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ABSTRACT

This summary of a program of research in children's learning describes the effects of pictures and visual imagery on children's cognitive performance. The role of individual differences is highlighted throughout the paper, as are variables which potentially limit the effects discussed. Some of the conclusions were that in a large number of learning tasks children seem to learn better when the materials are presented in pictures than when the materials are presented in words; there appear to be limitations on the effectiveness of pictures in terms of both learner and task differences; subject-generated organizational strategies (visual imagery in particular) greatly facilitate associative learning; and the benefits from an imagery strategy have also been obtained on tasks requiring comprehension of a passage. Areas for further investigation are suggested. (RB)

Theoretical Paper No. 49

WHAT HAVE WE LEARNED ABOUT MAXIMIZING WHAT CHILDREN LEARN?

by

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Report from the Project on
Children's Learning and Development

Wisconsin Research and Development
Center for Cognitive Learning
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Statement of Focus

Individually Guided Education (IGE) is a new comprehensive system of elementary education. The following components of the IGE system are in varying stages of development and implementation: a new organization for instruction and related administrative arrangements; a model of instructional programing for the individual student; and curriculum components in prereading, reading, mathematics, motivation, and environmental education. The development of other curriculum components, of a system for managing instruction by computer, and of instructional strategies is needed to complete the system. Continuing programmatic research is required to provide a sound knowledge base for the components under development and for improved second generation components. Finally, systematic implementation is essential so that the products will function properly in the IGE schools.

The Center plans and carries out the research, development, and implementation components of its IGE program in this sequence: (1) identify the needs and delimit the component problem area; (2) assess the possible constraints—financial resources and availability of staff; (3) formulate general plans and specific procedures for solving the problems; (4) secure and allocate human and material resources to carry out the plans; (5) provide for effective communication among personnel and efficient management of activities and resources; and (6) evaluate the effectiveness of each activity and its contribution to the total program and correct any difficulties through feedback mechanisms and appropriate management techniques.

A self-renewing system of elementary education is projected in each participating elementary school, i.e., one which is less dependent on external sources for direction and is more responsive to the needs of the children attending each particular school. In the IGE schools, Center-developed and other curriculum products compatible with the Center's instructional programing model will lead to higher student achievement and self-direction in learning and in conduct and also to higher morale and job satisfaction among educational personnel. Each developmental product makes its unique contribution to IGE as it is implemented in the schools. The various research components add to the knowledge of Center practitioners, developers, and theorists.

Acknowledgments

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Abstract

A summarization of a program of research in children's learning is presented. Major topics include the effects of pictures and visual imagery on children's cognitive performance. The role of individual differences is highlighted throughout the paper, as are variables which potentially limit the effects discussed. Continued investigation into the nature and development of cognitive processes is indicated.

I
Introduction

As a concerned year-in, year-out consumer of educational research, you are entitled to ask what we have learned about maximizing what children learn. As a concerned year-in, year-out conductor of educational research, I am compelled to answer. If what we have learned about maximizing what children learn were "little" or "nothing," I would not have chosen to initiate this venture. Happily, however, in recent years queries into the realm of children's learning have proven extremely fruitful, in terms of both currently accessible knowledge and promises of things to come. So let us continue.

The present paper does not pretend to encompass a complete summarization of the children's learning literature (for earlier reviews, see Goulet, 1968, and Keppel, 1964). Nor does it pretend to bear directly on educational policy or curricular decision making (see Glaser, 1972, and Rohwer, 1972). Rather, in this paper I shall provide an up-to-date account of our research program at the Wisconsin Research and Development Center for Cognitive Learning. Where appropriate, I will incorporate our findings into the larger body of children's learning literature, as was done in an initial report of our research (Levin, 1972b).

In the evolution of our research program, we--as others before us--have come to realize that the task of maximizing what children learn can generally be accomplished through the use of techniques which concretize what is to be learned. That is, we have opted for methods and materials which capitalize on children's previous encounters with their environments and which provide a closer approximation to those environments than can be provided through more abstract representations. Specifically, our efforts toward concretization have involved pictures, both as learning materials and as the principal ingredient in learner-initiated cognitive strategies. What follows, then, is essentially a case for pictures in children's learning, with occasional caveats where necessary.

II
Pictures As Learning Materials

One of the more ubiquitous findings in the literature is that pictorially represented objects are more memorable than their associated verbal labels. This, of course, comes as no surprise to the visual shapers of our culture and commercial society who are well aware that the form, the features, and even the phenomenal fool who "ate the whole thing" all contribute in their own pictorial way to the effectiveness of a communication. Yet despite the obvious contributions of these residents of Madison Avenue (and more recently, of our children's friends on Sesame Street), the puzzle of pictures continues to fascinate educational researchers at various levels of scientific investigation. Let us start by considering some empirical studies in which pictures and words have been compared.

Evidence for Picture Superiority

In 1967, Roger Shepard discovered that while adults have an unusually large capacity for storing verbal material, it is substantially smaller than their capacity for storing pictures. Shepard examined performance on three recognition memory tasks, each consisting of approximately 600 stimuli, and found that while previously exposed words and sentences were recognized with about 89% accuracy, pictures were recognized with about 97% accuracy; the pictorial level decreased to the verbal level only after a one-week interval between presentation and testing. An even more impressive demonstration of pictorial recognition memory capacity has been provided by Standing, Conezio, and Haber (1970), who reported over 90% accuracy for more than 2,500 pictures, even with delays of three days between presentation and testing.

Although such evidence of seeming "unlimited memory" for pictures may capture one's imagination, it does not address itself to the issue of concern here, namely, memory differences between pictures and words. Across-material comparisons in the Shepard (1967) data may be made only in an offhand way since (1) the data were obtained from different subject populations in sequentially conducted experiments and (2) the word and picture lists were not identical either in length or in content (the former consisting of English nouns and adjectives and the latter consisting of pictures taken primarily from magazine advertisements). However, subsequent research with adults (e.g., Paivio & Csapo, 1969) in which recognition memory for line drawings of familiar objects (e.g., a clock, a house, a piano) was better than that for the verbal labels of the same objects permits a more direct inference.

Precisely the same conclusions are reached when the children's learning literature is examined. That is to say, recognition memory for pictures is extremely high, even for preschoolers (e.g., Brown & Scott, 1971), and direct picture-word comparisons reveal the superiority of pictures (e.g., Corsini, Jacobus, & Leonard, 1969).

Our own research conducted primarily with elementary school children has uncovered the same consistent trend, both in learning tasks that do not require the subject to reproduce the previously studied items (i.e., tasks that demand item recognition) and in those that do (i.e., tasks that demand item recall). This research includes a reading comprehension study in which subjects had to acquire the gist of a fictitious passage either by reading a regular printed version or by looking at a specially constructed cartoon-like sequence of pictures that told the story (Levin, 1973). The finding that slightly more questions based on the passage were correctly answered by "picture" subjects than by "print" subjects is interesting and of potential educational significance. During our discussion of individual differences in the use of learning materials and learning strategies which follows we will return to this point.

The Role of Individual Differences: An Empirically Derived Representation

Although the picture-over-word effect has been found to generalize across a wide variety of populations as represented by such subject variables as age, sex, IQ, and SES/race (cf. Rohwer & Levin, 1971), we have noted in a number of studies that the magnitude of the effect varies reliably with certain of these variables. For example, we have observed several instances in which the relative superiority of pictures to words has increased with age from childhood through adolescence (see also Ghatala & Levin, 1973, and Reese, 1970). As an illustration, in one of our studies (Levin, Davidson, Wolff, & Citron, 1973) across two different methods of assessing associative learning (recognition and recall), we found that younger children (second graders) correctly associated an average of 14% of the pictorial items and 12% of the verbal items--a difference of 2%. For older children (fifth graders), however, this difference increased to 15%; these children correctly associated 28% of the pictures and 13% of the words. While the age populations and experimental tasks sampled across studies are not sufficiently comparable to provide a strict confirmation of an age by picture-word interaction (specifically, an increasing difference between picture and word learning with increasing age), the trends abstracted from a composite of several studies are consistent with this suggestion.

Picture-word differences appear to interact with other subject characteristics as well, much in the manner that I have described elsewhere (Levin, 1972a) and which will be expanded upon here. Figure 1 depicts an admittedly oversimplified conceptualization of individual differences in learning as a function of variations in methods or materials.

As will be seen, both the "Population" and "Method/Materials" labels in Figure 1 can be adapted to characterize a number of learning outcomes that have been noted in our own research and in that of others. For now, in order to concretize the intent of Figure 1, let us assume that the Population variable represents a gross breakdown of the academic accomplishments of students in a particular classroom; that is, students from Population I are "good" learners, students from Population II are "average" learners, and students from Population III are "poor" learners, where individual students are loosely allocated to one of the three populations, let us say, on the basis of a teacher's long-term assessment of in-class achievement. Let us assume further that we wish to determine each student's mastery of a particular instructional lesson.

This is where the Method/Materials variable comes in. Suppose that the students were taught the lesson in a mildly disorganized, uninspiring fashion (due either to a fault of the teacher or the textbook or to some combination). If we assess mastery following such "impoverished" instruction, which might be Method A in Figure 1, we will note that only the good learners (from Population I) succeed--in a sense, they will have learned in spite of the instruction. In contrast, the average and poor learners (from Populations II and III) will fail; at least some of them will not have learned because of the instruction.

On the other hand, suppose that the lesson were presented to the students in a highly organized, effective manner (Method B). The good learners will still succeed, probably to an even greater degree than before. However, the clarity of the instruction will now enable those students (from Population II) who would otherwise fail (under Method A) also to succeed. At the same time, some of the nonlearners under Method A (those from Population III) will continue to fail even with optimal instruction--they will fail in spite of the improved instruction. (This is not to say that Population III students can never be taught the lesson successfully, but rather that the variable considered here, viz., a poor versus a good presentation to a group of students, may not be sufficient to effect mastery for them.)

What is important in this example is that for a large number of students the probability of mastery is closely related to the quality of instruction received. With poor instruction many children who would otherwise succeed will fail. It would, therefore, appear to be a worthwhile endeavor to identify instructional techniques which maximize the success ratio for a given group of students. Following my (Levin, 1972a) distinction between external and internal variables which affect learning, we will be concerned with identifying student-initiated cognitive strategies which enable learning to occur despite a lack of optimal instructional methods and materials.

But first let us look at a few experiments dealing with picture-word differences in learning from which the representation in Figure 1 was itself modeled. In an earlier study conducted by Rohwer, Ammon, Suzuki, and Levin (1971) concerned with learning differences among certain age, sex, and socioeconomic

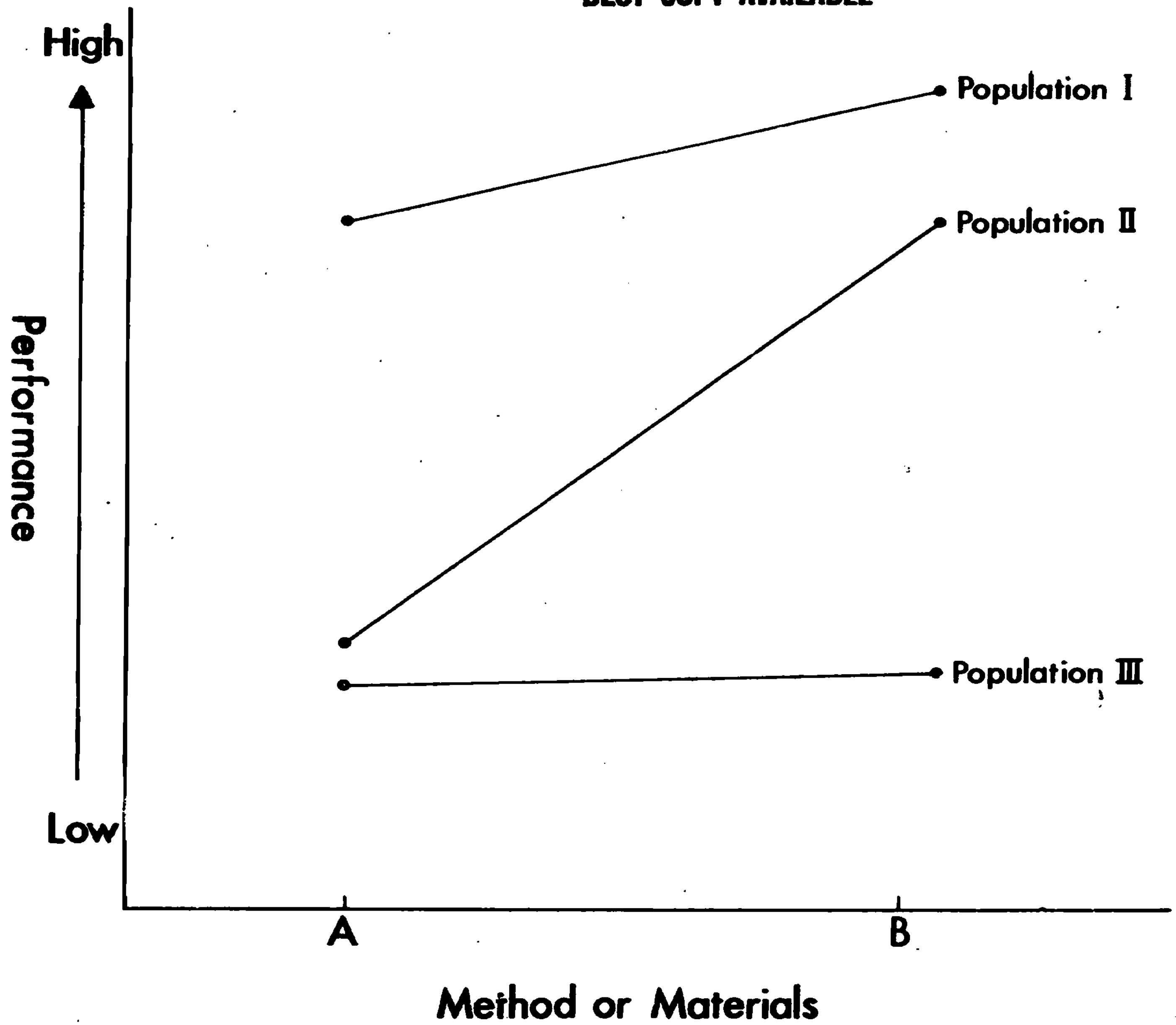

Figure 1. A conceptualization of individual differences as related to the potential effectiveness of a cognitive strategy. (A connected line graph is utilized here simply to emphasize the interaction of interest that is discussed throughout the text.

groups, we (Levin, Rohwer, & Cleary, 1971) noted that even within these demographically defined groups there appeared to be reliable individual differences in learning from pictures and words. In particular, subjects who were classified as exhibiting either relatively large or relatively small picture-word differences tended to be similarly reclassified on a parallel form of the task administered two days later. This was found to be true in ten of the twelve samples studied; the effect was statistically significant in six of them.

Following up this notion, Levin, Divine-Hawkins, Kerst, and Guttmann (1974) discovered that with such a task, the vast majority of subjects--in this case, fourth graders--could be classified into three learner types: subjects who learn relatively well from both pictures and words (Hi P, Hi W); subjects who learn relatively poorly from both pictures and words (Lo P, Lo W); and subjects who learn relatively well from pictures but relatively poorly from words (Hi P, Lo W). It is interesting to point out that, in accordance with the research findings reported thus far, virtually all subjects learned picture items better than word items. The evidence for this was (1) consistently superior picture recall within the Hi P, Hi W and Lo P, Lo W groups and (2) a very small number of subjects classified as Lo P, Hi W subjects (a result which led to our eventual decision that the Lo P, Hi W category is not a learner-type classification of practical importance).

To investigate the stability of the three learner types identified, a parallel form of the learning task was administered to the subjects on the day following their initial classification. These tasks, unlike those of our earlier study, were group administered. The results of the study are summarized in Table 1; it may be seen that 30 out of 41 initial classifications (nearly 75%) were confirmed by the second assessment. While such data do not speak to the <u>long-term</u> stability of learner types nor to their concomitant characteristics, they should encourage future investigations into an area which has been beset by serious methodological and substantive difficulties (cf. Levin, Rohwer, & Cleary, 1971). A preliminary effort in this direction was made in a second experiment by Levin, Divine-Hawkins, Kerst, and Guttmann (1974), which will be described in a later section.

For now, it is worth noting that in the two experiments reported by Levin, Divine-Hawkins, Kerst, and Guttmann (1974), 36 Hi P, Hi W subjects, 40 Lo P, Lo W subjects, and 22 Hi P, Lo W subjects were identified by initial classification procedures. On the basis of these data it certainly appears that the ability to learn from pictures and the ability to learn from words are highly correlated in our task (since most of the classifications are of the Hi P, Hi W type, or the Lo P, Lo W type). However, it is also apparent that for a good 20% of the children, the ability to learn is related to the type of materials presented.

TABLE 1
CORRESPONDENCE BETWEEN INITIAL AND SUBSEQUENT LEARNER-TYPE CLASSIFICATIONS

		Day 1		
		Hi P, Hi W	Lo P, Lo W[a]	Hi P, Lo W
Day 2	Hi P, Hi W	9	1	
	Lo P, Lo W	2	14	[illegible]
	Hi P, Lo W	1	2	[illegible]

[a] Three additional subjects, initially classified as Lo P, Lo W were later classified as Lo P, Hi W.

That is, the Hi P, Lo W children function like poor learners (Lo P, Lo W children) when words are presented but like good learners (Hi P, Hi W children) when pictures are presented.

This situation is represented in Figure 1 by the seeming inability of subjects from Population II (here, Hi P, Lo W children) to perform successfully when materials of one kind (words) are presented and their startlingly different performance when materials of another kind (pictures) are presented. In the experiment just reported, for example, when word pairs were presented the Hi P, Lo W subjects correctly recalled an average of 16%, as compared to 14% by Lo P, Lo W (Population III) subjects and 50% by Hi P, Hi W (Population I) subjects. On the other hand, when picture pairs were presented, the mean performance of Hi P, Lo W subjects (61% correct) clearly surpassed that of Lo P, Lo W subjects (33% correct) and rivaled that of Hi P, Hi W subjects (66% correct). Since Figure I was derived from a composite of several experiments, it does not portray this result exactly, but it surely approximates it.

Pictures and the Comprehension of Prose

I now wish to focus on two recent findings which further substantiate the essentials of Figure 1 with regard to individual differences in learning from pictures and words. Unlike the experiments just discussed, in these studies the criterion task was not one of simply associating lists of words or pictures. Rather, subjects were presented prose passages which resembled those encountered in their school readers and were subsequently asked questions about the factual material contained in the passages.

In one experiment, Rohwer and Matz (in press) compared the comprehension skills of middle-class white and lower-class black fourth graders. Passages were presented to the subjects aurally by means of a tape recorder. For one of the experimental conditions (Aural/Print), subjects were simultaneously shown the printed version of the passage, in much the same way as in the elementary school classroom when students read along with the teacher or with another student.[1] For the other condition (Aural/Pictures), instead of "reading along with Mitch," subjects were shown a series of line drawings that incorporated the details of the aural passage. Not surprisingly, under the school-like Aural/Print presentation, middle-class whites answered substantially more questions about the passage correctly (an average of 82%) than did lower-class blacks (an average of 58%). However, in the Aural/Pictures condition, this difference was markedly diminished; in the spirit of the Populations (I versus II) by Materials interaction of Figure 1, middle-class whites averaged 90% correctly and lower-class blacks averaged 81% correctly.

Levin (1973) wanted to see whether the same type of interaction could be detected within a relatively homogeneous SES/racial population. Subjects consisted of predominantly lower middle-class white fourth graders who were classified as good or poor readers on the basis of standardized reading test performance and reading group assignment within the school. Passages were presented to subjects either as a sequence of printed sentences or as a sequence of pictorial (cartoon-like) representations; no aural accompaniment was provided in either case. Although the interaction of interest was statistically nonsignificant, performance differences between good and poor readers were found to be slightly less when the pictorial version of the passage was presented (averages of 85% correct and 75% correct, respectively--a 10% difference) than when the printed version was presented (81% correct and 67% correct, respectively--a 14% difference).

Possible reasons that this effect was not larger are discussed by Levin (1973) and include the speculation that poorer readers may not have attempted to translate the pictorial message into verbal form or may not have been successful in translating them. Unlike the Rohwer and Matz (in press) study, *where* an aural description accompanied the pictures, in this experiment the pictures by themselves were sufficient to tell the story. The suggestion that a dual verbal/pictorial representation of text may be required was indicated by the performance of subjects in a third condition of the Levin (1973) study. However, these data will be examined in a later section, where a rationale for considering learner-initiated cognitive strategies is presented.

A Footnote to the Benefits of Pictures in Learning

In a number of experiments that have focused on the learning and use of concepts by

[1] In a different context, some research from our laboratory indicates that this commonly used instructional format may not be a terribly effective one (Kaplan, 1971; Levin, Horvitz, & Kaplan, 1971).

subjects, pictures have been found to be not only nonfacilitative in comparison to words but frequently inferior. For example, Runquist and Hutt (1961) found that concepts selected to represent a series of stimulus instances (e.g., the concept "soft" for the instances bed, fur, pillow, and moccasin) were acquired more rapidly when the stimuli were words than when they were pictures. Just how is this curious reversal of picture-word differences--based on what we have learned till now--explained? Runquist and Hutt suggest (as does Hollenberg, 1970, in another context discussed later) that the vast number of unique perceptual details associated with pictures may impede the formation or retrieval of broader, more abstractly defined concepts. Support for the notion that irrelevant perceptual details may contribute to such "conceptual blindness" was obtained in the Runquist and Hutt study, where the word-over-picture effect was diminished when pictures were used which perceptually highlighted the intended concept (e.g., for the concept "soft," the bed was made to appear "soft and billowy").[2]

Additional support for this view may be extracted from an experiment by Deno (1968), in which subjects were presented an associative-learning task consisting of either familiar picture or word stimuli paired with 12 unfamiliar Japanese words. In one version of the task the stimuli were 3 different instances from each of 4 conceptual categories (buildings, clothing, furniture, and animals), and in the other they were 12 unrelated items. According to verbal-learning theory, performance in the conceptually related list should suffer relative to that in the unrelated list since the conceptually similar items should produce intralist interference. The result of concern here is that while this was indeed the case when the stimuli were presented as words, there was little interference when the stimuli were presented as pictures. This result is consistent with the notion that the conceptual categories were not elicited as readily in the picture condition where the perceptual details of the pictures dominated the subjects' attention (although other interpretations are possible). We have recently obtained a similar result in a study dealing with item recognition rather than item recall (Levin, Bourne, Yaroush, Ghatala, DeRose, & Hanson, in press).

It is worth noting that the "detraction" explanation also fits a large number of studies in which it has been found that children's initial word decoding is retarded by the inclusion of pictures (cf. Samuels, 1970). That is, the addition of a picture to represent a to-be-decoded word is thought to pull subjects' attention toward the picture and away from the critical letter configurations. This notion has received some support by Lippman and Shanahan (1973), who observed that when pictures were physically integrated with the letters themselves (e.g., striped letters resembling candy canes to represent the word candy), word learning was facilitated.

To conclude this section, let me reiterate that in the vast number of learning studies that I have come across in the psychological literature, there is precious little evidence to refute the claim that pictures are learned better than words.[3] One notable exception to this statement consists of a class of experiments, some of which were noted above, dealing with the acquisition and utilization of concepts and/or semantic categories (not to be confused, however, with situations in which pictures may be used in conjunction with [or as "adjuncts" to] verbal descriptions--a technique which has frequently been found to facilitate the understanding of abstract concepts as well). Such a counterexample is an intriguing one and should do much to further our understanding of the basic processes or mechanisms underlying picture-word differences in a variety of learning tasks. Efforts in this direction have been initiated by a host of investigators, and although a recounting of current theoretical positions is beyond the scope of this paper, they will be dealt with in a forthcoming paper by Elizabeth Ghatala, Larry Wilder, and myself.

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[2] Further evidence comes from Wohlwill's (1968) research utilizing Piagetian class-inclusion tasks, where mastery is assumed to be synchronous with the emergence of concrete operations in the child. Wohlwill has found that verbally presented class-inclusion problems are answered more accurately than pictorially presented problems, but that the difference can be reduced by presenting the pictures in ways that help to break down their perceptually biasing features.

[3] However, this statement may be restricted to normal rates of stimulus presentation, since Paivio and Csapo (1969, 1971) have found that pictures are serially recalled more poorly than words when they are presented too rapidly for verbal labeling to occur.

III
Visual Imagery As An Organizational Strategy

While one way to maximize what children learn is to use pictures, another is to embed the materials in a meaningful context or organization in which learning can occur. For example, it will take most children several trials to recall a 14-item list of words such as cat, log, street, bowl, milk, chair, . . . in their correct serial order. However, this becomes virtually a one-trial proposition when the items are presented as: The grey cat jumped over the log and crossed the street to find the bowl of cold milk under the chair . . . (Levin & Rohwer, 1968). As Rohwer (1967) has aptly noted, in such situations performance is greatly enhanced by *adding* to the to-be-remembered stimuli, a finding which prompts the seemingly paradoxical inference that the more there is to learn, the better the learning. Thus, in this example the number of words to be processed in the first case (14) is substantially less than when the sentence context is added (52); yet the learning in the first case is substantially worse. Of course, this finding poses no paradox at all for students of organizational processes in memory who view the difficulty of a task in terms of associational and contextual factors rather than in terms of individual items *per se*.

One can also apply the notion of organization to the data considered in the previous section. Recall that a consistent finding is that pictures are more easily associated than words. However, the magnitude of this effect is typically not nearly as great as that produced when the experimenter provides an organizational context for the paired items. Thus, the sentence context, "The cat jumped over the log," has a marked facilitative effect on the learning of the pair, cat-log, as does a pictorial context in which a cat is depicted jumping over a log. Examples of the potency of such context effects in associative learning for both younger and older subjects, as well as for subjects from different social class and ability strata, may be found in Rohwer (1967).

While others have embraced strategies in which the experimenter provides a sentence or pictorial context to facilitate learning, our preference has been to provide learners with a strategy for generating their own organizations. This distinction between *imposing* an organization on learners and *inducing* an organization in learners has been discussed elsewhere (Levin, 1972b), as has our rationale for opting for the latter approach (Levin, 1972a).

Essentially, our argument is that most "real world" learning situations are less than optimally structured in that they require active mental transformations and elaborations on the part of the learner in order for him to process the to-be-learned material effectively. Accordingly, efficient learning will occur only if the learner is equipped with organizational strategies that will free him from the typically impoverished quality of incoming stimuli. By hypothesizing about the nature of such strategies and then by testing these hypotheses in samples of presumed effective and ineffective learners (e.g., older versus younger subjects) we should be able both to document their psychological reality and to determine whether or not it is experimentally plausible to instruct others in their usage.[4]

We have begun to launch an attack in this direction. For instance, in an associative-learning task, rather than "spoon organizing" the pairs for subjects by providing them with

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[4] This is not to say that an equally convincing case cannot be made for the "imposed" approach, where variations in stimulus materials (e.g., semantic and syntactic properties) may be precisely defined and carefully controlled and their effect on subsequent learning noted.

an effective sentence or pictorial context, we have instructed subjects to generate appropriate sentences--and especially, dynamic visual images--for themselves. Thus, when the items cat-log appear, subjects are instructed to think up a sentence or to make up a vivid picture in their mind which relates the pair members to one another in some meaningful way. The results of such instructions have been astounding in that learning gains have been observed which rival--and in some cases surpass-those obtained from supposedly optimally defined (i.e., experimenter-imposed) organizations. In the following sections, then, I will discuss certain of our investigations into visual imagery as an organizational strategy.

The Development of a Visual Imagery Strategy

One of the more intriguing findings that we have uncovered is that the ability to benefit from an experimenter-induced organizational strategy is, in large part, a function of the cognitive maturity of the learner. Thus, it has been noted that while children younger than six or seven years of age have little difficulty in using an experimenter-imposed strategy effectively, they are typically unsuccessful when requested to generate such a strategy on their own. And the developmental disparity between "using" and "generating" appears greater for visual imagery than for sentence production, as indicated by some recent evidence refuting Jensen and Rohwer's (1965) claim that young children are unable to generate appropriate mediating sentences in an associative-learning task (McCabe, 1973; McCabe, Levin, & Wolff, 1974).

But let us concentrate here exclusively on the development of visual imagery. In their most recent work on the topic, Piaget and Inhelder (1971) distinguish between two general classes of visual imagery in the child. The first, reproductive imagery, is ontogenetically more primitive in that it emerges in the child's preoperational years. Being static in nature, it is typified by internalized copies or imitations of external events. The second, anticipatory imagery, does not emerge until a later stage of development--in particular, the onset of operations at about age seven or eight. This type of imagery is dynamic in nature in that with it the child is capable of employing unique mental operations (e.g., spatial rotations and transformations) to static or physically removed events.

We may distinguish between reproductive and anticipatory imagery in terms of our associative-learning paradigm. The preoperational child is capable of imagining only a perceptual copy of the to-be-associated items, whereas the operational child is capable of manipulating these images in novel ways (e.g., conjuring up an imaginal interaction between the paired items). If a thematic interaction is the basis for optimal associative-learning performance, then it would not be surprising to find that an operational child who is successfully employing an imagery strategy learns more quickly than either a preoperational child who is unsuccessfully employing one or an operational child who is not employing one. This prediction was tested and further elaborated in a series of studies conducted by Peter Wolff, myself, and others.

In one experiment we found that both second and fifth graders benefited from an induced visual imagery strategy (i.e., "make up a picture in your head of the two things in each pair doing something together") in an associative-learning task (Levin, Davidson, Wolff, & Citron, 1973). On the other hand, Montague (1970) had previously reported that her sample of first grade inner-city children did not benefit from such a strategy. Thus, indirect support for the proposed anticipatory imagery deficit in younger children might be inferred.

However, in order to make a direct test of this proposition (i.e., by utilizing the same task and materials with subjects from a geographically and demographically similar location), Wolff and Levin (1972) compared the performance of third graders and kindergartners, assuming that the former possessed well-developed anticipatory imagery while the latter did not. The outcome was precisely as anticipated: in the third-grade sample, instructions to employ an imagery strategy facilitated performance relative to a nonimagery control condition (77% correct versus 32% correct, respectively); however, in the kindergarten sample a nonsignificant difference (41% versus 30%) was observed. Apart from these performance data, the children's attitudes during imagery generation (i.e., holding their heads motionless, keeping their eyes closed or gazing upward, and obviously concentrating) and their subsequent verbal reports, lent credence to the conclusion that third graders could indeed comply with the imagery request while kindergartners could not.

But this is not the whole story. One fundamental assumption of Piagetian theory is that operational thought grows out of the early sensorimotor activity of the child. In the present context, visual imagery is regarded as internalized motor activity in that it originates in the child's early play and imitation, which later become internalized. If the child's overt motor activity does in fact provide the basis from which covert imagery evolves, then it is not unreasonable to assume that children approaching the operational stage (i.e., our kindergartners) could produce an external motoric representation which in turn might mediate the formation of an internalized imaginal representation.

In the Wolff and Levin (1972) study just reported, the stimulus materials consisted of children's toys. While in the first part of the study the child was instructed to generate a visual interaction between the paired toys internally, in the third experimental condition he was permitted to generate the visual interaction externally by actually manipulating the toys. Clearly this was no problem even for the kindergartners, and it was clear that the interactions they produced had memorial consequences as evidenced by the increased learning in this condition (64% correct), surpassing by far the kindergarten control condition (30%) and approximating the imagery condition performance of third graders (77%).

While it is tempting to interpret these results in terms of the overt motor activity eliciting covert visual imagery, a more straightforward interpretation is that subjects in the manipulation condition actually were provided with an imposed interaction in that not only were they generating an interaction (a process), but they were able to view the result of this activity (a product) as well. Since it is well known that imposed visual interactions facilitate associative learning (as also found in the Wolff-Levin study when the experimenter actually created the interaction), it could be argued that these interactions--and not the motor activity preceding them--were the proximate causes for performance differences between the manipulation and the imagery conditions in the kindergarten sample.

To resolve this problem, Wolff and Levin (1972) conducted a second experiment in which some children were permitted to manipulate the object pairs but were not permitted to see the resultant interactions since the manipulations took place behind a curtain which shielded the toys from the children's view. The learning of the manipulation-instructed subjects was 58% better than that of the imagery-instructed subjects who were permitted to hold onto the toys through the curtain but not allowed to manipulate them. This finding compares favorably with the 55% facilitation figure in the first experiment where visual inspection of the interaction was allowed. As further evidence of the nonessentiality of visual feedback to the motor effect, in a subsequent study Wolff, Levin, and Longobardi (1972) independently varied the visual and tactual components of the motor activity. It was found that relative to appropriate control conditions, the quality of the subject-produced interactions and subsequent learning were not related to the presence or absence of visual feedback.

These experiments suggest that anticipatory visual imagery constitutes a useful organizational strategy in associative-learning tasks. While older children can benefit directly from covert imagery instructions, younger children appear unable to do so. For them, however, it is possible to induce covert visual imagery through overt motor activity; when this is done, the learning of younger children approximates that of older children given simple imagery instructions.[5] (Note that these induced imagery findings can be easily incorporated into the representation in Figure 1 which will be done in a later section.)

Furthermore, a study by Varley, Levin, Severson, and Wolff (1974) indicates that even though young children do not appear to benefit from covert imagery instructions per se (i.e., in the absence of concurrent motor involvement), they can be trained to do so. Essentially, it was found that after prolonged practice involving motor manipulations kindergartners successfully accommodated imagery instructions (with no concurrent motor activity) on a subsequent task, in comparison to children who were given covert imagery practice without accompanying motor activity. Thus, the possibility of eliciting anticipatory imagery in young children via motor training is promising.[6] Clearly, the long-term benefits of such

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[5] The notions of "mediational," "production," and "control" deficiencies (Flavell, 1970; Kendler, 1972) are applicable and differentially evident throughout this research, although they will not be pursued here.

[6] But just as there appears to be a lower age limit--of about seven years--in the ability to benefit from a simple imagery instruction, we have recently discovered that motor inducement of visual imagery may also have a lower age limit--of about five years (Levin, McCabe, & Bender, in press).

efforts, as well as their breadth of transfer, deserve careful study.

Some Further Evidence for the Age-Imagery Relationship

In the preceding section we proposed that the ability to benefit from simple visual imagery instructions in associative learning develops in children beyond the age of six or seven. In this section, however, we examine evidence that suggests that the ability does not become fully realized until a later stage of development--something once again interpreted in terms of Piagetian theory.

Let us begin with the empirical observation that while imagery instructions have been found to facilitate the learning of adults (cf. Bower, 1972), this has not been true as consistently for children--even for those well into the concrete-operational stage. Although it is difficult to compare results across studies (where subject and task characteristics vary considerably), Levin (1972b) has observed that in experiments where imagery instructions have failed to improve children's associative learning, the stimuli have typically consisted of verbal materials (i.e., printed or aural noun pairs). To pursue this observation further, we conducted two experiments with 11- and 12-year-olds and found that although the children benefited from an imagery strategy when the stimuli consisted of line drawings, they did not when the stimuli consisted of printed words (Levin & Kaplan, 1972). And in a follow-up to this study, Eoff and Rohwer (1972) detected a developmental shift within the elementary school grades: initially subjects could not employ an imagery strategy either with pictures or with words; at a later age, they could employ the strategy with pictures but not with words; finally, they could employ it with both.

On the basis of these results, it may be tentatively concluded that the effectiveness of an imagery strategy (especially for children at the elementary school age) depends on the concreteness of the materials to be organized. That is, just as Paivio (1971) has reported that imagery generation proceeds more slowly with abstract nouns (e.g., truth, democracy) in adults, it is reasonable to suppose that children find imagery generation from words a relatively difficult task. Levin (1972b) has presented a flow chart depicting the hypothesized steps required when transforming either picture or word pairs into an interactive image; with words (less concrete) the number of transformations involved in the encoding and decoding phases is seen to be greater than with pictures (more concrete).

Thus, it may be presumed that even though children benefit from an organizational imagery strategy under certain conditions (e.g., when objects or pictures are the stimulus materials), they may not under others (e.g., when the stimuli are words). However, as was stated previously vis-à-vis the differing task and subject characteristics of the studies investigated, this generalization should be interpreted loosely at present, for although Horvitz and Levin (1972) found that third graders could not effectively utilize imagery instructions with verbal materials, Levin, Davidson, Wolff, and Citron (1973) found that second graders could when these materials were embedded in a single list containing both word and picture pairs. It is clear that a more systematic investigation of the "stimulus concreteness" phenomenon needs to be conducted and its limiting parameters specified.

The same type of systematic documentation needs to be assembled for a finding that we have repeatedly noted in our research, exemplified here by the data of Kerst and Levin (1973). In that experiment, fourth and fifth graders were instructed to generate visual imagery to facilitate their learning of a list of paired pictures. As would be anticipated on the basis of the research reviewed so far, the performance of the induced imagery subjects was by far superior to that of control subjects and, in fact, equalled that of subjects who were shown experimenter-imposed pictorial interactions. But what is of particular interest here is that the distribution of the induced imagery group was considerably more variable than the distributions of the other two groups.

On the basis of the Kerst and Levin (1973) data it was concluded that (1) some but not all children benefit from a self-generated imagery strategy (as evidenced by the greater variability of the induced imagery distribution), but (2) for those who do, performance surpasses that of subjects given experimenter-generated organizations (as evidenced by the slightly greater number of extremely high scores in the induced imagery distribution than in the imposed imagery distribution). We have interpreted this latter result as being consistent with the plethora of American, Genevan, and Soviet data demonstrating the importance of the organism's active role in the learning process. That is, we believe that optimal learning occurs when the subject interacts with his environment in a meaningful way, and clearly our own research with induced organizational strategies supports this position. Moreover, in accordance with "active participation" theorists, there are associative-learning data to suggest that given a well-organized event, the memorial consequences are superior when the event has been constructed by the subject himself than when it has merely been presented to him (e.g., Bobrow & Bower, 1969; Wolff, Levin, & Longobardi, 1974).

Let us now attempt to account for the finding that imagery instructions seem to produce a variable effect with children, as reflected by performance both within a task as in the Kerst and Levin (1973) study and from one type of material to another (e.g., from pictures to words) as in the Levin and Kaplan (1972) study. To do this, we will capitalize on the Piagetian belief that the concrete-operational thought of elementary school children evolves to the formal-operational thought of adolescents (at about 11 to 13 years of age). It is only at this later stage of development that the child becomes completely free from the stimulus-boundedness of his earlier concrete-operational thought in the sense of being able to exploit symbolic representations more fully and to deal with abstractions more proficiently.

The elementary school grades encompass children representing a wide range of cognitive-developmental levels: from transitional preoperational/concrete-operational children to transitional concrete-operational/formal-operational children. And, based on our own observations and those of others, within any particular grade level at a given school (especially in the middle elementary grades, grades 3 to 5) virtually this entire developmental spectrum is represented. Given that certain task demands (e.g., imagery generation) are related to the cognitive-developmental maturity of the learner (see, for example, Levin, Labouvie-Vief, & Urberg, in press), it is, therefore, not surprising that increased performance variability would result because some subjects are able to comply successfully while others are not. On the other hand, when the task demands are sufficiently obscure (as in an imposed organization condition), performance tends to be less variable (even when ceiling and floor effects are ruled out). It should also be noted here that the same variability argument may be applied to Rohwer's (1972) model where subjects exhibit, during the adolescent years, an increasing propensity for employing organizational strategies spontaneously (i.e., as they would have to do to succeed in a control condition).

Finally, the Kerst and Levin (1973) data have implications for the "active participation" hypothesis mentioned earlier. That induced imagery led to performance which was comparable in mean level to, yet considerably more variable than, that of performance in the imposed imagery condition is clearly compatible with the hypothesis, as long as individual differences are considered. That is to say, if the poor performance of certain induced imagery subjects stems mainly from their being at a stage of cognitive development which precludes their benefiting from the strategy, it would be expected that had the task been administered a year or two later, their performance would have increased dramatically, thereby creating a mean increase and variance reduction relative to the performance of imposed imagery subjects. Unfortunately, such a "wait till next year" hypothesis has yet to receive empirical verification, as does the simpler cross-sectional hypothesis that an imagery strategy will produce increasingly less variable performance from the elementary school years into adolescence.

Visual Imagery and the Comprehension of Prose

Just as it has been demonstrated that experimenter-imposed pictures can serve as adjunct aids to facilitate prose learning (i.e., Rohwer & Matz, in press), we have found that experimenter-induced visual imagery is similarly facilitative. Thus, the effects of a visual imagery strategy that were discussed in the context of associative-learning tasks seem to generalize to more complex forms of information-processing as well. For example, our imagery/comprehension research has been conducted with children in the upper elementary grades where, as noted in the previous section, visual imagery has been found to be a process accessible to many children. For children at this stage of development, simple examples and instructions to "think up pictures in *your* head while you are reading (or listening to) the story about what the people are doing, what they look like. . . ." seem to improve performance on a subsequent test of factual recall. And, in accordance with the motor-imagery relationship suggested by the Wolff-Levin studies, we (in collaboration with Alan Lesgold at the University of Pittsburgh's Learning Research and Development Center) are in the process of exploiting this relationship with regard to the improvement of comprehension skills in young (preoperational) children.

Similarly, some of the individual difference variables (apart from age) which were identified earlier have proven to be worth studying in a comprehension context. Recall the experiment in which we classified children on the basis of how well they learned from pictures (Hi P versus Lo P). Given the validity of these classifications, it is not unreasonable to assume that the Lo P subject, like the child who has not yet acquired anticipatory imagery, probably experiences some difficulty in pictorially representing stimulus materials and/or mentally manipulating them to enhance learning. Whatever causes Lo P subjects to have difficulty in learning from externally presented pictures should also operate to reduce the effectiveness of an internalized pictorial strategy.

In a second experiment of the Levin, Divine-Hawkins, Kerst, and Guttmann (1974) study, we presented Hi P and Lo P subjects a prose passage to be read either in the presence or in the absence of visual imagery instructions. As may be seen in Figure 2, while the performance of the Hi P subjects (including that of both Hi P, Hi W and Hi P, Lo W subjects) increased under imagery instructions, the performance of Lo P subjects did not, and in fact, decreased. (Perhaps the addition of an unfamiliar strategy complicated a task on which Lo P subjects have learned to succeed through the use of other cognitive processes.) At any rate, even though there was an overall increase in performance when visual imagery was induced, the important point here is that not all subjects appeared to benefit from such a strategy.

Precisely the same conclusion is reached when we examine in more detail another reading study reported earlier (Levin, 1973). It will be remembered that differences between good readers and poor readers tended to be smaller when children viewed a sequence of pictures than when they read the printed text. Obviously for children whose comprehension difficulties may be traced to vocabulary or word-decoding problems, a different representation of text (in this case, via pictures) should be helpful. But as Wiener and Cromer (1967) have argued, many children with adequate vocabulary and decoding skills may also be labeled "poor readers" if they have not learned to combine words and phrases effectively to derive meaning from them. These authors have referred to poor readers of the first type (i.e., those with vocabulary and/or decoding problems) as Deficit Poor readers and to those of the second type (those with organizational problems) as Difference Poor readers. Under normal reading conditions, Difference Poor readers are assumed to behave differently from good readers in that they do not spontaneously summon up effective organizational stragegies to help them comprehend what they are reading.

Accordingly, we speculated that inducing Difference Poor readers to employ an imagery organizational strategy while reading would improve their comprehension of the passage. On the other hand, inducing such a strategy in Deficit Poor readers should not prove helpful since they are lacking the vocabulary/decoding skills which are prerequisite to receiving assistance through organization. Good and poor readers were identified through standardized reading achievement scores, teachers' ratings, and reading-track placement within the school. Within the poor reader category, Difference and Deficit subjects were identified in terms of their respective standardized reading Vocabulary and Comprehension subtest scores. That is, the Comprehension scores of both types of poor readers were low, but the Vocabulary scores of Deficit Poor readers were substantially lower than those of Difference Poor readers.

As in the Levin, Divine-Hawkins, Kerst and Guttmann (1974) study, half the subjects received imagery instructions before reading a passage and half read it under normal conditions. Although imagery instructions were facilitative overall (84% correct versus 72% correct), the predicted interaction emerged. When the Difference Poor readers were given imagery instructions, they correctly answered more questions than their nonimagery counterparts (a difference of 26%); Deficit Poor readers given imagery instructions exhibited no improvement (actually a difference of 2% in favor of the nonimagery group). And, in accordance with the comparative performances of Population I and Population II subjects in Figure 1, while under normal reading conditions the good readers by far surpassed the Difference Poor readers (81% versus 60% correct), when the Difference Poor readers were provided with an organizational strategy their performance (86% correct) approximated (in this case, slightly exceeded) that of good readers reading under normal conditions.

The results of these investigations accord well with predictions, in that they (1) document the possibility of improving comprehension through the implementation of a self-generated organizational strategy and (2) suggest that the potential benefits from such a strategy are closely tied to the prerequisite skills of the user. With regard to the second point, this is not to say that we should give up on children who do not seem to profit from simple imagery instructions and regard them as doomed to failure. Quite to the contrary, it is of especial importance to

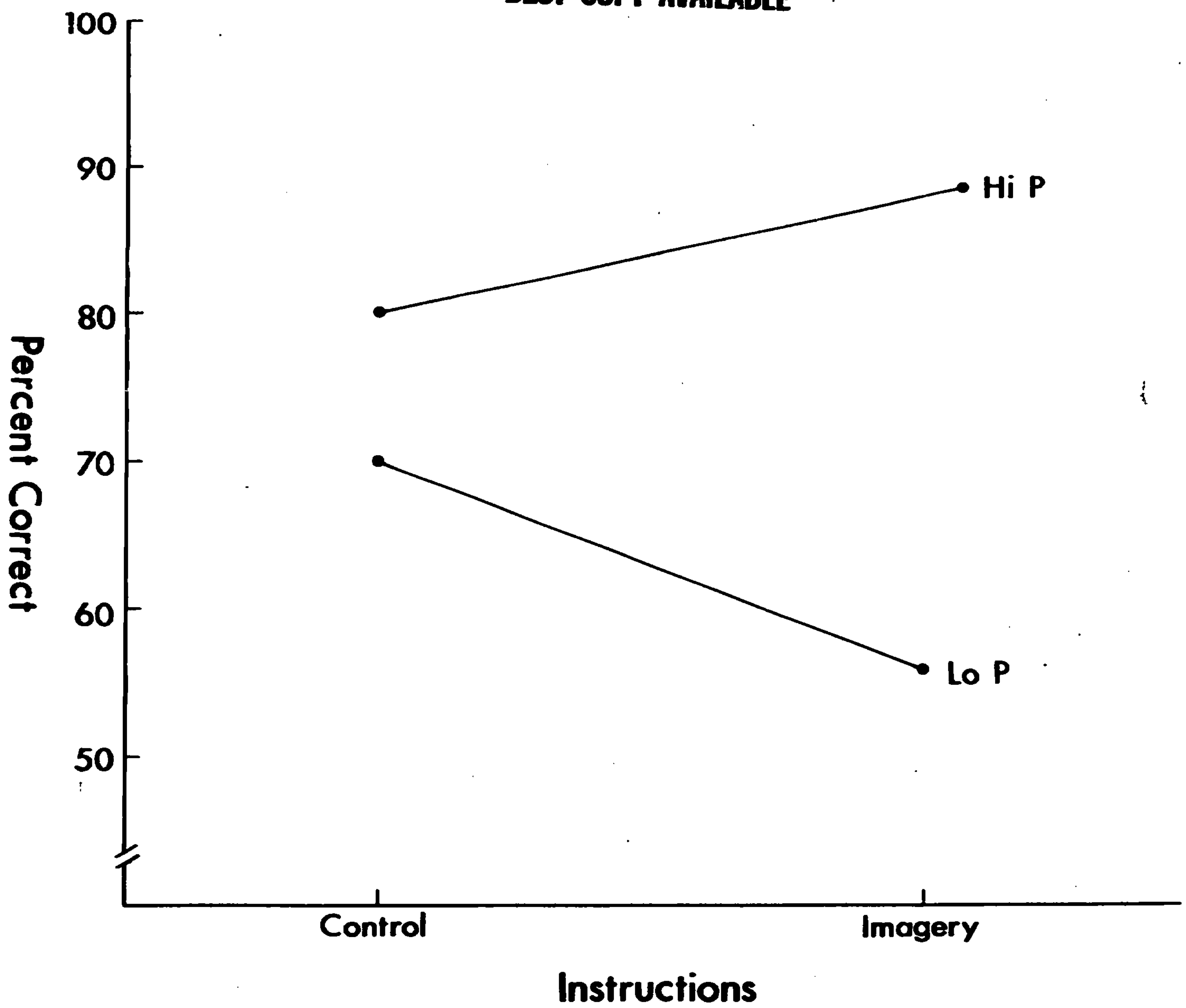

Figure 2. Reading comprehension of two types of learners under different instructional conditions. (A connected line graph is utilized here simply to emphasize the interaction of interest that is discussed throughout the text.)

determine whether Deficit Poor readers will benefit from imagery instructions if vocabulary and decoding demands are eliminated and whether Hi P, Lo W children will benefit from alternative types of organizational strategies (e.g., verbal paraphrase) or from subject-generated supplements to an imagery strategy (e.g., relevant motor activity) in much the same way that the learning of "pre-imagery" children has been facilitated by sentence production (Levin, McCabe, & Bender, in press; McCabe et al., 1974) and motor involvement (Varley et al., 1974; Wolff & Levin, 1972).

A Footnote to the Benefits of Visual Imagery in Learning

Thus far we have presented evidence compatible with the assertion that a visual imagery strategy facilitates learning and comprehension. But, as with our earlier discussion of pictorial facilitation, we must ask how universal this assertion is. We have already argued that the success of an imagery strategy depends on the capabilities of the user, and we have identified the individual's cognitive-developmental level as a particularly relevant subject variable. Similarly, we will now show that the unique features of a particular task may also moderate the strategy's effectiveness.

For example, Bower (1970) has demonstrated that imagery per se does not facilitate associative learning. To do this, he instructed subjects to form an image of the pair members one next to the other (i.e., not interacting). He found that performance was no better than that of subjects given rote-rehearsal instructions and appreciably worse than that of subjects given interactive imagery instructions. Thus, it may be safely concluded on the basis of these and other data that if the imagery is devoid of an organizational component, associative learning is not enhanced. Similar conclusions have been reached about strategies which would and would not be expected to facilitate other types of learning (cf. Levin & Rohwer, 1968; Rowe & Paivio, 1971).

Unfortunately, knowledge of these nominal task characteristics is not sufficient to permit speculation on whether or not a particular strategy will be effective. Rather, procedural factors and the nature of the stimulus materials provided in the task also need to be considered. With regard to procedural factors, we mentioned previously that the usual picture-over-word effect in serial learning vanishes when the presentation rate is too rapid for the pictures to be implicitly labeled, even though they are perceived (see Footnote 3, Chapter II). The same may be assumed to be true of the imagery strategy effect in learning and comprehension tasks when a fast rate of presentation is employed (cf. Levin & Divine-Hawkins, 1974; Paivio, 1971). Now let us show how the effectiveness of an imagery strategy may depend on the stimulus materials provided.

Earlier it was stated that it may be easier for children to utilize an interactive imagery strategy in associative learning when the stimulus materials are pictures than when they are words. This was assumed to be related to the differing transformational complexities associated with each. For different reasons, imaging the referent of individual words for subsequent recall should be more effective than simply pronouncing the word (Paivio & Csapo, 1973), whereas pronouncing the label of a picture or object should be more effective than imaging it (Davies, 1972; Paivio & Csapo, 1973). Aspects of this interaction have recently been discussed by Levin, Ghatala, DeRose, Wilder and Norton (in press) in the content of a discrimination learning task where recall is not required.

Such observations clearly limit the potential benefits accruing to visual imagery as a cognitive strategy. So do observations that indicate that the magnitude and direction of imagery effects vary across tasks which ostensibly require different cognitive processes. A case in point is a study by Hollenberg (1970). Recall the earlier suggestion that while experimenter-provided pictures facilitate certain types of learning, they may interfere with others. In particular, they may be assumed to be a deterrent to concept acquisition/utilization if the perceptual characteristics of particular exemplars prevent the learner from retrieving the more abstract conceptual information required. Hollenberg reached the same conclusions when comparing the learning skills of children identified as high and low imagers on the basis of selected tests for imagery ability. Her finding of major concern here is that even though high-imagery children outperformed low-imagery children on an associative-learning task, they were subsequently less able to transfer this knowledge to a conceptual-learning task involving the same items.

Considering Hollenberg's (1970) data alongside the comparable results produced from picture-word comparisons discussed previously, suggests that what is true of "pictures" when defined as externally provided (imposed) representations may also hold for "pictures" when defined as internally generated (induced) representations. With reference to our own research, the finding that children who learn well from pictures can benefit from an imagery strategy on a comprehension task while children who do not learn well from pictures cannot (cf. Figure 2) certainly serves to corroborate this notion. The finding also serves as a basis for inferring that similar cognitive processes are evoked when pictures are perceived and images are generated (Levin & Divine-Hawkins, 1974, and Paivio, 1971; but see Anderson & Bower, 1973, and Pylyshyn, 1973). This paper will be concluded with a discussion of that inference.

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IV
Inferred Cognitive Strategies: A Proposed Approach and Some Illustrations

Throughout this paper I have distinguished between imposed and induced cognitive strategies; a desired mental process is presumably evoked directly in the case of the former (via experimenter-provided materials) and indirectly in the case of the latter (via experimenter-suggested strategies). However, when investigating a covert process such as visual imagery, one of the nagging questions that must be addressed is whether such procedures evoke covert mental processes and, if so, whether these are in fact the processes desired. Although some investigators have taken advantage of subject reports, typically answers to the first part of the question are inferred on the basis of performance differences between subjects presented with a strategy and those not presented with one (e.g., imagery instructed versus control subjects); and answers to the second part are inferred on the basis of performance differences between subjects presented with one strategy and those presented with another or on the basis of performance differences obtained with different tasks or different sets of materials.

It should be noted that such indirect measures of a cognitive process are abhorrent to some who believe that only through direct, visible methods (like "peeking into the brain" by means of electrode implantations and associated EEG readouts) are inferences about cognitive processes warranted. However, in the absence of refinements of such techniques (where "noise" and variability are the order of the day), others consider indirect measures of a cognitive process to be acceptable, if not preferable, at present. It should also be mentioned that questions dealing with the psychological reality of a cognitive process like visual imagery encompass far-reaching theoretical issues. Because of the essentially applied focus of this paper, only scant attention will be paid to them here. However, the reader is referred elsewhere for a discussion of some of these issues (cf. Bower, 1972; Neisser, 1967; Paivio, 1971; Pylyshyn, 1973; Sheehan, 1972).

To illustrate the matter of inferring that a cognitive process such as visual imagery is operating, I have presented a prototypic paradigm and idealized data set (Figure 3). In Figure 3, two "tasks" are represented; in this discussion, "task" refers loosely to procedural or stimulus-material variations within a task, as well as to the literal meaning of nominally different tasks. Various imposed or induced strategies are labeled A, B, and O in the figure; A and B represent experimental strategies and O denotes a control strategy.[7] With reference to our question about the existence and nature of covert mental processes, differences between experimental (A or B) and control (O) performance may be taken as evidence that subjects presented with a strategy have done something differently from subjects not presented with a strategy, while performance differences between Strategy A and Strategy B within tasks (or, preferably, in interaction with tasks) may be taken as evidence that the two strategies have evoked different cognitive processes.

A sentence-learning study recently completed by Joseph Guttmann, Ann McCabe, and myself illustrates a within-task manipulation, while a discrimination-learning study by Levin, Ghatala, Wilder, and Inzer (1973) illustrates a differential strategy effect from one task to the next. In the sentence-learning study, sixth graders were required to remember the content

[7] As will be seen shortly, however, this variable can also incorporate strategy differences as inferred from identifiable differences among learners.

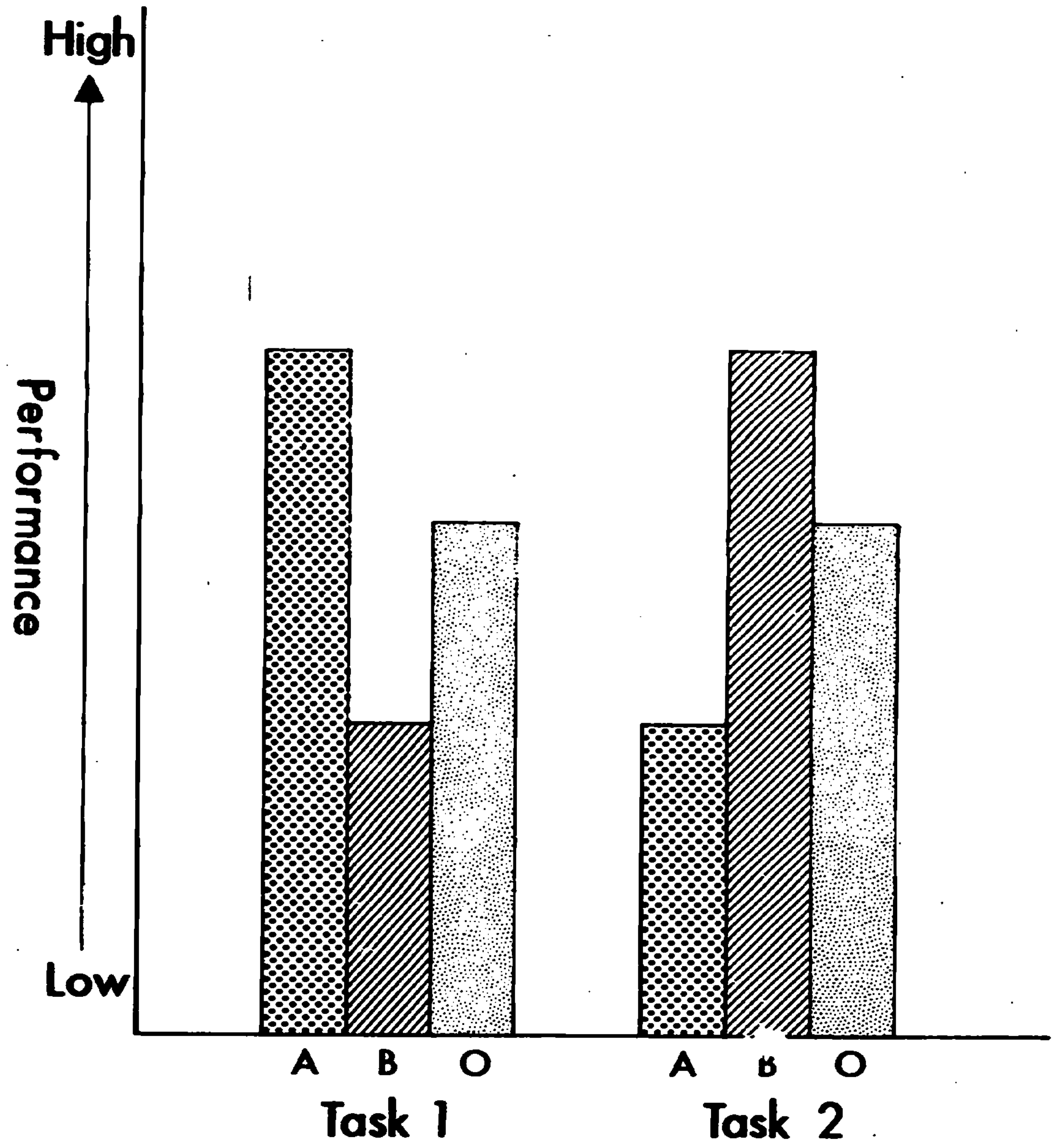

Figure 3. A proposed approach to the investigation of inferred cognitive processes.

of 20 aurally presented sentences under basically three types of rehearsal strategies: Imagery, in which subjects were instructed to image the content of each sentence as it was presented; Repetition, in which subjects were instructed to repeat each sentence three times as it was presented; and Control, in which no rehearsal strategy was suggested. The mean prompted recall of subjects in the respective conditions is adequately represented by the Task 1 profile in Figure 3. That is, Imagery organization (A) was superior to (either overt or covert) Repetition (B), with Control (O) intermediate to the two. This pattern suggests that subjects in conditions A and B were doing something different from the control subjects (or possibly that some control subjects were spontaneously employing Strategy A and others Strategy B?), but more importantly, it shows that the two strategies resulted in different levels of performance. The result is consistent with the data of Bower (1972) and Rohwer (1972) which show that filling the study interval with an irrelevant or ineffectual rote-rehearsal strategy is interfering, relative to both a semantic-organizational strategy such as the imagery instruction here and a no-strategy control where at least some (and especially older) subjects are presumably adopting an effective semantic-organizational strategy. What is of additional interest here, however, is that the negative effect of repetition holds (albeit not as strongly) for subjects instructed to repeat the sentences silently to themselves as well as for those told to repeat them aloud, indicating that when subjects were instructed to do different covert things (imagery versus repetition), they apparently complied faithfully with the instructions.

Now let us incorporate Task 2 of Figure 3 in order to approximate the results of the Levin, Ghatala, Wilder, and Inzer (1973) discrimination-learning study. Before doing so, however, a word about the discrimination-learning paradigm is in order. In it, the subject must learn which item in each of several pairs has been arbitrarily designated "correct" by the experimenter. Rowe and Paivio (1971) have demonstrated that an effective rehearsal strategy in this paradigm is one that provides rehearsal of the "correct" item, thereby increasing its familiarity (Ekstrand, Wallace, & Underwood, 1966). In the Levin, Ghatala, Wilder and Inzer (1973) study, the stimulus materials consisted of printed nouns and the subjects were requested to employ one of three rehearsal strategies during the informative feedback interval: Imagery, in which subjects were instructed to form an image in their mind of each "correct" item's referent; Verbal, in which subjects were instructed to pronounce aloud each "correct" item; and Control, in which subjects were left to their own devices. Included in the stimulus materials were pairs of homonyms, e.g., sun-son (Task 1 in Figure 3), and pairs of synonyms, e.g., boy-lad (Task 2); it was predicted that if subjects were actually adopting the specified strategies, a different pattern of strategy effectiveness would emerge on each task. In particular, Imagery (A) should constitute a relatively more effective strategy than Verbal (B) when the subject is discriminating between homonyms (similar-sounding items), whereas the reverse should be true for synonyms (similar-looking items). This is because the lack of a relevant discriminative cue might retard increased familiarity with the "correct" item. The results of two experiments essentially confirmed the predictions--depicted by the idealized representation in Figure 3.

Experiments such as these are important in that when the same strategy can be shown to produce different effects with different materials, inferences are strengthened about the psychological reality of the processes assumed to be involved. Other studies in which we have attempted (not always successfully) to produce differential effects by manipulating procedures and materials are those of Davidson and Levin (1973), Horvitz and Levin (1972), Levin and Divine-Hawkins (1974), and Levin and Horvitz (1971).

An alternative inferential approach would incorporate subjects who are assumed to employ (or benefit from) different strategies into the ABO distinction of Figure 3. Hollenberg's (1970) study and our study in which Hi P and Lo P subjects responded differently to visual imagery instructions are illustrative of this approach. However, one of the most clever illustrations is by Paivio and Okovita (1971), who found that subjects deficient in visual imagery (blind subjects) did not benefit from materials rich in visual imagery-arousal as sighted subjects do. On the other hand, they did benefit from materials rich in auditory imagery-arousal whereas sighted subjects did not. This utterly fascinating and fertile research area dealing with cognitive processes deserves continued investigative efforts, as the wealth of information contained therein promises to be of value to both the psychologist and the educator.

V
Summary

What have we learned about maximizing what children learn? Let us attempt to summarize the highlights.

1. In a large number of learning tasks children seem to learn better when the materials are pictures than when the materials are words. This has been noted not merely for simple item-learning tasks but also for tasks which demand comprehension of facts and relationships.

2. There appear to be limitations to the the effectiveness of pictures in terms of both learner and task differences. With regard to the learner, we have found that certain children learn appreciably better from pictures than from words and, for these children, the type of materials presented during learning largely determines whether they will resemble good or poor learners. With regard to task differences, in tasks demanding the formation or utilization of abstract conceptual categories, pictures tend not to be facilitative and may even impede performance.

3. Subject-generated organizational strategies (visual imagery in particular) greatly facilitate associative learning. The ability to generate effective imaginal organizations appears to be closely related to the cognitive-developmental level of the learner. However, even children below the necessary level may be induced to generate imagery by means of appropriate auxiliary activity or training. The ability to generate effective verbal organizations appears to be developmentally an earlier process than the ability to generate effective imaginal organizations. This is interesting in that it suggests that (1) even young children can benefit from an induced organizational strategy if it is an appropriate one and (2) covert verbal and imaginal processes may be differentiated in the young child.

4. Benefits from an imagery strategy have also been obtained on tasks requiring comprehension of a passage, but once again there are identifiable learner and task characteristics that are useful in predicting the effectiveness of the strategy. With regard to the former, subjects lacking prerequisite word-decoding skills and those who do not learn well from pictures do not seem to generate effective imaginal organizations. With regard to the latter, throughout this research we are constantly reminded that the potential effectiveness of a strategy is dependent on the nature of the task and materials. What constitutes an appropriate strategy in one context may be completely inappropriate in another, and it is up to the experimenter (and, more practically, the "cognitively mature" learner) to recognize which strategy will be helpful when.

5. We have also learned that a great deal remains to be understood about the external and internal mechanisms responsible for the phenomena that have been observed. For example: Why are pictures generally easier to learn than words? What is accomplished by imaginal or verbal organizations that make them effective learning strategies? What other individual difference variables are related to the ability to profit from a particular strategy? While the picture is far from complete, one cannot help but imagine the glittering psychological treasures buried just beyond the next horizon.

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