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A Review of Note-Taking: The Encoding-Storage Paradigm and Beyond

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This review article investigates the encoding and storage functions of note-taking. The encoding function suggests that the process of taking notes, which are not reviewed, is facilitative. Research specifying optimal note-taking behaviors is discussed as are several means for facilitating note-taking, such as viewing a lecture multiple times, note-taking on a provided framework, or generative note-taking activities. The storage function suggests that the review of notes also is facilitative. Research addressing particular review behaviors, such as organization and elaboration, is discussed as are the advantages of reviewing provided notes, borrowed notes, or notes organized in a matrix form. In addition, cognitive factors related to note-taking and review are discussed. The article concludes with an alternative means for defining and investigating the functions of note-taking, and with implications for education and for research.

KEY WORDS: notetaking; studying; academic performance.

INTRODUCTION

Educational psychologists long have been interested in investigating student note-taking (Crawford, 1925). After all, note-taking is a pervasive activity among students, particularly at the secondary and postsecondary levels (Palmatier and Bennet, 1974). Considerable research has established that note-taking serves two functions: an encoding function suggesting that the process of recording notes is beneficial, and a storage function suggesting that the

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review of notes is helpful. This line of research was instigated by DiVesta and Gray (1972) and has been the focus of nearly 100 studies (see Hartley, 1983, and Kiewra, 1985a, for reviews). Most of these studies have confirmed that note-taking serves a particular function or that one function is more important than the other. Kiewra (1985a, p. 10) has criticized research that compares the encoding and storage functions because it lacks instructional utility. He suggests that if both functions do, in fact, contribute to achievement, then their relative importance is not the primary concern. He believes that the important issues involve *how* students should take notes and *how* they should subsequently review for exams. This article briefly summarizes the encoding and storage literature, and then discusses research aimed at improving note-taking and review activities. It concludes with a new perspective of how the encoding and storage functions should be defined and measured. Avenues for further research and implications for effective note-taking and review are suggested.

THE FUNCTIONS OF NOTE-TAKING

Beginning with DiVesta and Gray (1972), researchers have distinguished two functions of note-taking—storage and encoding. In this section the storage and encoding functions are briefly described with respect to definition, theoretical foundation, assessment, and empirical support. In the case of the encoding function, explanations for the mixed findings are offered.

The Storage Function

The storage function suggests that the review of notes stored in a writen form facilitates retention. Theoretically, review helps learners to consolidate noted information (DiVesta and Gray, 1972), reconstruct previously unrecorded lecture points (Rickards and Friedman, 1978), stave off the natural process of forgetting, or relearn forgotten information. The storage function is tested by comparing the performance of students who review their notes with those who are forbidden to review their notes.

The efficacy of notes as a form of external storage has been well-documented. In 24 studies reported by Hartley (1983) and/or by Kiewra (1985a), students who reviewed their notes had higher achievement on various performance tests than those not permitted to review. Eight other studies reported no differences between reviewers and nonreviewers; no study indicated that review was dysfunctional.

The Encoding Function

The encoding function of note-taking suggests that the process of recording notes facilitates learning even in the absence of review. This facilitative effect may occur because note-taking activities encourage increased attention, more elaborative processing of specific ideas, and/or greater organization of lecture material (see Einstein *et al.,* 1985).

The encoding function is measured by comparing the performance of students who listen to the lecture but do not take notes with those who listen and record notes. Neither group is permitted to review following the lecture. Results of research on the encoding function, however, have been mixed relative to those associated with the storage function. In 61 studies reviewed by Hartley (1983) and/or Kiewra (1985a), 35 found facilitative encoding effects, 23 indicated that note-takers and listeners did not differ significantly on performance tests, and three studies reported that listening without note-taking led to better performance than note-taking. Among studies comparing the storage and encoding functions, the storage function has proven more beneficial (e.g., Carter and Van Matre, 1975; Fisher and Harris, 1973; Kiewra, 1985b; Rickards and Friedman, 1978).

According to Cook and Mayer (1983), some studies fail to demonstrate note-taking's encoding function because presentation rates are rapid (e.g., Peters, 1972) or lecture information is very dense (Aiken *et al.,* 1975). In such cases, more attentional resources must be spent to process the rapid or dense lecture presentation, thereby leaving few resources for note-taking activities aimed at encoding. Peper and Mayer (1978, 1986) further argued that note-taking is a process that helps learners to build external connections between lecture content and prior knowledge; therefore, the encoding benefit of note-taking may be realized only when performance tests measure generative learning, involving relating new material to existing knowledge. Support for this argument was first offered by Peper and Mayer (1978) who had subjects either listen or take notes while a videotaped lecture was presented. Note-takers and listeners did not differ in their recall of basic technical facts, but note-takers did perform better than nonnote-takers on far transfer problems, which required general conceptual information for solution. This pattern of results was confirmed by Einstein *et al.* (1985) who found that note-takers recalled many more high-importance ideas than low-importance ideas, whereas nonnote-takers recalled an equal (but relatively lower) number of each. Support also came from Peper and Mayer (1986) who observed that note-takers performed better than nonnote-takers on far transfer tasks such as problem solving, but worse on near transfer tasks such as fact retention and verbatim recognition. Overall, Peper and Mayer concluded that note-taking is a generative activity that encourages students to build connections between what is presented and what they know, and that this specialized aspect of encoding only can be observed when generative types of tests are used.

Another factor that may influence encoding is the completeness of the recorded notes. Several studies have indicated that when notes are not reviewed the number of lecture ideas recorded in notes is correlated positively and significantly with test performance (e.g., Crawford, 1925; Fisher and Harris, 1973; Kiewra and Fletcher, 1984). In addition, Aiken *et al.* (1975) reported that noted lecture information had a 47% chance of being recalled, whereas neglected information had only a 17% chance of being recalled. These results suggest that taking notes will aid but not ensure recall, whereas not recording notes will almost invariably result in an inability to recall information following some delay and no opportunity to review.

The unfortunate news is that students are notoriously incomplete note-takers. The range of reported findings indicates that freshman students recorded only 11% of lecture ideas (Hartley and Marshall, 1974), whereas "A" students noted 62% of lecture ideas (Locke, 1977). Most studies show that students capture less than 40% of available lecture items (e.g., Crawford, 1925; Hartley and Cameron, 1967; Howe, 1970a; Kiewra, 1985c, d).

IMPROVING THE STORAGE FUNCTION OF NOTE-TAKING

Given the incomplete state of student note-taking and the relative importance of note-taking's storage function, some researchers have suggested that students might perform best when they are provided with a set of notes to review. This practice conceivably could permit the student to concentrate fully on the lecture, rather than divide attention between listening and note-taking, and could provide the learner with a complete record of the lecture for review. Of course, it also would be possible to permit note-taking such that any positive effects of encoding are realized, and additionally provide notes to bolster the review process. The following section examines the benefit of reviewing provided notes furnished by the instructor or by another student. It also examines various forms of provided notes. Last, it describes how students might best review notes.

Providing Notes for Review

Several studies have compared the review potential of personal lecture notes and provided notes under varying acquisition and testing conditions. Under immediate review and testing conditions, provided notes apparently interfere with recall and, therefore, are dysfunctional when compared with the review of personal lecture notes. On an immediate recognition test of factual information following a review period, Kiewra (1984a) found that subjects who took and reviewed their own notes achieved more (93% correct) than did learners who took notes but reviewed provided notes (71% correct) or students who only listened to the lecture and then reviewed provided notes (79% correct). Similar findings, reported by Fisher and Harris (1973), also favored reviewing one's own notes over reviewing provided notes—especially when those given notes for review previously recorded notes during the lecture. Apparently, reviewing provided notes has a more interfering effect on learners who have just recorded notes than on learners who have simply listened to the lecture.

Some investigations comparing the relative advantages of reviewing personal or provided notes prior to delayed exams have found little benefit in reviewing provided notes. For example, Thomas (1978), Annis and Davis (1975), and Fisher and Harris (1973) all have found no apparent differences on delayed scores between subjects who reviewed their own notes or provided notes. In each case, however, the review period lasted only 10 minutes for exams delayed from two days (Thomas, 1978) to three weeks (Fisher and Harris, 1973). These factors perhaps neutralized the relative effectiveness of the review materials.

Reviewing provided notes did produce higher achievement than reviewing personal notes when the review period lasted for 30 minutes and when the provided notes were of sufficient detail (Maqsud, 1980). Maqsud emphasized the importance of detailed notes, speculating that such notes are best for reviewing knowledge acquired during the lecture and for additionally supplying "new" lecture information originally overlooked or misunderstood. Unfortunately, Maqsud's experiment did not assess what was originally learned by note-takers and listeners independent of review. Without this contrast, the apparent delayed differences simply may have been due to listening rather than note-taking during the lecture.

When the contrast between note-takers and listeners was investigated by Kiewra (1985c), Maqsud's interpretation (that apparent differences were the result of the type of notes reviewed and not the result of acquisition condition) was confirmed. Kiewra found that note-takers and listeners did not differ on an immediate test (without review) of factual information, but that listeners who reviewed the provided notes achieved significantly more on the delayed factual exam than did note-takers who reviewed their own notes. The relative effectiveness of the provided notes apparently was due to their breadth and organization when compared with students' notes, and to the delay between acquisition and review. A delay might have reduced the saliency of the original acquisition cues in memory, such that what was learned originally no longer interfered with later learning from the provided notes. In addition, the provided notes simply contained more information directly relating to the factual test items than did students' notes. Naturally, the number of test-related ideas contained in notes is related to achievement (Crawford, 1925; Kiewra and Fletcher, 1984).

A subsequent study by Kiewera (1985d) reconfirmed that provided notes are a better means of storage than personal notes for a delayed test of factual knowledge. In fact, students who did not even attend the lecture but who subsequently reviewed the provided notes scored significantly higher (69%) than did students who took and reviewed their own notes (51%). In a similarly designed study involving various combinations of acquisition and review activities, Knight and McKelvie (1986) also found that students who did not attend the lecture but who reviewed provided notes just prior to a delayed exam actually performed at a higher level than those who recorded and reviewed personal notes. In both cases provided notes were far more complete and organized then were students' personal notes.

In summary, students learn more when provided with a complete set of notes to review than if they review notes which they recorded. Apparently, it is not solely the activity of note-taking that constrains learning, as studlents who record notes and also review provided notes learn more than those who take and review their own notes. The advantage for provided notes apparently stems from their storage capabilities; they generally contain more lecture ideas for review than do personally recorded notes.

Borrowing Notes for Review

Although there are some clear advantages to students receiving a complete set of instructor's notes, instructors ordinarily do not make them available. My personal conversations with faculty suggest that instructors perceive themselves as too busy to provide such a service. More emphatically, they see note-taking as a student responsibility. This latter view also is held by a cross section of college presidents who publicly denounced college note-taking services in a June 1984 column written by Ann Landers. These presidents' major argument was that sidestepping the process of note-taking would be avoiding personal responsibility for learning. To date, however, the literature is silent with respect to the use and value of notes provided by note-taking services (Kiewra, 1984b).

A more common practice involving provided notes has, however, been examined by Kiewra and his colleagues (Kiewra *et al.,* 1988b) who investigated what happens when absent students study notes "borrowed" from classmates. In that study, subjects either took notes from a 20-minute lecture and reviewed them, took notes but did not review them, or absented themselves from the lecture but reviewed a unique set of notes "borrowed" from one of the original note-taking subjects. Results from several performance tests indicated that the note borrowers performed comparable to those who took but did not review notes and those who took and reviewed notes. The note-borrowers actually out-performed the note-takers who did not review on a synthesis test requiring the forming of relationships among lecture ideas. These relationships were not explicitly stated in the lecture. Apparently, note-borrowers had time to form these types of internal connections during review, whereas note-takers did not have an opportunity to form additional connections during the lecture presentation, possibly because they had the difficult task of trying to process the lecture and record notes simultaneously. This finding suggests that the encoding process, relative to the review process, fails to facilitate the generative connection of ideas not explicitly connected in the lecture. This finding somewhat contrasts with those of others (Einstein *et al.*, 1985; Peper and Mayer, 1978, 1986) who found that note-taking encouraged generative processing relative to simple listening. Perhaps that is the case; however, the present finding suggests that generative activities are more likely to occur during review than during note-taking. In a more practical sense, this finding suggests that the popular activity of borrowing and reviewing notes actually has some merit.

The Structure of Provided Notes

The optimal structure of provided notes has received only minimal experimental attention. One study that has investigated the structure of provided notes was conducted by Kiewra *et al.* (1988a). In that study, students listened to a lecture without taking notes. One week later they were assigned to one of three study conditions defined by the structure of the notes provided for review. Students received either a complete text, detailed outline, or a completed matrix. The complete text was a typed, seven-page, double-spaced, verbatim transcript of the lecture. The outline notes appeared in a linear form and contained all of the lecture's 121 idea units. The matrix notes also contained all of the lecture ideas typed on a large single page. The horizontal axis of the matrix named the major categories of information (i.e., types of creativity); the vertical axis named the repeatable categories of information contained within each major category (e.g., definition, distinguishing characteristics, myths). The cells of the matrix contained ideas about the intersecting categories. Results indicated that the outline and matrix notes generally produced higher recall than the text notes, but only the matrix notes produced higher transfer performance than the text notes. A representation of the matrix notes appears as Table I.

The advantage of outline and matrix notes over the complete text for recall performance was that the former systems perhaps encouraged students to form more internal connections among lecture ideas. Internal connections are formed when ideas within the learning materials become interrelated in

Table I. Representation of Matrix Notes[a]

Type of creativity	Expressive	Adaptive	Innovative	Emergentative	School
Definition	Ability to generate rapid response	Ability to use past knowledge and strategies to acomdate to problem solving situations	Ability to significantly change a major process, product, or school of thought	Ability to profoundly change existing ideas, beliefs, or styles Whole direction of discipline is reshaped	Generation of reasonably novel but unskilled rapid response
Time demand to display creativity	Few seconds or less	Day to several weeks	No spontaneous response		Rapid
Time denand to develop creativity	8-12 years	Many years	Lengthy periods of time Total adult life	Lifetime	Minimal
Motivation	Create momentary flash of brillance that is appropriate yet stands apart	To maintain or slightly improve the status quo	Stems from dissatisfaction	To set trends	None, except personal satisfaction
Distinguishing characteristic(s)	Maintain flow of responses in rapidly occurring sequence	Ability to analyze day-to-day problems Plan effective solutions Execute successful plans	Desire to make significant changes	Proclivity to attack basic assumptions More faith in own ideas than in the assumptions of the discipline	Fluency (rapid responses) Flexibility (change direction of one's thoughts) Originality (produce novel responses)
Related characteristics	Consistency Automaticity Calculated style Rapidly perceive patterns Anticipate future patterns Rapid and accurate interpretation of environment	Flexibility Pattern recognition slower than for expressive creativity Develops systematic search strategies to compare current and previous situa-	Use of personal models, beliefs, analogies, or styles to guide productivity Highly predictable creativity Highly driven people Goal directed Interested in change	Great risk takers Trend setters Trend followers There at the right time to redirect future Janusian thinking Reconcile opposites to	

	Timing—when to make the response	tions Identifies similarities and combines strategies in novel ways to solve the problem	Carefully control thought processes while maintaining cognitive flexibility	construct new connections Metaphorical reasoning	
Examples	Athlete feigning opponent Musician playing progressive jazz Actor improvising Comedian interacting Professor answering questions rapidly and succinctly	Homemaker who develops a cleaning and meal-planning strategy when unexpected guests are arriving A college professor who draws on past experiences to plan and organize a first presentation	Inventors who improve or produce products Writers Artists Musicians who alter styles Scientists who alter theories Coaches who modify defensive strategy Edison's inventions stem from basic principles discovered early in productive years Monet's painting style based on systematic strategy	People who have given rise to intellectual or sylistic revolutions (e.g., Copernicus, Darwin, Freud, Einstein, Marx, Beethoven, Picasso) Pasteur—reconciled paradox of safe-attack by attacking milk's bateria safely Aristotle—"Master of the methaphor" Bronowski—"Find likeness in things not thought alike before"	Doodling Finger painting Occasional humor Thinking of uses for a brick
Myths	Creative response is spontaneous and person is spontaneous	Flexibility is the key to problem-solving	Stems from originality	Products or ideas rise above the time or the Zeitgeist (Zeitzgeist is existing beliefs, ideas, assumptions, and products at the time)	Related to real-life creativity
Myths dispelled	Person has actually overpracticed the response Person makes us believe response is spontaneous like magician deceives us Person has actually developed habitual and calculated style that produces the response	Person actually highly systematic Has overlearned effective strategies Can identify similarities between situations Can use strategies in new ways and new situations	Originality stems from highly developed model or idea, not from fluent or flexible cognitive style Innovater reuses major model, idea, image, metaphor, or similar strategy over and over to guide thought processes	Tremendous syntehzier Senses incongruities of theories Senses direction of Zeitgeist Reads past and present and takes next calculated step into the future	Does not require skills, strategies, or style like real-life creativity No real motivation except personal satisfaction No meaningful thought or product is derived

[a]Matrix notes provided in study by Kiewra *et al.* (1988a).

memory (Mayer, 1984). When ideas are interconnected the recall of one idea may prompt the recall of logically associated ideas as well. Such connections, made at acquisition, also may reduce potential interference among related lecture ideas and thereby support the accurate categorization of ideas at recall.

The superior performance of the matrix-note reviewers on the transfer test perhaps can be explained by the nature of the internal connections they made. The matrix encouraged them to make superordinate-subordinate connections down the columns of the matrix, but also to make connections across columns and categories. For example, reading vertically would foster connections about different aspects within a type of creativity; reading horizontally would foster connections about an aspect of creativity (e.g., myths) across the various types of creativity. By comparison, this latter information would be scattered throughout the complete text, and would appear on several different pages of the outline notes. Theoretically, matrix reviewers not only made more individual connections, but also gained a more integrated understanding of the material. With this more integrated structure, transfer tasks involving synthesis and application were facilitated. These findings, then, indicate that the structure of notes is an important factor in determining the benefit of provided notes.

The Activity of Review

Although the importance of the review process is well-established, research has, unfortunately, offered few suggestions as to how students actually should review notes. For example, the literature essentially is silent with respect to the optimal placement and length of a review period, or how often a learner should review notes. Tangential research studies involving prose learning, in which notes were neither recorded nor reviewed, indicate that multiple review periods significantly boost recall beyond a single review opportunity (Annis and Annis, 1987; Bromage and Mayer, 1986; English *et al.,* 1934), and that review is equally effective whether it occurs soon after acquisition or just prior to testing (Petersen *et al.,* 1952). A more recent study (Kardash and Kroeker, 1988) in which notes were recorded from text indicated that the optimal placement of a review period was prior to the two-day delayed recall test, as opposed to immediately following reading.

Investigations also are limited with regard to the most effective types of review behaviors. In a recent study, Kiewra *et al.* (1989b) had one group of note-takers study their own notes in an unrestricted manner for 25 minutes immediately following a 20-minute lecture, while a second group used their own notes to write an integrative essay. Following the review/writing period, all subjects were administered four post tests. The two groups performed similarly on recall, application, and factual recognition tests. However, reviewers out-performed the writers on the synthesis test. The authors speculated that the essay writers performed relatively poorly on the syntehsis test because while writing their essays they tended to discuss the major categories in turn rather than compare and contrast particular subtopics across categories. More explicit instructions for essay-writing might constrain such a linear approach in the future.

Two other studies have investigated the role of reorganization as a review activity. A study by Shimmerlick and Nolan (1976) compared the relative effectiveness of two forms of review. Subjects either listed or reorganized previously acquired textual information. Immediate and delayed free-recall exams favored the subjects who reorganized the information into specified categories.

In a similarly designed study, Kiewra (1983) found that students who reviewed by classifying textual information into an organizational matrix achieved more on a delayed free-recall exam than did students who were without an organizational device. The unstructured reviewers, however, achieved more than reorganizers on a delayed cued-recall exam. Kiewra speculated that these results occurred because such cues restricted the recall attempts of reorganization subjects (see Flexser and Tulving, 1978, with respect to episode-matching).

A final study investigated the effects of elaboration as a review activity. Barnett *et al.* (1981) had subjects review for testing either by making an outline of the lecture or by elaborating information through relating it to nonlecture knowledge. Their results showed that elaboration during review interfered with performance on a cued-recall test for subjects who had taken notes. A second experiment also revealed that those who reviewed by constructing outlines recalled more factual information than elaborators. However, when each subject was given particular questions congruent with his or her encoding process (questions based on his or her own elaborations or outlines), no differences were observed between those who reviewed by outlining and those who elaborated. The authors concluded that if there is a match between elaboration activities and the criterion measured, elaboration also facilitates performance. The authors' conclusion, however, is misleading because the benefit of elaboration apparently does not generalize beyond one's understanding of personal elaborations. Although elaboration subjects did perform best on elaboration items appropriate to their individual elaborations, the elaboration group in general, did not perform better than did the outline group on a pool of general elaboration items. For example, if elaboration subjects drew an analogy between familiar information about baseball and new, to-be-learned, information about cricket during review, then they likely would do better than outline subjects on transfer questions concerning the relationship between cricket and baseball, but not better than outline subjects on novel transfer questions relating cricket to handball, for example. Thus, elaboration as a review activity appears to have no additional transfer value for responding to general elaboration items than does outlining.

IMPROVING THE ENCODING FUNCTION OF NOTE-TAKING

An alternative to providing students with notes is to improve the quantity and quality of notes that students record. This approach is supported by research indicating that students actually recall a higher proportion of personally recorded ideas than ideas appearing in provided notes (Thomas, 1978) and fits the theory of encoding specificity (e.g., Thompson and Tulving, 1970), which suggests that the best retrieval cues are those present both at encoding and retrieval.

A summary of the ideas presented in this article suggests that notes can be made more effective in any of three ways: they can be made more complete (e.g., Fisher and Harris, 1973); they can specify internal connections or relationships among existing lecture ideas (e.g., Kiewra *et al.,* 1988a); and they can connect lecture information to previously acquired knowledge (e.g., Peper and Mayer, 1986). This last function is what Peper and Mayer (1986) call generative note-taking or the forming of external connections.

Improving the Quantity and Quality of Notes

With respect to increasing the quantity and quality of notes, several techniques have proven successful. Cueing during the lecture is one approach. Moore (1968), for example, actually presented conspicuous green or red cards while lecturing to experimental subjects. These cards signaled whether or not notes should be recorded. Subjects who received the cues achieved higher posttest scores than uncued subjects on information related to the cued lecture content.

Writing information on the board is also an effective cue. Locke (1977) reported that students involved in 12 different course lectures recorded 88% of the information written on the board in their notes, but only 52% of the critical lecture ideas not written on the board. Several researchers are in agreement that information written on the board is likely to appear in students' notes (e.g., Hartley and Cameron, 1967; Hartley and Fuller, 1971; Maddox and Hoole, 1975).

A note-taking training program was implemented by Robin *et al.* (1977) that successfully increased the number of critical lecture points appearing in the notes of 23 underachieving college students. The 12-day training program involved the instructor modeling detailed note-taking, prompting students to record critical points and associated details, eventually fading prompts, and ultimately providing students with corrective feedback about their note-taking. Although the particular components of this program most responsible for increasing note-taking behavior were indeterminable, all procedures seem manageable, especially considering the relatively short time used to implement the program.

Repeating a videotaped lecture presentation also works to increase student note-taking in both a quantitative and qualitative fashion. In two experiments, Kiewra and several colleagues had students record notes while watching a videotaped lecture presented either one, two, or three times. In the first experiment (Kiewra *et al.,* 1988c), students were asked to record a unique set of notes on each occasion. Results indicated that subjects viewing the lecture three times recorded significantly more of the lecture ideas in their final set of notes (41%) than did subjects who viewed the lecture a single time (32%).

Idea units additionally were classified by levels. Level 1 ideas were the most superodinate ideas; level 3 ideas were the most subordinate. Subjects viewing the lecture three times captured a significantly greater number of level 2 ideas in their final set of notes (41%) than did subjects viewing the lecture a single time (34%). The groups did not differ significantly with respect to level 1 and 3 ideas, although results favored the three-repetition subjects.

In the second study investigating repetition (Kiewra *et al.,* 1989c), students viewing the lecture more than once were not required to record a unique set of notes on each occasion; they were permitted simply to add to their existing notes if they desired. Students used a different colored pen to record notes on each occasion, so that the development of a person's notes could be evaluated. The results indicated that subjects viewing the lecture either two times (53%) or three times (60%) recorded significantly more of the lecture's idea units than those viewing it once (38%). With respect to the three levels of idea units, subjects viewing the lecture two or three times recorded more level 2 and more level 3 ideas than those viewing it just once.

In the context of the second repetition experiment Kiewra *et al.* (1989c) also examined the effects of repeating a videotaped lecture under unrestrained conditions. A free-viewing group was permitted to watch the videotape in any manner they desired. They were free to stop, fast-forward, and rewind the tape at any time and to view it as often as they desired during the experimental session. Similar to the structured-repetition groups, they knew in advance that a review period would follow acquisition activities. These subjects generally recorded about the same number of notes as the three repetition subjects with respect to total, level 1, and level 2 ideas. They did, however, record significantly more level 3 ideas. This advantage may not, however, have been worth the costs. The free-viewing group elected to spend almost twice the time on acquisition activities relative to the time spent by the three-repetition group.

Data from these two experiments indicate that the repeated presentation of a lecture produces increasing note-taking behavior. From a qualitative perspective, repeating a lecture presentation most noticeably increases the number of supporting ideas in notes which modify or embellish the most superordinate notions. Previous research (Kiewra *et al.,* 1987) indicates that the number of subordinate ideas in notes is significantly correlated with factual and higher order test performance. Students apparently do a fairly good job of transcribing the most superordinate ideas during an initial presentation, but especially benefit from additional repetitions of the material in terms of recording more subordinate notions. It might be that students first record the more superordinate ideas in order to construct a framework of the lecture and then embellish that framework upon subsequent presentations.

Increasing Internal Connections Among Lecture Ideas

Attempts to increase internal connections in students' notes have not been made in training programs. Indirect efforts through instructional aids such as skeletal outlines or matrix frameworks, designed to encourage students to build internal connections, however, have occurred. Two early naturalistic experiments (Collingwood and Hughes, 1978; Klemm, 1976), conducted over several classroom lectures, found that students who took notes on skeletal outlines achieved higher scores on classroom examinations than those who took notes without skeletal outlines. Skeletal notes are incomplete outlines that present the lecture's main ideas in an organized form with spaces between ideas for learners to detail or embellish those points throughout the lecture. Theoretically, skeletal notes may be effective because they simply increase the quantity of note-taking or because they increase internal connections within and across categories of information.

The reason that skeletal notes are effective was determined in a study by Kiewra *et al.* (1988b). Subjects in that study took notes on a skeletal outline, a matrix framework, or in their conventional manner without any instructional aid. The matrix framework contained the exact same headings and subheadings as the skeletal notes except the headings appeared along the horizontal axis whereas the subheadings appeared along the vertical axis. The intersecting cells of the matrix were left blank for note-taking. To determine which note-taking format led to quantitative differences, the numbers of total lecture ideas recorded in notes and recalled on a subsequent cued-recall test were assessed. To determine which note-taking format produced a qualitative effect, such that more internal connections were formed in memory, a synthesis test was administered. The synthesis test required subjects to identify similarities and differences across categories of information which were not stated explicitly in the lecture. With respect to quantitative differences, results indicated that skeletal and matrix note-takers each recorded more notes than did conventional note-takers, but only the matrix note-takers recalled significantly more ideas than conventional note-takers. With respect to qualitative differences, matrix note-takers performed higher on the synthesis test than did skeletal note-takers. These findings suggest that the primary value of a skeletal outline is to increase note-taking but not to increase connections across categories of information, at least relative to a matrix framework. The advantage of a matrix framework is that it permits learners to readily observe relationships not only within a category of information, but across categories of information as well.

Facilitating Generative Note-Taking

Some researchers (e.g., Peper and Mayer, 1978, 1986) posit that the process of recording notes automatically serves a generative function, such that connections are built between what is presented and what is known. The result of such integrative processing by note-takers is better performance on far transfer tasks relative to those who listen to the lecture without taking notes (Peper and Mayer, 1978, 1986). Before we conclude that the process of note-taking automatically results in generative processing, I suggest that generative processing (a) should be evident in the content or structure of notes, and (b) should be controllable experimentally. The evidence supporting these two conditions is either not yet available or is weak.

With respect to notes showing evidence for integrative processing, Peper and Mayer did not examine notes in their 1978 study. They did examine notes in their 1986 study, but found no relationship between the presence or absence or appropriate inference premises (an index they believed was representative of generative note-taking) in notes and correct or incorrect problem-solving answers. In fact, they found that the conditional probability of correctly answering a problem-solving question, given that the inference premises were not in the subject's notes, was higher than if inference premises were in the subject's notes. Although the investigation of notes by Peper and Mayer (1986) did not find evidence for generative processing, they should be recognized for their attempt. A review of 10 lecture note-taking studies cited by Kiewra (1985a), supporting the encoding function, shows that notes were examined in only three of these studies. In no case were investigations directed toward uncovering generative note-taking behaviors.

Attempts to control generative processing during lecture note-taking are indeed rare and rather weak. In four lecture note-taking studies attempts were made to vary the quality of students' notes along some sort of generative continuum – from some level of shallow processing to some more generative level of processing. Fisher and Harris (1974) asked students to record notes that included either details or main points. Howe (1970b) asked subjects to record detailed, verbatim notes or brief highlights. McClendon (1958) asked students to record notes that were either restricted, detailed, or captured main points. In no case were performance differences found between the note-taking groups. In no case were qualitative analyses made on notes to confirm intended experimental manipulations. And in no case was there an attempt to have students truly process information in a generative fashion (such that an integration of new and old ideas occurred).

One study that attempted to manipulate note-taking further along the generative continuum was conducted by Kiewra and Fletcher (1984). They used verbal instructions and test expectancies to orient students to adopt a particular note-taking strategy (i.e., factual, conceptual, or integrative, in increasingly generative order). Integrative note-taking involved relating lecture ideas to previous knowledge outside of the lecture. Content analyses of notes indicated that experimental manipulations were only partially successful in controlling note-taking behaviors. Subjects instructed to take only factual notes or only integrative notes did so more than other students, but all took about the same number of conceptual notes. Consequently, the groups did not significantly differ on immediate or one-week delayed tests measuring factual, conceptual, or integrative knowledge. Correlational analyses, however, did confirm the relative independence of factual, conceptual, and integrative note-taking behavior, and the existence of a strong relationship between conceptual note-taking and all levels of test performance. The relationship between integrative note-taking and performance was very weak, and the actual amount of integrative note-taking was low. Students found it dfficult to relate personal information to lecture ideas, even though they had opportunities to record notes during pauses inserted throughout the lecture. The authors maintain, however, that integrative or generative note-taking may be both modifiable and effective if students were to receive programmatic training in generative note-taking. To date, no such training program has been researched. A final thought concerns whether generative note-taking is appropriate at all. Perhaps students would do well to record complete and organized notes during the lecture, and to later integrate lecture ideas and prior knowledge during the review process when processing time is less of a constraint.

COGNITIVE DIFFERENCES AMONG NOTE-TAKERS

In a previous review article, Kiewra (1988) indicated that most research investigating the encoding and storage functions of note-taking does not examine cognitive factors affecting note-taking and review behaviors. The few studies examining cognitive factors suggest that note-taking and/or review behaviors are affected by the learner's working-memory control processes, background knowledge, and cognitive style.

Working-Memory Control Processes

Note-taking may be influenced by cognitive differences in working-memory control processes. It is logical that the processes involved in recording sufficient lecture notes involve the control processes of holding and manipulating information in working memory, because note-takers must simultaneously select information from the task environment, maintain such knowledge while integrating it with new and old ideas, and transcribe representative notes. Initial studies examining note-taking and working-memory ability (Berliner, 1969, 1971; DiVesta and Gray, 1973) indicated that learners with greater working-memory ability profited from note-taking, whereas students with less memory ability were debilitated by note-taking. It could not be assumed, however, that working-memory ability directly affected note-taking because notes were not examined in any of these studies.

To determine whether differences in note-taking were related to differences in working-memory ability, Kiewra and his colleagues (Kiewra and Benton, 1988; Kiewra *et al.,* 1987) correlated working-memory ability and note-taking behaviors. Their tests of working memory, however, were not restricted to measuring capacity limitations—as was the case in the aforementioned studies (i.e., Berliner, 1969, 1971; DiVesta and Gray, 1973); they tapped ability to both hold and manipulate verbal information in working memory. This sort of assessment seems more closely aligned with the nature of processing actually required during note-taking.

Findings indicated that students less able to hold and manipulate information in working memory recorded fewer words, total ideas (Kiewra and Benton, 1988; Kiewra *et al.,* 1987), and particularly subordinate ideas (Kiewra *et al.,* 1987), relative to students with higher memory ability. Because these note-taking behaviors are positively related to achievement (e.g., Kiewra, 1984; Kiewra and Benton, 1988; Kiewra *et al.,* 1987), it is possible that note-taking was found debilitating for students low in memory ability (Berliner, 1969, 1971; DiVesta and Gray, 1973) because these learners did not profit fully from the processing advantages of recording notes or the product benefits of reviewing notes (see Kiewra, 1987, 1988, for reviews).

One means for facilitating note-taking and achievement among low-memory-ability students is to embed questions throughout the lecture that are to be answered in writing. This technique led to higher achievement among low-ability students than did concurrent note-taking (Berliner, 1969, 1971).

Prior Knowledge

Research indicates that background information about the lecture topic influences note-taking and performance. One study by Peper and Mayer (1986) used subjects that were either rich or deficient in knowledge about the lecture topic. Results indicated that among learners deficient in prior knowledge, note-takers performed better on far-transfer tasks than those who were not note-takers, who performed better on near-transfer tasks. For subjects possessing adequate background knowledge, however, the activity of note-taking failed to increase generative processing and far-transfer achievement. The authors speculated that subjects familiar with lecture content automatically form connections whether or not they take notes, whereas those who are less familiar must rely on generative activities like note-taking to build external connections between what is presented and what is already known. This interpretation is consistent with research findings indicating that an adequate knowledge base can diminish the need for strategy activation (see Pressley *et al.,* 1989).

An investigation of the main and interactive effects of note-taking and prior knowledge on the retention and transfer of knowledge was made by Barnett and Freud (1985). In addition, they examined the quality of notes recorded (i.e., verbatim, abstract, paraphrase, and intrusion) by learners either rich or deficient in background knowledge about the lecture topic. Similar to Peper and Mayer (1986), they found no positive effect for note-taking on a retention test but did find that note-takers achieved more than those who were not note-takers on a transfer test. There was, however, no interaction between note-taking and prior knowledge. Analyses of notes indicated that learners both with and without background knowledge recorded predominantly verbatim notes, although learners with greater knowledge did show a nonsignificant trend toward more generative, paraphrase note-taking. Once again, it may be that some form of training in combination with adequate background knowledge is necessary for varying note-taking strategies and behaviors.

From these findings, it appears that note-taking per se promotes generative processing and far-transfer learning among students relatively deficient in lecture-specific background knowledge. Perhaps note-taking encourages students with incomplete knowledge to find or to construct some sort of connection between what is presented and what exists in memory. Unfortunately, this remains speculative, because once again analyses of notes have not reflected a generative processing of new and old ideas.

Obviously, more work remains to be done. No study, to my knowledge, has investigated the effects of prior knowledge when notes are additionally reviewed. With more time allotted for processing information, it is possible that the effects of prior knowledge would be more readily observed.

Field Independence-Dependence

Another important cognitively oriented factor related to note-taking and achievement is field independence-dependence. Basically, field-independent and field-dependent individuals differ in their manner of processing information. Field-dependent learners display a passive and rigid approach to learning and are, therefore, generally bound by the inherent organization of the stimulus. Field-independent learners, meanwhile, are active processors, likely to spontaneously restructure a stimulus field. (See Witkin *et al.,* 1977 for a review).

These contrasting styles produced note-taking and achievement differences between field-independent and field-dependent learners in a study conducted by Frank (1984). Field-dependent learners achieved less than field-independent learners when lecture notes were taken. Achievement differences were probably attributable, in part, to the type of lecture notes that learners took. Although field-independent and field-dependent note-takers recorded a similar number of lecture ideas, field-independent learners took notes that were more outlined and contained fewer words than did field-dependent learners. Apparently, field-independent students engaged their more active processing styles to encode the lecture immediately as reflected by their tendency to abstract and order lecture ideas in their notes. Field-dependent students, apparently processing information more rigidly, diminished the encoding value of note-taking by recording more verbatim and wordy notes that held value primarily for review purposes. Because the test was immediately following the lecture, with only 10 minutes provided for review, field-dependent learners probably had little opportunity to compensate for their processing deficiencies.

In fact, a subsequent study conducted by Kiewra and Frank (1986) revealed differences between field-independent and field-dependent learners, who took notes, on an immediate test, but not on a delayed exam following a substantial opportunity to review. Apparently, field-dependent learners require more time to comprehend and to integrate lecture ideas.

In addition to providing field-dependent learners with ample time to encode lecture ideas, providing them with external structural support is also facilitating. In the study by Frank (1984), there were no differences in achievement between field-independent and field-dependent learners under conditions in which external support, in the way of outlines or notes, was provided. In fact, field-dependent students receiving outlines for note-taking or detailed notes achieved significantly more than field-dependent learners who took their own notes. Such support devices probably helped the field-dependent learner to encode the lecture more spontaneously.

A RECONSIDERATION OF THE ENCODING AND STORAGE FUNCTIONS

Although the encoding and storage functions of note-taking, as proposed by DiVesta and Gray (1972), have received considerable attention by researchers (see, e.g., reviews by Anderson and Armbruster, 1986; Hartley, 1983; Kiewra, 1985a), only recently has the definition and measurement of those functions been questioned.

A Problem of Definition

Kiewra and his colleagues (Kiewra *et al.*, 1988b) suggested that the encoding/storage paradigm fails to offer a true, independent test of the storage function. Students who take and review their own notes have actually experienced both the encoding plus the storage aspects of note-taking. These researchers, therefore, reclassified the traditional storage function as an encoding-plus-storage function, and proposed a new means for examining the storage function independently. This new function was represented by absent students who had no opportunity to view (nor encode) the lecture presentation, but who were each provided with a set of "borrowed" notes from attending students for review purposes. This variation produced three note-taking functions: the original encoding function (take notes/no review), the newly classified encoding-plus-storage function (take notes/review), and the new independent storage function (borrow notes/review).

Results from that study suggested that note-taking served a minimal encoding function and that its primary value was providing storage for study purposes. On four different performance tests, taking and reviewing notes (encoding plus storage) produced higher achievement than taking but not reviewing notes (encoding only). This occurred even though testing was immediate for the take-only group, and was delayed one week for those who took and reviewed notes. More revealing was the comparison between the independent functions of encoding and storage. On the synthesis test, subjects absent from the lecture who reviewed borrowed notes (storage only) scored higher than did subjects who took lecture notes but did not review them (encoding only). The synthesis test required the formation of relationships that had not been stated explicitly in the lecture. Evidently, it is the review of notes — when time permits — that facilitates the formation of internal connections (Mayer, 1987) among previously unassociated ideas. This pattern favoring the storage function over the encoding function was evident for scores on the other three performance tests, involving recall, application, and factual recognition as well.

A Problem of Measurement

In a second experiment, Kiewra and his colleagues (Kiewra *et al.*, 1989b) made yet a second adjustment to the long-standing research paradigm. They reasoned that in the past, the traditional encoding group had one opportunity to acquire the information (while viewing the lecture), whereas the traditional storage group had two opportunities (viewing the lecture and reviewing notes). The researchers thought that observed advantages of the storage function may be due to processing time rather than processing activities. Kiewra *et al.* (1989b) therefore provided each of the newly defined groups with two acquisition opportunities. The encoding group viewed the lecture and took notes on two occasions; the encoding-plus-storage group viewed the lecture on one occasion and reviewed their notes on the second occasion; the storage group twice reviewd their borrowed notes.

There were two important findings. One, the encoding-plus-storage function was still superior to the encoding function but only on recall and factual recognition tests. Two, the storage function was no longer greater than the encoding function when notes were either recorded (encoding) or reviewed (storage) two times. The first finding suggested that the opportunity to review notes, rather than record a second set, especially facilitates lower-order performance, requiring recall or recognition of factual ideas, but does not facilitate higher-order performance, requiring synthesis or application of ideas. If we look at these data in light of previous findings by Kiewra *et al.* (1988b), in which encoding plus storage was superior to encoding across essentially the same four performance tests used in this study, then apparently a second opportunity to record notes and encode lecture ideas leads to a more in-depth understanding of the material, but not necessarily to the recall or recognition of more isolated facts.

The second finding also suggested that the encoding function grows stronger with an opportunity to twice encode the lecture material. Students apparently need sufficient time (Peters, 1972) or opportunities to encode lecture material. When an additional opportunity is available, then the encoding function is as effective as the storage function.

SUMMARY AND CONCLUSION

In the 17 years since DiVesta and Gray (1972) introduced the encoding and storage functions of note-taking, considerable research has retested their position, examined means to facilitate the functions, investigated cognitive differences relative to note-taking, and, most recently, has questioned the definition and the measurement of the originally proposed functions. This latest advance may establish tighter controls for examining note-taking, and may force researchers to distinguish between performance differences due to simple exposure to materials vs. the nature of the note-taking and/or review activities.

The research that has followed the lead of DiVesta and Gray (1972) has implications for education and suggests avenues for further research. The last two sections discuss implications for education and for research.

Implications for Education

Whether or not notes are reviewed, there is strong evidence that more note-taking leads to higher achievement—particularly when notes modify or embellish the superordinate lecture points. Student note-taking can be increased in several ways by instructors. Methods include: reducing the lecture rate, reducing the information density of the lecture, presenting cues for note-taking, providing structural support for note-taking such as a skeletal outline or a matrix framework, and by repeating the lecture presentation.

Note-taking may especially aid students with low prior knowledge about the lecture topic on far transfer tasks. Conversely, note-taking may debilitate performance among field-dependent learners or those with low working-memory ability. Structural support may particularly aid the field-dependent learner, whereas embedded questions may help the low memory ability learner to encode the lecture.

Unfortunately, little can be said about the quality of notes students should record other than their need to be organized and to contain supporting detail. Although there is theoretical support for suggesting that students note relationships between lecture content and prior knowledge, there is as yet no empirical evidence supporting this claim.

Because note-taking behaviors are often incomplete, instructors may also facilitate learning by providng students with notes to review. Such notes should be complete and well-organized. Providing notes within a matrix structure is particularly effective when lecture content can conform to that structure.

Students who miss a lecture can generally perform as well as those in attendance by reviewing notes provided by the instructor or a classmate. It would be dangerous, however, to generalize this implication beyond learning from a single lecture presentation.

With respect to how students should review, distributed studying is important as is reviewing just prior to an exam. Students should reorganize notes during review and identify internal connections among ideas. Relating lecture ideas to nonlecture topics might improve test performance if generated connections are consistent with the type of associations appearing on the test.

Implications for Research

Research has distinguished and confirmed the encoding and storage functions of note-taking and has offered some implications for facilitating these functions. Unfortunately, too few implications are available—particularly for students. Research, I believe, needs to explore two directions in order to foster more useful implications.

First, research has to move away from an instructional design approach. In practically all research studies, experimenters have manipulated variables in order to produce a particular note-taking or review behavior. In few cases were students trained in the desired technique(s) and given the conditional knowledge necessary for understanding why and how a particular technique is useful. This sort of training is necessary in order to help students develop, maintain, and transfer learning skills (e.g., Pressley *et al.,* 1985) and to become autonomous learners.

The second direction involves investigating the activities of note-taking and review concomitantly, rather than dividing them. There is a need to examine how note-taking and review strategies can be orchestrated. An example of such orchestration is found in a study-skills program developed by DuBois and Kiewra (1989). There, students are trained to identify particular knowledge patterns from lecture or text, to represent those patterns using a corresponding note-taking technique, and then to review notes differentially depending on the pattern of representation and test expectancies. In this manner, note-taking and review are complementary activities determined by the nature of the learning materials and the expected criterion task. The research program developed by DuBois and Kiewra (1989) bridges the two research directions outlined above—training and the concomitant investigation of note-taking and review. Hopefully, these programs and others of its type will provide more implications for how students should learn from instructional lectures and texts.

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