in the answer; grades on the 5-mark questions ranged from 0 to 5; and grades on the 10-mark questions ranged from 0 to 10.

Procedure

Participants were randomly assigned to one of three experimental conditions: (a) Listen, take notes and review them later (Notetaking); (b) Listen to the lecture, and review provided notes later (Listening); and (c) Listen, take notes and review provided notes later (Combined). A detailed description of each session follows.

Session 1. Participants who were in the same conditions were scheduled in groups of not more than 20 per session. Participants in the Notetaking condition and the Combined condition were given a pad of paper and a pen and instructed to take notes on the videotaped lecture. They were instructed to treat this as a normal university lecture and informed that they would be given time to review the notes before being tested on the material. Participants in the Listening condition were given the same instructions, but were not asked or allowed to record any notes. They were told that they would be given a chance to review a set of notes before being tested on the material. After completion of the lecture, students were asked to answer the prior knowledge questions. It was made clear through oral instructions and wording of the prior knowledge instrument itself that students were to make judgments about their familiarity with the content before viewing the lecture.

Session 2. One week after the first session, the verbal ability measure was administered in groups. Participants were given their own notes (Notetaking condition) or provided notes (Listening and Combined conditions) to read. All groups were instructed to read the notes from beginning to end. The researcher observed to make sure participants read through the notes before writing a summary. They were then asked to write a summary of the notes, with the notes available for inspection. Participants were asked to consider this a one-page summary of the lecture that could be given to someone who missed the lecture and needed to review its contents for the exam. No time limit was placed on summary writing. Participants took between 30 and 55 minutes to complete this task. They were encouraged to write what they considered to be important. Text present summarization was chosen because it parallels what students typically do when they review.

Session 3. One week after session 2, participants met with the first author in groups of two. During this session students wrote a free recall of the lecture (i.e., write down everything you remember about the lecture), and completed the probed recall test. Average time to complete the probed recall and free recall measures was 40 minutes. Students were also tested individually on the reading span test. This measure was paced by the participant's reading speed and accuracy, so completion times differed significantly between individuals. This is not a timed test.

Results

Means and standard deviations for all measures are presented in Table 1. Comparisons using one-way analyses of variance showed that the mean scores for working memory capacity, verbal ability, and prior knowledge did not differ significantly across conditions (all F's<1.3, all p's>.25).

A series of multiple regression analyses was conducted to test the hypotheses following the procedure outlined by Pedhazur (1982) for conducting multiple regression analyses involving aptitude-treatment interaction designs. Effect coding was used for the categorical variable (treatment condition). Two vectors were created: (a) vector 1 assigned the scores 1, 0, and –1 to the Notetaking, Listening, and Combined conditions respectively, and (b) vector 2 assigned the scores 0, 1, and –1 to the Notetaking, Listening, and Combined conditions respectively. Vector 1 compared the Notetaking and Combined conditions, and vector 2 compared the Listening and Combined conditions. Unless indicated otherwise, all regression equations included both vectors and the interaction of each variable with each vector. A backward deletion procedure was used in

Table 1
Means (*M*) and Standard Deviations (*SD*) for Verbal Ability, Working Memory, Prior Knowledge, Note Content, Summary Content, Recall Content, and Probed Recall for Each of the Conditions (Notetaking, Listening, and Combined)

	Condition					
	Notetaking (n=29)		Listening (n=29)		Combined (n=24)	
Variables	M	SD	M	SD	M	SD
Verbal Ability	24.45	4.25	25.41	4.60	25.35	3.80
Working Memory	1.62	0.62	1.67	0.66	1.90	0.74
Prior Knowledge	11.28	5.03	10.65	4.97	9.58	4.06
Note Content	61.76	17.63	—	—	56.21	18.53
Summary Content	40.14	14.93	43.76	24.64	43.33	20.15
Recall Content	23.76	14.33	30.79	21.24	28.59	15.43
Probed Recall	7.81	3.33	10.60	4.57	8.33	4.80

which all variables and interactions were entered into the first regression equation, and the equation was reduced by eliminating nonsignificant interactions one at a time (beginning with that with the lowest beta coefficient). All statistically significant effects from the final models are reported in Table 2.

The Influence of Individual Difference Variables and Condition on Note Quality
The first regression analysis investigated the influences of verbal ability, prior knowledge, and working memory capacity on the quality of notes produced during learning. It compared only the Notetaking and Combined conditions (vector 1) because the Listening group did not take notes. The full regression model including all three individual difference measures failed to account for a significant amount of variance. Because previous studies have found working memory capacity to be a significant predictor of note quality, a second regression analysis was performed using condition and working memory capacity as the sole predictors of note quality. Working memory capacity predicted note content in a simple regression analysis, and the overall variance accounted for by this model was statistically significant (see Table 2). In Table 2 the results reported for the Full models are only those for the effects that were significant in the final or Reduced models. The results reported for the Reduced Models are only those for significant effects; results for nonsignificant main effects are not reported.

The Influence of Individual Difference Variables and Condition on Summary Content
The second set of regression analyses investigated the influence of working memory capacity, prior knowledge, verbal ability, and learning condition on summary quality (content). Results indicated verbal ability predicted summary content, and the overall variance accounted for by this model was statistically significant (see Table 2). Contrary to the experimental hypothesis, working memory capacity did not emerge as a significant predictor of summary quality, nor did it interact with learning condition.

Table 2
Significant Outcomes of a Series of Multiple Regression Analyses Using a Backward Selection Procedure

Significant Predictors	Full Model R^2	Beta	t	p	Reduced Model R^2	Beta	t	p
of Note Content	.18[a]			ns[a]	.12[b]			<.05[b]
Working Memory		.33	2.24	<.05		.32	2.32	<.05
of Summary Content	.22			ns	.18			<.05
Verbal Ability		.37	3.16	<.01		.35	3.21	<.01
of Recall Content	.51			<.01	.45			<.01
Vector 2				ns		−.66	−2.39	<.01
Summary Content		.47	4.46	<.01		.57	5.84	<.01
Vector 2 X Working Memory		.87	3.00	<.01		.89	3.02	<.01
of Probed Recall	.53			<.01	.51			<.01
Vector 2				ns		−1.04	−3.15	<.01
Prior Knowledge		.26	2.72	<.01		.21	2.32	<.05
Summary Content		.32	3.06	<.01		.35	3.46	<.01
Vector 2 X Working Memory		.89	3.18	<.01		.89	3.19	<.01
Vector 2 X Summary Content		.66	2.60	<.05		.58	2.51	<.001

Vector 1 = Notetaking compared to Combined.
Vector 2 = Listening compared to Combined.
[a]Model including only working memory, condition, and their interaction.
[b]Model including working memory and condition.

The Influence of Individual Difference Variables and Condition on Free Recall

The third set of regression analyses investigated the influence of working memory capacity, prior knowledge, verbal ability, summary quality, and learning condition on free recall performance. This analysis was conducted to investigate hypothesis 3. This analysis, summarized in Table 2, yielded a significant main effect for summary content, supporting the argument that recall is facilitated by writing a quality summary. There was also a significant interaction between working memory capacity and condition, shown in Figure 1. Separate regression analyses for each group indicated a significant positive relationship between working memory capacity and free recall in the Listening condition $t=2.46$, $p=.02$. Thus, contrary to our hypothesis, increased working memory capacity facilitated recall in the Listening condition but not in the other two conditions. For students at the lower end of the working memory measure, performance was statistically similar regardless of learning condition.

Variables and Condition on Probed Recall.

A similar set of regression analyses was performed to investigate the influence of working memory capacity, prior knowledge, verbal ability, summary quality, and learning condition as predictors of probed recall. The analysis, summarized in Table 2, yielded a significant main effect for summary content, supporting the argument that probed recall is facilitated by writing a quality summary. A significant main effect also emerged for prior knowledge, indicating that probed recall is facilitated by prior knowledge. There was a significant

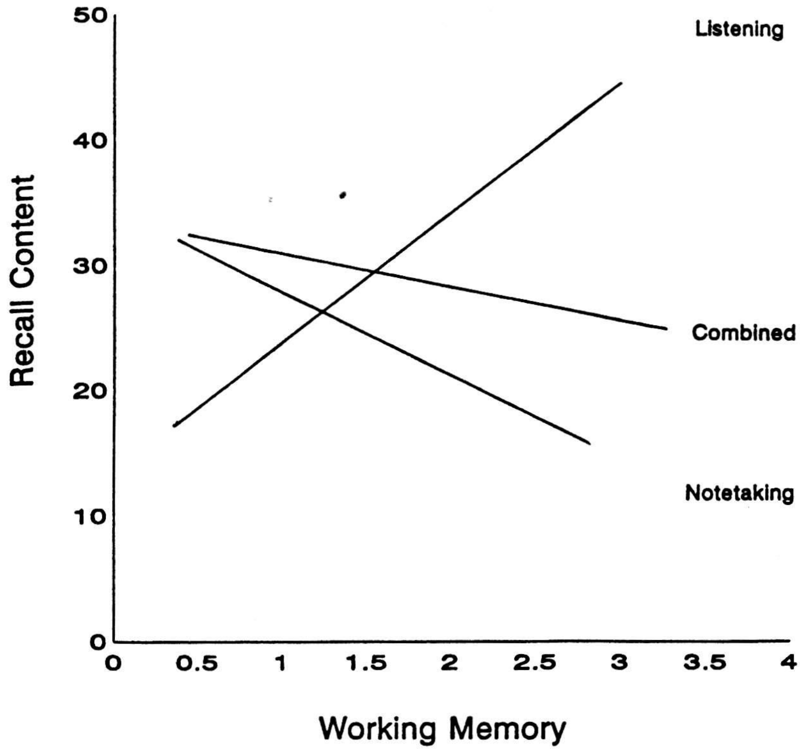

Figure 1. Interaction between learning condition and working memory for predicting recall content in the presence of summary content. All regression lines have been plotted to 1.5 standard deviations from the mean; therefore, caution should be taken when interpreting extremes of the regression lines.

interaction between working memory capacity and condition, and summary content and condition. Separate regression analyses for each group indicated a significant negative relation between working memory capacity and probed recall in the Combined condition, $t=-2.36$, $p=.03$ (see Figure 2). Thus, contrary to our hypothesis, as working memory capacity scores increased, the benefit of being in the Listening condition emerged. Separate analyses of the summary content interaction indicated that students who wrote better summaries remembered more; however, summary quality was only more facilitative for probed recall in the Listening condition, $t=5.42$, $p<.001$ (see Figure 3).

Discussion

Evaluation of Hypotheses

Notetaking and summarization are both complex cognitive processes because they require students to hold and manipulate information mentally while simultaneously recording the important information in written form. Recent research has suggested that these kinds of higher level cognitive processes are constrained by working memory (Just & Carpenter, 1992). Thus two of the three hypotheses focused on the working memory variable.

Effect of working memory capacity. We hypothesized that students with higher working memory capacity would write better notes (i.e., notes that contained more of the main and important ideas presented in the lecture) than students

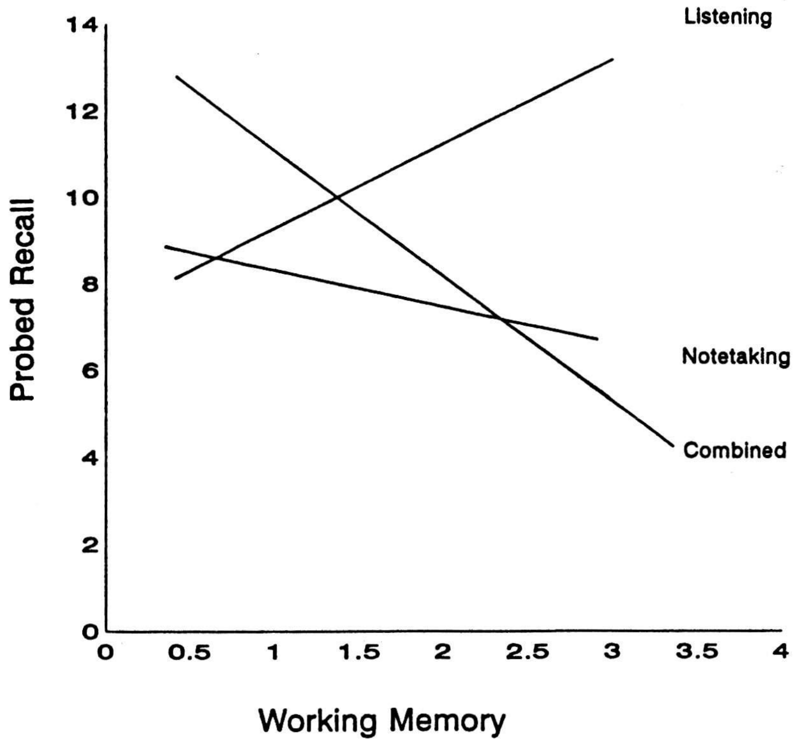

Figure 2. Interaction between learning condition and working memory for predicting probed recall in the presence of summary content. All regression lines have been plotted to 1.5 standard deviations from the mean; therefore, caution should be taken when interpreting extremes of the regression lines.

with lower working memory capacity. The directional hypothesis that working memory capacity would facilitate the quality of lecture notes was supported in the regression analysis. Unfortunately, this finding was not as strong as expected, but working memory capacity did predict note content in a simple regression analysis model (without Verbal ability and Prior knowledge). These findings suggest that working memory does have an effect on note content, but some of this effect comes from the overlap with verbal ability and prior knowledge. Therefore, when these variables are included in the regression model, the contribution of the working memory variable is weakened.

Interaction of working memory and condition. Working memory capacity and condition were expected to interact such that students at the lower end of the working memory measure would perform better in the Listening condition and worse in the Notetaking condition because there would be fewer demands on working memory in the former condition. In contrast, students with higher working memory scores were expected to perform best in the Combined condition and worst in the Listening condition, because previous literature suggests that students with higher working memory capacity benefit from notetaking, and students in the Combined condition reviewed complete notes in addition to notetaking.

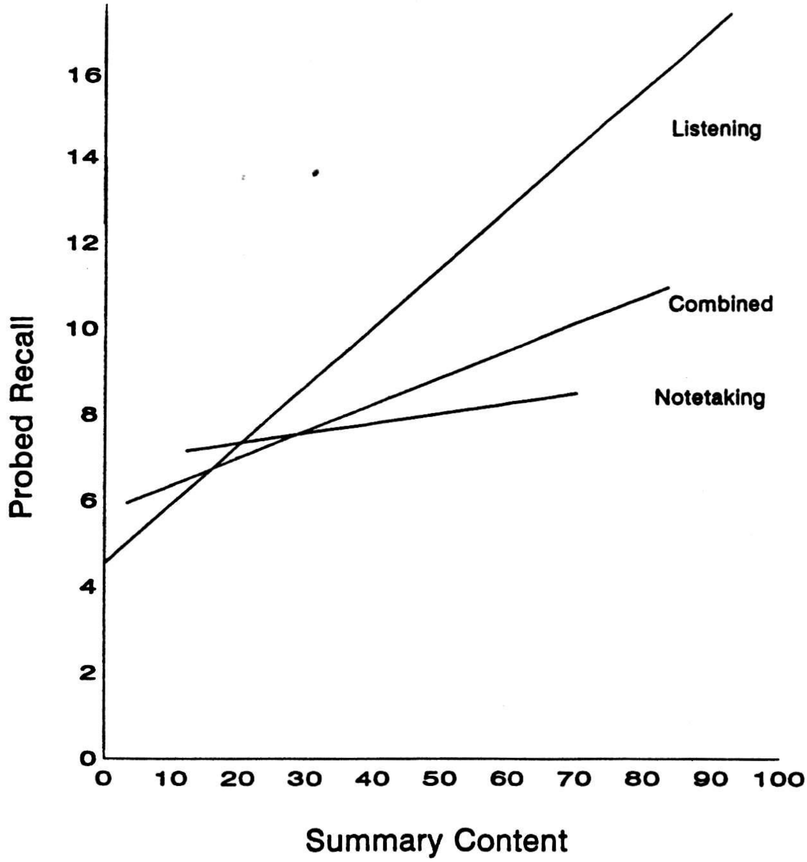

Figure 3. Interaction between learning condition and summary content for predicting probed recall. All regression lines have been plotted to 1.5 standard deviations from the mean; therefore, caution should be taken when interpreting extremes of the regression lines.

We found an interaction between working memory capacity and condition. Contrary to the hypothesis, for students with lower working memory capacity, condition made little difference to summarization, recall (see Figure 1), or probed recall results (see Figure 2). As working memory increased, the benefits of being in the Listening condition emerged for recall and probed recall performance. It can be noted that participation in the Listening condition resulted in the highest recall and probed recall scores overall (see Table 1). These results suggest that notetaking during a lecture may not always be advantageous when alternative resources for review are available.

Effect of summary quality. We hypothesized that the quality of summaries students wrote would predict their recall (and probed recall) of the lecture material. This hypothesis was strongly supported; the quality of summaries students wrote was a more consistent and powerful predictor of their performance than any of the individual difference variables including working memory capacity, verbal ability, and prior knowledge (see Table 2).

Conclusions

The storage function of notetaking. The findings of the present study lend support to the storage function of notetaking, which suggests that notetaking is useful because it provides a written record of the lecture material for later review. There was a benefit for students who listened to the lecture without taking notes and reviewed a set of provided notes. The mean probed recall scores of the Listening condition were significantly higher than those of the Notetaking and Combined conditions (see Table 1). A similar trend occurred for free recall, but the difference was not statistically detectable. Although this finding is contrary to that of Kiewra et al. (1991a), the superiority of their encoding and storage condition (equivalent to our Combined condition) may have been due to the group's additional exposure to the material, as well as the time available for generative processing to occur.

Our study ensured that all conditions (Notetaking, Listening, and Combined) received equivalent exposures to the lecture material and the opportunity to engage in generative processing through summarization. Our findings indicated an overall benefit for students who listened to the lecture without taking notes and then reviewed a set of provided notes. Rather than supporting the notion that notetaking is useful because it allows the student to encode while taking notes and also store the information (in the form of notes) for review afterward, this study supports the notion that notetaking is useful because of its storage function. Students seem to be able to encode during the lecture by just listening. There may in fact be some benefit for students to listen to the lecture without the distraction of taking notes. Of course, effective use of this approach to lecture learning would require the provision of a set of notes for review. Future studies should determine whether this effect was due to the rather comprehensive notes provided in this study, and more generally what kinds of provided notes are optimal.

The importance of summarization and review. King (1992) found that trained summarization facilitated short-term retention. Our findings indicate that the quality of summaries students write, as measured in this study, is strongly associated with recall, even when students are not explicitly trained in summarization strategies. This association was strongest when students listened to the lecture without taking notes. The value of summarization as a review activity is also supported in the text processing literature (Kirby & Pedwell, 1991; Stein & Kirby, 1992; Woodhouse, Kirby, Simpson, & Hadwin, 1992). Findings such as this are promising—although there is little we can do to improve an individual's working memory capacity or verbal ability, the literature does suggest that we can teach university students to use appropriate summarization strategies (Brown & Day, 1983; Hidi & Anderson, 1986; King, 1992; Palincsar & Brown, 1984).

The role of working memory. Haenggi and Perfetti (1992) suggested that working memory is more important for attaining text-implicit information (e.g., combining information from two sentences). Therefore, it makes sense that working memory capacity was important for students in the Listening condition because they had to integrate some of the ideas as they were listening to the lecture rather than focus on many details that they would not be able to remember. Because these students had already done some of that integrating in the lecture period, it might have been easier for them to see those connections in the detailed notes. For students in the Combined condition, higher working memory capacity was not helpful at all. These students may have been so focused on text-explicit information as they took notes that they had little time for integration. Furthermore, the provided notes presented them with a second detailed account of the lecture and may have required them to devote working memory resources to selection and understanding of content stated explicitly, leaving fewer working memory resources for integrating and drawing inferences.

Typically, students with lower working memory capacity are debilitated by the notetaking process (DiVesta & Gray, 1973); therefore, assignment to the Listening condition (listening, not taking notes, and reviewing provided notes) was expected to improve their performance. Instead, we found that the Listening condition was advantageous for those with higher working memory capacity. The most plausible explanation for this finding, given the previous literature, is that the lecture we chose was challenging and therefore taxing on working memory resources. The difficulty of the lecture made notetaking debilitating for all students, including students with higher working memory capacity who had been shown to benefit from notetaking in previous studies (DiVesta & Gray, 1973; Kiewra & Benton, 1988). Thus being able to listen to the lecture without taking notes and then reviewing a set of provided notes reduced the demands on working memory and facilitated recall of the information for students with higher working memory capacity. This suggests that the effects of lecture difficulty on the demands of working memory during notetaking, summarization, and recall warrants further investigation.

The relationship between note content (the quality of notes students take) and working memory capacity has emerged in a number of studies, including the present one. Similar to the findings of Kiewra and Benton (1988), a positive correlation emerged in the present study; as working memory capacity increased, note quality improved. Kiewra and Benton found that working memory capacity predicted the number of words recorded in notes. We found that working memory also predicts the quality of those notes as measured by the number of themes, main ideas, and important ideas that were recorded.

The results of this study highlight the complex involvement of working memory capacity in notetaking and learning from lectures. Researchers may be advised to grapple with this complexity by including more variables in their studies. Furthermore, there may be an advantage to considering these variables as continuous rather than using median splits to compare high versus low working memory groups. Regression analysis provides a means for considering the unique contribution of each predictor variable, as well as their overlap with each other. This process provides information on the predictive value of variables and contributes to our methodological understanding of notetaking and working memory theories.

As practitioners, we invest a fair amount of time delivering information in lecture format and teaching students how to select and record that information. These findings suggest that we may be emphasizing the wrong aspect of lecture learning. Instead students should be encouraged to engage in some generative activities (such as summarization) in order to encode information more deeply. Lecture learning is a complex process with many intervening variables; therefore, students and teachers should be advised to beware of simple prescriptions for studying.

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