Stimulus Control Analysis of Language Disorders: A Study of Substitution Between Voiced and Unvoiced Consonants

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This study attempted to analyze defective stimulus control relations underlying persistent substitution between voiced and unvoiced consonants in the speech and writing of two children. A series of 20 tests was administered repeatedly. Some tests consisted of matching-to-sample tasks, with dictated words, printed words, or pictures as samples. Comparison stimuli were arranged in pairs of printed words or pictures, such that the only difference in their corresponding spoken words was the voicing of one consonant phoneme. In other tests, a stimulus (dictated word, printed word, or picture) was presented, and the subject was required to emit an oral response (repeat the dictated word, read the printed word, or name the picture) or a written response (write to dictation, copy the word, or write a picture name). Other tests required the subjects to make a same/different distinction in pairs of dictated words that did or did not differ in the voicing of a single phoneme. Results showed distinct deficit profiles for each subject, consisting of patterns of defective stimulus control relations. The subjects were able, however, to distinguish between voiced and unvoiced sounds and to produce these sounds.

A behavioral account of language is particularly useful in the study of language disorders, because it distinguishes different functional units that may involve similar response topographies. An aphasic patient, for instance, may be unable to

speak a word in a particular situation, although he will readily speak the same word in a different situation. As Skinner pointed out, "... it is only traditional theory that makes this surprising. The aphasic has lost some of the functional relationships

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which control his verbal behavior." (Skinner, 1957, p. 190). Thus, the behavioral investigation of language disorders may permit us to specify the functional relations affected, the degree to which each relation has been affected, and their different patterns of recovery or remediation.

The series of studies conducted by Sidman and colleagues (e.g., Mohr & Sidman, 1975; Mohr, Sidman, Stoddard, Leicester, & Rosenberger, 1973; Leicester, Stoddard, Mohr, & Sidman, 1971; Sidman, 1971; Sidman, Stoddard, Mohr & Leicester, 1971) exemplifies the fruitfulness of this approach. Mohr and Sidman (1975) observed that three major classes of variables are to be considered in the analysis of behavioral deficits: a) the controlling relation between behavior and its consequences, b) the controlling relation between stimuli and responses (stimulus control), and c) "instructional" variables, involved in any assessment condition, to guarantee that the patient will emit behavior relevant to the purposes of the test.

Sidman and colleagues presented stimuli commonly used in aphasia research (words, pictures, colors, digits, letters, and trigrams) in a series of tests. Different response modes (naming, writing, simultaneous matching to sample, and delayed matching to sample) were combined with different stimulus modalities (visual, auditory, and tactile). It was possible, therefore, to determine whether deficits involved reception in particular stimulus modalities, production of specific responses, or defective stimulus control relations. Sidman and colleagues observed that many aphasic deficits involve a breakdown in the controlling relations between stimuli and responses; that is, they are deficits in stimulus control (e.g., Mohr & Sidman, 1975; Sidman *et al.*, 1971).

Sidman and Kirk (1974) extended this approach to the investigation of letter reversals in children with reading disabilities. Their results suggested that persistent reversals may be a stimulus control deficit and a component of a more general language deficiency. We may also conclude that this test methodology may have a more general

applicability in the functional analysis of poorly understood language problems.

One such problem is persistent substitution between voiced and unvoiced phonemes in speech and/or the corresponding graphemes in writing. For some children these speech errors may be very frequent and, upon writing acquisition, transfer to spelling. Errors may persist through first grade, so as to compromise the intelligibility of the written material and interfere with school performance (Bonatto & Gioielli, 1988).

It is not yet clear which variables are involved in this deficit. A failure in auditory discrimination has been suggested (Moraes, 1986; Rodrigues, 1981; Spinelli, 1983). However, this pattern of errors may also occur in children with normal scores in auditory discrimination tests. Individual children may present the problem mainly in speaking but not writing, in writing but not speaking, or in both response modes. This variability is not accounted for by diagnostic investigation through standard tests.

In the present study, we adapted the testing methodology developed by Sidman and colleagues in an attempt to analyze functional relations underlying persistent substitution between voiced and unvoiced consonants. Although the study was conducted in the Portuguese language, problems like those addressed here are likely to occur in other languages as well.

METHOD

Subjects

The subjects were two boys who attended a public elementary school. Both boys had been referred for speech therapy because of substitutions between voiced and unvoiced consonants in speech, reading and writing. Pure-tone and impedance audiometry tests revealed normal peripheral auditory acuity in both boys.

Subject 1 was 8 years-6 months old, and in the first semester of second grade. Prior to participating in this study, he had received speech therapy for 3 years because of a severe articulation disorder. During his first year of therapy, his articu-

lation problems were corrected. In his subsequent two years of therapy, he received treatment to correct his confusion between voiced and unvoiced consonants. He learned to articulate each voiced and unvoiced phoneme clearly in oral repetition (echoic) and picture naming (oral tacting) tasks and to discriminate their sounds accurately in informal matching-to-sample tasks. This improvement did not generalize outside the speech therapy context, however, and confusion between voiced/unvoiced consonants persisted in his everyday speech. Further, he exhibited confusion between voiced and unvoiced consonants when reading and writing after he achieved literacy.

Subject 2 was 11 years-7 months old, and in the second semester of third grade. He had never been in speech therapy and did not enter it until the end of this study. He was referred to this study because of hoarseness and substitution between graphemes corresponding to voiced and unvoiced sounds. His teacher reported generalized school difficulties. According to his father, the boy made many errors in speech until about the age of 9 or 10; however, he was unable to specify the nature of the errors and whether or not they involved confusion of voiced and unvoiced phonemes. An otolaryngology evaluation of his speech and hearing mechanisms revealed no problems.

Setting and Materials

The study was conducted in the speech therapy rooms of the city's Health Department. The rooms were not sound-proof, but external noise was minimal. Each room had a child-size desk and chairs, an adult size desk and chairs, a wooden cabinet, and a mirror.

Visual stimuli were either printed words (meaningful or nonsense) or picture representations of meaningful words. These stimuli were pasted on sheets of white, unlined paper measuring approximately 22 cm by 28 cm. Words were uppercase letters printed in black; each letter measured approximately 1.5 cm in height and 0.35

cm in width. Pictures were photocopies of black and white drawings, each picture measured approximately 5 cm by 5 cm.

Auditory stimuli were words (meaningful or nonsense) dictated by the experimenter. Tape recordings were not used to avoid distortion of the subtle voicing feature. In order to prevent discrimination of the words based on visual cues, the experimenter held a sheet of white paper in front of her mouth while dictating a word.

For tasks that required a written response, the subject was given a pencil and paper. Oral responses by the subject were recorded with a cassette recorder.

The stimulus set was composed of word pairs. They are referred to as minimal pairs because the words in each pair differed in only one feature – the voicing of one consonant phoneme in either the initial or medial position (e.g., *vaca/faca*; *gola/cola*; *dia/tia*; *doze/doce*; *gato/gado*, for meaningful words; *bamelo/pamelo*, *dofito/tofrito*; *gabora/cabora*, for nonsense words). Minimal pairs were selected to provide a sample of plosive phonemes (/p/ and /b/; /t/ and /d/; /k/ and /g/) and fricative phonemes (/f/ and /v/; /s/ and /z/; and /sh/ and /zh/). The frequency of each minimal pair was balanced in the tests, so that each minimal pair occurred equally often.

Procedure

Overview. The tests had four different task requirements: 1) oral responses to test stimuli; 2) written responses to test stimuli; 3) simultaneous matching to sample; and 4) oral responses stating whether two dictated words were the same or different. The combinations of stimuli and response types resulted in 20 different tests. Table 1 shows the type of stimuli presented, the type of response required for each test, and the type of verbal operant assessed. The complete set of tests was administered three times to each subject. Each subject received two sessions per week; the maximum session time was about 30 minutes. The number of tests conducted in each session, as well as the order of the tests, varied for each subject. Subjects 1 and 2

Table 1

Type of test or sample stimulus, comparison stimuli, response, and verbal operant on each test.

Test No.	Test or Sample Stimulus	Comparison Stimuli	Response	Verbal Operant
1	Dictated word		Repeat word	Echoic
2	" " (nons.) ^a		" "	Echoic
3	Printed word		Read word aloud	Textual
4	" " (nons.)		" " "	"
5	Picture		Name picture	Tact
6	Dictated word		Write word	Transcription
7	" " (nons.)		" "	"
8	Printed word		" "	Copy-a-Text
9	Picture		" picture name	Tact
10	Dictated word (e.g., "faca")	2 pictures (e.g., faca and vaca)	Select picture	Receptive (Mand compliance)
11	Printed word (e.g., gola)	2 pictures (e.g., gola and cola)	" "	"
12	Picture (e.g., cinco)	2 pictures (e.g., cinco and zinco)	" "	----- b
13	Dictated word (e.g., "bote")	2 printed words (e.g., bote and pote)	" word	Transcription (selection-based)
14	Dictated word (nons.) (e.g., "tofito")	2 printed words (nons.) (e.g., tofito and dofito)	" "	"
15	Printed word (e.g., giz)	2 printed words (e.g., giz and xiz)	" "	-----
16	Picture (e.g., vaca)	2 printed words (e.g., vaca and faca)	" "	Tact (selection-based)
17	Pair of dictated words (e.g., "faca"/"vaca")	3 pairs of pictures (e.g., faca/faca, etc.)	" pair of pictures	Receptive (Mand compliance)
18	Pair of dictated words (e.g., "faca"/"faca")	3 pairs of printed words (e.g., faca/faca, etc.)	" pair of words	Transcription (selection-based)
19	Pair of dictated words (e.g., "vaca"/"vaca")		Say "same" or "different"	-----
20	Pair of dictated words (nons.) (e.g., "cabora"/"gabora")		Say "same" or "different"	-----

^a nons. indicates nonsense words

^b identity matching, which does not constitute a verbal operant

received 20 and 18 sessions, respectively. Immediately before each test began, the experimenter provided oral instructions; these instructions briefly stated the type of stimuli that would be presented and the response requirement.

Correct responses were followed by social reinforcement in the form of praise or approval. Incorrect responses had no programmed consequences other than termination of the trial. The intertrial interval was the time required for the experimenter to record the response, remove all stimuli used in the trial (and the response sheets used in writing trials), and present stimuli for the next trial.

The tests provided differential consequences to enhance test validity (Sidman et al, 1971), thus introducing a training variable to the analysis. Hence, performances that were defective on initial testing might show improvement across repetitions of the tests. The potential influence of this variable within a given test was minimized, however, by presenting different stimuli on each trial.

Tests requiring oral or written responses. Tests 1 to 5 required oral responses. In Tests 1 and 2, test stimuli were dictated words (meaningful and nonsense words, respectively), and the subject was asked to repeat each word (echoic). In Tests 3 and 4, the stimuli were written words (meaningful and nonsense, respectively), and the subject was asked to read each word aloud (textual). Test 5 presented pictures as stimuli, and the subject was asked to say the name of each pictured object (tact).

Tests 6-9 required written responses. The stimuli were dictated words in Tests 6 and 7 (meaningful and nonsense, respectively), and the subject was asked to write each word to dictation (transcription). Test 8 presented meaningful printed words, and the subject was asked to copy each word (copy-a-text; no test was conducted requiring subjects to copy nonsense words for reasons of economy). In Test 9, the stimuli were pictures, and the subject was asked to write the name of the pictured object (tact).

Matching-to-sample tests. Tests 10-18 in Table 1 show the combinations of samples

and comparison stimuli in matching-to-sample tests. The subject was required to select the comparison that corresponded to the sample. In Tests 10-16, the sample was a single dictated word, printed word, or picture. In Tests 10-12, comparisons were two pictures; in Tests 13-16, comparisons were two printed words. The comparison stimuli presented on a given trial always formed a minimal pair. Thus, if the sample was the dictated word "faca" (knife), the comparison stimuli were the printed words FACA and VACA (cow) (Test 13; selection-based transcription), or the pictures of a knife and a cow (Test 10; receptive [mand compliance]).

In Tests 17 and 18, the sample was a pair of dictated words. The words were either a minimal or identical pair (with the test phoneme either voiced or unvoiced). Three pairs of corresponding pictures or printed words were presented as comparison stimuli. Thus, when the comparison stimuli were the pairs faca/faca, vaca/vaca, and faca/vaca (or vaca/faca), the experimenter could dictate any of these pairs of words as a sample.

On matching-to-sample trials with visual samples, the sample stimulus was centered at the top of the sheet of paper. When the sample was an auditory stimulus, it was dictated immediately after the comparison stimuli were presented. Comparison stimuli were presented on the lower portion of the sheet. When the comparisons were two words or pictures, they were presented at the left and right of the sheet. When the comparisons were three pairs of words or pictures, they were displayed at the left, center, and right. The printed words or pictures in each pair were presented close together and side by side.

Tests for auditory discrimination of voicing differences. Tests 19 and 20 in Table 1 correspond to standard tests for auditory discrimination of differences between voiced and unvoiced sounds. The experimenter dictated a pair of words, and the subject was asked to say whether the words were the same or different. Meaningful words were used in one of the tests; nonsense words were used in the other.

These tests may be regarded as a "yes/no" variant of identity matching with dictated words. The first word of the pair may be considered the sample stimulus and the second word as the comparison stimulus. The subject was required to say "same" (yes) when the comparison stimulus was identical to the sample, and "different" (no) when the comparison stimulus differed from the sample in the voicing of a phoneme.

Pretraining: Matching pictures to dictated names. Because of the small number of minimal pairs available in the Portuguese language, some words not easily representable had to be used. Therefore, these words were illustrated by pictures that ordinarily would be given a more familiar name. For example, one word was a proper name "Juca" (Jack) represented by a picture of a boy. Another was "zinco" (zinc) represented by a picture of a roof (supposedly a zinc roof). Hence, in order to conduct the intended evaluation, it was necessary to establish and/or verify, within the experimental context, a one-to-one correspondence between each picture and its experimentally-defined name. This was done with matching-to-sample tests. Naming (oral tacting) tests were then conducted. This training ensured that subjects would assign the experimentally-defined name to each picture and would not refer to the pictures by any other name, at least in the experimental context. Frequent voicing errors in the subjects' naming responses were not corrected. For example, if a subject named the picture of a boy as "Juca" (Jack) or any form resulting from a voicing error, such as "Juga," but not "menino" (boy), the subject was considered to have learned the experimentally-defined relation.

Each picture from the test set was presented as one of the comparison stimuli in one four-choice matching-to-sample trial; the remaining comparisons were unambiguous pictures not from the test set. The experimenter then dictated the name of the picture from the test set and asked the subject to point to it. Correct selections were

reinforced. During this pretraining neither subject made an incorrect selection.

Naming (oral tacting) trials were then conducted with each picture from the test set. If the subject spoke the experimentally-defined name, his response was reinforced. If the subject emitted a different tact to any picture, another series of matching trials was conducted, followed by another tacting test. This sequence was repeated until the subject tacted each picture with the experimentally-defined name.

Agreement. An independent observer (a certified speech pathologist) transcribed the names spoken by the subject from audio-tapes of all oral tacting sessions. This transcription was compared to the one made by the experimenter. Agreement (agreements/agreements plus disagreements) was 95.8% for Subject 1's tacting responses and 99.5% for Subject 2's tacting responses. An independent observer also transcribed all the words written by the subjects in writing tests, and this transcription was compared to the one made by the experimenter. Agreement was always 100%.

RESULTS

Results are expressed in terms of percent correct responses on each test. In tests that required oral or written responses, the only errors actually made by the subjects were substitutions between voiced and unvoiced phonemes or between the corresponding graphemes. In these tests, unlike matching-to-sample tests, a single trial could present more than one opportunity for a voicing error. For example, the word "faca" (knife) was used in a minimal pair with "vaca," to assess the voiced phoneme /f/ and its voiced counterpart /v/. However, in writing or saying the word, the subjects could make an error in the other consonant phoneme, by confusing the phonemes /k/ and /g/ and producing the forms "faga" or "vaga." Hence, these words presented two opportunities for a voicing error. On the other hand, the words "varinha" and "farinha" presented only one opportunity for such an error, the phonemes /v/ and

Fig. 1. Percent correct scores of Subject 1 in the first and last application of each test. Graphs show, from bottom to top, test requiring oral responses, written responses, matching with pictures as comparison stimuli, matching with printed words as comparison stimuli, and same/different discriminations. The abscissa shows the type of sample or test stimulus used for each test. When bars are absent, no test was conducted with the corresponding combination of stimulus response. Tests requiring identity performances are indicated by bold outlines.

/f/ or their corresponding graphemes. Therefore, in tests of oral and written responses, the percent correct was calculated relative to the total number of opportunities to make a voicing error.

Figures 1 and 2 present the percent correct scores for Subjects 1 and 2, respectively, in the first and last administration of each test. Each row of bars shows accuracy on tests that require the same type of response. The abscissa identifies the type of test or sample stimulus used for each test in the column(s) of bars above it. Absent bars indicate that no test was conducted with the corresponding combination of test or sample stimulus and type of response (For example, no tests with picture comparisons could be conducted when sample stimuli were dictated or printed nonsense words.). Bars for identity tasks are highlighted by bold outlines. These tasks require the subject to select (matching tests) or produce (naming and writing tests) a stimulus identical to the sample or test stimulus presented by the experimenter or to state whether two dictated words are the same or different. Nonidentity tasks require previous learning of arbitrarily established relations between stimuli (see Sidman *et al.*, 1971), or, in the case of nonsense words, mastery of the phoneme-grapheme relations. For each subject, the description of the results will begin with those obtained in the initial tests. These tests most accurately reflect the subjects' levels of performance on entering the study, before repeated exposure to differential feedback provided on the tests. Description of any changes observed in the final tests will follow.

Analysis of Results for Subject 1

Identity performances. On all identity tasks except those that required oral responses, the subject's scores show perfect to near-perfect accuracy. In marked contrast, on the identity task that required him to repeat the word spoken by the experimenter, he was able to do so with only about 50% correct accuracy (Figure 1, bottom row). On the other hand, he was able to state accurately whether two dictated

words were the same or different (top row). Although this test permitted comparison of the words presented in close temporal juxtaposition, which might be considered an easier task, there was other evidence of the subject's good discrimination of the phonemes (see below). The echoic problem, therefore, did not appear to be based on failure to discriminate voiced and unvoiced phonemes.

Nonidentity performances. On nonidentity tasks, the subject obtained his highest scores when required to match printed word and picture comparison stimuli to meaningful dictated word sample stimuli (transcription and tacting, selection based, with both single words and word pairs; Figure 1, second and third rows). All these scores approached 100% correct and show excellent discrimination of the dictated phonemes. He did slightly less well when the dictated samples and printed word comparisons were nonsense words (selection-based transcription) and when he had to write the dictated words (transcription; second and fourth rows), but his scores were still relatively good (approximately 80% correct). He also matched pictures to printed word samples at better than 80% correct accuracy (third row).

As with the identity tasks, the subject's lowest nonidentity scores are again seen on those tasks that required oral responses. When asked to name printed meaningful words (textual responses), his score was only slightly above 50% correct, and his scores were even lower when he had to name (tact) pictures and printed nonsense words (textual responses; Figure 1, bottom row). This observation may explain his relatively poorer scores on the remaining nonidentity tasks, matching printed words to picture samples (selection-based tacting; second row) and writing the picture names (written tacting; fourth row). We will discuss this point in reviewing the subject's deficit profile (see below).

Differences in performance in the first and last test applications. On repetitions of the tests with differential consequences, the subject's scores increased from the first to the last application on 12 tests, remained

the same on 7 tests, and decreased on only one test. The greatest increases occurred in all tests on which his initial scores were lowest and is most evident in all tests that required oral responses. The other two tests that show appreciable increases in accuracy are the ones in which pictures were presented as stimuli for written tacting (Figure 1, fourth row) or as samples for matching to printed words (selection-based tacting; second row).

Deficit profile. The results show clearly that the subject was able to distinguish between voiced and unvoiced phonemes. His major difficulty was in oral responding. His poor scores on these tests were not due to lack of capacity to produce any particular phoneme. He was able to produce each phoneme correctly on at least half the trials (across all tests). Moreover, an analysis of his errors showed that they were bidirectional; he sometimes substituted a voiced for a unvoiced phoneme and sometimes did the opposite with the same minimal pairs. His errors, therefore, had to be a product of defective stimulus control. The error analysis did reveal a bias, however; he unvoiced a voiced phoneme more often than voicing an unvoiced one. The bias suggests that it may have been somewhat more difficult for this subject to produce voiced phonemes, which may have been a contributing factor.

It is possible that the poor oral responding of the subject could have affected other performances that may have involved tacting as a mediating response. Several features of the data provide support for this interpretation. First, if writing picture names and matching printed words to picture samples required an antecedent vocal stimulus (saying the picture name covertly), and if at the same time the subject tacted the pictures inaccurately, that would explain the relatively lower scores in writing and matching to picture samples. Second, when the subject's oral tacting of the pictures showed marked improvement, as it did on the last test, that was accompanied by substantial increases in his writing and matching scores with picture samples. Third, when the experi-

menter provided a vocal stimulus (or stimuli) as the sample, the subject's writing and matching scores were generally much higher, even approaching perfect accuracy.

Analysis of Results for Subject 2

Identity performances. Figure 2 shows that Subject 2 obtained virtually perfect scores on all identity tests, including those that required him to repeat words dictated by the experimenter. Thus, like Subject 1, he showed good discrimination of the voiced and unvoiced phonemes, but unlike Subject 1, he could produce the phonemes under accurate stimulus control.

Nonidentity performances. Subject 2 provided further evidence that he discriminated the phonemes without difficulty, by matching pictures and pairs of pictures to dictated words and word pairs as samples with perfect or near perfect accuracy (Figure 2, third row). In addition, he tacted the pictures orally at approximately the 90% correct level. He showed little to no problem, therefore, with controlling relations between the pictures and their names.

All of this subject's deficient nonidentity scores (accuracy scores of 80% correct or lower) involve written words, both as stimuli (whether sample or comparison stimuli; Figure 2, second and fifth rows) and as productions by the subject (fourth row). He did least well with nonsense words, in writing them to dictation and in naming them. He obtained his best score with written words in writing the picture names (written tacting).

Differences in performance in the first and last test applications. For this subject, improvement in performance with repetitions of the test with differential consequences was not as clear as for Subject 1. However, an improving trend is discernible if only the tests which yielded poor scores in the first test administration are considered. His performance in the final tests was better in six out of seven tests on which the initial scores were lower than 80%. All these tests involved printed word stimuli or written productions.

Deficit profile. Responding by Subject 2

Fig. 2. Percent correct scores of Subject 2 in the first and last application of each test. See Figure 1 caption for other details.

was highly accurate on all identity tests, and on all nonidentity tests that did not involve printed words or writing. His performance was impaired on all nonidentity tests that required him to write or respond to printed words. His deficits were largely specific, therefore, to all controlling relations that involved correspondence between voiced and unvoiced sounds and their graphemes.

DISCUSSION

The present study adapted the test methodology introduced by Sidman and colleagues (e.g., Sidman et al., 1971) to analyze performance of two children referred to speech therapy because of substitution between voiced and unvoiced sounds or the corresponding graphemes. The tests revealed that, for the present subjects, there was no deficiency in their capacity to distinguish between voiced and unvoiced sounds or in their capacity to produce them. Some of the stimulus control relations involving voiced or unvoiced phonemes and/or graphemes were defective, however.

The test methodology permitted us to identify different relations that were deficient for each subject, and distinct deficit profiles were revealed. Deficient performance of Subject 1 derived primarily from poor stimulus control over emission of voiced and unvoiced sounds. This subject scored most poorly in tests that directly required vocal responses. As noted above, his deficient performance in other tests might have been related to mediation by covert and imperfect vocal responses; that is a reasonable and logical assumption. For Subject 2, on the other hand, stimulus control over emission of the sounds was virtually perfect. For this subject, writing the graphemes corresponding to voiced and unvoiced sounds was under poor stimulus control, and these written graphemes also exerted poor stimulus control over different non-identity naming and matching performances.

An assumption underlying the analysis of the deficit profiles was that a virtually perfect performance was to be expected in

all tests from subjects who did not present reception, production, or relational deficits. This seems particularly important regarding the performance with nonsense words. If "normal" subjects also show a decrease in accuracy with nonsense words, similar to the one observed with the subjects in the present study, this decrease may be attributed to unfamiliarity with the words. We conducted the tests with one normally capable subject, and his score on all tests, including the ones with nonsense words, was 100% correct. To the extent that this result may be generalized to other normal subjects, the decrease in accuracy shown by subjects with a pattern of phonemic substitution would indicate that, for these subjects, contextual cues are also important in the discrimination and production of voiced and unvoiced sounds.

Determining the specific relations that are impaired has clear implications for speech therapy. First, it is apparent that not much can be gained by attempting to improve the subjects' distinction between voiced and unvoiced sounds, or their production of these sounds. It is clear that specific stimulus-response relations are impaired for each subject, and they require different treatment approaches. For example, Subject 1's major deficits involved oral responding, but his oral performance tended to be somewhat better when he had a meaningful textual cue (Figure 1, bottom row). This finding suggested that one might profitably build upon his relative strength by teaching accurate oral reading, and then examining transfer to other forms of speech and to performances that might be mediated by naming. Remediation efforts for Subject 2 might concentrate on developing stimulus control over writing and stimulus control by written material.

The mere repetition of the tests seemed to improve performance for both subjects, very likely due to the provision of differential consequences during testing. Similar results were reported by Sidman and colleagues (e.g., Mohr et al., 1973; Sidman & Kirk, 1974; Sidman et al., 1971). If reinforcement of correct responses emitted in a trial and error format was enough to produce a

marked improvement in performance, it seems likely that a more significant improvement can be achieved by the use of stimulus control shaping methods. Identification of the deficiencies in stimulus control is a necessary step in order to determine the stimulus control relations to be taught. A likely continuation for this research program would be to apply the stimulus shaping methods already reported in the literature to improve the stimulus control relations shown to be deficient for each subject. This remedial technique was implemented successfully in Subject 1's therapy, by enhancing letters corresponding to voice and unvoiced sounds and then gradually removing the emphasis.

With respect to an analysis of the subjects' stimulus control deficits in terms of the types of verbal operants affected, we can make the following observations. In the case of Subject 1, his greatest deficits were with the operants that involved oral productions – echoic and textual responses and oral tacting. Also affected, but to a lesser degree, were written and selection-based tacting, operants that might be presumed to depend on accurate oral (but covert) tacting. Other operants, such as written and selection-based transcription and receptive mand compliance, were not affected. All of Subject 2's deficient performances, even those affected only slightly, involved either printed word stimuli or written production – written and selection-based transcription and tacting, textual responses, and receptive mand compliance with printed word samples. Oral tacting, echoic responses, and receptive mand compliance with dictated samples were not affected. These results support Skinner's (1957) speculative analysis that a complete verbal repertoire is composed of verbal operants that are functionally independent.

The data also extend other research that supports that conclusion (e.g., Hall & Sundberg, 1987; Sundberg, San Juan, Dawdy, & Argüelles, 1990).

REFERENCES

- Bonato, M. T. L., & Gioielli, S. (1988). Abordagem preventiva quanto ao trabalho em releção ao traco distintivo de sonoridade nos períodos pré-escolar e escolar. *Anais do Encontro Nacional de Fonoaudiologia Social e Preventiva*, 163-164.
- Hall, G., & Sundberg, M. L. (1987). Teaching mands by manipulating conditioned establishing operations. *The Analysis of Verbal Behavior*, 5, 41-53.
- Leicester, J., Stoddard, L. T., Mohr, J. P., & Sidman, M. (1971). The nature of aphasic responses and methods for study. *Neuropsychologia*, 9, 141-155.
- Mohr, J. P., & Sidman, M. (1975). Aphasia: Behavioral aspects. In S. Arieti (Ed.), *American handbook of psychiatry*, Vol. 4: *Organic disorders and psychosomatic medicine* (pp. 279-298). New York, NY: Basic Books.
- Mohr, J. P., Sidman, M., Stoddard, L. T., Leicester, J., & Rosenberger, P. B. (1973). Evolution of the deficit in total aphasia. *Neurology*, 23, 1302-1312.
- Moraes, A. M. P. (1986). *Distúrbios de aprendizagem*. São Paulo: Edicon.
- Rodrigues, E. J. B. (1981). *Discriminação de aprendizagem*. São Paulo: Cortez.
- Sidman, M. (1971). The behavioral analysis of aphasia. *Journal of Psychiatric Research*, 8, 413-422.
- Sidman, M., & Kirk, B. (1974). Letter reversals in naming, writing, and matching to sample. *Child Development*, 45, 616-625.
- Sidman, M., Stoddard, L. T., Mohr, J. P., & Leicester, J. (1971). Behavioral studies of aphasia: Methods of investigation and analysis. *Neuropsychologia*, 9, 119-140.
- Skinner, B. F. (1957). *Verbal behavior*. New York: Appleton-Century-Crofts.
- Spinelli, M. (1983). Disfunção cerebral mínima e distúrbios da comunicação. In A. B. Lefebvre & B. H. Lefebvre (Eds.), *Disfunção cerebral mínima*. São Paulo: Sarvier.
- Sundberg, M. L., San Juan, B., Dawdy, M., & Argüelles, M. (1990). The acquisition of tacts, mands, and intraverbals by individuals with traumatic brain injury. *The Analysis of Verbal Behavior*, 8, 83-99.