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SAMPLE-MATCHING TECHNIQUES IN THE STUDY OF CHILDREN'S LANGUAGE

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The relationship between brain disease and disturbance in language disorder has been recognized for well over a century. The question of the extent to which specific language deficits may be correlated with specific localities of brain disease has aroused considerable controversy among neurologists and psychologists during this century. A few basic clinical-anatomical correlations appear to have survived this controversy thus far. They are illustrated in Figure 1 and are as follows:

1. Lesions of the posterior part of the third frontal convolution of the dominant cerebral hemisphere of the normal adult appear to give rise to an interruption of the motor productivity of language, that is to say oral speech (#2 in Fig. 1). This disorder is usually accompanied by apraxia for fine motor movements of the lips and tongue, and practically always by difficulty in the graphic expression of language as well. Intact language comprehension can ususally be demonstrated.

2. Lesions in the middle third of the superior temporal convolution (#4) produce a disturbance in language formulation and comprehension while leaving the fluency of verbal output relatively unimpaired. These are the

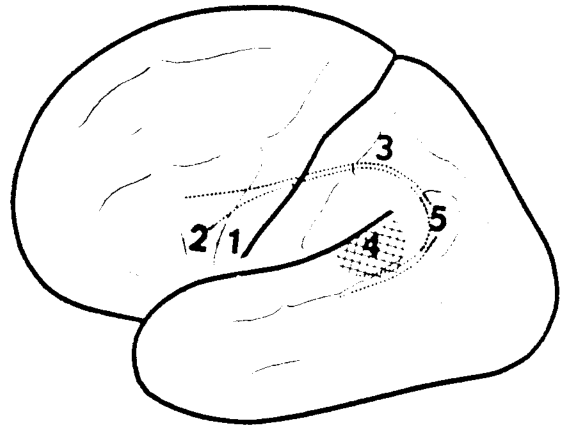

Fig. 1. Schematic diagram of language centers in the dominant hemisphere of the normal adult brain (Courtesy of Dr. Norman Geschwind).

patients whose speech includes jargon, phonemic substitutions, synonymous substitutions, circumlocutory phrases, and other similar linguistic abnormalities.

3. Lesions elsewhere in the dominant temporal lobe are frequently found in the patient whose language deficit is most prominently in the area of *word finding.* Such a patient usually has relatively intact language comprehension and relatively good verbal output, but is frequently unable to call forth from his memory precisely the right word for what he wants to say.

4. The angular gyrus of the dominant hemisphere (#5) is a much less well understood but critically important area for language. It appears that some sort of integration of visual and auditory information occurs in this region. Patients with lesions in this area are frequently dyslectic, that is, have lost their ability to read while retaining their comprehension of spoken language as well as their primary visual acuity and visual comprehension of non-verbal materials. We shall speak more of this later.

To complicate the picture even further, the child's brain violates some of the most sacred principles of classical neurology in its relation to language behavior. To begin with, a child under the age of ten years who has acquired normal language skills, and who then loses them as the result of a lesion in his dominant cerebral hemisphere, almost uniformly reacquires these language skills within a year; and there is considerable evidence that this reacquistion is accomplished by the *other hemisphere* something which rarely if ever occurs in the adult. Second, cerebral dominance is a different phenomenon in childhood; that is, its importance to language increases with age. Thus young children more frequently show disturbances of language behavior with lesions of either cerebral hemisphere than do adults. Third, fluent aphasias are rarely seen in childhood.

What do these above considerations have to do with language of the retarded? First of all, defective language is often a retarded person's outstanding handicap. A questionnaire circulated to the ward attendants of the Fernald State School revealed that only 747 of 1,752 residents evaluated are capable of speech understandable by a stranger; and 499 of these 1,752 residents have difficulty understanding even the simple communications of the attendants (Table 1). (It must be stressed that these

TABLE 1

Survey of language skills of Fernald State School residents

I.	*Communication to Others*	
	Form left blank	27
	Unknown	12
	Makes no sounds	102
	No meaningful communication	287
	Jabbers no words	192
	Makes sounds or signs	12
	Speech somewhat difficult to understand	373
	Speech understandable by a stranger	747
	Total residents surveyed	1,752
II	*Receiving Communication from Others*	
	Form left blank	32
	Unknown	35
	Does not respond to gestures and/or signs	138
	Responds only to gestures and/or signs	99
	Has difficulty understanding oral communication	195
	Understands oral communication	1253
	Total residents surveyed	1,752

are questionnaire replies from untrained attendants). Second, complete neurological evaluations of nearly 1,600 of our residents show that almost 80 per cent have clinical evidence of disease of the nervous system. It is, of course, not possible to draw conclusions from these two sets of figures concerning the portion of language deficits which are caused by neurological disease. However, the mere number involved have been sufficient to stimulate our interest.

RELEVANCE OF SAMPLE MATCHING TECHNIQUES

Our use of sample matching techniques in the study of children's language was prompted by both neurological and psychological considerations. The neurological issue was raised by Geschwind (1965), who offered evidence in support of the proposition that the language capability of the human organism may be related to the ability of his brain to make direct anatomical connections between auditory and visual associations of which the animal brain is incapable. Birch and Belmont (1964) developed simple tests for auditory visual correlation and demonstrated performance deficits on these tests among poor readers.

Psychological considerations were even more persuasive. Conventional techniques of verbal communication are nearly useless in the study of language deficits, especially more severe ones. Our laboratory was already engaged in the extensive use of nonverbal techniques to study the behavior of animals and subnormal human subjects. It occurred to us that these techniques might profitably be applied to the exploration of verbal deficits as well. Specifically, the sample matching technique permits the subject to indicate his selection of choices by nonverbal responses even when the stimulus materials are verbal in nature. The technique can use verbal and nonverbal sample and choice materials interchangeably without concern about whether the subject has mastered a new response skill. In general, it allows the precise specification of stimuli presented and mode of response which, as Geschwind (1965) and others have pointed out, is so crucial in the study of language deficits.

Our technique also incorporates other features of the operant conditioning laboratory. The first is the reinforcing consequence, which immediately follows each correct response by the subject. The reinforcement not only insures stable performance and cooperation, but serves to instruct the subject in the nature of the task required. In the case of severe language deficits, this instruction often represents the only effective communication between subject and experimenter. The second is complete automation of stimulus presentation and responses recording. This minimizes equivocation in the decision as to what constitutes a response, and helps us to control for such variables as position habits.

APPARATUS AND TECHNIQUES

The subject works in a well-ventilated room approximately five feet square with sound resistant walls and door. An electric fan aides in dampening incidental noises. The subject sits facing a wall in which is mounted a display and response panel consisting of a square matrix of nine translucent windows, each two inches square and arranged in three rows of three each, separated from one another by three-quarter inch barriers. Figure 2 shows this nine-window matrix, with the outer windows illuminated and the center one dark. Figure 3 shows a child pressing one of the windows, which activates a small microswitch behind the window delivering a signal to our electronic programming and recording apparatus, more fully described by Sidman and Stoddard (1966).

Visual stimuli to be presented on the windows are photographed on 35 mm color film and projected as slides from the rear. We use a Leitz automatic slide projector. Motor driven shutters behind the windows and in front of the projector lens control the presentation and removal of stimuli. Photoelectric cells behind the windows indicate to the control and recording apparatus which window contains the "correct" choice on any given trial. One and one-half seconds elapse between the end

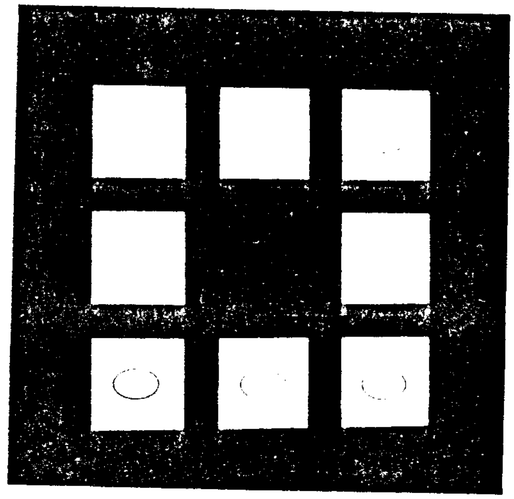

Fig. 2. Nine-window matrix of the sample matching apparatus with outer windows illuminated.

of one trial and the beginning of the next trial. The solenoid-driven shutters, the slide projector, the photoelectric cells, the rewarding devices, and the recording equipment are all controlled automatically by digital electronic circuitry.

On both the left and right sides of the matrix are plastic trays into which automatic devices deliver such rewards as candies, toys, or tokens that the child may trade later for other things. When the child presses a correct window, a chime above the matrix sounds and a reward dispenser operates. Most children receive candy-coated chocolates as their reward.

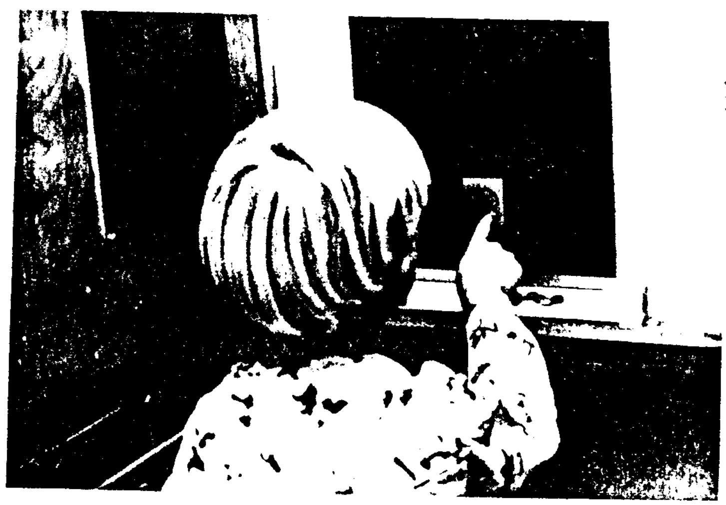

Fig. 3. Child pressing one of the windows to indicate a choice.

We tend to classify our modalities of stimulus and response somewhat over-mechanistically as "input" and "output." Of the input modalities, the visual has already been demonstrated. We are also able to provide auditory samples by means of recorded tape through a loudspeaker in the ceiling of the subject booth. The tape recorder is driven automatically and coupled with the slide projector by means of a photoelectric cell mechanism. An alternative method is to use a stereophonic tape recorder to record stimulus materials on one channel and to stop and start signals on the other. We provide tactile stimuli manually through a box which masks them from the subject's vision.

The only output modality which is automatically controlled is that of matching to visual choices. We also use vocal naming, which is recorded on tape through a ceiling microphone, and writing, which is collected on a separate piece of paper for each trial.

The various verbal and related materials available to us include single lower case

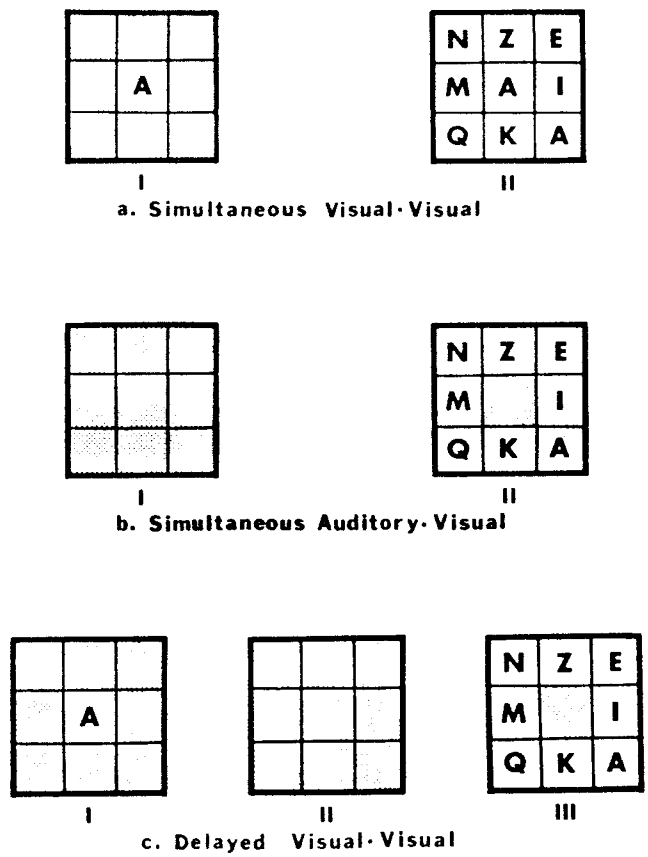

Fig. 4. Diagram of some of the sample matching paradigms available.

letters, single capital letters, simple three-letter words (which are the names of objects), pictures of the objects which those words name, three-letter nonsense syllables of consonant-vowel-consonant combinations, three-letter nonsense trigrams which cannot be pronounced, digits and names of digits, colors and names of colors, combinations of dots in various arrangements, small objects presented for tactile recognition, and photographs of those subjects.

We can also require a simultaneous or delayed sample-match, as illustrated in Figure 4. In the simultaneous match procedure, the sample appears on the center screen. The subject then touches this screen (makes an "observing response"), and the choices immediately appear on the other eight screens for simultaneous comparison with the sample. (It should be noted that in this context, "simultaneous" is a *procedural* specification. We have only indirect evidence for what the subject actually does in scanning the choices to make his selection). For the simultaneous auditory-visual match, the center screen remains blank as the auditory sample is presented repeatedly over the loudspeaker. The subject must touch the blank center screen to bring on visual choices. In the *delayed* matching procedure, the sample, either visual or auditory, *disappears* when the subject makes his observing response, and a delay of from zero to sixty seconds ensues before the choice appears. We can program either a fixed delay (same duration for every trial) or an *adjusting delay* (one which increases on subsequent trials after correct responses and decreases after errors).

APPLICATIONS TO THE STUDY OF LANGUAGE

We initially applied the above techniques to study the effects of acquired brain disease upon normally developed language in presumably normally intelligent children.

Study of Acquired Brain Disease Affecting Language

Case I (Rosenberger et al., 1969)

A 14-year-old boy, who was in excellent health and doing generally satisfactory work in school, suffered a sudden cerebrovascular thrombosis which left him with a right hemiparesis and severe incapacitation of language skills. A carotid arterigram showed complete occlusion of the left middle cerebral artery, suggesting extensive damage to his left or dominant cerebral hemisphere. On follow up examination two months after his acute illness he was nearly devoid of speech. Although he could write simple three-letter words to dictation, he was unable to write single letters to dictation, or to pick out on spoken command single letters which he had just written.

Over the next year we subjected this patient in a large number of separate sessions to various sample-matching tasks, usually in sets of 20 trials each. Figure 5 shows the results of these studies with single letters. Successive sessions, not equally spaced in time, are graphed along the abscissa, errors per 20 trials along the ordinate. When the samples were auditory and the choices visual, he consistently made large numbers of errors. Sessions 27 and 28, in which the error rates were low, occurred on the same day. We gave him the same series again immediately afterward with the samples removed. Error rates were still low, indicating that he had learned something about the stimuli besides what the task was calling for. New sets were constructed with samples and choices rearranged. In following sessions error rates were once again high. He also made errors in matching visual samples in auditory choices. With visual samples and visual choices, or auditory samples and auditory choices, however, error rates were consistently low.

Figure 6 shows his auditory-visual matching performance with other materials. When spoken three-letter words were matched against visually presented words, or names of simple objects against pictures of those objects, error rates were consistently low. When auditory samples were *spelled* rather than pronounced, error rates were high. When three-letter nonsense syllables or nonsense trigrams were used, error rates were even higher. The use of "nonrepresentative" nouns and non-nouns gave error rates somewhat in between.

Subsequent follow-up studies of this boy have shown nearly simultaneous occurrence of the following: drop in error rates on auditory-visual matching on single

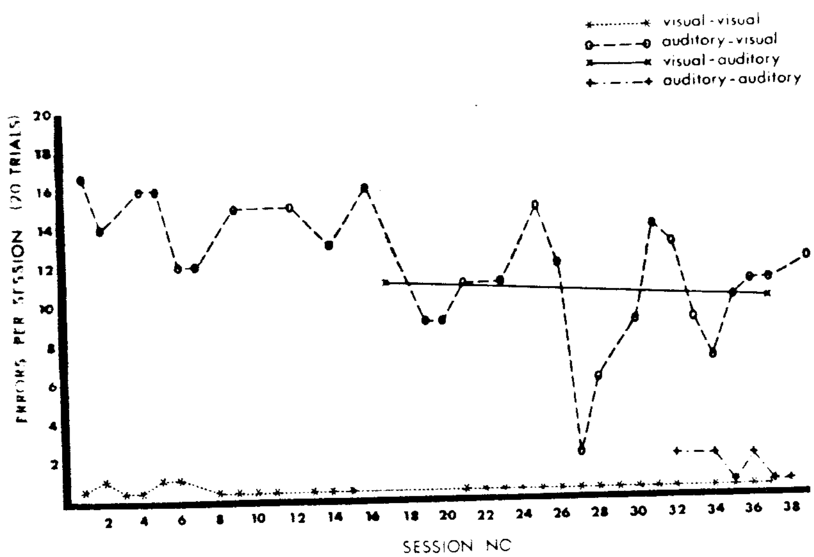

Fig. 5. Error rates in various sample matching tasks by the boy described as Case 1. The key indicates the modalities in which samples and choices respectively were presented; i.e., visual-visual indicates visual samples, visual choices.

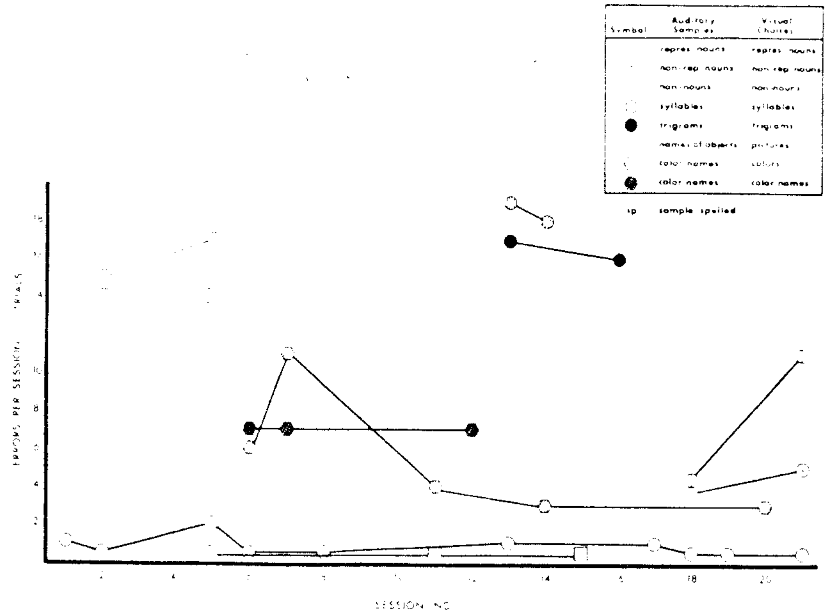

Fig. 6. Performance in auditory-visual sample matching tasks with various materials by the boy in Case 1.

letters, ability to *name* single letters aloud, and increase in amount of vocal speech. These findings suggest that the ability to make auditory-visual equivalences, especially with materials with which our only experience is auditory and visual, may indeed be crucially related to the formulation of language, although the direction of the cause-effect relationship is still obscure.

Case 2

An 8-year-old boy, again with a history of normal language development and satisfactory school work, developed a rapidly progressive right hemiparesis and aphasia following a mild gastrointestinal upset. A left carotid arteriogram showed congenital malformations of both internal carotid arteries and occlusion of branches of the left middle cerebral artery. On examination a week later, he was able to repeat single words spoken to him, and even to recite several lines of familiar songs and poems. He showed deficits in both reading and comprehension of auditory information, and was able to name only a few simple objects.

Figure 7 shows the results of repeated sample-matching sessions with this boy over a four-month period, during which a predictable marked improvement in his language was noted. There are interesting differences between this and the previous case. At the beginning, this boy had difficulty with auditory-visual match not only of single letters but also of words against words and words against pictures. In addition, he made errors on the visual match of words against pictures — equivalent to a reading comprehension difficulty.

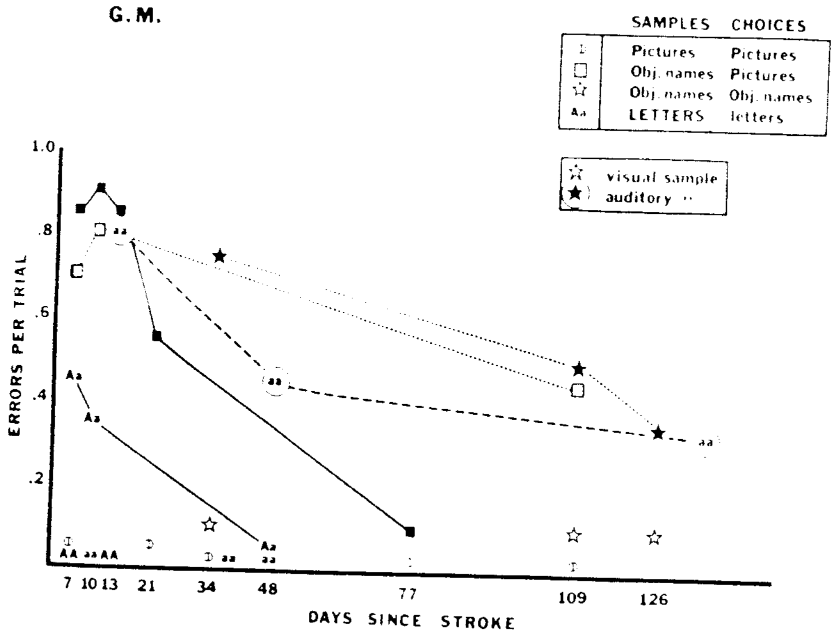

Fig. 7. Visual-visual and auditory-visual sample matching performance with various materials by subject G.M., described as Case No. 2. Shaded or encircled symbols indicate that an auditory visual sample match was required. Some of the more relevant points are connected by lines for easier comparison.

The boy also did quite well with simultaneous match or nonidentical pictures of the same object. Apparently he was either making this match purely on the basis of visual features in common, or he was able to formulate a name for the sample object to assist him in the match, although he was unable to say it aloud. We attempted to resolve this question by giving both identical and nonidentical pictures for delayed sample-matching. Table 2 shows the results. When an adjusting delay was employed, more errors were made (a shorter delay was tolerated) with nonidentical pictures in every case. Where the fixed delay was used, error rates with nonidentical pictures increased as the delay was increased; this was not the case with the identical pictures. These findings may be evidence that the boy was either not formulating a name for the sample object, or was unable to retain it as well as he retained visual images.

Case 3

A 3-year-old girl, with a normal developmental history, suffered a rapidly progressive loss of speech over a two-week period, followed by a 3-month period of decreased responsiveness to commands and conversation. The latter gradually improved, but she did not regain speech. She was seen in our clinic a year later, where the neurological examination was unrevealing. Pertinent laboratory data included electroencephalograms showing "focal

TABLE 2

Results of visual sample-matching tasks, pictures (errors/trials), Patient G. M. (MGH 159-16-68)

	Correct choice identical with sample	*Correct choice not identical with sample*
Adjusting delay (4 sec.)		
10-1-69		8/20
10-9-69	1/13	8/20
12-3-69	5/20	8/20
Fixed delay (10-22-69)		
4 sec.	6/20	8/20
20 sec.	5/20	13/20

epileptogenic activity in the left temporal and frontal regions," normal skull x-rays, normal hearing by GSR audiometry, and a normal IQ on the Leiter test.

After this girl had adapted to the experimental situation, we attempted without success to get her to match the spoken names of simple objects with pictutures of those objects. We then designed a simple ten-trial program to teach her this task. On the first trial of this program, the correct choice (the picture of the object whose spoken name was being given her as an auditory sample) was the only one visible. Over succeeding trials, the incorrect choices were gradually "faded in" by overexposure photography, until on the tenth trial all choices were of equal density. A back-up correction procedure was used; i.e., the projector reversed after each error and advanced after each correct choice.

Table 3 summarizes our experience with this procedure. Initial tests showed high error rates. She was able to get through the program well enough, but her performance broke down on subsequent test trials on which all incorrect choices were equally visible. It was important to ask at this point whether it was perhaps the skill of sample-matching which she could not manage. We know from other experiences

TABLE 3

Results of auditory-visual and visual-visual sample-matching tasks (errors/trials), Patient C. M. (MGH 131-57-24)

Date	*A-V Test*	*A-V Program*	*V-V Test*	*V-V Program*	*A-V Test*	*A-V Program*	*V-V Test*	*A-V Test*
12-11	20/20*				18/20			
12-15		0/10→3/5				0/10→ 6/10		
12-17				6/10→0/10		1/10→10/10	0/8	
7-23		0/14→7/10			7/8			
1-29				0/14→0/10		2/14→ 7/10		
						(letters)	2/20	18/20
						(Colors)	4/18	15/18

*Test materials are pictures of simple objects except where noted.

TABLE 4

Results of auditory-visual and visual-visual sample-matching tasks (errors/trials), normal controls

[illegible]	[illegible]	[illegible]	[illegible] Program	[illegible]	[illegible] Program
[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
2	[illegible]	[illegible]		[illegible]	[illegible]
3	3-8	1/4	6/9	8/13	16/13
4	3-11	1/10		1/10	
5	4-1	0/10		8/10	12/13
6	4-2	1/10		2/10	
7	4-7	0/10		0/10	
8	4-7	3/10		5/10	
9	4-8	0/10		0/10	
10	4-8	2/10		10/10	7/14—1/10
11	4-9	1/10		7/10	0/14—1/10
12	4-10	0/10		6/10	0/14—4/10
13	4-10	0/10		0/10	
14	4-11	1/10		10/10	0/14—2/10
15	4-11	3/10		4/10	
16	5-0	0/10		9/10	3/14—3/10
17	5-7	2/10		0/10	
18	5-10	1/10		0/10	
19	5-11	0/10		0/10	

that not every normal four-year-old has mastered this skill. We gave her the simple teaching program with visual samples. She apparently caught on to the task during the program, and managed subsequent tests without difficulty. Despite this, she retained her original difficulty with the auditory-visual sample-match.

Could it be that this discrepancy between auditory-visual and visual-visual sample matching is to be expected of the normal child in our experimental context? First of all, it is the experience of a number of investigators that one cannot expect to teach the task of visual sample matching by identity to a normal child under five years old, although many younger children may be able to grasp the task. On the other hand, it is rare to see a normal child over three years of age who is not able to pick out visual objects upon hearing their spoken names. Second, we administered these tasks to a small sample of normal children between the ages of three and five years. The results are shown in Table 4. The auditory visual match task was grasped immediately by nearly every child, while the visual match task was not grasped by many of the children. A number of these children were able to learn the task by the simple fading program to which we referred above.

Summary of Cases

In summary, our experimental findings in these three cases of acquired language disorder in childhood are in many ways more interesting for their differences than for their similarities. The left and presumably dominant cerebral hemisphere was involved in each case. Beyond this, it has not been possible for us to correlate specific behavioral deficits with specific locations of disease. However, the findings of all three cases have suggested that auditory visual equivalences are indeed important to language skills. In addition, these equivalences may be studied by essentially nonverbal techniques in the proper laboratory setting.

Teaching a Retarded Boy to Read (Sidman, 1970)

Children normally understand words they hear before they learn to read with comprehension. Also, they name objects before they learn to name printed or written words corresponding to the objects. For example, the subject of this experiment, an institutionalized 17-year-old boy, microcephalic and severely retarded, was able to match pictures, colors, and printed numbers to picture names, color names, and number names that were spoken aloud to him. But he was unable to do the matching correctly when the names were presented to him visually rather than spoken. Also, he could name the pictures aloud, but not the corresponding printed words. He could not write. He showed good auditory comprehension and picture naming, but little if any reading comprehension or oral reading.

Such behavioral observations, along with theoretical conceptions of central nervous system development and structure, have led many writers to postulate that reading, a visual task, evolves from the previous learning of auditory-visual equivalences. Birch and his coworkers (1964) report positive correlations between a test of auditory-visual integration and reading achievement. Most children break through the "sound barrier" in the first or second grade, and learn to understand not just words they hear, but words they see. Yet, whether auditory-visual learning is indeed a necessary or even sufficient prerequisite for reading comprehension seems not to have been studied experimentally. The data presented here will demonstrate that certain learned auditory-visual equivalences are sufficient prerequisites, even without explicitly teaching reading comprehension.

Preliminary tests evaluated the subject's proficiency at simple comprehension and naming tasks. He was then taught to match spoken to printed words. Final tests evaluated the effects of this teaching on his reading comprehension and word naming.

The subject sat before the panel of translucent windows described above. Visual word or picture samples appeared on the center window of the matrix. Auditory samples, repeated at 2-second intervals, were dictated from tapes over a speaker (Figure 8, left column).

In matching tests, the subject pressed the center window to bring choice stimuli, always visual, onto the outer windows of the matrix. Schematic examples of the displays are in the second column of Figure 8. On each trial, one choice, the correct one, corresponded to the sample; the other seven choices did not. The subject selected and pressed one of the choice windows. His correct choices were rewarded by chimes

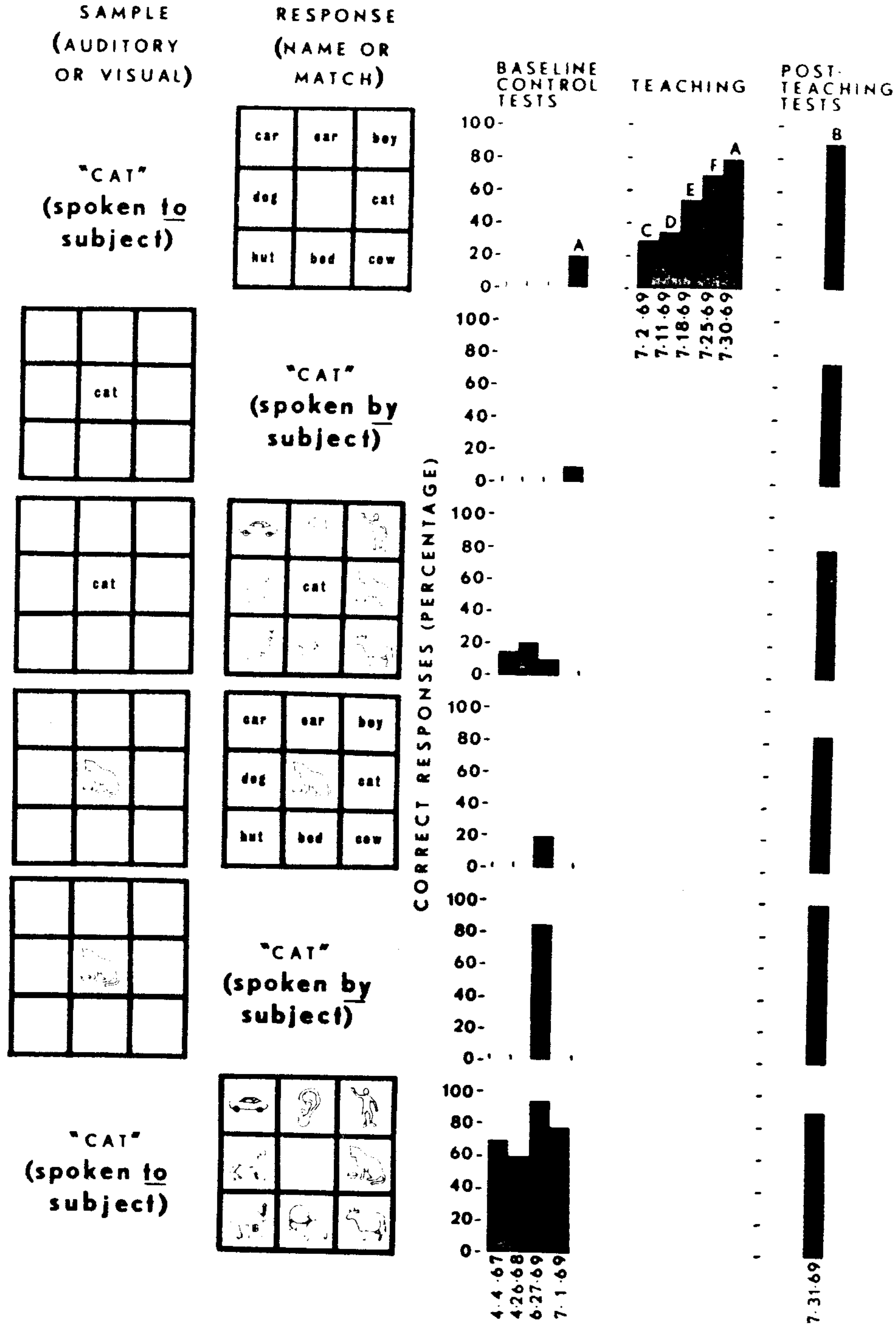

Fig. 8. Summary of results of sample matching teaching and test procedures with verbal materials in a single severely retarded boy. See text for explanation.

ringing and the delivery of a candy and a penny. No rewards followed incorrect choices. The stimuli disappeared after each choice and 1.5 seconds later a new sample began the next trial.

Each test had 20 trials. The sample and choice stimuli, taken from a list of 20 pictures, or the printed (lower case) or spoken names of the pictures, were: axe, bed, bee, box, boy, bug, car, cat, cow, dog, ear, hat, hen, hut, hoe, man, pie, pig, saw, zoo.

In oral naming tests, the subject had simply to name the sample picture or word aloud. Reward procedures were the same as in the matching tests.

The results of the preliminary tests are in the left column of bar graphs in Figure 8. Bars at the lower left show the subject's scores in tests that required him to match spoken word samples to picture choices. In four tests, administered from April, 1967, to July, 1969, he scored from 60 to 95 per cent correct, demonstrating a fair proficiency at this type of auditory comprehension. He also scored 85 per cent in naming the pictures (second row from the bottom).

In reading (all tests that involved printed words) the subject scored poorly. Continuing up the left column, these tests were: matching picture sample to printed word choices; matching printed word samples to picture choices; naming printed words; and matching spoken word samples to printed word choices. The possibility that the subject could not distinguish the printed words from each other was ruled out by his score of 95 per cent in matching printed word samples to printed word choices (not shown in Figure 8).

The subject came to the experiment knowing the equivalence of spoken words to pictures (Figure 9:I). Would teaching him the second auditory-visual equivalence, spoken words to visual words (Figure 9:II), suffice to establish reading comprehension, the purely visual equivalence of printed words to pictures (Figure 9:III, IV)? Also, would teaching him auditory-visual word matching suffice for oral reading (Figure 9:VI) to emerge?

In the teaching procedure, sample stimuli were words spoken to the subject. The

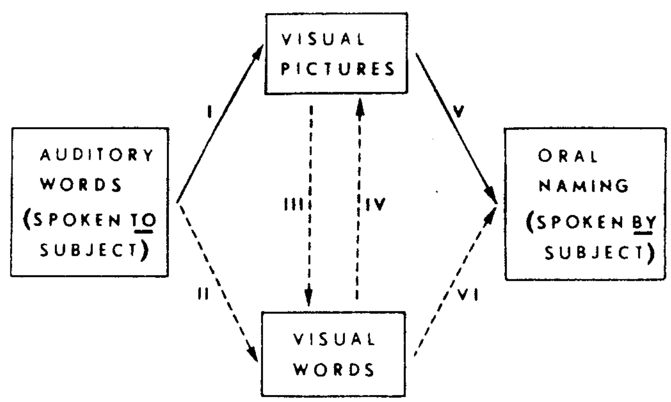

Fig. 9. Schematic diagram showing interrelationships of various specific skills involved in reading. See text for explanation.

choices were printed words. When the subject chose a wrong printed word, the display remained unchanged until he pressed the correct window. If he made one or more errors on a given trial the chimes rang when he finally pressed the correct window, but he did not receive candy or a penny. Each phase of the teaching procedure started with only two trials (sample-choice combinations), the two being repeated until the subject's first choices on both were correct. Then a third trial was added. When his first choices on all three were correct, a fourth was added. This progressive enlargement of the set continued as the subject attained each criterion of mastery, until his first choices were correct on the full set of 20 trials.

Six versions or sets of auditory-visual word-matching materials presented the same 20 sample words in different trials sequences, and each set displayed a different combination of seven wrong words along with each correct word. Set A was used for the preliminary control test. Then the subject was taught Set B until he scored 100 percent, and was tested on Set C. His low score on Set C (Figure 8, center section, first bar) suggested that his learning of Set B had been specific to the particular sequence of correct window positions and to the particular wrong words displayed along with each correct word.

The subject then learned Set C, reviewed Set B to the same 100 per cent criterion, and was tested on Set D. The process of learning, reviewing, and testing on a new set continued through Set F, and the center section of Figure 8 shows the gradual improvement on each new test. Finally, the subject was retested on Set A, which he had not seen since the preliminary test. The change from 20 to 80 percent correct on Set A demonstrated his new proficiency at the task.

After the teaching, all comprehension and oral naming tests were administered once more. Scores are in the right column of Figure 8. The subject maintained his good performance on the first auditory-visual word matching set he had learned (upper right), in matching spoken words to pictures, and in picture naming (lower right). His reading comprehension and oral reading improved greatly. Having learned to match spoken word samples to printed word choices, he was then able, without additional teaching, to match picture samples to the printed word choices, to match printed word samples to picture choices, and to name the printed words.

Given the subject's ability to match spoken words to pictures, teaching him the second auditory-visual equivalence, spoken to printed words, sufficed for the emergence of purely visual reading comprehension. A connectionistic interpretation might be that the visual words and pictures became equivalent to each other (Figure 9:III, IV) because each, independently, had become equivalent to the same spoken words (Figure 9:I, II). After the subject learned auditory-visual word matching, however, he also proved capable of visual-word naming, or oral reading (Figure 9:VI). Although the subject did not name the words or pictures aloud during the reading comprehension tests, it remains to be determined whether reading comprehension would have emerged if oral reading had not.

If naming is not necessary for visual word-picture equivalence to emerge, then words presented via the tactile modality, or even arbitrary visual nonsense syllables, would be substitutable for auditory words in this experiment. That deaf children learn to read suggests that such substitution is feasible. Furthermore, it may be possible to teach any two of the three equivalences, I, II, and III (or IV) in Figure 9, and find that the third also emerges. For example, if the subject is taught I and III (or IV), he may then be able to do II, matching auditory to visual words. If purely visual equivalences can facilitate auditory-visual equivalences, and if another modality can be substituted for the auditory, then auditory-visual learning, although sufficient for reading comprehension, will prove not to be a necessary prerequisite.

One may ask if oral reading will always emerge after a subject has learned auditory-visual word matching. Guess (1969) has shown that receptive language training need not facilitate the learning of productive speech, but the present data emphasize his conclusion that the relation expressive to receptive repertoires requires further experimental analysis. The present experiment indicates, however, that matching spoken words to pictures and to printed words (sufficient prerequisites for reading comprehension) can be taught without explicitly teaching oral reading, and therefore completely without the intervention of a teacher. It remains to be determined whether picture naming need be taught directly and whether the method can be extended to other reading material and other kinds of comprehension.

SUMMARY OF DISCUSSION

QUESTION: In the last case, where there is a failure to make auditory-visual match, what information do you have about the response to auditory signals in general?

ROSENBERGER: The best we could say was that her psychogalvanic audiometry was normal. We didn't have the materials then that we have now to test nonverbal auditory discrimination. We now have tests that can show whether a child can match a train whistle sound with a picture of a train, a police whistle with a picture of a policeman, and so forth.

QUESTION: Did she respond to verbal commands?

ROSENBERGER: We could get no response at all with verbal commands.

QUESTION: Did I undertand correctly that pretesting took place over two years, whereas the teaching took place over one month?

SIDMAN: Correct.

QUESTION: In terms of your Figure 9, would you be willing to speculate, if you were teaching these in sequence, whether you would teach the first, teach the second, teach the third, in the sequence in which they are numbered?

SIDMAN: There's a whole chain of changes to be learned here. For example, we are working with two children now who can't even do the straight visual discrimination. They can't tell the words apart as forms. We have to teach them that first before we can do any of this. So that would be a prerequisite. Other children will have to be taught literally to discriminate sounds before any of this can go on. Then they will have to be taught to produce those sounds. I don't know what the answer to that question would be. I suspect it is easier to teach them to name a picture than to name a word because children have equivalents of pictures, objects around them from the moment they can respond at all.

QUESTION: You didn't test III, but the implication is that if you teach III and not II you would generate IV.

SIDMAN: There are a number of implications like that, but there is no indication of the necessity for that sequence at all.

QUESTION: Did you have the opportunity to observe any induction of this facilitating effect outside of the set of training stimuli?

SIDMAN: No, we didn't check that. But that would really be a startling thing, wouldn't it, if we taught the child those 20 words and he not only could do those 20, but any others as well? That would really be fabulous but I just can't believe that is going to happen. It would be a miracle.

QUESTION: Would you think, however, that the bonus effect might be possible under at least extreme conditions; that is, that you would get some free ones?

SIDMAN: No, I don't think so.

QUESTION: If the child is taught phonetically, then, as it is termed in the reading field, can't he unlock the new words?

SIDMAN: Yes, having been taught phonetically and having been taught to name the picture, then I think he can do it.

QUESTION: What about any other generalizations beyond the specific pictures and the printed words you have used—that is, other representations?

SIDMAN: Our selection of pictures to start with was purely arbitrary. We didn't select a group of pictures that we had taught the child. We selected a group of pictures and then tested him on them, and he knew them. So probably he also knows the names of many other pictures as well. He also knows those same pictures in other views. We couldn't possibly have picked just the 20 views of each of those pictures that he knows and no others.

QUESTION: I'd like to ask a more general question. It doesn't relate specifically to this experiment. But you touched on the interaction of the organism, its neurological-physiological status, and certain kinds of environmental events. Now, could you speculate somewhat on the processes of language acquisition and development in the context of developmental processes? What do your data and what you have been talking about mean in terms of future directions of research with respect to problems of language acquisition and development?

SIDMAN: I'm looking forward to the very exciting prospect of being able to teach many children to read with comprehension who haven't been able to do so before, to at least get them started this way. So, even if we can't teach more complicated kinds of comprehension, at least they will now be amenable for work with a teacher. It's going to take a lot of my time in the near future, just for that one simple little bit of development of reading, of language. Giving children all of the specific prerequisites that one needs to do these tasks is a large curriculum development problem. Teaching a child to discriminate letters as forms and letter names as sounds and teaching him to produce those same patterns of sounds is a problem. I think a teacher program for retarded children must extend down to that level.

QUESTION: By extending this to more difficult material, can actual speech and more complex speech be generated by just reading?

SIDMAN: Can you do this same thing starting low with other children of single words? Could you do it with adjectives? Could you do it with prepositions? I think you can with those. Programs have been worked out using words and pictures for teaching adjectives and prepositions. I don't know about verbs. That will take more ingenuity. Probably the same general kinds of principles, but a different kind of set-up, perhaps using moving pictures rather than still pictures, will be needed to teach verbs and tenses, then phrases, sentences, paragraphs. Could the same kind of techniques be adapted? I don't know. These are all questions to be looked into. But I think they are now worth the effort.

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