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ABSTRACT

Experiments conducted to find ways of teaching two and three year olds mathematical concepts were found to have general implications for concept learning. The failure of an initial attempt to teach the concepts "fat" and "skinny" led to a design of instructional procedures that would utilize a concept's name while trying to teach its semantic content. A study of variant procedures used to teach the concept "round" emphasized the importance of verbal representation, and a final experiment, designed to teach "square," was performed to determine whether linguistic or concrete referential contexts were more important. The results supported the linguistic approach to semantics rather than the psychological: the relation of words to other words appears more crucial than the relation of words to things. Preschool instructional approaches should consider the communicative context of experiences as well as children's direct experience with materials. (DR)

Teaching Mathematical Concepts to Two- and Three-year-olds: Some Experimental Studies

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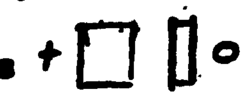
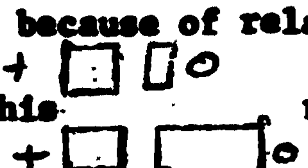
The concepts, "fat" and "skinny," "round" and "square," were vehicles in a search for ways to teach two-and three-year-old children mathematical concepts. Originally this search was directed by some ideas about modes of representation proper for instructing children at particular developmental levels. These ideas were based on Bruner's (1960, 1966) theory in which he describes three forms that cognitive maps of the world may assume — enactive, ikonic, and symbolic. The enactive mode encodes events in terms of action; the ikonic mode in terms of images; and the symbolic mode in terms of arbitrary systems such as language. Bruner (1960) has advanced the notion that concepts in a new area are best learned if instruction follows the developmental order of the three modes — (1) enactive, (2) ikonic, (3) symbolic. Applied to teaching extremely young children whose semantic systems are still fairly rudimentary (McNeill, in press) this theoretical position could imply first, that enactive and ikonic representation makes possible instruction in more advanced concepts than would otherwise be possible at a given age and, second, that once language has developed to a sufficient degree, verbal concepts may benefit from prior training in their enactive or ikonic forms.

Teaching "Fat" and "Skinny"

The first study was an attempt to develop an instructional sequence for teaching two concepts of intensive quantification — "fat" and "skinny." In the initial phase, which took the form of a classical discrimination learning experiment, twelve three-year-old children attending the Children's Center (described in more detail later) were required to discover under which of two cans or boxes a raisin had been placed. When the concept to be learned was "fat" the raisin was always under the container with the larger diameter; when "skinny" was the concept, the raisin was to be found under the container with the smaller diameter. To find the raisin consistently, the child had to induce the quantitative concepts from ikonic and enactive information. Seeing the cans allowed a visual image of the concepts to be formed, while the act of lifting up the cans to look for raisins provided the material for enactive representation. In the initial instructional sequence, the two cans were exactly alike save for their diameters. Thus, the stimulus situation was simplified to the maximum extent. Since the materials were maximally abstract or noise-free informationally, the child presumably had to do a minimum amount of mental abstraction to learn the conceptual principle.

Half the children were taught using the minimum number of examples to define each concept unambiguously. The other half of the children were also presented with an extra example of the concept. What this meant in practice was that one group received two examples of the concept while the other group received three. A single example like this  leaves the principle ambiguous: the left one could be correct either because of relative or absolute size. A pair of examples like this  resolves the ambiguity in favor of relative diameter. Additional examples offer no additional information from a logical point of view. The question was whether they would do so from a psychological point of view. The examples were intermixed and the order was basically a random one. The day after the presentation of a given concept was complete, the same concept was presented in a verbal form. Visual information was still present -- the child could see the pairs of stimuli -- but now the child was told: "Put this block in the fat can" or "Put this block in the skinny can." The conceptual problem is now a deductive one: to learn to apply the generalisation "fat" or "skinny" to concrete situations. The enactive element is gone, for the child no longer manipulates the stimuli. The sequence of problems in verbal form was to serve as a posttest to assess the effects of the nonverbal training procedure.

This study has been described in detail just sufficient to present the results that are relevant to the other studies in this project. The main outcome was that the basic nonverbal training procedure was a complete flop; only one child out of the twelve mastered the first and simplest learning sequence to the criterion of eight correct in a row within the first twenty-four trials or twelve in a row thereafter.

Despite this failure, it was decided to give the verbal posttest anyway to see what could be learned from it. Applying the same criterion of eight in a row to the eighteen items of the posttest, ten children out of twelve met the criterion for one or both of the concepts "fat" and "skinny."

As far as the extra example was concerned, it seemed to have a negative effect on learning. Those children who were given an extra instance of the two concepts fared worse in their ability to apply the corresponding verbal labels "fat" and "skinny" on the posttest. According to an analysis of variance, this finding attained the .05 level of statistical significance.

If verbal concepts are the ultimate pedagogical goal, then purely nonverbal means appear, at best, very inefficient, according to these results. Many studies have shown that verbal labels aid in the discovery of solutions to nonverbal concept attainment problems and a large number of others have indicated that verbalization makes conceptual principles more transferable to new situations. Few studies, however, have addressed themselves to demonstrating the value of formulating the conceptual problem itself in verbal terms.

Reese's (1966) study of intermediate size discrimination and transposition is directly to the point here. One group of children from 34 to 63 months of age was told during training that the reward was under the "medium" stimulus; another group was told nothing about where to find the reward. The first group learned the initial discrimination faster and transposed the principle to more new examples at varying distances from the original pair, even though the concept "medium" was no longer labeled for either group during the transposition tests.

If one thinks of the command "Put the block in the 'fat' one" as a verbal rule to obtain raisins, then Wittrock's (1963) experiment on learning by discovery is relevant, for he found that explaining the rule for deciphering sentences, then letting students use the rule to work examples, produced more learning, retention, and transfer of deciphering ability than simply letting students figure out examples without first being given a rule. The original learning, moreover, took twice as long on the average when the rule was not given.

As far as the number of instances optimal for learning a concept is concerned, these results are in accord with those from other studies indicating that more concrete examples of a concept more often impede learning than help it. The literature in this area could perhaps best be synthesized by saying that examples must be learned well to be of use and that a balance must be maintained between memory load and complete definition of the concept (Amster and Marascuilo, 1965; Stern, 1965). Where a concept is difficult for the person learning it for any of a number of possible reasons, a small number of instances may be most favorable to learning (Amster and Marascuilo, 1965; Marascuilo and Amster, 1966).

These considerations led to designing instructional procedures that would utilize a concept's name while trying to teach its semantic content. The adverse influence of the additional example of "fat" and "skinny" cans probably stemmed at least in part from the fact that all examples were presented before any single one was mastered. For this reason it was decided that in future teaching procedures, mastery in applying the concept within a particular concrete situation would be requisite to going on to a new situation. Examples beyond those required for complete conceptual definition were also to be abandoned.

A comparison of methods for teaching the geometric concept "round" was the next study in this project. All the methods used were built on these lessons learned from the study that has just been described.

Teaching "Round"

Granted that at least some verbal rules are called for when working with three-year-olds, one question still to be answered was how much verbalization to introduce and at what stage in the learning process. A second question involved the forms of action that are most productive for conceptual learning. The study on teaching "fat" and "skinny" demonstrated that mere manipulation of objects exemplifying conceptual relationships is not sufficient. The Montessori method emphasizes a certain type of action in the so-called "self-teaching" materials (Montessori, 1966). This type of action consists of manipulation with corrective feedback; an example is the action involved in fitting puzzle pieces together.

Three teaching methods were compared. All involved the same sequence of stimulus displays. In each display the child was asked to pick out the "round" one. Round sometimes meant a piece of wood, a hole, or a cup. The displays involved two or three stimuli; and "round" was contrasted with triangular, square, kidney-shaped, and hexagonal. Sometimes shape was the only variable; in other displays, color was introduced as an irrelevant variable. The displays were arranged from easy to hard on an *a priori* basis.

In all conditions the child was told whether he was right or wrong and induced to correct an incorrect response; he also was rewarded with a raisin when right and lost one when wrong. This reinforcement or feedback procedure was designed to maximize learning for all children, and it was based on the results of a number of different studies. One, by Meyer and Seidman (1960) has shown that young children learn best if they are given explicit verbal feedback on both right and wrong responses. Gollin (1966) and others have demonstrated that, once a wrong response occurs, learning is enhanced if the child is allowed to correct himself. Zigler, (Zigler and De Labry 1962) has shown that lower class children do relatively better on learning tasks when rewards are concrete, whereas middle-class children respond more to verbal feedback. Both kinds of reinforcer was therefore used in this study. In terms of contingencies, Master (Eisenberg, 1966) has demonstrated that lower-class children tend to be satisfied with "partial" reinforcement and that they will not necessarily try to solve a problem in order to be correct 100% of the time unless reinforcement is on an all-or-none basis. One way of approximating this situation is to take away concrete rewards when wrong responses occur. The feedback procedure described above incorporated all of these experimentally tested features.

The first instructional condition consisted of the label "round" (used by the teacher) in conjunction with the child manipulating the stimuli with corrective feedback of the Montessori type. The second method was identical, but the child manipulated the stimuli without receiving any corrective feedback for his action. In practice, this meant that, whereas in the first condition the round stimulus was the only one that could fit somewhere (for example, into a round hole), in this condition any stimulus would fit into the large oval hole where the child had been asked to place the "round" one. The third condition was just like the first, except the label "round" was not used until the beginning of the second half of the training. Up to that point the child was merely asked to find the one that "fit," e.g., a piece to fit a hole. There was also a control group who received no training.

There were sixteen children in the study ranging from two to three years of age. All the children were given a pre- and post-test, which were identical. Half the test displays consisted of new stimuli, that is, ones not used in the training, while the other half had been included in the training. Half the transfer items used the verbal concept "round" in the instructions but provided no action feedback, whereas the other half provided only action feedback. Similarly, the test items which had been directly taught were of these two types. The items on the test were randomly ordered and the children were not informed, either verbally or with raisins, as to whether they had given a correct answer.

Although all three of the training groups showed more positive change from pre- to post-test than did the untrained control group, the effect of training on the total test or any of its component parts was not statistically significant according to an analysis of variance, It is interesting to note, however, that the largest difference between the control and training groups occurred with respect to improvement on the verbal transfer items which, it will be remembered, provided no action feedback. Similarly, the differences between the changes produced by the various training methods were not large enough to be statistically significant, either for the total test or for any of its parts. Again, though, the largest gain occurred on the verbal transfer items and was made by the children whose training had consisted of manipulation with corrective action feedback, as well as labeling throughout.

Since the results of this study were largely negative, its main use was as a pilot to the next study to be described.

Teaching "Square"

The "round" study suggested that if correct referential use of the descriptive term "round," especially in new situations, was the ultimate goal of training, then "manipulation with corrective feedback plus labeling" might be the best method. The techniqués for teaching "square" were, consequently, all based on this method, although the sequencing was improved to reflect the order of difficulty that had emerged from the earlier data.

The principle question which this study asked was exactly what should the teacher say about the concept to be taught, granted the fact that some sort of verbal representation was critical. The hypotheses were derived as much from linguistic theory as from psychological theories of concept learning.

Psychologists generally stress the relations between word and referent in their treatment of the development of word meanings. Linguistic discussions of word meaning, in contrast, revolve around the relation of words to other words (Olson, 1968). The experiment on "fat" and "skinny," just described, indicated that increasing the number of referential relations of the word in question can, under some circumstances, have an adverse effect upon learning the concept. But what about increasing the number of verbal relations? How does variation in verbal context affect conceptual learning ? The particular way in which this question was applied to teaching the concept, "square," to two- and three-year-olds ~~the concept "square"~~ was derived from some Russian work on the effect of a variety of verbal and action contexts on very early vocabulary learning. In one study by Kol'tsova (Razran, 1961), twenty-month-old children were presented with a doll 1500 times. Half the children were presented the doll in three contexts: "Here is a doll," "Take the doll," and "Give me the doll." The other half were exposed to thirty different contexts: the same three plus others like "Rock the doll," "Feed the doll," and so forth. The test was to "pick a doll" out of an array including the experimental doll, other dolls, and other toys; the children were to learn the range of reference of the word "doll." Those children who had had the experience of thirty different contexts were more successful in discriminating dolls from non-dolls and they also responded to the task more quickly. Thus, the variety of verbal and action contexts in which a word is placed has a positive effect on learning its referential meaning, independent of the variety of concrete referents in which the word is associated.

In another experiment, Kol'tsova (Razran, 1961), using nineteen-month-old children, showed that the variety of contexts in which a word is placed is more effective in teaching the meaning of that word than is an identical amount of variety of referents or concrete examples. In this study, the children were taught the meaning of the word "book" in one of three ways: (1) using one actual book and the word "book" in only one sentence, with one corresponding response on the part of the child; (2) using one actual book but placing the word "book" in twenty different sentences, with twenty different corresponding responses on the part of the child; and (3) using twenty different books with the same single sentence and response used in method (1). The test was to "pick a book" in an array of books and other toys. The children exposed to the twenty contexts did the best; the children exposed to twenty books did next best; and the group exposed to one context and one book fared very badly indeed. Olson (1968) concludes from this and other evidence that "semantic meaning is advanced more by the definition of words by words and by using words in an appropriate linguistic context than by exposure to the referents." In terms of education, especially compensatory education, this conclusion would favor methods emphasizing linguistic rather than experiential enrichment. Bereiter and Engelmann's (1966) academically-oriented preschool for very deprived children is one example, as Olson points out.

Although the evidence points to the value of a variety of linguistic contexts on the stimulus side and a variety of action contexts on the response side in teaching concepts of all sorts, experimental work has been restricted to object names; no one has investigated this variable in relation to learning analytic or attribute concepts. The study to be described assessed the effect of variety of context on learning the meaning of the geometric term "square."

The role of verbal contrast in fostering conceptual learning was the other issue taken up by this study. The discussions of Brown (1958), Werner (1948), and Vygotsky (1962) suggest that "true" concepts are a synthesis of discrimination and generalization. In terms of the stimuli or examples of a concept given in a learning situation, this principle is tacitly assumed: the learner is exposed to both positive and negative instances of the concept in question. Within linguistics the role of contrast is more central and more explicit in its relation to language learning. On the phonological level, for example, the functional sound units, phonemes, are traditionally defined by oppositional pairs. When a difference between phonetically similar sounds can make a difference in meaning, then the linguist knows these sounds belong to different phonemes. For example, the existence of the pair of words "pit" and "kit" is proof that

/p/ and /b/ are two separate phonemes in English. This kind of contrast is postulated to be as important in original language learning as in technical linguistic discovery. Clearly the contrast case defines the boundary of the phoneme concept and thus is as crucial to its precise definition as the positive instance is. From a logical point of view, this is true of any concept. The function of contrast in conceptual definition is but another way of affirming Van de Geer and Jaspers' idea that "having a concept implies that one has more than one concept; it implies a conceptual system" (1964, p. 149). In perception, we know from the work of Garner (1966) that the array or contrasting items in which a particular item is found is critical to its identification. There are indications from work in West Africa (Greenfield, 1966: Price-Williams, 1962) that the nature of the contrast cases can be critical in determining whether or not a certain classificatory principle is brought into play at all and that this is more the case the less various classificatory principles are integrated into a single unified system. Similarly it is clear from the work of Lantz and Stefflre (1964) that the value of a particular linguistic encoding for identifying or remembering a stimulus depends on the array in which the stimulus is found, or more accurately, on whether there are contrasting ways of encoding the other stimuli in the array. Is it also the case, then, that the ease with which a conceptual label can be learned and applied to concrete examples depends on the existence of contrasting terms to denote the contrasting stimuli in the array? This question has never been asked experimentally. Bereiter and Engelmann (Osborn, 1969) have, nevertheless, exploited the idea of a system of contrasting terms in teaching disadvantaged preschool children, for they present attribute labels from the outset in the company of their polar opposites. Claparède (Olson, 1968) proved experimentally that dissimilarity leads to awareness. If contrast along a superordinate dimension is the essence of a conceptual system, then the embedding of a single concept within a larger system would be requisite to conscious awareness of that concept. This line of thinking leads Vygotsky to the conclusion that "a concept can be subject to consciousness and deliberate control only when it is part of a system" (1962, p. 92). Thus, one might hypothesize that contrasting terms would be of value not only in promoting the bare learning of a particular concept but also in fostering the sort of conceptual knowledge which could most readily be put to use by the learner for his own purposes.

The study to be described incorporated contrastive terms into the correction procedure and tested the value of doing this for teaching the meaning of "square" to two- and three-year-olds. The particular contrastive terms used were therefore dependent on a particular child's errors and on the stimulus array. The way in which this worked in practice will become clear when the teaching sequence and procedure is described in detail.

<u>The Children</u>

All the children in the study were attending the Children's Center in Syracuse, New York. The Center, organized and run by Dr. Bettye M. Caldwell, is a school for children from the age of six months until kindergarten age. Children attend school every day for either a full- or half-day. The Center is for the enrichment of lower-class children, but about one-third of the children are from middle-class homes. The project being described served as an experimental supplement to the regular program, described in detail by Caldwell, (Caldwell and Richmond, 1967). It contrasted with this program in that instruction was given individually rather than in small groups.

The children in this study were drawn from the two classrooms containing the age span from two years, six months to three years ten months. Because of the small numbers available there was in fact no sampling. All the children available for the duration of the study were used unless they had a sibling in the study or already knew the concept "square" as evidenced by a perfect score on the pretest. Four children attained perfect scores; their average age was three years, seven months. The average age for the eighteen children in the study was three years, 1 month. This contrast in age indicates that the concept was in fact developing in the group as a whole, although not at the same rate for everyone: there were children of exactly the same age who made errors on the pretest.

As for the social makeup of the groups, three of the four who had the concept at the outset were middle-class white children. The fourth was a lower-class Negro. In the group who failed to achieve a perfect score, only two out of eighteen were middle-class, one white and one black. Of the remaining sixteen lower-class children, ten were white and six were black. Thus, class background made a big and statistically significant difference in initial level of knowledge of the concept (Fisher Test, $p. < .05$). Putting this finding together with the first one, we may conclude that, on the whole, middle class children were developing the concept "square" as they grew older (within the age range of the study), whereas lower-class children were not.

Design of the Study

Eighteen children who did not demonstrate perfect knowledge of the meaning of "square" on the pretest participated in the study. The total group of eighteen children was divided into three age levels. Within a given level, children were randomly assigned to one of the five groups comprising the study. One-third of these children were in a control group. These children were not taught the concept "square," but they were given the "square" test twice -- at the same interval as the twelve children who were exposed to one of four types of experimental teaching.

All four groups who were exposed to some form of experimental teaching received the same sequence of instructional materials presented in different ways. Basically, all these children were given practice in picking out the square stimulus from arrays which became increasingly difficult as the instructional sequence progressed. The procedure and sequence are described in detail below. The word "square" was used in every instructional condition, and every child handled the square stimuli with corrective feedback at least some of the time. In other words, all four teaching methods were variants on what the "round" experiment had shown to be the most promising approach.

The first variable was variety of context. Half of the twelve children were presented the word "square" in a single verbal and action context. For example, if the task was to find a piece to fit a square hole, the child would be told "The square piece just fits in here(teacher pointing to hole). Can you find it and put it in?" The other half of the children were presented the word "square" in multiple verbal contexts. and consequently manipulated the square stimulus in a variety of ways. For these children, eight of the twenty-three instructional arrays were presented using the type of instructional sentence just described. But two other types of verbal contexts were also introduced: "Put the square piece in this can." and "Give me the square piece." The corresponding action contexts are clear, but it should be noted that they involve no corrective feedback; any piece in the array would "fit" equally well into the can or the teacher's hand. These two contexts appeared eight and seven times respectively in the instructional sequence.

Each of the two instructional groups was also divided in half according to the type of correction procedure used. For half of each group the correction procedure involved labeling the shape of the stimulus that had been wrongly picked. This was the "contrastive terms" group. The other half of the group was corrected the same way except that the contrastive label was omitted. For example; a child is presented with an array consisting of a square piece, a round piece, and a square hole, and he is told "The square piece just fits in this hole. Can you find it and put it in?" He responds by choosing the round piece.

If he is in the "contrastive terms" group, he is told: "No, this one(teacher points to it) is <u>round</u>. This(teacher points to it) is the <u>square</u> one. Can you put it in?" If the child is not in the "contrastive terms" group, he is simply told "No, this(teacher points to it) is the square one. Can you put it in?"

Thus, four instructional groups are generated. They can be described as follows:

<u>Group 1</u>: the word "square" is presented in a variety of verbal contexts, and errors are corrected by using a term contrastive to "square."

<u>Group 2</u>: the word "square" is presented in a variety of verbal contexts, and errors are corrected without introducing any contrastive terms.

<u>Group 3</u>: the word "square" is presented in a single verbal context and errors are corrected by using a term contrastive to "square."

<u>Group 4</u>: the word "square" is presented in a single verbal context and errors are corrected without introducing any contrastive terms.

<u>Procedure and Instructional Sequence</u>

<u>Testing the concept "square"</u>.

All the children except one(who was added to the study later because two children stopped coming to school) were given the "square" pretest individually by one of the regular teachers in the school whom the children all knew. The one exception was tested by the author. The same form was administered as a posttest by the author. The procedure was the same both times. Eight of the twelve children who were taught the meaning of "square" were retested the day after their training was completed. The maximum interval from teaching to posttest was eight days. The control group was retested at the same time.

When a child arrived, he sat down at a little table with the teacher-experimenter and was told "We are going to play a little game. When we're all finished I will give you this cup of raisins." A little cup of raisins was then put on the table within the child's sight but out of his reach. Raisins were necessary for the posttest in order to avoid a letdown after the teaching phase in which a raisin was contingent upon correct responses. The reason for using material reinforcers as well as verbal feedback has already been discussed. But if raisins were to be given on the posttest, it seemed better also to provide them on the pretest so that improvement from pre- to posttest could not be attributed to the differential strength of the two reward conditions.

Following this introduction, the child was given a warmup task in which he was given practice in taking the test without having to discriminate shapes. A 1/4" thick black wooden oval frame like this

was set out on the table along with a 1 7/8" square piece of the same thickness taken from the Playskool Form Board and painted red. The child was asked "Can you put this piece in here?" (the frame) and he was praised when he did so. The test proper then began. It comprised seventeen items arranged in a random order. In each one the task was to pick out the square element from an array and place it in the frame which was large enough so that all items fit equally well. The seventeen arrays varied along several different dimensions, as can be seen from Figure 1 in which the test is pictured. One dimension was the form of the object from which the shapes had to be abstracted. The form was either a flat shape, like the square piece just described, or a hole of the same size and shape set in a black frame, as in Item 1, or a cup, as in Item 2. Similar objects were used for the contrasting shapes, like "round" and "triangular." A third variable of the displays was color. In some arrays, the various shapes were all the same color. In others, they were different. A fourth variable was the particular shapes with which square was contrasted. Altogether, nine other shapes were used, ranging from round to cloverleaf. How these were distributed throughout the test should be clear from Figure 1. Finally, some of the displays (numbers 4, 11, 12, 13, 16 and 17) later appeared in the teaching materials, while all the rest (numbers 1-3, 5-10, 14-15) were to be found only on the test.

As for the materials, all the two-dimensional red shapes and black holes were adapted from the Playskool Form Board. The two-dimensional blue shapes were Creative Playthings Pattern Learning Forms. Europlastic Building Beakers and Building Cubes (distributed by Creative Playthings) supplied the round and square cups. The hexagonal cups came from the Child Guidance Learning Tower.

The instructions went like this:

> The square piece (or "hole" or "cup") goes in here (pointing to the large oval hole). Can you find it here (indicating the physical scope of the array gesturally) and put it in?

The exact words could be varied but the key elements -- "square" used as an adjective, and a gestural indication of the extent of the array and where the piece was to be put -- were kept constant throughout. General encouragement could be given but specific information about whether a response was right or wrong was not allowed. A child was allowed to change his mind and was given a chance to start over if he picked out more than one stimulus. The orientation of the figures was exactly as it is presented in Figure 1.

Teaching the concept "square". The teaching occurred about five weeks after the testing. (The only exception after the testing was the one child added to the study late who was trained two days after being tested). Nine of the children mastered the instructional materials in one session, two required two sessions, and one child took three sessions to master the sequence. None failed.

When the child and teacher-experimenter (the author) arrived at the same table and chairs used for the testing, the teacher introduced the instructional session like this: "We are going to play a game. Every time you are right I will put a raisin in your cup. When you make a mistake, I will take a raisin away and put it in my cup. O.K.?" A successful attempt was made not to let the child have any raisins to eat until the very end. On the last trial the child was told, "If you get this one, you can have all the raisins."

The sequence of materials, which was the same for all four experimental groups, comprised five sections, each of which had to be mastered before proceeding to the next, theoretically more difficult, one. The total sequence is pictured in Figure 2. Each section was made up of a set of related stimulus arrays from which the square item had to be selected. The procedural elements which varied from group to group will be described later.

In Section A, the "two-dimensional" red square piece used in the pretest was contrasted with one other flat red shape at a time == first kidney, then round, and finally triangular. This order was based on the suggestion from the earlier "round" study that the easiest contrast is between regular and irregular figures (square-kidney), the next easiest is between straight and curved (square-round), and the most difficult is between two straight line figures with different numbers of sides (square-triangular). Each pair of figures was presented twice with position counterbalanced. The child went through all six items in the order shown in Figure 2. Then the teacher went back to each pair in which an error had occurred. A given pair was repeated until the child got both numbers right in the original order.

The second section consisted of three arrays in which the same "two-dimensional" shapes were presented three at a time. Thus the necessary component skills had, in principle, already been mastered in Section A. Each shape appeared in two out of the three arrays, and the position of the square piece was systematically varied. The resulting sequence appears as section B in Figure 2. It was repeated until the child could do all three items correctly in their original order.

The third section was analogous to the first, but here the shapes were in the form of holes cut out of black wooden rectangles. The results of teaching "round" had suggested that these "negative" shapes were more difficult than the "positive" ones of sections A and B. The stimulus arrays are presented as section C in Figure 2 and the criterion for mastery was the same as for the first section.

The fourth section was composed of arrays in which color became a misleading attribute, In all four displays, a "two-dimensional" triangle was contrasted with a "two-dimensional" square The two shapes were always green and yellow. The correct choice, the square one, alternated between the two colors. Thus, if color was used as a cue, it would lead to error half the time. The position of color and shape was counterbalanced yielding the sequence pictured as section D of Figure 2. The "round" study had indicated that the misleading introduction of color made a geometric distinction more difficult. Other research (Meyer, 1968; Osler, 1966; Piaget, 1952) had also shown that the introduction of irrelevant dimensions makes a given concept more difficult to attain. If any errors were made, the section was repeated until the child got all four items right in the original order.

In the fifth section, the arrays were three-dimensional and consisted of pairs of cups. One cup was round; the other was square. As in section D, color was introduced as a misleading variable and the position of color and shape was counterbalanced. The resulting sequence is pictured as section E of Figure 2. The "round" results had indicated that the demand of abstracting the two-dimensional shape from a three-dimensional context would make this section the most difficult of all.

For the groups being presented the instructional task in a single verbal context, each display in sections A, B and D would be introduced as follows:

> The square piece just fits in there (pointing to the square hole). Can you find it and put it in?

The displays of section C, in which it was a matter of finding the square hole, were introduced in parallel fashion:

> This piece (pointing to the square) just fits in the square hole. Can you find it and put it in?

Similarly, the displays of Section E which involved cups were presented as follows:

> The square cup just fits in this one (pointing to another cup set off to the side). Can you find it and put it in?

For the groups who were exposed to a variety of verbal contexts, about one-third of the displays were presented in the above way. On another third of the items the children were asked to "Put the square piece (hole, cup) in this can." The contexts were randomly assigned to the twenty-three items in the instructional sequence with the restriction that each context had to appear in each of the five sections at least once and that they were each to appear in the total sequence the same number of times, so far as possible. The actual arrangement of the three contexts is indicated in Figure 2 by the letters a, b, and c in front of each item.

When the children erred and chose a nonsquare stimulus, half of each group were verbally corrected in a way that included the use of a contrastive geometrical term to label the stimulus that had been wrongly chosen. For example, if a child picked out a triangle, the teacher-experimenter would point to the chosen stimulus and say, "No, this one is triangular. This (pointing) is the square one. Can you put it in? The other half of each group would be corrected without being introduced to a contrastive term! "No, <u>this</u> (pointing) is the square one. Can you put it in?"

As has already been mentioned, there were some features of the feedback situation that were constant across groups:

(1) getting a raisin for each correct response;

(2) losing a raisin for each incorrect response;

(3) verbal acknowledgment of each correct response;

(4) self-correction.

Statistical Analysis

The main analytic tool was an analysis of variance and of covariance (Steel and Torrie, 1960) in which the dependent variable was the change in test scores from pretest to posttest. Initial level of knowledge of the concept square, as displayed on the pretest, served as the covariable. It was thought that the use of initial score as a covariable would increase accuracy in determining the effectiveness of the various instructional methods by taking into account the "law of initial values": the more initial errors, the more "room" for improvement. This turned out to be the case. There was a correlation of .27 between number of initial errors and amount of improvement. A comparison suggested by Steel and Torrie (1960) of the treatment variance before and after adjustment for initial level indicated that the introduction of the covariable into the analysis yielded a 9% gain in precision.

The basic analysis dealt with five treatment groups, each composed of three age levels.

Results

Age was not a significant factor in determining either initial score or improvement. Thus, the objective of comparing various instructional techniques in terms of their effect for a single age group could be pursued, and age was not taken into account in the remaining analyses. It must be remembered that the children spanned only the range from two years three months to three years ten months; and, in fact, the expected trend for older children to start out with higher scores did appear.

The basic fact about the instructional procedures was that they were successful. The average pretest score for the entire group of eighteen children was about 50% correct or 8.2 out of a total of 17 items. The control group showed, on the average, no change on the posttest in their knowledge of the concept square. In contrast, the four instructional groups eliminated an average of 5.3 errors. These groups had started a little lower that the control group with an average of 9.5 errors per child. In other words, training eliminated 56% of all errors. The analysis of covariance, summarized in Table 1, indicated that the various tratement groups, including the control group, did reliably differ from each other in amount of change from pre- to posttest, controlling for initial score. This overall effect attained the .005 level of statistical significance. Even without statistical control of initial level, however, the groups demonstrated reliably different amounts of improvement. The analysis of variance of the change scores yielded an overall difference that was statistically significant at the .01 level ($F = 5.68$; $df = 4,13$).

Pre- and posttest scores in terms of percentage correct are presented in Table 2. The largest improvement was registered by the group who were exposed both to the term "square" in a variety of verbal and action contexts and to contrastive terms when they made errors. This group had eliminated 96.4% of its errors upon retesting. Dunnett's test for making a series of comparisons with the mean of a single control group showed that this group was reliably different from the control group at the .01 level of statistical significance. As in the remaining results to be reported, this comparison relates to change scores corrected for initial level of competence.

The two groups who were not exposed to contrastive terms showed almost identical improvement. Of these two, the one which had been exposed to a variety of verbal and action contexts eliminated 63.6% of its errors; the one that had recieved the term "square" in a single context eliminated 57.7% of its errors. Both these changes were reliably different (at the .05 level of significance) from the total absence of change registered by the control group.

The fourth instructional group, the one exposed to the term "square" in a single contest and to contrastive terms in the correction procedure eliminated only 21.1% of its errors. This improvement was not large enough to differ from zero in a statistically significant fashion.

Let us now compare the four instructional groups with each other, rather than with the control group, in order to see precisely how the two instructional variables were operating.

Variety of context exerted a strong positive influence on learning the concept. A one-tailed *t*-test indicated that the effect of this factor was statistically significant at the .025 level ($t = 2.4$; *df* = 7). On the average, scores (corrected for initial level) improved 7.25 points more for children exposed to square in a variety of contexts than for those exposed to the concept in a single context.

The use of contrastive terms did not, in itself, affect learning the concept. There was, however, a sizeable interaction between the two factors such that the use of contrastive terms in the correction procedure did facilitate learning when it was used in combination with a variety of contexts. A two-tailed *t*-test indicated that this interaction effect achieved statistical significance at the .05 level ($t = 2.4$; *df* = 7). One may conclude that contrastive terms are of use under some conditions but not others. A look beyond the number of errors to the nature of errors provides some interesting insights into the cognitive processes involved in utilizing a contrastive term to learn a given verbal concept.

Let us first look at the errors on the pretest. The ultimate goal of this analysis will be to show how the preexisting semantic system of conceptually related terms determines the effect of contrastive terms in learning a concept.

The analysis of errors on the round test in the earlier study supported the idea that identifying an example of the concept became more difficult when the number of items in the array got larger and when it was necessary to abstract the two-dimensional shape from a three-dimensional object. An analysis of errors on the square pretest indicated that these factors were much less powerful. Instead, a tendency to confuse round and square emerged as the greatest source of error. In order to understand the underlying reasons for error, it is necessary to look at the relative difficulty of various sorts of array after differential chance rates of success have been statistically controlled. The larger the array, the lower the chance rate of success. The difference between the observed and the chance rates of success for a given item can be used as a measure of relative difficulty. It is clear from Table 3 that the inclusion of a round stimulus makes an array more difficult. This difference is statistically significant at the .01 level according to a Fisher test (two-tailed). In fact if we shift vantage points from item difficulty to the nature of errors, 50% of the total of 160 errors consisted of picking out the round stimulus instead of the square one.

What is the significance of this tendency to confuse round and square? Is it simply attributable to the fact that certain children (randomly distributed among groups) were exposed to the concept round in the earlier study? This is not the case, for both the "experienced" and the "inexperienced" group average between four and five of these errors per child on the pretest. The earlier experience with round does not affect total errors either: the experienced group averages 9.2 pretest errors out of 17 items, while the inexperienced group averages 8.5. Thus it appears that, somehow, round is the more basic, perhaps the unmarked concept in this particular situation.

The application of the unmarked-marked distinction originated by Jakobson (1969) would lead to the following hypothesis: the unmarked geometrical shape -- round -- will be the first to be recognized as such by the child and he may take for granted that all geometric terms refer to this category. This initial hypothesis must then be corrected through appropriate feedback.

This argument is based on the notion of a predetermined or natural order of concept acquisition. The only other possibility is that the round-square confusion reflects the influence of earlier geometrical teaching. Since twelve of the eighteen children in this study had been in a previous systematic study of geometrical discrimination conducted by Henning and Hayweiser (1968), we have some evidence that bears upon this point. In that study the children were to learn a circle-triangle discrimination. First they had to learn to choose the arm of a t-maze containing a large triangular stimulus. Then the rewarded stimulus was reversed and the children had to learn to choose the "round arm" of the maze. Since all the children had more experience with the triangle as the positive stimulus than with the circle and since only three out of the twelve ever mastered the concept round in the reversal situation, this nonverbal experience should, if anything, have worked in the direction of diminishing the tendency to choose a round stimulus. Therefore, their results tend to discredit specific experiences as the critical factor in generating the tendency to round-square confusions. Henning and Hayweiser (Henning, personal communication 1969) found, moreover, that there was a definite tendency to start out in their learning procedure by choosing the arm of the maze containing the round stimulus even though it appeared on the opposite side from the child's previously determined preferred position. Thus, the shape round seemed perceptually dominant for a substantial group of these very same children even a year or more before the present study was begun!

What is interesting is the way in which previous experience with the term "round" determines the effect of using contrastive terms in the correction procedure. It turns out that contrastive terms do effectively reduce confusion between "round" and "square" _if_ the child has been systematically exposed to the semantics of"round" in the study reported above. Without previous exposure to the term "round" the introduction of contrastive terms has a negative effect. This relationship is illustrated in Table 4, From the table, it seems as though failure to mention the term "round" is as effective for the "inexperienced" child as is the "round"-"square" contrast for the "experienced" child. This makes sense in terms of the hypothesis that round is the unmarked class. If this class is unlabeled, then a single label ("square") suffices to mark a new subdivision. In such a case, introduction of a second term simply means that two things must be learned at once, an additional cognitive burden. If, however, the unmarked class is already labeled ("round"), then this label tends to assimilate new labels to it semantically. In this case, explicit contrast between the names used to denote the two categories is needed to subdivide the generalized concept of round into round and square.

The effect of contrastive terms in the correction procedure is specific to the round-square confusion. Correction involving verbal contrast does not reduce other types of error, even for the "experienced" children. This result is certainly logical, for even the experienced children had not been systematically exposed to contrastive terms other than "round". In practice, moreover, the introduction of contrastive terms meant primarily contrasting "square" with "round", for 56% of errors during the teaching phase consisted of mistaking round for square.

From these data, emerges the idea of appropriate and inappropriate introduction of contrastive terms. Contrastive terms really means the single term "round" here. "Appropriate" applies both to the case where the term "round" is <u>not</u> introduced because of lack of requisite semantic experience <u>and</u> to the case where the term <u>is</u> introduced because the relevant experience has been acquired. Having redefined the contrastive term variable, we can now see whether it is in fact a significant factor in learning the concept square. The next step was to do new analyses where children were placed in groups according to whether or not they were exposed to multiple contexts and appropriately introduced to contrastive terms in the correction procedure. Since appropriateness of the correction procedure seemed to affect round-square confusions exclusively, reduction of this type of error was separated out from reduction of all other types of confusion. The two instructional variables -- variety of context and appropriateness of introducing contrastive terms into the correction procedure -- were assessed separately for their effect in reducing "round"-"square" confusions and in reducing all other types of error.

Let us first look at the effect of variety of contexts and appropriateness of the correction procedure on the round-square confusion. The relevant data are presented in Table 5. The two groups where presence or absence of correction by verbal contrast was appropriately fitted to previous experience show greater error-reduction than the two groups who were corrected inappropriately in this respect. Summing data for the two groups who were appropriately corrected, we find that 23 pretest errors were corrected on the posttest, five errors remained, and three new ones appeared on the posttest. By contrast, in the two inappropriately corrected groups, 13 pretest errors were corrected, 10 errors remained, and three new ones appeared on the posttest. Table 5 shows that multiple contexts have a somewhat smaller effect upon round-square confusions. The fact that multiple contexts reduce round-square errors less than the appropriate use of labels in the correction procedure lends further support to the idea that the development of the meaning of "square" can be understood in part as the superposition of lexical marking upon the unmarked concept "round."

Shifting now to all other types of error, we see from Table 6 that multiple contexts have a large effect on reducing those errors which consist of confusing square with shapes other than round. The appropriateness of the correction procedure does not affect these errors, however. Multiple contexts must, therefore, be functioning to help the child who is experienced with the label "round" to distinguish square from other shapes <u>not yet labeled</u>.

As for the "inexperienced" child who has presumably not yet labeled even round, multiple contexts may begin whiere simple labeling leaves off. They may help the child to make finer distinctions between shapes that are perceptually less distinctive.

Apart from the effects of various teaching procedures, it is of interest to take a closer look at what was happening while the children were being taught in order to obtain some direct information on the nature of the learning process itself. Are certain of the instructional variables under discussion conducive to fast learning and is fast learning really efficient in terms of growth in knowledge of the concept being taught? In fact, there is tremendous individual variability even within instructional condidtions. Table 7, which presents the number of errors before mastery for each child, shows how individual variability in speed of learning tends to be as large within a given instructional condition as from group to group. Similarly, looking at amount of improvement and rate of learning in terms of the possible influence of social class, we note first of all that the teaching mathod succeeded with a predominantly lower-class group. Although there were only two middle-class children in the instructional groups, it is interesting that, on the average, they improved virtually the same amount (7.50 points) as did the comparably taught lower class children (6.75 points). The two middle-class children did, however, master the instructional sequence somewhat faster on the average (2.50 errors to criterion) than the lower-class children (7.50 errors to criterion). These are desirable results from a pedagogical point of view, for they indicate that instruction has truly adapted itself to individual variation in learning rates whatever its origin, as well as to variation in initial level of mastery.

Discussion

The overall success of the instructional methods are relevant to a discussion of the question of what modes of representation are most effective in teaching two- and three-year-oldschildren. In all cases, the children being taught the meaning of "square" were presented during the teaching phase with a representation in three modes simultaneously -- the enactive, the ikonic, and the symbolic. The enactive mode entered when the child picked up the square object and did something with it. For some children, the particular act varied from array to array. The stimulus arrays themselves furnished an ikonic representation both of the class of square things and of contrasting classes of geometric shapes. More important was the fact that the solution to the problem was represented in all three modes. The word "square" inserted into a command provided a symbolic representation of the solution. There were moreover, perceptual cues and kinesthetic feedback on at least one-third of the training items in the form of something with which the square thing would fit. This additional square stimulus thus provided an ikonic and enactive representation of the solution to the problem of discovering the referent of the term "square."

The simultaneous representation of the problem in three modes during teaching resulted in an ability to deal with the concept later on in the posttest when primarily different exemplars were presented in a new action context with no ikonic or enactive cues to the solution. During testing the only representation of the solution was the symbolic term "square." These results suggest that the ideal sequence of representational modes for learning symbolic concepts can be imagined as a gradual peeling away of enactive and ikonic support from an originally trimodal representational structure.

The contrast between this experiment where the child is faced with a trimodal representation contrasts with the first study of teaching "fat" and "skinny." There, although the child has visual and kinesthetic contact with exemplars, the solution, i.e., the concept, is really not represented in any mode at all. The "fat" and "skinny" posttests, in which the solution was represented by a label, demonstrated the effectiveness of a verbal representation. The absence of any representation of the solution is what is usually meant by the term "discovery" learning. In the literature, it is opposed to directed teaching or to "guided" discovery." Evidence seems to be accumulating that pure discovery is the least successful method for teaching specific concepts and that it does not improve the transferability of a concept either (Kersh and Wittrock, 1967). Discovery methods seem to be useful when the aim is to teach techniques of discovery, per se. If, however, the task is so difficult that the learner does not succeed in discovering the concept, then the discovery technique will not be reinforced either (Kersh and Wittrock, 1967). The impossibility of discovering the concepts "fat" and "skinny" in the first experiment suggests the idea that other analytic concepts and, indeed, most concepts upon which school focuses may be too difficult at young ages to be "discovered" successfully. If so, then the practice of requiring discovery, as in the methods used to teach "fat" and "skinny," not only fails to teach the concept but may also discourage the development of the discovery process itself.

The methods used to teach "fat" and "slinny" contrasted with those used to teach the concept square in a second respect: two or three examples of the concept had to be mastered simultaneously. The results there indicated that the extra example actually hindered learning. In the methods used to teach the meaning of "square," a given example (presented in positional permutations) was always mastered before the child was exposed to new examples. (Where it was a question of learning that color was irrelevant, a single example actually consisted of two displays.) A third difference from the earlier study was the absence of prolonged repetition of stimulus displays. This time it was possible to face each stimulus display only once, whereas in the earlier study the minimum number of repetitions in the learning sequences was four under two of the conditions. Repetition had had such a negative effect on the children in the first study that it was almost impossible to complete this experiment. This was one of the motives for making variety an explicit variable in the final study.

One feature that the two studies had in common was the use of both material and verbal corrective feedback for right and wrong responses, and self-correction for wrong responses. The results of the two experiments clearly show that such theoretically optimal feedback is not a sufficient condition for learning a given concept, although it may be effective when the proper representational conditions are met.

While it is interesting to compare the methods used in the two studies, the difference in the success of their teaching techniques could be due to any or all of these three reasons and to some others besides. Nevertheless, it seems useful both for future research and for practical application to make these differences explicit.

Similarly, a comparison of the techniques used to teach round with those used to teach square suggests some interesting possibilities. The variable in the round study dealt with the forms of action representation and the timing of verbal representation. Neither seemed to matter very much. In the square study the variables all involved the forms of verbal representation, and the differences were much larger. Also, the untaught control group showed some improvement in the round study whereas they did not in the square one. Perhaps it was natural to attach a label to the most perceptually dominant category of stimuli, the round ones, whereas it demanded more specific experience to label the less dominant square category. This result, therefore, is another piece of evidence in favor of the hypothesis that round is the unmarked or more basic geometric concept on which the square category is superposed.

The experiment on teaching "square" actually varied the form of the verbal context in which the term "square" was placed while holding all other factors constant. Psychologists have tended to devote a great deal of energy to the question of whether verbal representation enters into concept formation at all and have generally neglected the problems of what form this representation should take. It is, therefore, interesting that variables relating to form of verbal representation should turn out to be such powerful ones. This point is especially interesting since the children were so young. Clearly, the original idea that pure action might be most suited to this developmental level was exploded by the results of several studies. The experiment on teaching square seems to indicate that what is said about a given concept label is as important to the development of the child's definition as whether the concept is labeled at all. The main effect of a variety of verbal contexts on the stimulus side seems to be in making exemplars of a given concept distinguishable from contrasting stimuli which have not yet been organized into definite categories. Once a contrasting category along a given dimension has been organized the effect of multiple contexts is much smaller. Such a category tends to be over-generalized to other stimuli in that dimension and the form of correcting this overgeneralization becomes crucial. Labeling the category to be learned is an ideal way to mark it if the child has not yet labeled the overgeneralized contrast class. If he has, however, then effective teaching seems to require explicit contrast between the two labels in the correction procedure.

The deleterious effects of using a contrastive label to correct children who do not already understand that label fairly well seems analogous to the deleterious effects of adding an extra exemplar in the "fat"-"skinny" study: there is too much to learn at once and partial learning results in interference.

Note that multiple verbal contexts on the part of the experimenter involved multiple action contexts on the part of the childre This latter may be crucial to the effectiveness of a variety of contexts, although speech and action factors cannot be disentangled in this experiment. We may have found a more precise way of understanding the frequent observation that children do not learn what is irrelevant and that they sometimes do not display their "true" abilities for want of motivation. If one thinks of the action context as providing a goal, then the meaning of a particular word included in the directions becomes a means to this goal. One could say, at a molecular level, that the concept has "relevance" in a broader task structure and that the child now has a "reason" to learn its meaning. Recent studies of nonverbal skill development suggest that, indeed, the goal precedes the means ontogenetically: and that when a successful means first comes into being it is indissoluble from the goal which motivated its existence. Only gradually does it beomce a separate entity (Bruner, 1968). If this is true for concept learning as well, then the implication is that the breader the variety of ends for which a given concept can be used, then the more likely it is to achieve an independent life of its own. Surely in everyday life these concepts most important to action are the ones placed in the greatest variety of contexts and therefore learned the most thoroughly. If this is true, then [redacted] motivation to learn and the hierarchical structuring of a task in terms of means-end relationships turn out to be one and the same thing. The role of familiarity then becomes that of providing a higher order structure into which the unfamiliar can be fitted as a necessary component.

There are several types of variety in this study, and variety probably has several different effects. First of all, there is the variety or non-repetitiveness of the stimulus displays, a quality which contrasts with the approach of the first study. Certainly this difference must be partly responsible for the much more enthusiastic response of the children to the procedures used to teach the concept square. At the same time, we see that sheer variety can have adverse effects on learning if it is associated with increasing the number of things to be measured simultaneously. One way to deal with this potential conflict is to ensure mastery of each new element as it arises. This was one strategy in the square study. Another way is to provide a variety of familiar elements. The verbal and action contexts in which square was embedded did exactly this.

All these types of variety -- stimulus arrays, words, and actions -- could be operating to improve learning through enhancing attentional processes. Certainly there is a great deal of evidence that variety has this effect (Fiske and Maddi, 1961). This effect ought to be operative in all kinds of variety, but it cannot explain why a variety of verbal and action contexts has a positive effect on learning that is much larger than that produced by a variety of referents.

The variety of verbal and action contexts certainly promotes the relevance of the concept, as has been discussed before. Multiple verbal contexts may also be particularly useful in illustrating the semantics of terms which have no stable relation to extralinguistic contexts, that is, to concrete referents. Some vocabulary test data indicate that it is just such words which pose the greatest problems for lower-class children (John and Goldstein, 1964). This finding is consistent with this line of reasoning, for it is fairly well established that lower-class people tend to rely relatively more on extralinguistic context and relatively less on linguistic context in their use of language for communication (Greenfield, 1967).

The results of a study by Werner and Kaplan (1950) provide yet another reason why multiple contexts might be more effective than a single context in teaching a concept. They found that younger children do not differentiate a word from its verbal context and may regard a given word as carrying the meaning of the whole of a part of the context. If this is so, then variable contexts may help in establishing the invariant properties of word and referent.

In terms of preschool education, and in particular, the results of this series of studies seem to indicate that what is said about concrete experience is more important in the semantic development ofanalytic terms than the nature of the experience itself. This conclusion seem to support Bereiter and Engelmann's (1966) approach to the education of severely deprived preschool children, for they use a wide variety of statement forms or logical relations in connection with a small variety of concrete referents. On the other hand, if the action context constitutes a goal which given relevance to the words embedded in a related sentence, then use of a given concept in a wide variety of meaningful situations could be a critical factor.

In general, these experiments support the linguistic approach to semantics rather than the psychological: the relation of words to other words appears more crucial in semantic development than the relation of words to things. They also call for a rethinking of preschool instructional approaches. These have emphasized direct experience with materials and have left unspecified the communicative context in which all such experience must take place. The study of ways to teach the meaning of the term "square" to two- and three-year-olds that has been reported here suggests that systematic examination of this question may bear fruitful results.

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Table 1

Analysis of Variance and Covariance for Change in Knowledge of "Square" from Test to Retest under One Control and Four Instructional Conditions

Source	df	Σy^2	F	Σxy	Σx^2	df	Σy^2 Adjusted	F
Conditions	4	177.1	5.7*	17.1	59.8			
Error	13	101.3		70.0	252.0	12	81.9	
Total	17	278.4		87.1	311.8	16	254.1	
Conditions Adjusted						4	172.2	8.4**

* $p < .01$

** $p < .005$

Table 2

Percentage Items Correct on "Square" Test
Before and After Instruction

Group	Number of Children	% Correct before Instruction	% Correct after Instruction
Multiple contexts: Contrastive Terms	3	45.1	98.0
Multiple contexts: No contrastive terms	3	56.9	84.3
Single context: Contrastive terms	3	25.5	41.2
Single context: No contrastive terms	3	49.0	78.4
Uninstructed control	6	54.9	54.9

Table 3

Rate of Success on Pretest for
Arrays with and without Round Stimuli

	Arrays with round stimuli	Arrays without round stimuli
High success rate (from 28% to 11% above chance)	1	7
Low success rate (from 16% below chance to 8% above chance)	8	1*

*$p < .01$

Table 4

Improvement in Making Round-Square Distinction from Pretest to Posttest: Effect of Introducing the Contrastive Term "Round" with and without Previous Semantic Experience

	Round introduced as contrastive term	No contrastive term introduced
		Previous experience with round -
Individual improvement	+2 +3 +4	-1 +1 +4
Group Mean	3	1.3
		No previous experience with round -
Individual improvement	+1 +2 +3	+3 +4 +5
Group Mean	2	4

Table 5

Change in Round-Square Confusions from
Pretest to Posttest under Four Instructional Conditions

	Single context — appropriate correction procedure	Multiple contexts — appropriate correction procedure	Single context — inappropriate correction procedure	Multiple contexts—inappropriate correction procedure
Number of round-square confusions corrected on posttest	13	10	7	6
Number of round-square confusions not corrected on posttest	5	0	7	3
Number of new round-square confusions on posttest	1	1	2	1

Table 6

Change in All Errors Other than Round-Square Confusions from Pretest to Posttest under Four Instructional Conditions

	Single context-appropriate correction procedure	Multiple contexts-appropriate correction procedure	Single context-inappropriate correction procedure	Multiple contexts-inappropriate correction procedure
Number of errors corrected on posttest	6	15	11	14
Number of errors not corrected on posttest	7	0	8	2
Number of new errors on posttest	7	1	4	1

Table 7

Total Number of Errors Made by Each Child
Before Mastery of Instructional Sequence

	Multiple contexts-inappropriate correction procedures	Multiple contexts-appropriate correction procedure	Single contexts-inappropriate correction procedure	Single context-appropriate correction procedure
Individual Error Totals	0	0	3	0
	4	3	5	3
	27	12	11	7
Group Means	10.3	5.0	6.3	3.3

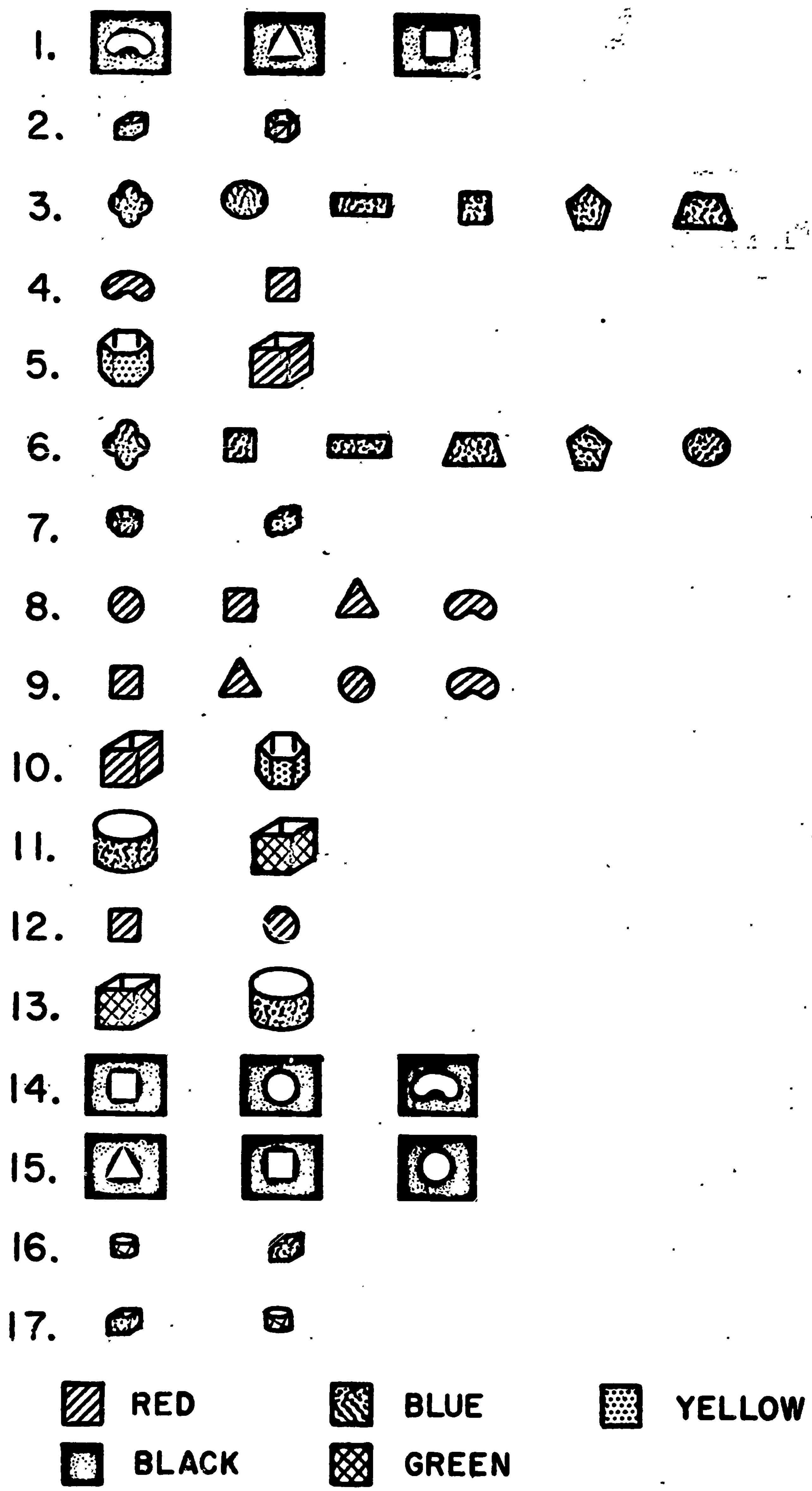

Fig. 1. Displays for testing understanding of term "square"

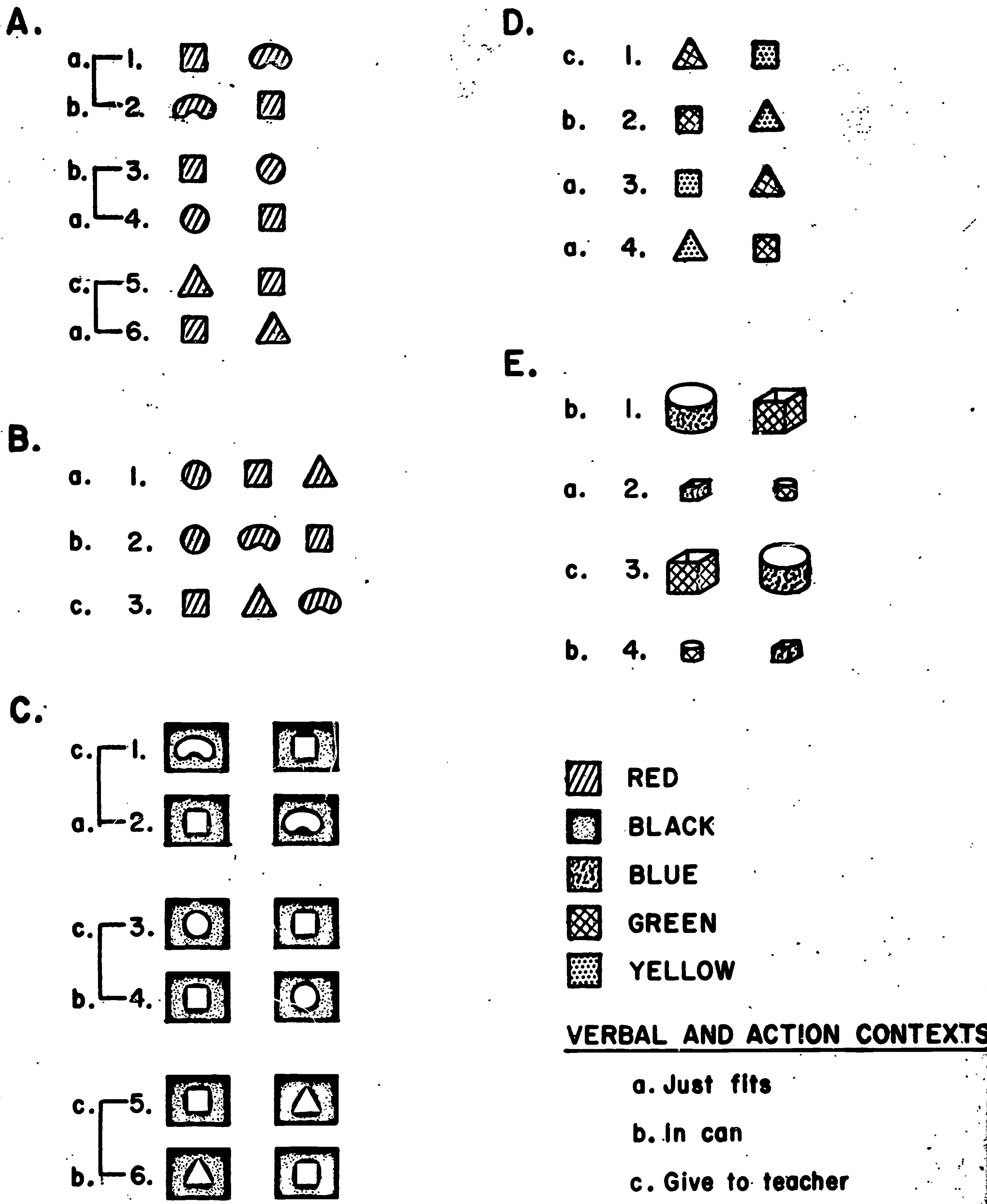

Fig. 2. Sequence of displays used to teach meaning of term "square"