Degree of Mnemonic Support and Students' Acquisition of Science Facts

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Eighth-grade students silently read passages that described dichotomized attributes of nine North American minerals. One-fourth of the students were given instruction in the use of mnemonic techniques, and were provided with "keywords" and mnemonic illustrations of the passage content; one-fourth were provided with keywords and given instructions for creating internal mnemonic images of the passage content; one-fourth were given instructions for creating their own keywords and internal mnemonic images; and the remaining fourth were given motivational instructions and told to use their "own best method" of studying while reading the passages. Mnemonic instruction, when accompanied by experimenter-provided keywords and mnemonic illustrations, produced superior recall of the mineral attributes in comparison to the other three conditions on both immediate and eight-day delayed performance tests. Implications of the findings are discussed with regard to the amount of external support necessary for effective use of mnemonic techniques by students reading expository prose passages.

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Reviews of research on mnemonic techniques, or systematic procedures for enhancing one's memory, have documented numerous successful applications of these techniques to a variety of curriculum contents, ranging from vocabulary lists to expository prose passages. Students representing very different levels of academic skill, from average college students to educable mentally retarded children, have benefitted from mnemonic instruction (see Levin, 1985, and Pressley, Levin, & Delaney, 1982, for reviews).

The basic rationale underlying the use of mnemonic techniques in educational settings follows directly from what has come to be known as elaboration theory (Rohwer, 1973). The relevance of elaboration to memory processes has been established in a variety of experimental contexts (e.g., Bransford et al., 1982; Pressley & Levin, in press). Elaborative strategies involve the formation of memorable associations. When applied in an educational context, associative mnemonic techniques capitalize on elaboration to improve students' memory for factual curriculum context.

Levin (1983) has identified three critical components of effective associative mnemonic techniques, which reduce to what he termed the "three Rs": recoding, relating, and retrieving. Stimulus recoding consists of transforming an unfamiliar nominal stimulus into a concrete familiar word. Semantic relating involves forming a thematic relationship between the concrete familiar word and the information that is to be associated with the nominal stimulus.

These two components, when implemented successfully, provide a systematic path for retrieving the information to be associated from the re-presented stimulus.

To illustrate, the keyword method (Atkinson, 1975) can be used to remember that the Spanish vocabulary item *carta* means *postal letter*. The unfamiliar stimulus *carta* can be recoded into a concrete familiar word such as *cart*. The learner can then relate the recoded stimulus (the keyword) to its meaning, either by studying a provided illustration or by generating an interactive mental image, such as a letter inside a shopping cart. A systematic means of retrieving the meaning of the new word has now been established, that is, a direct retrieval path leads from the foreign word to the keyword to the interactive picture to the meaning. Bellezza (1981) has proposed that this method results in a "cognitive-cueing structure" that is activated when retrieval of the relevant information is desired.

The keyword method has proven very successful when applied to lists of vocabulary items and science/social studies facts (Levin, 1985; Pressley et al., 1982). Although students are often required to remember such "unconnected" facts in school, they are also expected to acquire factual information that is presented in a prose format. Levin (1982) has argued that mnemonic devices such as the keyword method can be adapted to prose-learning tasks, and several studies have done just that.

The first controlled investigations of the keyword method in a prose-learning context involved orally presenting short passages to middle-school students. In one study where the passages detailed the names and accomplishments of fictitious people (Shriberg, Levin, McCormick, & Pressley, 1982), students using the keyword-method adaptation outperformed free-study controls by a substantial margin. Another study utilized biographical passages that were mutually interfering, and again students who applied the keyword method exhibited recall that was superior to that of free-study controls on both immediate and two-day delayed tests (McCormick & Levin, 1984).

Although these oral prose-learning studies provide encouragement for classroom implementation of mnemonic instruction, in many or most instances students are required to read passages on their own. How effective is the keyword method when it is adapted for use by students independently reading factual material of the kind that appears in school textbooks? Peters and Levin (1986, Exp. 2) investigated that question by providing small groups of seventh-grade students with short biographical passages taken from a book used by teachers to supplement reading instruction. Again, students in the mnemonic condition recalled more name/accomplishment information than did students in a free-study control condition. In two subsequent experiments conducted by Levin, Morrison, McGivern, Mastropieri, and Scruggs (in press), eighth-grade students were provided with highly structured mnemonic illustrations to apply to an independently read passage that described several attributes of North American minerals. Relative to subjects in two other study conditions, mnemonic subjects remembered more mineral attributes on both immediate and three-day delayed tests.

The present study was conducted to replicate and extend the Levin et al. (in press) findings. The primary extension was to investigate the potential of two mnemonic variations that represented a lesser degree of external support than the mnemonic illustrations that were provided by Levin et al. In one of these variations, students were given mnemonically recoded words (i.e., keywords for the mineral names), but they had to generate their own interactive images. In the other variation, students had to generate both their own mnemonically recoded words and the associated interactive images. Of interest was which of these three mnemonic variations would be beneficial (or most beneficial) for the present students, who were recruited from a middle school characterized by relatively lower and more variable academic achievement in comparison to that in the Levin et al. study.

METHOD

Subjects and Design

The subjects were 85 eighth-grade students comprising five classrooms from a midwestern university community. In contrast to the high-achieving students in the Levin et al. (in press) study, whose average standardized reading performance was above the 95th percentile nationally, the average standardized reading performance of the students participating in this study was substantially lower, at about the 66th percentile. Within each of the five classrooms, students were randomly assigned to one of four conditions. Thus, within each classroom, all four treatments were represented in approximately equal numbers.

Students in the first condition (Illustration) were provided with both keywords and appropriate illustrations for study purposes. Students in the second condition (Imagery) were provided with keywords, along with instructions for creating their own interactive images. Students in the third condition (Unstructured) were given instructions for creating both their own keywords and interactive images. Finally, students in the free-study condition (Control) were instructed to use their own best method of studying to remember the mineral attributes that were presented in the study booklets.

Materials and Procedures

One week prior to instruction, a booklet containing several different pretest measures was administered to each class during a regular class period. The 25-item vocabulary subtest of the Cognitive Abilities Test (Houghton-Mifflin, 1971) was used as a measure of students' general ability. A number of specific information-processsing skills were also measured in conjunction with the first author's dissertation research, but those will not be discussed here.

Instructional booklets contained a 1726-word (21 page) passage that presented one to three dichotomized attribute(s) of nine minerals (hard vs. soft, pale vs. dark in color, and home vs. industrial use). Three minerals were described in terms of their hardness level (e.g., "*Apatite* [Number 5 on the hardness scale] is a *soft* mineral"). Three minerals were described in terms of the hardness level and their primary use (e.g., "*Talc* [Number 1 on the hardness scale] is the *softest* of the minerals that will be discussed today. It is used in the *home* as a soothing powder"). Finally, three minerals were described in terms of their hardness level, primary use, and color (e.g., "*Wolframite* [Number 4 on the hardness scale] is a *soft* mineral that is a *dark* color [usually black]. This mineral has a *home* use as part of light bulbs"). Each mineral was discussed in a paragraph presented on a separate page of the instructional booklet. Thus, the passage was "name organized" (Levin et al., in press, Exp. 1), in that the topic sentence of each instructional page included a specific mineral name, followed by a description of that mineral's distinguishing attribute(s). Students were explicitly informed that even though elaborated information about the attributes was included, their task was to focus on the dichotomous attribute information.

In the *illustration* mnemonic condition, subjects were given instruction in how to employ a mnemonic strategy for remembering each mineral and its attribute(s). Each mineral name was recoded into an acoustically similar concrete keyword, which was then semantically related to symbolic representations of the dichotomous attributes in the context of an experimenter-provided line drawing. Hard and soft attribute values were symbolically represented respectively by an old man and a baby, dark and pale attribute values by a mean dark cat and a friendly pale cat, and home and industry attribute values by a living room and factory setting. For example, the mnemonic illustration for the mineral *wolframite* (see Figure 1) consisted of a *baby* (*soft* mineral) hiding from a *mean dark cat* (*dark* mineral) riding a *wolf* (keyword for *wolframite*) in a *living room* setting (*home* use).

In both the *imagery* and *unstructured* mnemonic conditions, subjects were also given instructions about how to employ a mnemonic strategy for remembering each mineral and its dichotomous attribute(s). In the imagery mnemonic condition, the same keywords and symbolic representations of attributes that were used in the illustration condition were provided. However, the line drawings were replaced by instructions to students to "form a picture in your mind" in which the mineral and attribute representations were all doing something in an integrated image that made sense (see Figure 2). In the unstructured

FIGURE 1
Mnemonic Illustration for Wolframite.

WOLFRAMITE (wolf) SOFT Mineral (baby)
DARK Color (mean dark cat)
Used in HOME (living room)

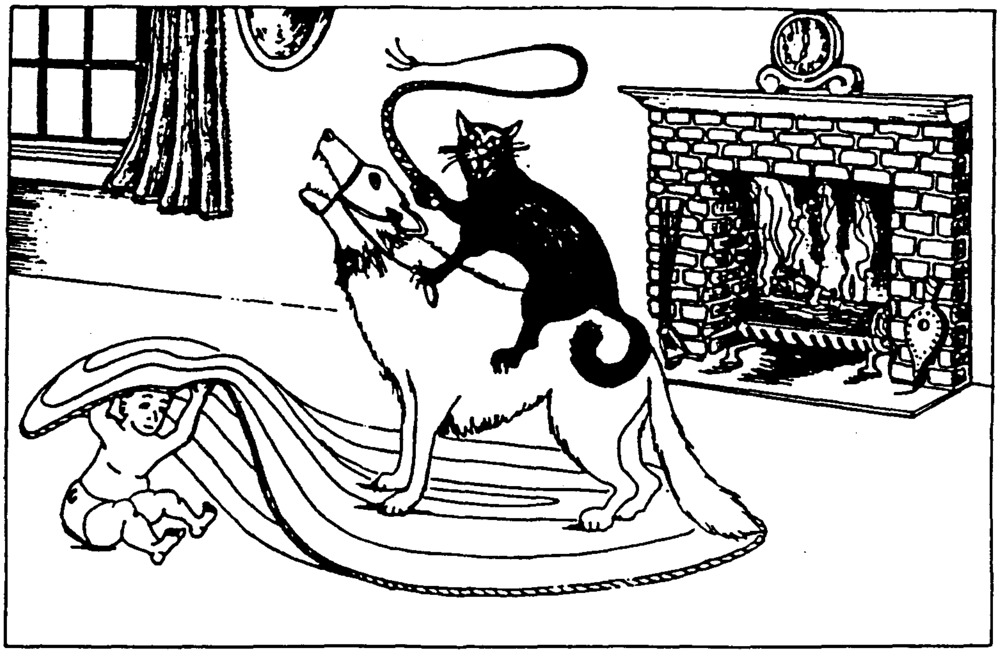

FIGURE 2
Instructions for Wolframite *in the Imagery Mnemonic Condition.*

To remember that Wolframite is a *soft, dark* mineral used in the *home,* form a picture in your mind that has a *wolf* (*wolframite*), a *baby* (*soft* mineral), a *mean dark cat* (*dark* mineral), and a *living room* (*home* use) all doing something together that makes sense. In the box below, describe the picture in your mind.

WOLFRAMITE (wolf)

SOFT Mineral (baby)
DARK Color (mean dark cat)
Used in HOME (living room)

Describe the picture in your mind: ______________________________

____

____

mnemonic condition, neither keywords nor illustrations were provided. Students in this condition were instructed to generate their own keyword for each mineral name, and then to form an integrated image that incorporated the keyword and all of the appropriate experimenter-provided symbolic representations of the corresponding attributes (see Figure 3).

In the own-method *control* condition, subjects were initially instructed to describe the method of studying that had worked well for them in the past. It was emphasized that each student is likely to have developed his or her own best method for learning new information, and that this method should be used for studying the information in the passage. Following the description of each mineral, a "space for notes" was provided to encourage active information processing by students.

Two experimenters supervised each instructional session. All students independently read their booklets containing instructions, passages, and passage adjuncts. Students were allowed 20 minutes to complete the task, and were instructed to review the material if time remained. They were also encouraged to raise their hands to request help from an experimenter if they experienced any difficulty reading the passage. Students were informed of the time remaining (10, 5, and 2 minutes remaining).

Students then completed an immediate identification task that consisted of a nine (mineral names) by six (two categories for each of three dichotomous attributes) matrix. Subjects were instructed to put an X in the appropriate box(es) for each mineral, having been reminded that some minerals had one attribute, some had two attributes, and some had three attributes. Students were allowed five minutes to complete this mineral-attribute matrix.

Eight days later, one of the experimenters returned unannounced to retest the students on their memory of the mineral attributes. Students were first instructed to think back to the mineral passage and to the method of studying that had been described in the passage. They were then instructed to write the name and attribute(s) of any of the nine minerals they could remember from the passage (free recall). Following this, students were given three minutes to complete the name/attribute identification matrix (presented in a different random order than in the previous session).

FIGURE 3
Instructions for Wolframite *in the Unstructured Mnemonic Condition.*

Mineral	*Your Word Clue*	*Characteristics*
Wolframite	____________ (fill in)	*soft = baby* *dark = mean dark cat* *home = living room*

Now, form a picture in your mind that has your word clue ____________ (fill in)

(*wolframite*), *a baby* (*soft* mineral), a *mean dark cat* (*hard* mineral), and a *living room* (*home* use) doing something that makes sense.

Describe the picture in your mind: ____________

____

____

RESULTS

Because students' prior vocabulary knowledge was highly related to their prose-learning performance (e.g., the pooled within-condition correlation on the immediate identification test was .65), vocabulary knowledge was incorporated into the analyses. This was done in two stages. First, it was of interest to determine whether experimental conditions and vocabulary knowledge interacted. Such interactions would suggest that the treatments had different effects for students representing different levels of vocabulary knowledge. Second, for dependent measures where no interaction was found, analyses of covariance were performed, with vocabulary-knowledge scores serving as the covariate. (The lack of a covariate-by-treatment interaction, or parallelism of the regression lines, is an assumption underlying the valid application of analysis of covariance [see Kirk, 1982, pp. 716-734].)

On none of the dependent variables was an interaction between students' vocabulary knowledge and experimental conditions found, $p > .05$ in all cases. Consequently, the results that follow are based on analyses of covariance. For each dependent measure analyzed, all pairwise comparisons between conditions were conducted using an unequal N adaptation of the Bryant-Paulson extension of the Tukey procedure (Kirk, 1982, p. 736) and a familywise Type I error probability of .05. The critical Bryant-Paulson value for all comparisons, expressed as a t statistic, is given by $t\ (80) = 2.64$. The covariate-adjusted means for four different dependent measures are presented in Table 1.

Attribute-Identification Measures

On both the immediate and delayed attribute-identification tests, condition-related differences were detected on a measure representing "hits" (the number of attributes correctly marked) minus "false alarms" (the number of attributes incorrectly marked). All differences were attributable to the illustration mnemonic condition being superior to all others, $t > 2.68$ in each case, and $t < 1.34$ in absolute value for all others.

Free-Recall Measures

Two additional performance measures were derived from the delayed free-recall test. One of these, total number of mineral names recalled, would not be expected to differentiate among conditions, as it does not capitalize on the previously established mnemonic links. Nonsignificant differences were found on this measure, $t < 2.32$ in absolute value in all cases. In contrast, recall of mineral names *and their associated attributes* (again based on "hits" minus "false alarms") should differentiate among conditions, and it did. Even though the amount of attribute information recalled was quite low in *all* conditions, the mean performance of illustration mnemonic subjects was significantly higher than that of subjects in each other condition, $t > 3.09$ in each case. No other differences were significant, $t < 1$ in absolute value in all other cases.

TABLE 1
Adjusted Mean Percent Correct, by Experimental Condition

	CONDITION			
Measure	*Illustration Mnemonic (N=22)*	*Imagery Mnemonic (N=23)*	*Unstructured Mnemonic (N=20)*	*Own-Method Control (N=20)*
Immediate Identification[a]	65.6	39.2	39.3	41.5
Delayed Identification[b]	50.5	31.0	20.9	27.6
Delayed Name Recall[c]	56.6	41.6	42.6	43.4
Delayed Name/Attribute Recall[d]	36.4	11.3	13.9	18.1

[a]Adjusted $MS_E\ (80) = 743.0$
[b]Adjusted $MS_E\ (80) = 594.5$
[c]Adjusted $MS_E\ (80) = 471.8$
[d]Adjusted $MS_E\ (80) = 362.9$

DISCUSSION

The between-condition differences in performance indicate that mnemonic instruction can facilitate acquisition and retention of prose-embedded geology facts by middle-school students. These findings replicate the Levin et al. (in press) results, in that the illustration condition proved superior to an own-method control group, even though the present sample consisted of average academic achievers rather than high academic achievers as in the Levin et al. study. That no facilitation was produced by the two mnemonic conditions with less external support suggests that the present students could not readily implement the critical mnemonic components on their own. This latter result is in contrast to recent vocabulary-learning and prose-learning findings, where even students at very low levels of academic achievement have benefitted from less-than-completely-structured mnemonic strategies (e.g., McGivern & Levin, 1983; McLoone, Zucker, Scruggs, & Mastropieri, in press; Peters & Levin, 1986). Yet the mnemonic representations that had to be generated in those studies were decidedly less complex than the interactions involving multiple symbolized attributes that were required here. Perhaps with additional practice with the present symbolic representations, subjects in the two other mnemonic conditions would have experienced more success.

The superior performance of students provided with mnemonic illustrations lends additional support to the use of such materials for teaching factual science information. Numerous studies have established the effectiveness of completely structured mnemonic materials in enhancing students' memory for an assortment of factual material. Two associated comments are offered in that regard: First, it should be noted that in such studies, the content to be learned often is not specially selected for "mnemonic hospitality." That is, mnemonic strategies have been successfully implemented with both representatively and randomly sampled labels and facts (see, for example, Levin & Pressley, 1985). Consequently, there is no reason to expect that a different sample of mineral names would have yielded different results. Second, mnemonic success has been obtained even when the material to be learned is coherent and comprehensible. For example, the present mineral passage was clearly "name organized" and easy to understand, and the passage used by Levin et al. (in press, Exp. 2) was "attribute organized," lending the information contained therein to a compact taxonomic classification. Nonetheless, in both cases, mnemonic facilitation was produced. Even well-written expository passages can contain information (e.g., technical terms and associated facts) that is not readily remembered. Mnemonic strategies facilitate such remembering.

Efforts are currently under way to explore the versatility of mnemonic instruction in a variety of curriculum contexts. Of particular interest is the degree to which students of different ages and abilities can be taught to devise their own mnemonic recodings and relatings, and to exhibit strategy maintenance over the long term. These questions, as well as those focusing on mnemonic instruction in relation to differences in students' information-processing skills, are potentially important from both an educational and a theoretical perspective (see Levin & Pressley, 1985; and Morrison, 1988), and therefore deserve further investigation.

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