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Classroom Applications of Stimulus Equivalence Technology

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We review basic concepts and methods of stimulus equivalence research and suggest applications in teaching rudimentary language arts skills in the classroom. We describe methods of establishing equivalence-based networks of matching-to-sample, writing, and naming performances. The methods may be used as a supplement to classroom instruction to assess whether standard curriculum-based approaches establish such integrated networks. Methods derived from equivalence research may be useful for remediation when traditional teaching approaches fail. Recent research suggests that direct focus on spelling performances may be required if entire networks of language arts skills are to be acquired. In addition, the equivalence relations themselves may require concentrated teaching in some children.

KEY WORDS: stimulus equivalence;, language arts instruction;, reading; spelling; matching to sample; computer-assisted instruction.

We describe a systematic approach for assessing, analyzing, and remediating some types of problems in learning that teachers of language arts often encounter. We address problems children may have in recognizing, naming, writing, and spelling words. Many problems that arise may be reducible to difficulties children may have at the single-word level. It seems

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patently evident that "word recognition is the foundation of the reading process" (Gough, 1984, p. 225).

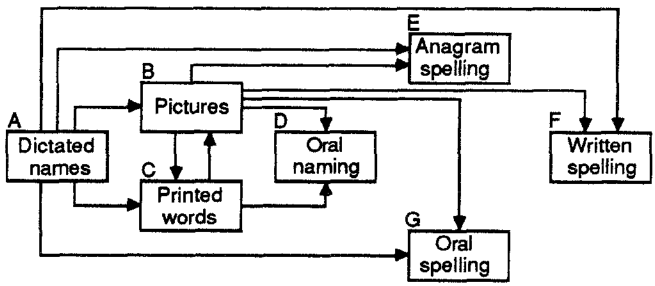
The approach is an integrated set of methods that derives from research on what is called "stimulus equivalence." When the stimuli include words, equivalence can be loosely defined as learning what the words "mean." Other forms of behavior, like writing and spelling the words, can also be involved. The relevance of that research to early instruction in reading has been an appealing prospect for some time. It is especially so now, based on recent advances in our knowledge in this area. Hence, we welcome this opportunity to communicate the relevance in a forum devoted explicitly to education. We write particularly for teachers in regular and special education classrooms at early primary levels and for the teachers of those who aspire to that demanding profession.

To aid communication, we define all needed technical terms. Also, we recast or restrict the definition of some terms commonly found in Teachers Editions of reading curricula, terms like "match," "read," and "spell," for example, since their meaning may be ambiguous. The term spelling alone can mean the oral production of the letter names in the correct sequence or writing the word, as in a class-wide spelling test. Terms like "identify" we omit. Although that term often means naming a word, picture, object, etc., it may also refer to many other forms of behavior. For example, a child may be asked to identify a word or picture by circling or drawing a line to it because it "goes with" another stimulus, by underlining it when it contains a particular consonant blend, or by writing the number one beside it because it happens first in a story, and so on. The term may even apply to writing a word. Thus identify appears to be a catchall term for "knowing" something, but what is known is specified only by the characteristics of the particular task. The point here is to stress the importance of accurately descriptive terms when talking about the extraordinarily complex behavioral phenomena involved in language arts instruction. Doing so helps to break down the complex behavior into manageable units.

THE STIMULUS EQUIVALENCE NETWORK

The following illustrates the tasks with single words whose referents can be represented visually, as in picturable nouns, action verbs, colors, quantities, and so on. Stimulus equivalence research has thus far focused mainly on these individual elements of language. Figure 1 diagrams a network of stimuli and performances that maps out the stimulus equivalence territory. Teachers already use all of them in some form, but what may be new is their integration into one package. In subsequent sections we discuss

A Network of Matching, Naming, and Writing Performances



Task Descriptors

1. AB: Matching pictures to dictated names
2. AC: Matching printed words to dictated names
3. AE: Constructing words to dictated names
4. AF: Writing words to dictated names
5. AG: Naming letters to dictated names
6. BC: Matching printed words to pictures
7. BD: Naming pictures
8. BE: Constructing words to pictures
9. BF: Writing words to pictures
10. BG: Naming letters to pictures
11. CB: Matching pictures to printed words
12. CD: Naming printed words

Fig. 1. The stimulus equivalence network: Arrows represent 12 performances and connect sample stimuli to comparison stimuli and to oral or written responses. The stimuli are sets of dictated names (A) and their corresponding pictures (B) and printed words (C). Oral responses involve naming whole words (D) or naming the letters that spell those words (G). Written responses involve construction of words with moveable letters (E) or handwriting (F).

complexities in this network that may not be immediately apparent. Here we describe classroom applications of the tasks and define some technical vocabulary used later.

Matching-to-Sample Tasks

At the left, the boxes A, B, and C represent stimuli: dictated names (A), pictures (B), and printed words (C). The stimuli can be related to each other, and the relations are examined in tasks that are termed *matching to sample.* The arrows connecting the boxes point from the stimuli used as samples to those used for choices from which the children make selections. In the classroom, teachers can supply the visual stimuli by distributing picture cards and word cards.

Conducting the sample-matching tasks is straightforward. For those involving the dictated word names, the teacher says one of the names (A; the sample) and asks the children to choose and hold up a picture (B) from the array in front of each child. This task evaluates the relations between the sample names and the picture choices. The same thing can be done using a choice array of printed words (C), to examine the name-word relations. These tasks are designated as *auditory-visual sample matching* for obvious reasons. For convenience, we specify the tasks as AB and AC matching.

The other sample-matching tasks examine the relations between the pictures and printed words and are conducted in the same way, by the teacher holding up either a picture card as the sample and asking the children to choose from the printed word array, or vice versa. These BC and CB matching tasks are termed *nonidentity visual-visual sample matching* to distinguish them from *identity matching.* Doing the latter type of task depends only on detecting the identical physical characteristics of the sample and choice stimuli. The child need know nothing else about the stimuli. Doing the former tasks, on the other hand, depends on having learned the relations between the stimuli. Auditory-visual matching is also a nonidentity task. The child has no basis for relating the names with the words (or pictures) until learning has taken place.

Production Tasks

Each of the four boxes at the right specifies productions by the child in response to presentations of the stimuli at the left. The arrows point from stimulus to product. The productions are *oral naming,* saying the names of the pictures and printed words out loud (BD and CD) and three forms of spelling words that the teacher dictates or that correspond to pictures that the teacher displays. Two of the spelling performances are straightforward: *written spelling* (AF and BF) and *oral spelling,* saying the letter names of each word consecutively (AG and BG), in response to the dictated names or pictures. The third type, *anagram spelling* (AE and BE), probably requires clarification. For group administration in the class, we envision the use of single letters perhaps drawn on individual pieces of cardboard with Velcro attached to the back (or perhaps magnetic or felt letters). Each child would have an appropriately selected pool of these letters. When the teacher says a name or displays a picture, the child selects the letters for that word and arranges them on some surface that the letters will adhere to and, when the word is thus constructed, holds up the word and shows the teacher. Later we discuss potential advantages of this task.

General Testing Considerations

Recording the data and giving the children feedback on their responses are probably the most critical aspects of the testing procedures. In order for the approach we propose to be maximally helpful to teachers, it is essential to write down what the children do. That may be difficult in a group format. We describe one way to go about it. The data sheet has a list of the children's names in a column at the left. To the right are blank columns, each headed by one of the six or so words to be tested that day. We use picture:printed word matching to illustrate (where the stimulus before the colon is the sample, and the one after it is the choice to be made). At the top, the teacher records the date and the type of task. When the teacher holds up one of the pictures, s/he makes a mark at the top of that column to indicate a trial with that picture:word relation. When each child holds up the word card he or she has selected, the teacher can make an "x" in the row for each child who selected the incorrect word. We presume that testing will follow instruction and that most children will make correct selections. Hence recording errors will be simplest. After an 18- to 30-trial test (three to five trials with each of the six words), the teacher can tally the errors to track which children need additional instruction. If the test is a pretest, when errors are likely to predominate, the teacher can do the opposite, using a check mark to record correct responses.

With respect to feedback, the teacher can deliver praise, generally, with large groups, and individually if the group is small. How to handle errors is problematic. Perhaps the simplest method would be for the teacher to hold up the correct word and have the children who chose the wrong word correct their errors by making the identity match. It will be important to remember that this type of correction will not necessarily help in teaching the picture:word relations. Presenting the correct word also provides confirmation for children who did choose the right word. Additional motivating consequences could be provided by dividing the group into two or more smaller teams who compete for some rewarding activity. Recording the children's cumulative progress has also been found to be helpful (Graham, 1983; Graham & Voth, 1990). Creative teachers will find many ways to interest the children.

All of the tasks except those involving oral production can be conducted in relatively large groups. Even written spelling can be conducted in a group format also, by having the children write on individual slips of paper which they can hold up, or with washable ink on a plastic or metal surface. An inexpensive children's toy permits writing on a clear plastic sheet with a stylus that marks the surface below. Lifting the sheet erases the word. Naturally, written spelling tests can be done in the usual way to yield a permanent product. With respect to oral naming and spelling, group testing is virtually ruled out, since after the first child has responded the others can merely imitate the response. Selective testing is feasible. Of course, copying is not precluded in the other tasks as well, and teachers will have to be alert for it.

Discussion

We must qualify what we propose in two ways. First, the methods should supplement the reading curriculum the teachers are using and not supplant it. Second, we make no claim beforehand that the methods are sure to be helpful. That depends on a number of factors. Among them are: how well we do our job in communicating and the extent of teacher interest and effort. Translation of the methods into actual classroom use will depend on creative modification, by the teachers, and by researchers who may want teachers to try the methods. The ultimate test will be empirical evidence of success or lack of it in individual cases. Every attempt by a teacher to see what one or another method can accomplish will itself constitute an important bit of research.

What does the equivalence network offer? One answer is that it can help to focus teacher attention on individual performances — the assessment and remediation of behavior of individual children on each separate task. In our experience, many exercises in reading curricula combine several tasks together, as in a Look–Say–Cover–Spell (orally or silently)–Write sequence (e.g., Heron, Okyere, & Miller, 1991; Lee & Sanderson, 1987). If the picture is also involved, perhaps displayed on a picture-word card during the Look stage, the hoped-for learning of the picture-word relation is also embedded in the sequence. In a group setting, the teacher can monitor the written product, but little else. If the product is faulty, where did the problem originate? With a little planning, the tests we propose can take little time and permit detailed monitoring of the results of teaching. In subsequent sections, we discuss further reasons to use the equivalence network for analyzing what is going on, as we delve into the relationships among the tasks.

STIMULUS EQUIVALENCE RESEARCH METHODS

Understanding the importance of the stimulus equivalence network requires a review of some of the research on the topic. We build the network by stages, to isolate and clarify critical features of the methods. We describe the studies as they are being replicated in our laboratories today, where the experiments are conducted with computer methods. Computer applications of the methods provide unambiguous and precise illustrations of how the methods work. When teachers are informed about such methods, coupled with their understanding of the equivalence network and analytic approach, they will be better prepared to evaluate the adequacy of educational software that is becoming available.

The subjects in most of the illustrative studies were people with varying degrees of mental retardation, mainly young but some older. Some subjects were children diagnosed with learning disabilities. Considerable research has also been done with normally capable children and adults, showing the broad applicability of the methods (e.g., Mackay, 1991; Stromer, 1991).

The First Stimulus Equivalence Experiment

The first experiment on stimulus equivalence used stimuli and tasks much like some of those encountered by children at the readiness and early primary reading levels, making it an apt illustration of research on the topic (Sidman, 1971). The stimuli were 20 dictated names such as "BED," "CAR," and "EYE" (A) and their corresponding pictures (B) and three-letter printed words (C). (Our descriptions will use the term "word" only for printed words, and dictated words will be referred to as "names." The distinction is made only for reasons of convenience and brevity.)

In our laboratory, the principal apparatus is a portable Macintosh computer (Apple) fitted with a touch-sensitive screen (Microtouch). The 19 × 14 cm screen displays stimuli, and the student responds to a stimulus by touching it (see Fig. 2). Responses are automatically recorded, and the data are saved in disk-based files (Dube & McIlvane, 1989).

The computer displays illustrated in Fig. 2 show the principal methods used in the experiment. Each panel shows a different type of standard matching-to-sample task. The two upper panels show auditory-visual matching. The student selects a picture (left panel) or printed word (right panel) in response to a name dictated through a loudspeaker, here "DOG" (Tasks AB and AC in Figs. 1 and 3). The sample name repeats at approximately 2-sec intervals until the student makes a selection. The two lower panels

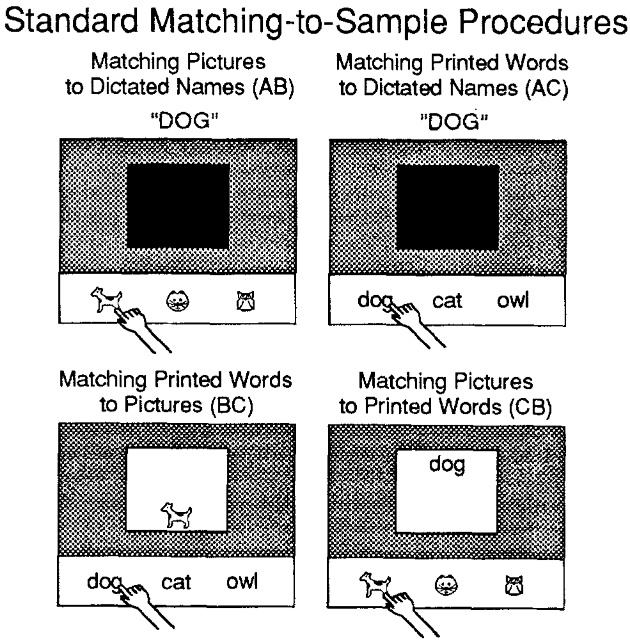
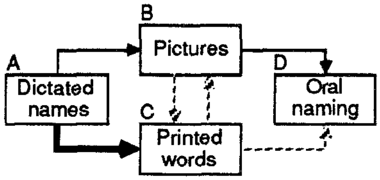


Fig. 2. Illustration of computer displays for four matching-to- sample procedures: matching picture or printed-word comparisons to dictated-name samples (AB and AC), matching printed words to pictures (BC), and matching pictures to printed words (CB).

illustrate visual-visual matching, selecting a printed word to a picture sample (left panel) or a picture to a word sample (right panel; Tasks BC and CB). The displays in the figure show the final step of each task, when the student makes a selection. Each trial begins by presenting the sample alone, and the student must touch the sample picture or word, or the blank (black) area when the sample is a dictated name. Doing so produces the choice stimuli at the bottom of the screen. Touching the correct choice turns off the stimuli and can produce a brief tune, a flashing screen, and delivery of a reinforcer (such as a penny). After a brief period of a blank screen, the next sample is presented. Incorrect selections produce only the blank screen.

Figure 3 shows the portions of the equivalence network addressed in the study. Pretests showed that the student began the study already capable of matching the pictures to the names (AB) and naming the pictures (BD; thin solid arrows). He could do none of the tasks involving the printed



Descriptors of Network Tasks

AB: Matching pictures to dictated names
AC: Matching printed words to dictated names
BC: Matching printed words to pictures
CB: Matching pictures to printed words
BD: Naming pictures
CD: Naming printed words

Fig. 3. Stimulus equivalence network investigated by Sidman (1971).

words. He was then given training in matching the printed words to the names (AC; heavy solid arrow) until he mastered all 20 name-word relations. The critically important results are that without any more training he matched the words to the pictures (BC) and the pictures to the words (CB; dashed arrows). He also named the words (CD; the third dashed arrow).

Tasks with the Pictures and the Names

To clarify what is important about these findings, let us now look at each performance separately. Like many children at early primary levels, the student demonstrated familiarity with the pictures. He could perform the AB task, which verified *auditory comprehension,* understanding what the spoken names refer to. Such behavior is commonly referred to as receptive vocabulary. The BD task showed he could also name the pictures, evidence of some expressive vocabulary. Also like children learning to read, his problem was with printed text.

Tasks with the Printed Words and the Names

The next step shows little by itself, teaching the boy to relate the printed words and spoken names, the AC task. We might call this performance *auditory receptive reading,* discriminating a word when its name is spoken, but is it reading? Looked at separately, it is merely an auditory-visual matching task that the boy could do without comprehending anything about what the printed words mean. If the stimuli were Spanish names and words, most English-speaking adults who knew no Spanish could easily learn what to do (probably based on phonetic decoding, helped by the regularity of Spanish pronunciation; e.g., "toro"). With sufficient exposure to memorize the list, the adults could even name the Spanish words (Task CD). We would not call that performance reading either, just decoding words or word naming. With practice, children could do the same. However, no adult or child could go on to match the printed Spanish words and corresponding pictures; knowledge of the name-picture relations is also critical.

Emergent Equivalence Relations

As we stated earlier, the important finding in Sidman's study is that the boy matched the pictures with the printed words. He did so even though he had never before seen the stimuli together. He did not require any explicit teaching with the tasks in order to do them. These brand new performances emerged full-blown. Doing them demonstrated *reading comprehension,* knowing what each word refers to or means. The boy was not merely behaving in a rote fashion, because the emergent performances showed that each name and its corresponding picture and printed word were all equivalent. "BED," the picture of a bed, and the printed word bed formed a class of equivalent stimuli (and so on, for the other 19 stimuli of each type). (The experimental evidence that permits a conclusion of equivalence class formation is complex and need not concern us. We refer the interested reader to Mackay and Sidman [1984] and Sidman [1986] for discussions of this evidence.)

Economy of Teaching

Recall that the boy began the study able to select each of the 20 pictures when its name was spoken and to name each picture, 40 separate performances. He was taught 20 more, to match each printed word to its name. Then the experimenter/teacher got 60 new behaviors for free: The boy also demonstrated 20 BC relations, 20 CB relations, and the 20 CD naming performances. He did not have to be taught them directly. The economy and efficiency of this approach might have considerable appeal for teachers.

Equivalence and Naming

Stimulus equivalence research informs us that emergent naming of the words will not necessarily occur, even though the student demonstrates the equivalence relations in the sample-matching tests (Sidman, Willson-Morris, & Kirk, 1986). Such negative outcomes may be especially likely with children who have learning difficulties. There are many possible reasons for failure to name, many of which are topics of current research. Among the reasons is the acknowledged greater ease of recognition than of recall, although this is a complex matter in itself. We mention these possibilities here to underline the need to examine each of the performances diagrammed in Fig. 3. If the boy's naming had been incomplete or inaccurate, a potentially helpful step might have been to intersperse the tests among review trials of the name:word matching relations.

Here we must underline another critical point: In Fig. 3, what matters in evaluating stimulus equivalence are only the three sets of stimuli (A, B, and C) and their relations as assessed by the sample-matching tests. Naming and spelling (oral or written) tests do not suffice to do that. There is considerable evidence that the receptive (matching) and expressive behaviors may at least sometimes be independent (e.g., Guess & Baer, 1973; Lee, 1981; Lee & Pegler, 1982; Mackay & Sidman, 1984; Sidman et al., 1986; Stromer & Mackay, in press). The child may be able to match the stimuli but not to do the naming and spelling tasks, as we will see. Only the matching tests provide unambiguous proof of equivalence learning.

Discussion

If we picture the crucial equivalence relations as a triangle formed by boxes A, B, and C in Fig. 3, we need not always follow the auditory-visual AB and AC paths in teaching the initial matching relations. One could teach AB and the visual-visual CB tasks, and then test AC. Moreover, the A stimuli need not be auditory. As one example, they could be signs in American Sign Language used for instruction of deaf children or perhaps for teaching communication skills to a nonvocal child with mental retardation or autism (e.g., Osborne & Gatch, 1989; Remington & Clark, 1983; VanBiervliet, 1977). Or the teacher might want to concentrate on all visual stimuli, such as numerals, printed numeral names, and quantities — omitting the spoken numeral names for the time being. In that case, the AB and BC tasks might be taught, with CA as the critical test. The advantages

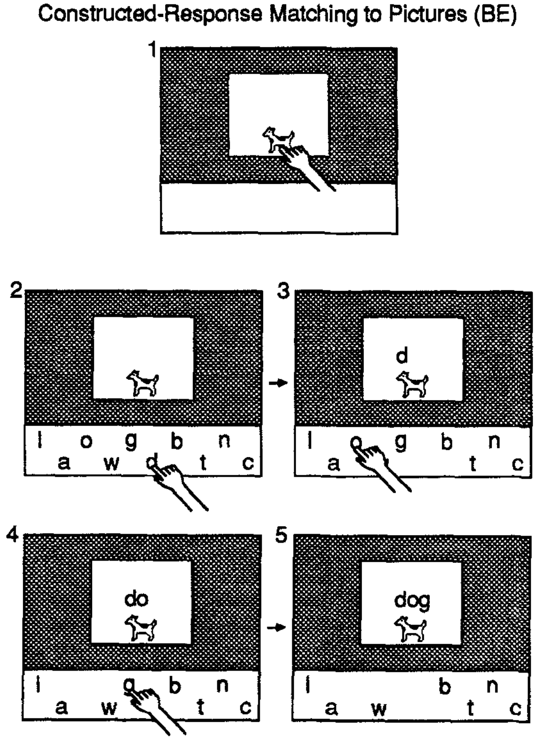


Fig. 4. Illustration of computer displays for constructed-response matching to pictures (BE), a kind of anagram spelling. See text for explanation.

of particular training and testing pathways is a complex issue and not important here. The point is merely that teaching any two paths around the triangle in any direction may suffice to establish the desired equivalences.

Anagram Spelling and Stimulus Equivalence

Our next research illustration adds anagram spelling to the stimulus equivalence network. When the student constructs words to dictated name and picture samples, we can refer to the behavior as spelling, even though the student spells the word merely by selecting the printed letters. The anagram spelling tasks were developed to allow students to use that method to "write" words even before they had learned to form the letters themselves.

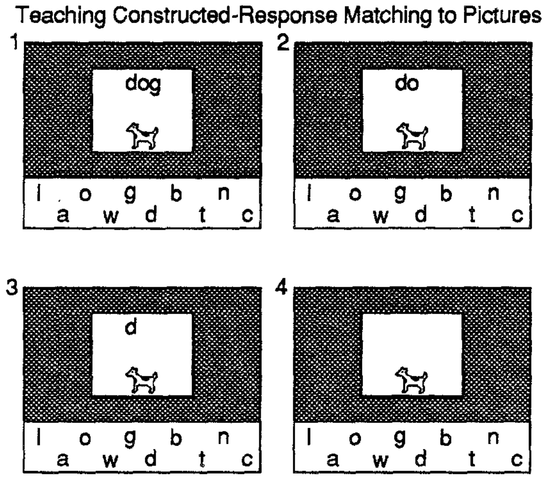


Fig. 5. Illustration of program for teaching contructed-response matching to pictures. See text for explanation.

Anagram Spelling to Pictures

Figure 4 shows the computer displays for the anagram spelling task with picture samples. Panel 1 shows the student touching the picture of a dog, thus showing that the student looks at it. Doing so produces a choice pool of letters at the bottom of the screen (Panel 2). When the student selects the letter *d* by touching it, it moves to the center of the sample area (Panels 2 and 3). Subsequent selections of the *o* (Panels 3 and 4) and the *g* (Panels 4 and 5) move these letters up also, thus constructing *dog* and completing the trial.

Figure 5 illustrates a simple computer program for teaching the picture:word constructed response task (Dube, MacDonald, McIlvane, & Mackay, 1991). Each panel shows what the computer displays look like at successive stages of the program before the student makes the first selection. Panel 1 shows the initial display of both the picture and the printed word as a paired sample. The student can copy the word at this stage. Subsequent stages remove each successive letter of the word sample (Panels 2 and 3) until no letters remain (Panel 4), a simple kind of fading out the word. At that point, the student must construct the word from memory. There are intermixed trials with one or more other picture-word pairs, so that the student must discriminate each picture in order to respond correctly. The success of the program depends on the student's observing each

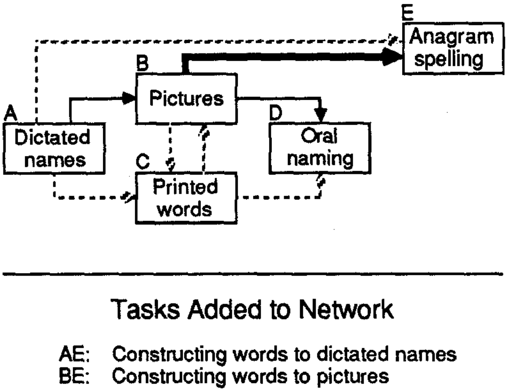


Fig. 6. Stimulus equivalence network with two anagram spelling performances added, constructed-response matching to dictated names (AE) and pictures (BE).

picture while constructing that word. Note that letter removal occurs backwards from the end, a method that may facilitate learning. When done this way, the student's selection of uncued letters that have been omitted completes the word and produces rewarding events.

Effects of Teaching Anagram Spelling to Pictures

Figure 6 shows the stimulus equivalence network for a replication of one of the first experiments on anagram spelling (Mackay, 1985; Mackay & Sidman, 1984). These earlier experiments used tabletop procedures and colors, dictated and printed color names, and moveable anagram letter tiles as stimuli. Our computer replications of this work used pictures, as we have illustrated in Figs. 4 and 5. The students, like Sidman's (1971) student, entered the study already capable of name:picture matching and picture naming (Tasks AB and BD). With training like that shown in Fig. 5, they learned to construct a number of words to picture samples (Task BE; shown by the bold arrow). After this training, all the remaining matching and naming tasks were tested (dashed arrows), which the students had been unable to do on pretests. Note that training involved only visual stimuli, constructing words to the picture samples. Therefore, the critical tests were those that involved the names, to test for the emergent (not directly trained) matching of the printed words to the dictated names (AC) and oral naming of the words (CD). The students did well on the tests. The emergent AC performance supported a conclusion that the subjects had learned equivalence classes, each composed of a name, a picture, and a word. The original experiment omitted a test of the other spelling task, constructing words to dictated name samples (AE), but the replication did include it. The students passed that test also.

Effects of Teaching Anagram Spelling to Dictated Names

Further replications of the experiments taught the students to construct the words to their dictated names (Task AE in Fig. 6), instead of to pictures. As in the other experiments we have described, the students had already learned the AB and BD performances. Figure 7 illustrates the computer methods for conducting this auditory-visual task. The top panel shows the empty black sample area that accompanies the initial dictated name, before the student touches it to produce the choice pool of letters. When the name has been dictated once, touching the black area also changes that area to blank white to permit display of the word that the student constructs (Panels 2-5). The dictated name is repeated (at 2-s intervals) until the entire word is constructed and the trial ends. After this auditory-visual training with several names, the critical outcome tests for emergent equivalence relations are the visual-visual matching tasks with the pictures and printed words (BC and CB), as in Sidman's (1971) original study (see Fig. 3). The students passed these tests, as well as the other tests that involved the names (AC and CD; indicated by dashed arrows in Fig. 6). Success on the BE spelling test also followed.

Constructed Response Identity-Matching

The programs for teaching anagram spelling begin by having the student copy the printed word. Many students require special instruction in how to do the copying task, before the letter-removal program can begin.

The programs for teaching the prerequisite constructed response identity-matching performance begin by presenting only a single letter (Dube et al., 1991). The letter changes from trial to trial, and only two letters are in the choice pool at the beginning. When the student touches the matching letter, it moves to the sample area for a brief period before the screen goes blank to end the trial. Next, the size of the choice pool is increased gradually across trials from two to ten letters. Then the number of letters in each sample is increased to two, three, four, and five letters, in turn. If the student touches a wrong letter or even a correct one in the wrong order (e.g., *g*

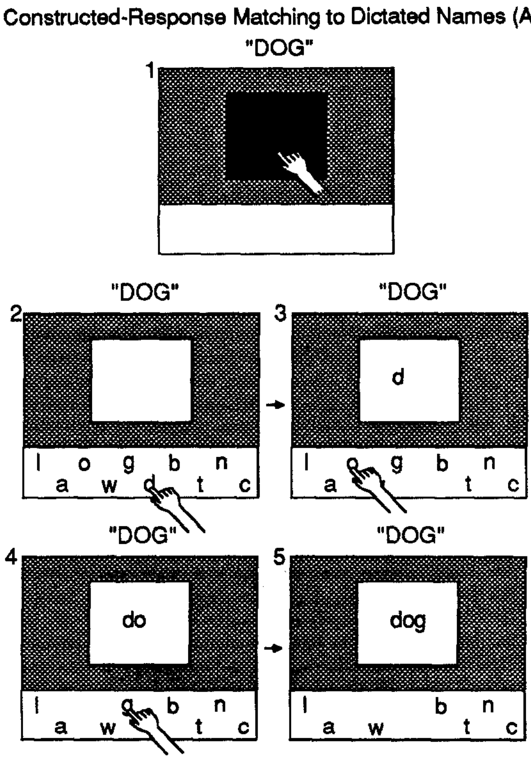


Fig. 7. Illustration of computer displays for constructed-response matching to dictated names (AE).

after *d*, if the sample word is *dog*), the trial ends without reinforcement. Thus, there is no possibility of accidentally rewarding correct constructions that result from letter selections in the wrong order.

In our experience, the most difficult stage for the students has been when two-letter samples are first introduced. There are two problems. It is the first time the student is asked to make more than one selection on a trial. The critical problem, however, is to teach the student to select letters in the appropriate order. One program uses a flashing prompt to cue the order of letter selection. First, the left letter flashes on and off. After that matching letter has been selected from the choice pool, the letter on the right begins to flash. Tests without the prompt follow. Another program uses a more complex procedure that we will not describe here, which involves gradual changes (*fading*) of the intensity of the letters in the sample display (see Dube et al., 1991).

Discussion

The first of these two anagram spelling experiments clearly shows another way to go about establishing equivalence relations. Training the BE relations can be viewed as analogous to teaching the BC relations, which would involve matching each whole printed word to its picture. Instead of constructing words to picture samples, the student would merely select those words in a matching task. Hence, that path around the triangle is suggested as an alternative and effective teaching route.

It may not be particularly surprising that competence in picture:word matching should follow the teaching of picture:word anagram spelling. However, the opposite — competence at spelling after matching training — is by no means equally likely, as we will see.

Delayed Constructed-Response Identity Matching in Remediating Spelling Problems

This section describes another useful way to use the word construction method. The problem we address is failure on spelling tests after mastery of all matching and naming tasks with the words. When that happens, comprehension of the words' meaning is obviously not the problem, since the student matches them accurately with their pictures. Also, the student clearly discriminates the words from each other when they are displayed in entirety and can even name the whole word when it is presented alone. Hence, to account for spelling errors, it is reasonable to conjecture that the student's successful discrimination of the whole word does not include either (a) discrimination of every letter in the word, or (b) full recollection of all the letters or their correct order (or some combination of these reasons). Our next illustrative experiment asked whether having the student copy the words from memory would establish these prerequisites for accurate spelling.

Delayed Identity Matching

As just discussed, a student in the experiment (Stromer & Mackay, in press) already performed all the matching and naming tasks indicated by the thin solid arrows in the network diagram in Fig. 8; despite that, he failed all of the spelling tasks (dashed arrows). These tasks now included tests of written and oral spelling to dictated name samples (AF and AG), as well as anagram spelling (AE and BE). He had learned to name and write the individual letters previously.

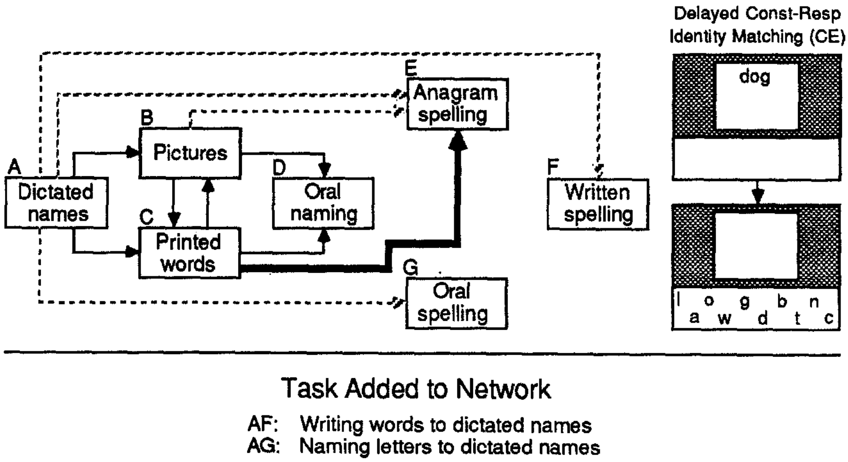


Fig. 8. Stimulus equivalence network with written and oral spelling to dictated names added (AF and AG, respectively). Panels at right illustrate the task represented by the thick arrow, delayed constructed-response identity matching (CE). See text for explanation.

The computer task for solving this problem was delayed identity matching that required letter-by-letter construction of the printed words (CE; the bold arrow in the Fig. 8 diagram). The right portion of Fig. 8 illustrates the computer displays. To start each trial, the word to be matched appears in the top area of the screen (upper panel). When the student touches it, the word disappears and the choice pool of letters appears at the bottom (lower panel). He must then remember how to construct the word. In this application, the letter pool appeared immediately after the removal of the sample.

After the student learned the delayed anagram construction of all the printed words that were in the spelling tests, his spelling performances were retested. All improved dramatically (AE, AF, AG, and BE). Merely learning to discriminate the letter-by-letter formation of the words sufficed to help the student spell all the words accurately, in writing and in speech. Note that only the picture:anagram task (BE) assessed comprehension, but further verification of that capability was not needed (see Discussion below).

Delayed Identity Matching to Paired Picture and Printed Word Samples

Our final example explored the use of delayed identity matching to teach not only discriminations of the letters in the printed words but also

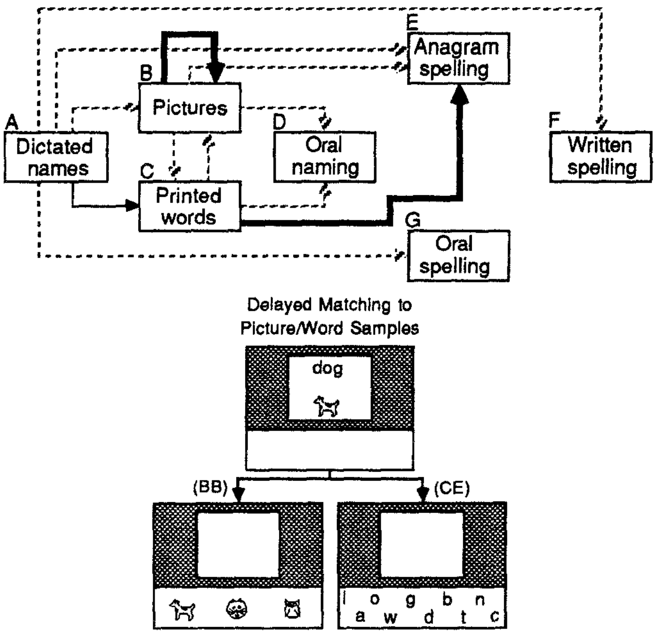


Fig. 9. Panels on the bottom depict the tasks represented by the thick arrows in the network: delayed identity matching of pictures (BB) and delayed constructed-response identity matching (CE). See text for explanation.

the relations between the words and their pictures (Stromer & Mackay, 1990; in press). The computer displays in Fig. 9 illustrate the combined task. The trial starts with the display of both a word and its picture. When the student touches the sample area, both stimuli disappear and either pictures or letters appear in the choice area. In each case, the student must do an identity match, by selecting either the same picture or by constructing the identical word. Note that nothing about the paired sample gives any information about which type of choice stimuli will be encountered next. In order to respond correctly, the student must look at and memorize both of the stimuli in the sample area before touching it, and that includes observing the letter-by-letter formation of the word. This dual requirement of having to observe both the word and the picture may suffice to teach the relations between them.

The combined task is shown by the bold arrows in the diagram at the top of Fig. 9 (Tasks BB and CE). After the student masters the delayed matching performances, comprehension of the picture-word relations is assessed by asking the student to match each with the other (Tasks BC and CB).

One of the experiments by Stromer and Mackay (in press) was additionally interesting, because the student's phonics training permitted her to match the printed words to their dictated names (Task AC in Fig. 9, a phonics-related skill discussed before). The words included ones like *canine* and *avian*. Moreover, she could do none of the tasks involving the pictures, thus showing no comprehension of the meaning of the words. After she learned delayed identity matching to the paired picture and word samples, she showed she had learned the relations between them. However, she was proficient not only in these comprehension tasks (BC and CB) but also in matching the pictures to their dictated names (Task AB). Success on these tests satisfied the requirements of proof that the student had learned equivalence classes, each consisting of a name and its corresponding word and picture. Further, she passed all spelling tests. Her success in doing anagram spelling to picture samples (Task BE) gave further evidence of her new comprehension.

Discussion

This experiment makes several points. Perhaps the most important is the obvious efficiency and economy of the teaching that was required. At the outset, the student's phonic decoding skills permitted her to match each printed word to its dictated sounds (Task AC). Since oral and written spelling of the dictated names can also be done on a phonetic basis, she might have succeeded on these tests also (but they were not tested until after teaching had occurred). It is also possible that she might have failed these tests for reasons related to not discriminating all aspects of the words during her matching tests. However, she could do none of the five tests that involved the pictures (AB, BC, CB, BD, and BE). Thus, teaching her identity matching to paired words and pictures paid remarkable dividends, since she became proficient at all five picture tasks after that teaching.

Second, the teaching also made success on the spelling tests more likely. The copying requirement ensured that the student had to observe and learn the letter-by-letter formation of each word.

Third, this method of pairing two stimuli to teach the relation between them seems to overcome the major deficiency of other pairing procedures. For example, in prompt-fading (e.g., Dube et al., 1991) and time-delay procedures (e.g., Kenney, Stevens, & Schuster, 1988; Stevens, Blackhurst, & Slaton, 1991) students do not have to pay attention to both stimuli when they are presented together. Delayed identity matching to paired samples, on the other hand, appears to solve that problem. Requiring a response to each sample stimulus demands joint observation of both of them. The motivated student will perform accordingly.

Finally, would delayed identity matching to paired samples succeed in teaching the relations between dictated names and their corresponding printed words or pictures? This technique has not been formally studied, but it seems promising. Requiring the students to construct the word or select the picture first would interpose a delay before asking them to remember and repeat the name. That small hurdle might encourage them to pay attention to the name when it was dictated, and to remember it.

CLASSROOM IMPLEMENTATION OF THE STIMULUS EQUIVALENCE ANALYSIS

At the outset we said that equivalence methods should supplement, not supplant, methods presently used in the classroom. There are two logical ways to use the methods. The first is to provide a guide for assessment. Keeping in mind the full equivalence network (Fig. 1) will help to remind the teacher of the interrelated skills that must be taught. The second way is more adventurous — to use selected methods as teaching supplements to the curriculum exercises. We will first review one illustration of assessment practices.

Classroom Assessments

Tasks from the equivalence network can be used to assess key performances before and after a lesson or unit of curriculum-based instruction. They can serve as a data-based check on whether the curriculum procedures work, or whether some form of remedial teaching is needed. To use the tasks, the teacher would need to: 1) identify the words to be assessed, 2) develop the assessment procedures (including assembly and distribution of word and picture cards, and letter cards as appropriate), 3) administer the assessment, 4) teach, 5) re-assess, 6) remediate if necessary, and 7) re-assess.

It is important that both a pretest and a posttest phase be included. The proposed test-teach-test procedure tends to be superior to a teach-test procedure, at least with respect to spelling (e.g., Graham, 1983). One advantage of the initial test may be to inform the children about what they have to learn. A working principle is that the more frequent the test-teach-test process occurs the better. However, the frequency of testing will depend on practical constraints and how testing fits into the curriculum lessons.

To make this suggestion meaningful we discuss its use in more detail with examples taken from a recent language arts curriculum (*Preprimer 1*, D. C. Heath and Company, 1991). The words to be assessed are from a lesson in a preprimer portion of the curriculum (early first grade level). This lesson includes key vocabulary words (e.g., this and balloon) and words used to practice decoding initial consonants (e.g., g/girl and k/kitten), final consonants (e.g., n/pan and t/hat), and short vowels (e.g., a/stamp and i/ring). Students are exposed to approximately 40 different words in all, some new and others that were covered in prior lessons. Our hypothetical assessment could include a selection of 20 words, all new ones and a sample of previous words for review.

To introduce new words, the curriculum suggests group teaching activities that include matching printed words to their dictated names, reading (naming) the printed words, and producing sentences orally that include the new words. These words are also used in a story that is read and discussed as a group activity. Individual seat-work activities in the students' workbooks include those for developing decoding skills by matching each of a set of pictures to the initial (printed) consonant of its name (by circling the correct picture), and writing the missing final consonant or short vowel in printed words that are paired with pictures.

The assessments are made manageable by narrowing the selection of tasks to a few critical ones. Figure 10 illustrates a way of organizing these tasks with a few of the words. The left column shows the tasks grouped under the categories of matching pictures, matching words, naming, and writing. Each category contains three subcategories of tasks that differ by the type of sample presented, making 12 tasks in all. For example, at the top, we see matching pictures to dictated names (AB), to printed words (CB), and to pictures (BB, an identity task). The far right column in the figure labels the tasks by the letter notation used in Fig. 1. Across the top are five words from the curriculum. Within the matrix are boxes for tallying correct (+) or incorrect (–) performances during pretesting and posttesting.

The assessment focuses on the eight nonidentity tasks. The four identity tasks (gray boxes) are assessed only if other test data suggest a student has difficulty making the basic discriminations. Anagram spelling would also be included only as a remedial method.

Figure 10 shows hypothetical test data for one child. Data for five words are shown to illustrate some possible outcomes of the assessments. The word *can* (Column 1) was taught previously and was included for review. Pluses in the boxes indicate that the student was perfect on all performances before and after the teaching activities.

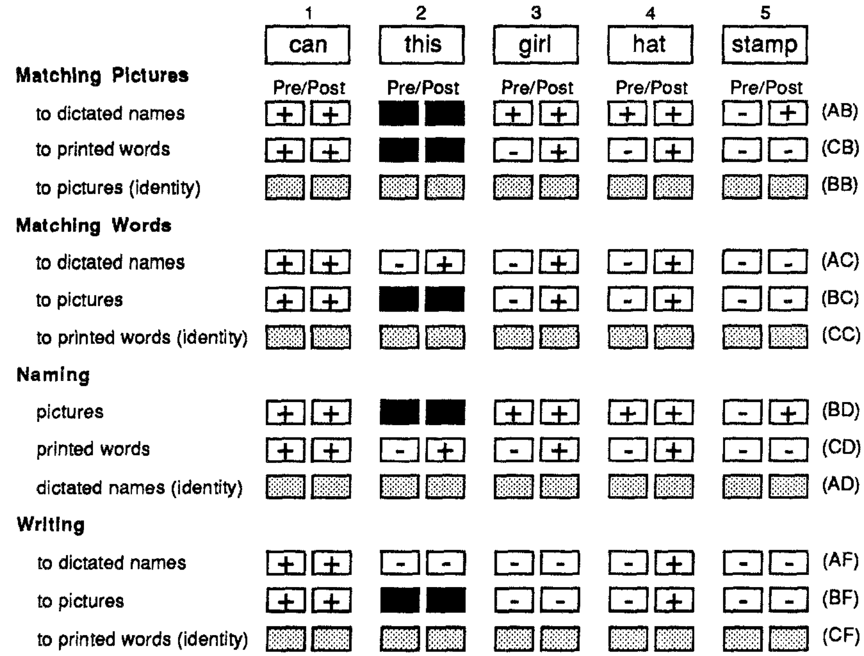


Fig. 10. Matrix depicting hypothetical pretest and posttest performances ("+" = pass; "–" = fail) with five words (across top) presented in matching, naming, and writing tasks (denoted in left and right columns).

The word *this* (Column 2) is one of the key vocabulary words introduced. Because *this* is not picturable, only three nonidentity performances were assessed. During the pretest, the student was unable to match the printed word *this* to its dictated name (AC), to name the printed word (CD), or to write it to a dictated name (AF). Performance on Tasks CD and AC improved after teaching, but not AF, writing *this* to dictation.

The word *girl* (Column 3) is among those used for teaching initial consonants. During pretests, the child matched the picture to its dictated name and named it, but could do none of the other performances. Again, all improved after teaching except for the two writing tasks.

The word *hat* (Column 4) was used to teach the final consonant *t*. Pretest scores were like those for *girl*. However, posttests showed improved writing, perhaps because *hat* combines letters worked on in all three curriculum components devoted to decoding skills.

The word *stamp* (Column 5) was used to teach the short vowel *a*. The child did none of the performances initially. After teaching, the child had learned only picture naming (BD) and matching pictures to dictated words (AB). This outcome may have occurred because the student's experience with this word was limited to exercises designed to teach short vowel discriminations. The student had no immediate history of learning to decode the initial or final consonants. This word might be a candidate for assessment in identity matching (CC).

Note that of the five words, only two were spelled correctly in writing. An examination of the teaching activities provided in the curriculum suggests why this might happen. None of them explicitly focus on spelling per se. This omission is not uncommon in early first grade materials. Formal testing of spelling, and teaching devoted to learning to spell, are usually introduced in later grades. Of course many students do learn to spell, perhaps incidental to the teaching devoted to other language arts skills. The problem with this approach is exemplified in the study reviewed previously (Stromer & Mackay, in press), which showed that reading and writing function as independent tasks for many students. Unless spelling activities are explicitly integrated into other language arts activities early, the gap between reading and spelling can only widen (cf. Tierney & Shanahan, 1991). Having the students copy the words from memory, in writing or as in the delayed identity constructed-response task, might be a helpful strategy. We will expand on use of this method in the next section.

Classroom Teaching

The teacher who is inquisitive and a little adventurous may want to try some of the stimulus equivalence methods in actual teaching, to supplement the curriculum. Such usage might help to prepare students for the curriculum exercises and even might bypass some of them. Our illustrations will focus particularly on the method used in the final experiment described previously (Stromer & Mackay, 1991b). We begin with discussion of what the students will need to know already in order to profit from that instruction.

Prerequisites

Children at the same stage of teaching as the girl in Stromer and Mackay's (in press) study will have already learned many skills that are prerequisite for going on to learn what she did. These skills will probably have been taught through "readiness" curricula at the kindergarten and early first grade level. We list them here: (a) to do identity matching of pictures, single letters, and at least short multi-letter strings and words, and to copy (in writing) the letters and letter strings; (b) to match some pictures and printed words to their names and with each other; (c) to name some pictures and probably some printed words; (d) to name the printed letters and write them to dictation, including oral and written spelling of some words; and (e) sufficient phonic decoding skills to permit discrimination of at least some printed words on hearing their dictated names. In the course of that earlier teaching, the children probably will have also learned (f) to recite and write the alphabet; and (g) to match upper- and lower-case letters, but these skills are not critical at this stage.

Obviously, the children need not have learned to do all these things with the words and pictures to be used next in teaching. It is important only that they have previously performed all the tasks with other stimuli, so that the teacher can be confident that the children understand "the rules of the game" for each type of task.

We take this opportunity also to note that the stimulus equivalence approach is applicable during this prior teaching of readiness skills. As merely one example, it should be easy to visualize a network that has dictated letter names as set A, printed upper-case letters as set B, and lower-case letters as set C. The box D is naming the printed letters. In doing the matching tasks, the children would use the single-letter cards described in our introduction to the network. The children could even have constructed the cards themselves by copying the teacher's chalkboard model of each letter.

Teaching with Delayed Identity Matching

One teaching possibility would be to train the word-picture relations of all the new (picturable) words when starting a new lesson, using the method of delayed identity matching to paired samples. After the teacher displays the word and picture cards and removes them, the children would have to find the correct picture card in their array and either write the word or construct it from anagram letters (depending on the level of the children's writing skills). On each trial, the teacher could require an identity match either to both stimuli, or to one or the other in an unpredictable sequence from trial to trial. If to both, the teacher would vary the order of her requests for each, so that the longer delay before making the second response would occur equally often with each stimulus. After several trials with each of the word-picture pairs, the teacher would conduct the nonidentity matching tests (Tasks BC and CB in Fig. 9). If the children can already match the words to their dictated names (Task

AC, doing so on a phonics basis, as discussed above), that training might establish all the other performances in the equivalence network, as we saw in Stromer and Mackay's (in press) experiment. As noted in our discussion of that experiment, the dramatic finding would be the emergence of matching the pictures to the names and naming the pictures (Tasks AB and BD).

Alternatively, the children might already know the name-picture relations. Teaching the word-picture relations could then lead to emergent name-word matching and word naming, in children less capable at phonic decoding. If the children can match neither the pictures or the words to the names at the outset, delayed matching trials with name-picture (or name-word) pairs could be interspersed among the word-picture trials or be taught separately. The children would match the name by repeating it after first writing (or constructing) the word.

It is always a possibility to dictate the name on the paired word-picture trials, thus presenting all three stimuli together. There is evidence that this method can be successful in teaching all the relations (Wulz & Hollis, 1979). However, when all are presented at once, all the relations are taught directly in essence, and there are no relations left to be tested for emergence. It is probably a good idea always to include at least one emergence test, to make sure that you are not just teaching rote skills (see Final Comments, below).

If some of the new words in the lesson are not picturable, as with *this* in our assessment illustration, the teacher still could do delayed identity matching of name-word pairs. The teacher could then test for word naming and writing to dictation, a nonidentity task. As we discussed in the assessment, spelling is often the behavior that reveals problems. We also suggested that delayed identity matching of only the words, either in writing or via anagram construction, can be an avenue to remediate the spelling problems. Based on our data, it would be the solution of choice. Doing that with all the new words, both picturable and not, before embarking on the curriculum lessons, could give the children a head start in learning to recognize and deal with the words in text. If the children can spell the words, even if only with moveable letters, the teacher can be confident that discrimination confusions are unlikely to impede progress in reading.

We conclude this set of teaching illustrations by addressing a problem children may have with the pictures used in some reading curricula. Many exercises that involve pictures assume that each child will give only the desired correct name for each picture. Our inspection of the pictures for these types of tasks in several curricula suggests that many pictures may be ambiguous for naming. If a child gives another name to any of the pictures, tasks that require the child to circle a picture that begins with a particular sound will inevitably produce errors or omissions. It would probably be helpful for the teacher to review the name-picture relations before assigning the tasks. Sometimes the teacher's editions of the curricula show recognition of this possibility and may include directions like, "Before beginning ..., have the pictures identified," without instructions on how to do so *(Finding Places,* p. 309, American Book Company, 1980). A simple method would be to conduct a few trials of delayed identity repetition/matching of each name-picture pair.

Teaching with Other Stimuli

The wider relevance of the methods can be seen when we consider the possibility of using other stimuli, specifically to replace the dictated names with the sounds of letters and letter combinations to teach and/or assess phoneme-grapheme relations. An example would be to use vowel sounds as set A, pictures of word families as set B (e.g., cat, hat; hit, pit; boat, coat), and the printed letters corresponding to the sounds as set C. Other possibilities include initial and final consonants, consonant blends, and so on.

Discussion

The outcomes of the studies conducted with the constructed response matching-to-sample task are consistent with other experiments that illustrate how training in spelling may yield reading performances (cf. Chomsky, 1971; Ehri & Wilce, 1987; Stromer, 1991). Constructed response training may be advantageous because it requires explicit behavior with respect to each letter in a word. Hence, this form of training might discourage, even if it did not eliminate, control of reading by restricted visual features of printed words. For example, with beginning readers, the initial letter, the last letter, the general outline, or some other characteristic of a printed word may occasion oral naming of the word. Such characteristics can also provide the basis for matching the word to other stimuli. In such cases, the presence of some of the letters and/or the order of the letters are irrelevant.

These performances based on control of word naming by some salient graphic feature are common in the earliest phases of learning to read. Frith (1985) identified such performance as the first of three major phases of reading and called it logographic reading. As Ehri (1991) notes, however, the logographic reader has predictable difficulties in reading words that are written alphabetically, as in English. For example, logographic readers mistake "visually similar words ... for each other because the visual cues selected are not unique to individual words. As more words are learned, it becomes increasingly difficult to find attributes that distinguish among the words because different words contain the same visual cues. Rather than reading the exact word symbolized in print, logographic readers may produce synonyms or semantic associates of written words because the visual cues selected do not systematically target a particular pronunciation... ." (p. 388).

The constructed response procedure may minimize the occurrence of errors related to selective stimulus control, since it emphasizes the individual letters that are the components of printed words. From a developmental perspective, then, constructed response procedures may decrease the frequency of errors that characterize logographic reading and thus aid the transition to rudimentary alphabetic reading (see Ehri, 1991).

The same points can be made, of course, with respect to writing the words. But many if not most beginning readers are also struggling to learn to write at the same time. There are many possible reasons for having difficulties in writing. Many are addressed by occupational therapy and include problems with fine-motor skills, visual-motor coordination, and motor planning. The constructed response task bypasses all motoric and coordination problems and isolates the critical requirements having to do with visual discrimination, organization, sequencing, and memory. The use of anagram letters lightens the demands on the child by removing the additional burden of having to form the letters in print or script. That extra demand can be added later.

SUMMARY AND FINAL COMMENTS

The concepts and methods of stimulus equivalence research suggest a framework for analyzing language arts performances involving pictures, printed words, and dictated names. The methods may be used as a supplement to classroom instruction to assess whether standard curriculum-based approaches establish integrated networks of matching-to-sample, writing, and naming performances. When these traditional teaching approaches fail, methods derived from equivalence research may be useful for remediation.

The capacity to learn equivalence relations of the kind illustrated in Sidman (1971) appears to be closely related to the capacity for language acquisition, and is usually interpreted as a uniquely human characteristic. The fact that equivalence relations may be acquired universally by humans (or nearly so) might make us inclined to take the emergent performances for granted, especially if the learner were a normally capable beginning reader. Caution is needed, however, because much experimental evidence tells us that emergence of new performances will depend on our teaching practices.

Research described earlier suggested that a focus on spelling instruction may be necessary if the full network of language arts skills is to be acquired. In addition, however, traditional teaching approaches may fail to establish equivalence relations in a significant number of children. Children with attention deficits, development lags, and specific learning disabilities may be at special risk for failure to learn equivalence relations. For such children, we recommend remediation tactics much like the research methods used in studies reviewed previously. In particular, children showing persistent learning difficulties might profit from a direct application of Sidman's (1971) procedure: Teach the auditory-visual relations AB and AC directly and then verify equivalence relations by testing for the emergence of BC and CB (see Figs. 1 and 3).

This procedure takes advantage of modality variables that may also play a role in the formation of equivalence relations. Upon entering school, children are probably much better at matching pictures to their dictated names than to their printed words (cf. Sidman & Cresson, 1973). Equivalence relations may be more likely if teaching builds carefully upon these existing auditory-visual relations. Research relevant to this point suggests equivalence relations with some children emerge more readily if teaching involves auditory-visual relations rather than visual-visual relations (cf. Green, 1990; Sidman et al., 1986). Workbook exercises may fail in part because they attempt to establish equivalence relations with only visual stimuli.

However, even under optimal circumstances, equivalence relations may emerge gradually after repeated testing (e.g., Devany, Hayes, & Nelson, 1986; Lazar, Davis-Lang, & Sanchez, 1984; Sidman, Kirk, & Willson-Morris, 1985; Spradlin, Cotter, & Baxley, 1973; Stromer & Osborne, 1982). Repeated cycles of training and testing may be necessary before the emergence of equivalence relations occurs immediately. Nonetheless, the only way to be sure that the teaching has established equivalence relations is to test at least some untaught performances. If all are taught directly, one cannot be sure that the child is not merely memorizing a set of specific, independent performances. The assessment of emergent performances may even be an important instructional step for children having difficulty learning equivalence relations from traditional classroom teaching approaches.

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