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Teaching Generative Reading Via Recombination of Minimal Textual Units: A Legacy of Verbal Behavior to Children in Brazil

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Abstract

This paper reports results of two studies that sought to teach generative reading skills to a large group of Brazilian children who were exhibiting protracted failure in school. Inspired by Skinner's analysis of verbal relations and minimal verbal units, the methodology took advantage of certain characteristics of Portuguese. Many words in this language are comprised of two-letter syllabic units (e.g., BO+LA= *ball*, CA+BO= *handle*, LA+TA= *can*) that can be recombined to form new words (e.g., BOCA= *mouth*, BOTA= *boot*), thus establishing a route to generative reading via *recombinative generalization*. Such syllabic units were incorporated within curricular framework that used matching-to-sample and *learning by exclusion* methods to teach matching relations involving pictures, printed and spoken words, and printed and spoken syllables. Study 1 was conducted within a university-based learning center that maintained certain aspects of laboratory conditions. It showed that teaching textual relations between dictated and printed syllables could control procedurally the inter- and intra-participant variability observed in past studies that lacked this feature -resulting in virtually universally positive teaching outcomes. Study 2 was conducted in a public school programs that applied the same basic training methodology. Positive training outcomes in an experimental group were approximately 3–5 times greater than that in a placebo control group. Together, these studies illustrate that the functional analysis in *Verbal Behavior* is having a direct impact in educational science in Brazil. It has led to procedures that can be effectively translated from the laboratory to the community via delivery systems that can be implemented in the developing world.

Keywords

Functional verbal relations; textual units; matching-to-sample; recombinative generalization; reading prerequisites; developmental disabilities

Keywords

relaciones verbales funcionales; unidades textuales; igualación a la muestra; generalización recombinativa; prerrequisitos de la lectura; problemas del desarrollo

In *Verbal Behavior* (1957), Skinner proposed a novel taxonomy of verbal relations defined in terms of their functional antecedent and consequential controlling relations. This taxonomy

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provided an alternative to structural analyses that had predominated earlier. Skinner's analysis was primarily conceptual in nature. His emphasis on function and its general foundation in empirically established principles of behavior (e.g., Skinner, 1938) rendered this analysis naturally applicable to the design and analysis of pedagogical techniques for establishing verbal relations. Applications of functional analysis have become particularly useful in learners who do not acquire verbal relations via the educational experiences that suffice for other learners (Sundberg & Partington, 1998).

Some twenty years ago (1989), the 2nd International Institute on Verbal Relations was held in the town of Lindoya in the state of São Paulo in Brazil. This meeting brought together some of the most prominent figures in behavior analysis in the United States (e.g., Murray Sidman, Steven Hayes, Alan Neuringer) and in Brazil (Carolina Bori, Maria Amelia Matos, Elenice Ferrari, Maria Teresa Araujo Silva), along with a substantial number of persons who would become prominent as the years went by. The meeting was highly stimulating intellectually, featuring occasional fireworks during the discussion periods, and it provided major input to the 1992 volume *Understanding Verbal Relations* (Hayes & Hayes, 1992). Perhaps more important than these contributions, however, was its role in increasing attention to the empirical study of verbal relations in Brazil.

This paper will describe a program of research that emerged from formative discussions of preliminary data that were considered at the Lindoya meeting -a sustained and accelerating effort to develop an effective program for teaching foundations of reading and spelling to Brazilian children, many of them socially disadvantaged and/or intellectually disabled. This program had its roots in Skinner's (1957) analysis of "minimal units" in verbal relations and in laboratory-derived methods for promoting emergent behavior. The program addressed two key components of reading repertoires identified by behavior analysts (e.g., Skinner 1957; Staats 1968): *textual/echoic behavior* and *reading comprehension*.

Minimal Units in the Analysis of Textual/Echoic Behavior

Textual behavior has been defined as verbal responses under point-by-point control by the text (Skinner 1957). Textual stimuli are typically visual but they need not be (e.g., as in the tactile stimuli used in Braille). To illustrate point-by-point discriminative control, consider that the printed word BAT controls one response whereas physically similar words (BAD, BATH, RAT) control other responses. The responses that occur in conventional reading repertoires are not random but rather determined by discriminative control of the letters in sequence. Moreover, point-by-point control does not depend upon the "meaning" of the letter sequence. Readers of this article will find it trivial to read the letter sequences GAK, NOOB, and FLUP even though they have no defined meaning in English.

A textual behavior counterpart in the auditory domain is *echoic* behavior whereby an individual proves capable of reproducing, typically orally, the point-by-point stimulus produced by another. As with textual behavior, an echoic need not necessarily reflect established meaning (e.g., the reader could likely repeat orally the nonsense words just exemplified if they were spoken to him/her). Development of textual and echoic repertoires may be critical to the development of a skilled reading repertoire. Indeed, in calling attention to these functional relationships, Skinner pointed to *phonological awareness*, the ability to recognize the sounds that constitute words as repeatable units (in behavioral terms, discrimination and abstraction of within-word sound units -cf. Mueller, Olmi, & Saunders, 2000) that is now assumed to underlie skilled reading repertoires (Cunningham, 1990; Goswani, & Bryant, 1990; Liberman, Shankweiler, Fischer, & Carter, 1974; Lundberg, Frost, & Petersen, 1988; Torgensen *et al.*, 1992).

Another important contribution of Skinner's analysis of verbal relations was his recognition that the unit of analysis in verbal relations was not fixed; analytical units can be enlarged or reduced depending upon the nature of the behavior to be analyzed. In particular, his notion of the "minimal units" has proven directly relevant to the behavioral analysis of rudimentary reading repertoires (Saunders, O'Donnell, Vaidya, & Williams, 2003) and is applicable also within cognitive analyses of such repertoires (cf. Blachman, 1997). In the context of reading, minimal units include the phonemic and syllabic units common to other analyses of reading processes (Adams, 1994; Snow, Burns, & Griffin, 1998). Flexible phonemic and syllabic recombination is an essential behavioral process for "word attack" skills (e.g., Mueller, *et al.*, 2000).

Words within a phrase, sentence, or other word sequence, for example, can function as minimal textual units. To illustrate, research on *recombinative generalization* (cf. Goldstein, 1983, 1993) has shown that teaching behavior appropriate to, for example, the meaningful Portuguese word pairs CAMISA VERMELHA and CALÇA VERDE may render the learner able to behave appropriately with respect to the meaningful pairs CAMISA VERDE and CALÇA VERMELHA. Units are thus recombined in novel and appropriate ways to describe behavior with respect to novel stimuli or stimulus combinations.

Illustrating the flexible nature of verbal relations, one can extend the recombinative approach to minimal units within individual words. The Portuguese language is especially well-suited to illustrate such minimal unit recombination, because many of its words are composed of combinations of consonant-vowel units. Much research within the Brazilian program has shown, for example, that when direct teaching that establishes appropriate oral naming of words comprised of such separable units (e.g., BOLO (BO+LO), VACA (VA+CA), that learning may be accompanied by emergent naming of recombinations of the constituent units (i.e., BOCA, CABO, LOBO) (de Rose, de Souza, Rossito, & de Rose, 1992; Matos & Hübner-D'Oliveira, 1992).

Analysis of Reading Comprehension

Neither textual nor echoic behavior nor their joint operation alone defines the totality of the verbal relations that comprise a functional reading repertoire. To illustrate, readers of this article who are not familiar with Portuguese will nevertheless likely be able to approximate correct oral reading or repetition of the words shown as examples in the preceding two paragraphs, thus exhibiting textual and echoic behavior respectively. Additional learning will be required, however, to allow the reader to comprehend the meanings of the various words and word sequences. The Skinnerian analysis of verbal relations also addresses this further learning, particularly in the specification of the functional relationship termed the *tact*.

A tact is evoked by a nonverbal discriminative stimulus, such as an object or event, or the relation between objects or events, and is maintained by generalized or social reinforcers (Skinner, 1957). Speakers of Portuguese agree that CAMISA and CALÇA tact stimuli that English speakers tact as SHIRT and PANTS respectively. They agree also that VERMELHA and VERDE tact items that English speakers tact as RED and GREEN respectively. Merely observing the behavior of individuals speaking these Portuguese and/or English words correctly, however, does not necessarily mean that appropriate tact functions have been established. The individuals might be exhibiting merely textual or echoic behaviors.

Empirical evidence to support an inference of true tact function may be obtained using the Sidman (1971) stimulus equivalence paradigm. Within a matching-to-sample paradigm, a learner may be taught to select a given comparison picture (displayed simultaneously with other pictures) in response to a dictated sample "CAMISA." S/he may be taught also to select

a comparison printed CAMISA in the presence of the same dictated word. If teaching has been done with care, one is likely to observe emergent matching-to-sample performance - bidirectional matching of the picture with the printed word without any further training. Moreover, one may find additionally that the learner who has never before done so before will spontaneously say "CAMISA" when shown the comparison picture and printed word CAMISA. In this case, a reasonable inference is that the learner is tacting that picture and printed word in a manner that is conventionally reinforced within the verbal community of Portuguese speakers. For speakers of English, the same analysis could be done substituting the dictated word "SHIRT" for "CAMISA" and the printed word SHIRT for CAMISA.

Applying the Functional Analysis of Verbal Relations to Reading Instruction

The failure of much conventional reading instruction is a global problem, especially in developing nations. Our working hypothesis is that this problem can be resolved via a well-defined behavioral technology inspired by key aspects of Skinner's (1957) analysis of verbal behavior and other advances in behavior analytic science, such as methodology for developing equivalence relations. In the years since the Lindoya meeting, we and a number of other behavior analysts working in Brazil have sought reliable methodology for teaching the behavior prerequisites for rudimentary reading to the many children of families with low socio-economic status (SES) who have exhibited or are at substantial risk for school failure (e.g., de Rose *et al.*, 1992, Matos *et al.*, 1992). An overarching goal of this research program has been to develop methodology that imbeds within it procedures for establishing the range of functional relations that constitute the basis for a functional reading repertoire. The methodology has evolved over a number of years of research that has progressively refined the techniques (e.g., de Rose, de Souza, & Hanna, 1996; Goyos, Souza, Silvares, & Saunders, 2007; Medeiros, Fernandes, Simone, & Pimentel, 2004; Melchiori, de Souza, & de Rose, 2000; Matos, Avanzi, & McIlvane, 2006; Hübner, Gomes, & McIlvane, in press). Methodology described in the present article represents one exemplary implementation of contingencies to instantiate functional relations defined in *Verbal Behavior* within the context of an effective program to teach rudimentary reading.

One aspect of the reading research program in Brazil has focused on the "constructed-response" procedure that was first described by Mackay and Sidman (1984). In that matching-to-sample variant, children were presented with sample stimuli -both pictures and printed words- and a comparison stimulus "pool" composed of individual letters. By touching these letters in sequence, children could "construct" comparison stimuli that were valid matches to the sample -either as identity matches or arbitrary matches. Such constructed response matching procedures are a flexible match to the subject matter, permitting comparison responses at the level of the phonemic (e.g., C-A-B-O), syllabic (e.g., CA-BO), or whole word level.

Overview of Present Study

Our working hypothesis was that contingencies designed in line with the analysis of Skinner (1957) and the procedures of Mackay and Sidman (1984) could prove sufficient to establish generative reading (i.e., performances that emerge without direct training). As already noted, our procedures took advantage of a useful characteristic of Portuguese -many words are comprised of two consonant-vowel combinations (e.g., BO+CA=BOCA [mouth])- minimal units that might be spontaneously recombined into other meaningful combinations (e.g., CA +BO=CABO [handle]). We sought to encourage such behavior by also teaching the children to match printed to dictate syllables and to construct words with syllables -thereby establishing/ verifying the necessary discriminations and relations involving syllable sounds and corresponding printed syllable units. As in past studies, the procedures were designed to

encourage generative reading also via provision of multiple-exemplar training with a series of word sets.

Study 1 was conducted within a university-based learning center that maintained certain aspects of laboratory conditions. It showed that teaching textual relations between dictated and printed syllables could control procedurally the inter- and intra-participant variability observed in past studies that lacked this feature -resulting in virtually universally positive learning outcomes. Study 2 was conducted in a less controlled public school environment using the same basic methodology.

Study 1

Method

Participants—Participants were 12 children aged 8–12 years. All were selected based on teacher reports of protracted failure to acquire reading skills in school and a preliminary assessment test in which they failed to read and spell simple words. The assessment presented a 15-word subset of the words that would be used during the teaching program. Children were asked to read orally words presented one by one on a computer screen and to spell those words to dictation. Two response modes were assessed in spelling: constructed response and cursive writing. Ten of these assessment words were included in the teaching program (Training words) and five were used only during tests (Generalization words). No feedback was given for correct or incorrect responses during assessment.

Setting and Materials—The study was conducted in a laboratory at Universidade Federal de São Carlos. The laboratory had six workstations, each equipped with an IBM-compatible computer and a touchscreen (Microtouch Inc.) monitor (Mitsubishi Diamond 15”). Experimental operations on the computer were controlled by custom software written for that purpose.

Stimuli: All children were exposed to a computer-based teaching program that was organized in a series of units. The teaching program used common words in Portuguese that could be easily represented by pictures (the same words used by de Rose *et al.*, 1996). Some words were used for training (Training words), while other words were used only for assessing recombinative reading (Generalization words). Training and generalization words had two or three syllables, usually of the consonant-vowel type, and three to seven letters. For example, for training words *bolo* [cake], *mala* [suitcase], and *pato* [duck], generalization words included *bola* [ball], *mato* [weed], and *mapa* [map], all of which recombine letter pairs from the original words. Also, the sets of words were selected such that each consonant corresponded to a single phoneme.

The teaching program presented four types of visual stimuli in the matching-to-sample format: (1) color pictures and printed (2) words, (3) syllables, and (4) individual letters, the latter three in lower case 65-point Arial type. Auditory sample stimuli were dictated words and syllables, recorded as *.wav* files and presented through headphones. Two types of matching-to-sample procedures were used: (1) standard matching to sample and (2) constructed response matching to sample (CRMTS). Examples of both procedures are presented in Figure 1.

Visual sample stimuli were centered at the top of the screen. Comparison stimuli on standard MTS trials were presented in a row at the bottom of the screen. Comparison stimuli on CRMTS trials were presented in unsystematic locations within a rectangular area at the bottom of the screen (henceforth, the *pool* area). When touched, comparison stimuli moved to a rectangular area immediately below the sample (henceforth, the *construction* area); touches to stimuli that had moved there returned them to their original position in the pool area.

Scheduling: Sessions were scheduled five days a week (from Monday to Friday), but the actual number varied because of occasional absences. Typical session duration was approximately 20 min, and no session was longer than 40 min. Total length of participation in the study was variable due to factors such as the schedule of academic semesters, but 3–6 months of exposure to the curriculum was typical.

Procedures—During sessions, the child sat facing the computer screen and the experimenter sat behind the child. Both the child and the experimenter used headphones during sessions. As noted, the child responded to comparison stimuli by touching them. When oral responses were required, the experimenter recorded them on the computer keyboard.

Overview of the Teaching Program—The teaching program was a superset of the procedures described by de Rose *et al.* (1996). The main teaching goal was to establish accurate matching of printed word comparison stimuli to dictated-word sample stimuli. To that end, a CRMTS task was implemented to require children to copy printed-word sample stimuli (i.e., CRMTS identity matching), a procedure that verified letter-by-letter discrimination of the printed words. Additions to the program were (1) a requirement that children learn to match printed syllables to dictated syllable names (i.e., the minimal units) and (2) computer-based teaching rather than the tabletop procedure used in previous versions (cf. de Rose *et al.*, 1996; Melchiori *et al.*, 2000). Syllable matching procedures were implemented in each teaching unit only after the child had learned to match the corresponding printed words and dictated words.

General Program Structure: The program was comprised of 17 teaching units and 11 assessment units distributed in the sequence shown in Table 1. This implementation differed somewhat from previous ones, with the combined objectives of increasing the efficiency of training and testing and rendering the program suitable for automating most tasks. Table 2 lists the pre- and post-tests that were scheduled before and after each teaching unit.

Pretests assessed behavioral relations (1) AB, matching pictures with their corresponding dictated names, (2) BD, naming each of the pictures, (3) CC, matching identical printed words, (4, 5) BC and CB, matching printed words to pictures and *vice versa*, and (6) CD, naming printed words. Stimuli included on pretests were all words included within a given teaching set (i.e., 15 in Set 1, 12 in Set 2, etc.). Relations AB and CC were prerequisite skills that were necessary to the success of subsequent teaching. If these performances were unconventional (i.e., the child named a picture with an unexpected word) or inaccurate, then these skills were taught directly before proceeding.

Post-tests included behavioral relations BC, CB, and CD, and a new relation AE, spelling words in response to dictation. Post-tests, distributed across two sessions, included (1) all of the words from a given training set, (2) newly introduced common Portuguese words to assess generalization, and (3) pseudo-words having the structure of Portuguese but not defined in that language to assess development of textual responding. Echoics were not assessed formally during the program because all children could repeat words accurately to dictation prior to their participation in this study.

Learning by Exclusion: The primary methodology for teaching new relations between dictated words (and later syllables) and corresponding visual stimuli was *learning by exclusion* (McIlvane & Stoddard, 1981). The procedure consists of programming *baseline* trials, *exclusion* trials, and *learning outcome* trials. On baseline trials, the student is presented with previously mastered tasks, for example, matching the dictated words *tatu* (armadillo), *selo* (stamp) or *bolo* (cake), to the corresponding printed words. On exclusion trials, the student is presented with a task that contrasts baseline stimuli that have thus been defined in relation

to dictated names and new stimuli that have yet to be defined. Extending our example, the student might be presented with a comparison display that includes the defined stimulus *cake* and the as yet undefined stimulus *popcorn* (*pipoca*). Extensive research, including our own, has shown that students are highly likely to select undefined comparison stimuli (i.e., *pipoca* in our example) in response to dictated words that are also as yet undefined (i.e., *pipoca*) while continuing to select defined comparison stimuli in response to defined samples (i.e., they select *cake* in response to *bolo*). Various types of *outcome* trials are available to assess whether the exclusion history suffices to establish new defined relations between the formerly undefined sample and comparison stimuli that do not depend upon the exclusion context. Our outcome tests will be described in presenting our procedures.

Summary of teaching and assessment units (Table 1): Following initial assessment of prerequisite skills and the first round of pretests (Units 1 and 2), Unit 3 was programmed to establish a three-word baseline of matching and spelling as preparation for further teaching. Units 4–7 were exclusion units designed to teach the remaining 12 relations involving dictated and printed words that had been pretested in Unit 2 and their constituent syllabic (i.e. minimal unit) relations. Unit 8 conducted post-tests with the 15 words that comprised Set 1, 8 generalization words, and 4 pseudo words. The post-test relations are listed in the second and third rows of Table 2, which included the potentially emergent picture-printed word and printed word-picture equivalence relations BC and CB. Accurate reading (CD) and spelling (AE) of all training words presented on the post-test was required to progress to the next set of teaching units. If any errors occurred, the relevant teaching units were repeated. Then, the post-test was repeated. Units 9–14 systematically replicated these procedures with a second set of 12 word-picture relations. Unit 15 was a follow-up post-test involving all 27 new dictated word-printed word relations, 13 generalization words, and 2 pseudo-words, including all of the post-tests shown in Table 2. Units 16–27 were a systematic replication of the procedures used in Units 3–14. The curriculum concluded with comprehensive post-tests involving all 51 words that were taught and tested during Units 3–27 and a final assessment of the 15 words that replicated the original pretest conditions.

Consequences: On all tasks, correct responses were followed immediately by either confirmation (a brief musical phrase) or verbal praise, both delivered by the computer. Confirmation was used with the matching-to-sample procedures, whereas praise followed accurate naming of pictures and printed words (as judged by the teacher who initiated the praise via a keyboard command). Incorrect responses were typically followed by the next scheduled trial. Exceptions were correction procedures described in the context of specific teaching tasks.

Specifics of Teaching, Test, and Remedial Procedures

Teaching children to match and tact pictures: Children came to the study able to match and tact many common items with words intended for use in the study. Some words, however, were difficult to represent unambiguously in pictures. It was necessary, therefore, to teach the children to match and tact certain items with the specific words that would be used.

On pretests preceding each set of training units, we scheduled a block of trials that required the child to match each picture to a corresponding dictated name. The block was comprised of trials presenting all of the words that would be included in the unit (15 words in Set 1 and 12 words in Sets 2 to 4) and eight trials with pictures corresponding to generalization words. All such matching-to-sample trials displayed three comparison stimuli. Correct matching selections were followed by positive consequences and the intertrial interval. Errors were followed only by the intertrial interval. Such blocks were repeated until the child matched all pictures to dictated words without error.

Following attainment of criterion on a matching-to-sample block, tact assessment and training commenced with all of the pictures that had been displayed on that block. Pictures to be tacted were displayed singly at the top of the computer screen, and the Portuguese equivalent of "What is this?" was dictated. Correct tacts were followed by positive consequences and errors were not. If any errors occurred in the series, a new round of matching-to-sample training was programmed. Naming-blocks followed criterion matching performances. This sequence was repeated until the child tacted every picture in the sequence with the name that would be used in the study.

Matching to sample and spelling with printed words and syllables: Teaching the initial baseline: To set the stage for implementing the *learning by exclusion* procedure, we taught an initial three-word baseline of matching and spelling. The training procedure was an automated version of the one described by de Rose *et al.* (1996). On six initial matching trials (two with each training word), only one printed word was presented as a comparison stimulus. The sample dictated word was embedded in the following sentences (Portuguese equivalents): "This (printed) word is ['dictated sample']. Point to ['sample']." Selections were followed immediately by positive consequences. Thereafter, two comparison stimuli were presented for the next 30 trials (ten with each of the three training words dictated as samples). The final six trials of this training block presented all three printed word comparison stimuli (two with each of the three corresponding dictated samples). If any errors occurred in this final six-trial block, the session ended, and the training block was repeated in the following session(s).

When criterion was achieved on dictated word-printed word relations, *minimal unit training* began. To establish context for teaching these dictated syllable-printed syllable relations, trials were first organized into three separated training blocks, one for each of three words that comprised the relevant teaching unit. Each block began with an AB trial type (i.e. requiring the child to match a picture to the dictated word). Next followed a second trial type, requiring the child to copy a printed word via the constructed response procedure (e.g., selecting BO-CA in sequence in response to BOCA as a sample). On such trials, the printed word sample appeared in the top window along with a pool of eight printed syllable comparisons. The student was instructed verbally to "write" the word by touching the syllable comparisons in the correct sequence. Each touch moved that syllable to the construction area beneath the sample. Correct constructions were followed by verbal praise. Incorrect constructions were corrected by repetition of that trial until a correct construction occurred. The next two trial types in the training sequence also required syllable response construction, this time in response to the picture and then the dictated word that had appeared on the first trial type. The trials probed the emergence of constructed response spelling, and both were conducted without differential consequences.

Following the probes, explicit training of dictated syllable-printed syllable relations commenced. Over a six-trial sequence, each of the two dictated syllables that comprised the training word were presented three times each. Comparison stimuli on each such trial were single printed syllables that corresponded to the sample. The next six trials presented the two printed syllables simultaneously as comparisons, and one or the other corresponding dictated syllables alternated irregularly as the samples. There followed a trial in which the entire training word was dictated, and the child was required to select each of the corresponding printed syllables in the correct sequence (i.e., constructed response spelling with syllables) from an array that included those syllables and six new ones. If constructed response spelling was correct on this trial, training was initiated with the second training word. If not, the block for the first training word was repeated until (1) criterion was achieved or (2) three repetitions had occurred without reaching criterion. If the latter occurred, the session was ended and training was reinitiated in the following session.

The block of trials programmed to teach syllabic matching with the second training word followed the same general sequence just described for the first word. However, in this block, the two syllables that comprised the second training word were introduced using a variant of the exclusion procedure. The two printed syllables that comprised the first training word served as the defined baseline comparisons, and one or the other of the printed syllables that comprised the second training word alternated irregularly as the third comparison. On syllable exclusion training trials, the sample was a dictated syllable corresponding to the syllable from the second word. Syllable control trials presented the same three-comparison display (i.e., one or the other new printed syllables and two baseline syllables), but the dictated sample was a baseline syllable. When all selections and constructions within a block were executed correctly, the syllables from the second word were added to the cumulative baseline and training progressed to the third block that trained the syllables of the third word in that unit.

A final block of trials in this initial teaching unit assessed constructed spelling to dictation. On each trial, one of the three training words was dictated and the student's task was to construct the word with the printed, movable syllables presented in the pool area. To move on to the next training unit, the student was required to make six consecutive correct syllabic spelling constructions (two with each of the three dictated samples). If this criterion was not reached, then the session ended, and the student was required to repeat the entire training sequence in the following session.

Matching to sample and spelling with printed words and syllables: Extending the baseline via exclusion training: Each subsequent teaching unit was designed to teach the student to read three new words with comprehension and to spell those words accurately via syllabic construction to dictation. The training method was learning by exclusion with both whole printed words and printed syllables. Tests for emergent equivalence relations involving printed words and pictures were conducted following mastery of matching printed words and syllables to dictated samples. Each unit was repeated until the student exhibited accurate syllabic spelling of all three words. Thereafter, these words were added to a cumulative baseline and used as defined stimuli in subsequent teaching units. What follows immediately describes the procedures employed with most children, but certain children required additional remedial procedures that will be described at the end of this section.

Details of exclusion training procedure: Training by exclusion was conducted in two blocks, the first matching whole words to dictated samples and the second matching syllables to dictated samples. Detailed procedures were reported by de Rose *et al.* (1996). To summarize, *training blocks with words* were comprised of 48 trials: 12 exclusion trials, 12 control trials, 6 outcome trials, 12 baseline trials, and 6 constructed-response matching-to-sample trials. Each of the three training words within a unit was the correct comparison four times each on exclusion trials. Defined baseline comparisons were the correct comparisons on the corresponding control trials. Outcome trials contrasted two words that were newly defined by the exclusion procedure without a baseline comparison stimulus available to exclude. Baseline trials displayed only previously defined words from prior training units as comparisons.

One noteworthy feature of this particular training procedure was inclusion of constructed-response matching-to-sample trials that required letter-by-letter construction of printed words corresponding to printed samples (Dube, McDonald, McIlvane, & Mackay, 1991; Mackay & Sidman, 1984; see Figure 1). Such trials were programmed immediately following each of the first two exclusion trials with each of the three training words within a unit. On such trials, the printed sample stimulus (the same that was selected on the immediately preceding auditory-visual trial) was presented in the sample area and 14 moveable letters were presented in the pool area. When a letter in the pool was touched, its color changed from black to blue and it moved dynamically from the pool area to the construction area under the sample. Touching a

letter in the construction area changed its color from black to red and returned it to its former position in the pool area. Such constructed-response matching trials ended when the student touched a "done" button located to the right of the sample stimulus. Correct constructions were praised, and incorrect constructions resulted in re-presentation of the same trial. This correction procedure was repeated until the child emitted a correct construction. Whole-word training for each unit was continued until the student met an accuracy criterion of 100% on the entire block of standard and constructed-response matching-to-sample trials.

The procedure for *teaching syllable matching to dictation* was essentially the same as that described for the second and third components of the initial baseline training unit. When a new syllable was dictated, comparisons were the corresponding printed syllable and two baseline printed syllables (defined in previous units). Each of the syllables that comprised a training word was a comparison on three trials each, intermixed with trials presenting other new syllables. For each word within the training unit, a final trial required the student to exhibit accurate syllabic spelling to dictation. If errors occurred, then the entire training block with that training word was repeated until accuracy was achieved. Thereafter, all three training words were intermixed on a 6-trial syllabic spelling to dictation test (two trials with each sample). Criterion for advancing to the next training unit was 100% accuracy on this 6-trial block. If errors occurred, the training sequence was repeated until criterion was achieved.

Reading with comprehension: Stimulus equivalence tests: The training procedures for each of the four sets of training units had established matching pictures (B) and printed words (C) to dictated samples (A). Thus, it was possible to assess the formation of equivalence relations via BC and CB tests (Sidman & Tailby, 1982) at the end of each set (Table 1). Both BC and CB tasks had been included in pre- and post-tests, thus allowing comparison of scores before and after training. Stimuli used on equivalence test trials were all the training words from the teaching units that comprised a particular set of units (i.e., 15 words in training Set 1 and 12 words in Sets 2–4) and (2) eight generalization words formed by recombination of the training words in the same set. For each word, there was one trial on which the printed word appeared as the sample and one trial on which the picture appeared as the sample. The order of test trials varied unsystematically in equivalence-test blocks.

Oral reading was also assessed at the end of each set of training words. Stimuli were the training words, the generalization words, and four pseudo-words composed of the syllables from training words in each set. Correct responses were praised and incorrect responses were followed by the next trial. Training, generalization, and pseudo-words were presented in an unsystematic order during the test.

Constructed spelling to dictation was also assessed during these post-tests. The stimuli were five training words and four generalization words. Children were instructed to spell each of these words via the constructed response procedure, moving individual letters to the construction area. Correct responses were automatically praised and incorrect responses followed by the next trial.

Mid-curriculum and final tests for extended oral reading and syllabic spelling to dictation: These performances were assessed in extensive tests conducted at the middle and at the end of the program (Units 15 and 28, see Table 1). All training words were tested, along with generalization words (common words and pseudo-words) not used in the previous tests. In each such test session, a sequence of oral reading trials was mixed with a sequence of spelling trials. On reading trials, the printed word was presented alone and the child was asked to name it. On spelling trials, the word was dictated and the child was asked to construct the word by touching the printed syllables displayed in the pool area (8 syllables simultaneously available). The final session directly replicated the tests conducted during the initial assessment (for the

purpose of comparing pre-and post-tests data). Also presented in this session was a *written spelling to dictation test* in which the child was required to spell each dictated word using pencil and paper.

Remedial procedures were used whenever a child repeatedly failed to achieve criterion in a particular unit or when a child made repeated errors reading one or more training words on the post-test for a set of training units. If a student failed to achieve criterion in an exclusion unit, after three repetitions of the training block, the initial procedure was to reduce the number of training words in the unit. The number of training words was reduced by omitting all but one of the training words not spelled correctly in the last block of the teaching unit. Hence, the modified blocks of training trials (for both, words and syllables) presented only training words spelled successfully, plus one training word not spelled in the spelling test. After criterion was achieved with this modified unit, each succeeding session reintroduced one of the omitted training words.

When a child made repeated oral reading errors on one or more training words in the post-test for a set of units, the remedial procedure was to repeat the training units that contained the words read inaccurately. Retraining units required the same accuracy criterion required for the initial training and was followed by another post-test.

Results and Discussion

Preliminary assessment and results of direct training—No child read more than three words correctly during the preliminary assessment. During the training, all children acquired highly accurate performances that were targeted by direct training aspects of the curriculum including (1) matching pictures to corresponding dictated words, (2) matching printed words to dictated words, and (3) matching printed syllables to dictated syllables.

Mastery of these performances was explicitly required to continue within the curricular framework, and no child failed to do so. These results thus replicate systematically the results reported by de Rose and colleagues (1996) using a tabletop implementation of the curriculum.

Reading comprehension—All children also exhibited accurate emergent matching of printed words with pictures and *vice versa* (i.e., BC and CB matching), either immediately on initial unit post-tests or after the prerequisite matching relations were reviewed (data not shown). In doing so, they demonstrated true reading comprehension according to the stimulus equivalence criteria defined by Sidman and Tailby (1982).

Emergent oral reading and spelling—The outcome tests of primary interest here were those that concerned oral reading and spelling of printed words in response to dictated words. None of these performances had been taught explicitly; they were merely tested following the direct whole-word and syllable matching to dictation training via the exclusion procedure.

Individual data concerning oral reading of training words are shown in the upper portion of Figure 2. These oral reading scores approached perfection in most children (mean= 97% correct), a substantial contrast with the very low scores that were exhibited on pretests conducted at the beginning of the study. Perhaps even more impressive, however, were the results of the oral reading tests with generalization words that had appeared thus far only on pretests. The lower portion of Figure 2 shows substantial emergence of oral reading performances of novel combinations of the minimal units that had comprised the training words (mean= 80%; range= 36%–100%).

Regarding emergent spelling to dictation, Figures 3 and 4 show the results on tests conducted in the syllabic constructed response and cursive writing formats, respectively. Much

improvement was observed over the course of the study, although there was substantial variability across children. The variability notwithstanding, however, most children achieved intermediate or high scores, a substantial contrast with the generally very low scores that were exhibited on the pretests.

Participant 2's data were a great surprise to us. Although qualifying for the study based on low accuracy on our oral reading pretest (and included on this basis), his scores on the corresponding constructed response and cursive writing tests were fairly high even on the pretests and did not improve much over the course of the teaching program. Perhaps these data illustrate once again the possible independence of verbal repertoires noted by Skinner (1957) and demonstrated occasionally since then (e,g, Lee, 1981; Lee & Pegler, 1982).

Summarizing the data on emergent oral reading and spelling, Figure 5 presents group data for the twelve children. It shows two clear order relationships. First, across the three types of tasks, children as a group were more likely to exhibit accurate oral reading of words than spelling of those words by either constructed response syllabic matching or cursive writing. The second relationship was that children as a group tended to do better with training words than with the generalization words across all three tasks. Nevertheless, (1) the performance differences between those with training words and those with generalization words were of a fairly small magnitude and (2) scores on both training words and generalization words were much higher than those obtained on pretests (e.g., compare post test scores in Figure 5 with Figures 3 and 4). Thus, although the program did not achieve total procedural control of the relevant learning processes, the children clearly showed substantial benefit from it. Recall that all of the participants had exhibited more-or-less protracted histories of failure to acquire performances such as these in their school programs.

We speculate that the children's prior schooling had some positive effects that supported the present program. Otherwise, it is difficult to see how improvements in cursive spelling could have emerged from the computer-based matching-to-sample procedures -which required entirely different response topographies. We think it likely that the behavioral prerequisites for cursive spelling can be traced to a common practice in early primary education in Brazil - requiring children to copy words shown on a blackboard or other type of display. Not only does copying identical words by hand establish the response topographies needed to exhibit emergent cursive spelling, but it also requires and may thus help to establish accurate discrimination of one letter from another. Virtually all children achieved very high scores on identity matching of printed words (CC relations on pre-tests), but in this task the student was required only to select the whole word. In future versions of the curriculum, we think it will be beneficial to assess formally the accuracy of such copying repertoires prior to initiating instruction. It may be that the differences in constructed response and cursive spelling to dictation can be eliminated by verifying and maintaining accurate copying during training (using for this purpose, for example, the delayed copying procedure described by Hanna, de Souza and de Rose, 2004).

Study 2

One question concerning the positive training outcomes shown in Study 1 is the degree to which those outcomes were due to the curriculum per se and not some other variable correlated with passage of time spent in our instructional environment. For example, our children continued to attend their regular school programs during their participation in Study 1. Although their prior achievements in school had been modest indeed, one cannot discount emergent improvement from continued schooling as one logical possibility. Also, because children in Study 1 were seen in groups constituted in specific academic semesters, we did not

have the benefit of a *de facto* naturalistic multiple baseline across participants had the children's participation been carefully staggered across a number of months.

For this reason, our group has been endeavoring to assess program efficacy via a group designs comparing performances of groups of children who were exposed to our regular program to groups of comparable children who were exposed to a control program that did not teach reading. Our control groups can be considered as "placebo groups" (Wampold, Minami, Tierney, Baskin, & Bhati, 2005) or as non-specific treatment groups (Kazdin, 2003): participants are exposed to the same setting of instruction, but they are required merely to match pictures to dictated words (AB) and to name the pictures (BD). In a very recent such study (e.g., Reis, de Souza, & de Rose, under review), we obtained results that were similar to those in the present Study 1 in an experimental group and little or no progress in a matched control group.

Another aspect of this line of research has been to assess whether the methodology that had been implemented in our university-based learning center could be implemented effectively within a public school environment. Can local personnel resources (and not university researcher) be employed to supervise small groups of students as they worked individually on the computers? To address this question, Study 2 systematically replicated the procedures of Reis and colleagues (under review) using student proctors to supervise the instruction instead of teachers or researchers.

Methods

Participants in this study were 17 children aged 8–11 years who had levels of school participation and achievement similar to those of children in Study 1. The primary qualification for participation in the study was failure to read orally or spelling words on an initial pretest. In addition, school records were available to characterize these children. The children were assigned either to an Experimental Group (09) or to a Control Group (08) of comparably functioning children.

The setting was a quiet area within the children's public school program, with the computer equipment necessary to implement the program in that environment. Procedures for the Experimental Group systematically replicated those described in Study 1, the primary difference being the change in the setting of instruction. The Control Group was exposed to a similar program, along the same academic period, except that (1) the tasks included only matching pictures to dictated words (AB) and naming the pictures (BD); (2) each unit taught 9 word-picture relations; there were 30 word sets and these sets did not include the words used with the Experimental Group.

Results and Discussion

Figure 6 presents the most important findings of this study, showing pre- and post-test results for individual participants (isolated points) in the Experimental and Control groups, and the median for the groups (solid lines). Learning outcomes comparable to those in Study 1 were obtained with the Experimental group whereas the Control group made little progress.

Although suggestive, the present findings cannot be taken as definitive proof of the sufficiency of the curriculum, by itself, to establish the performances of interest. One logical possibility is that our curriculum served to potentiate learning in the children's school programs (many children do learn how to read in school). Nevertheless, experience of longstanding and the findings of Study 2 and the findings of Reis and colleagues (under review) do indicate that exposure to the curriculum was the key factor in allowing initially non-reading children to begin reading -performances that have served as the foundation for extensions of our larger

program to teach reading of text passages, the results of which will be featured in a separate report.

General Discussion

Studies reported here demonstrated the effectiveness of a curriculum derived in part from Skinner's (1957) "minimal unit" analysis of verbal operants and in part from more recent work on basic symbolic processes (i.e., undergirding stimulus equivalence and related phenomena) that may supplement his functional analysis of verbal repertoires. Although the concept of stimulus equivalence was implicit in *Verbal Behavior*, its explicit application in work of the present nature introduces certain conceptual challenges to resolve. How does one classify emergent oral reading performances emitted in response to "What is this?" or an equivalent query? The simple answer, of course, is that the child is emitting a textual response. When training words are named more accurately than generalization words (see Figure 5), however, one is led to ask whether the teaching procedures establish a *de facto* verbal "community" (albeit a teacher-computer interface) in which the verbal stimuli (i.e., words) refer to nonverbal stimuli (i.e., their corresponding pictures). In this sense at least, one recognizes elements of the tact classification. One might argue also that oral naming of words has certain properties of an interverbal (i.e., a verbal response -the name spoken- occasioned by verbal stimuli -the printed word and the question [or instruction]; cf. Chase, Johnson, & Sulzer-Azaroff, 1985).

Classification complexities notwithstanding, the present work is very clearly in line with the essential concepts underlying Skinner's (1968) objective of applying systematic principles of behavioral science to develop a true technology of teaching. His original vision was very much the inspiration for a generation of Brazilian behavior analysts to apply their energies to address the challenges of literacy development in this country. Two aspects of Skinner's analysis seem noteworthy in the present study. First, our addition of explicit teaching of relations between dictated and printed minimal syllabic units in the curriculum is consistent with the concept of fostering progressively evolving, empirically inspired improvements in instructional technology. Regarding oral reading of training words in Study 1, for example, the children averaged about 97% correct and the lowest scoring child exceeded 90% correct, a finding in line with the data reported in previous studies (de Rose *et al.*, 1996; Melchiori *et al.*, 2000). Overall performance with generalization words was far superior, however. To make this point more concrete, Figure 7 plots individual data from our Study 1 (gray bars) along with those reported by de Rose and colleagues (1996). It shows that the accuracy of oral reading of new words following explicit training with minimal syllabic units in the present study was substantially better than that obtained without that added curricular feature. Children as a group read generalization words with about 80% accuracy (range: 36%–100%), a clear improvement over the 40% accuracy levels in the earlier study. Further, every student in the present study read at least some generalization words correctly, whereas about 25% of past students failed entirely on this task.

Perhaps even more important than the incremental improvement, however, was the demonstration that improvements in learning outcomes could be made outside the very controlled environment of the university-based learning center. Study 2 showed virtually the same levels of achievement when the curriculum was implemented within a public school environment. This finding shows that protracted failures to acquire reading fundamentals, as exhibited by many children in Brazilian primary grades is potentially correctable via the systematic application of an evidence-based technology of teaching.

Acknowledgments

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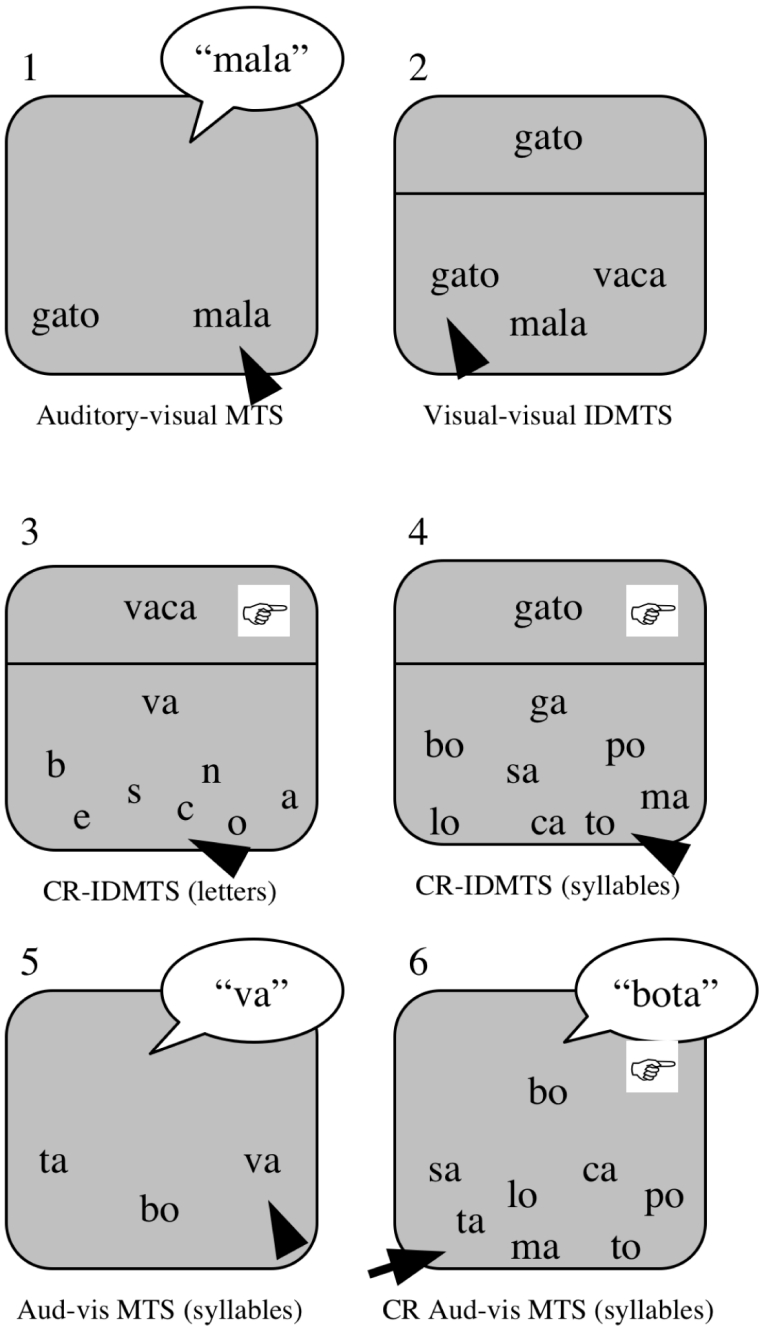

Figure 1.
Examples of the trial displays presented on the screen of the computer during teaching and test sessions (see text for details).

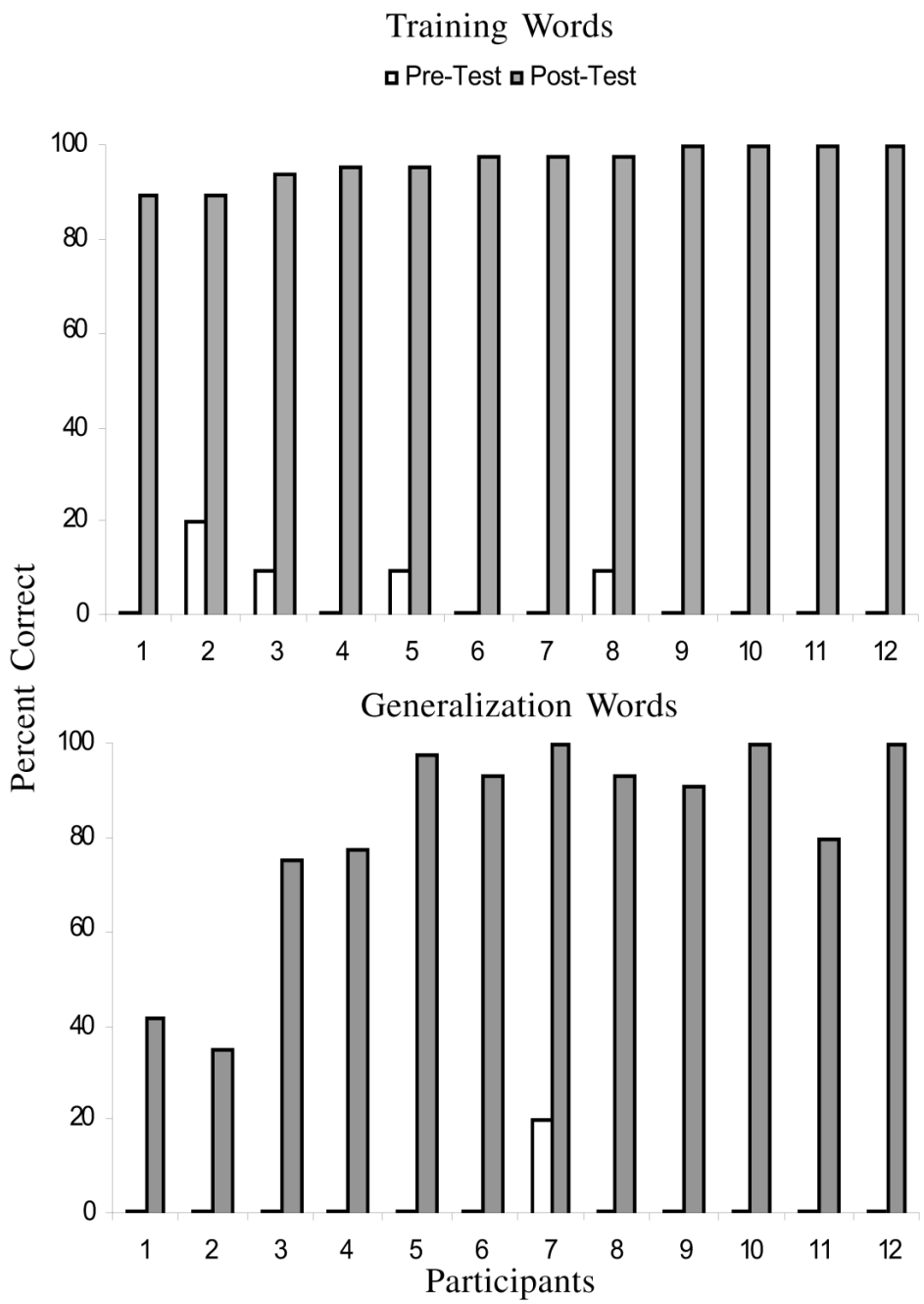

Figure 2.
Pretest and posttest oral reading scores for the 12 participants in Study 1 on training and generalization words.

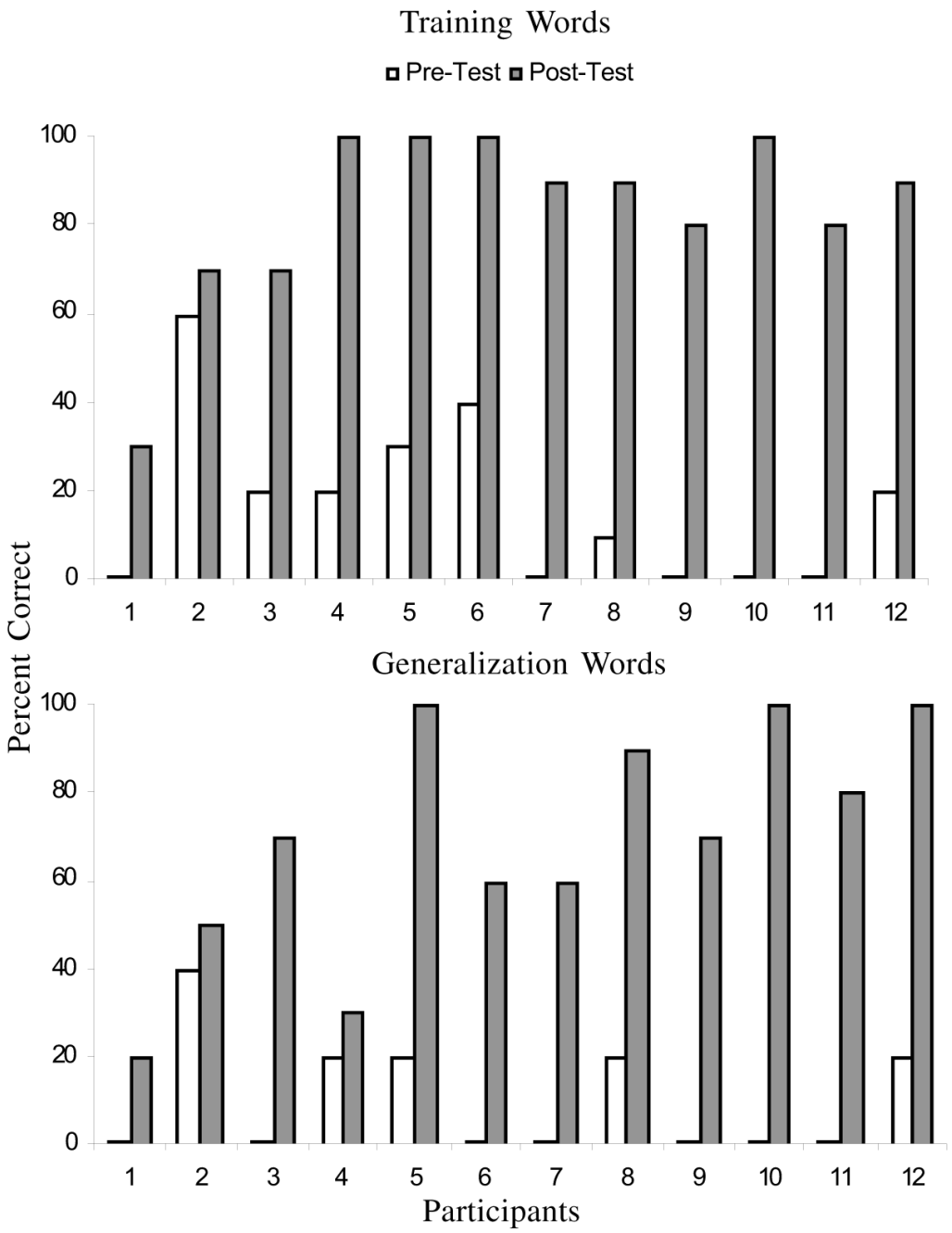

Figure 3.
Results of the spelling to dictation tests conducted in the constructed response format in Study 1.

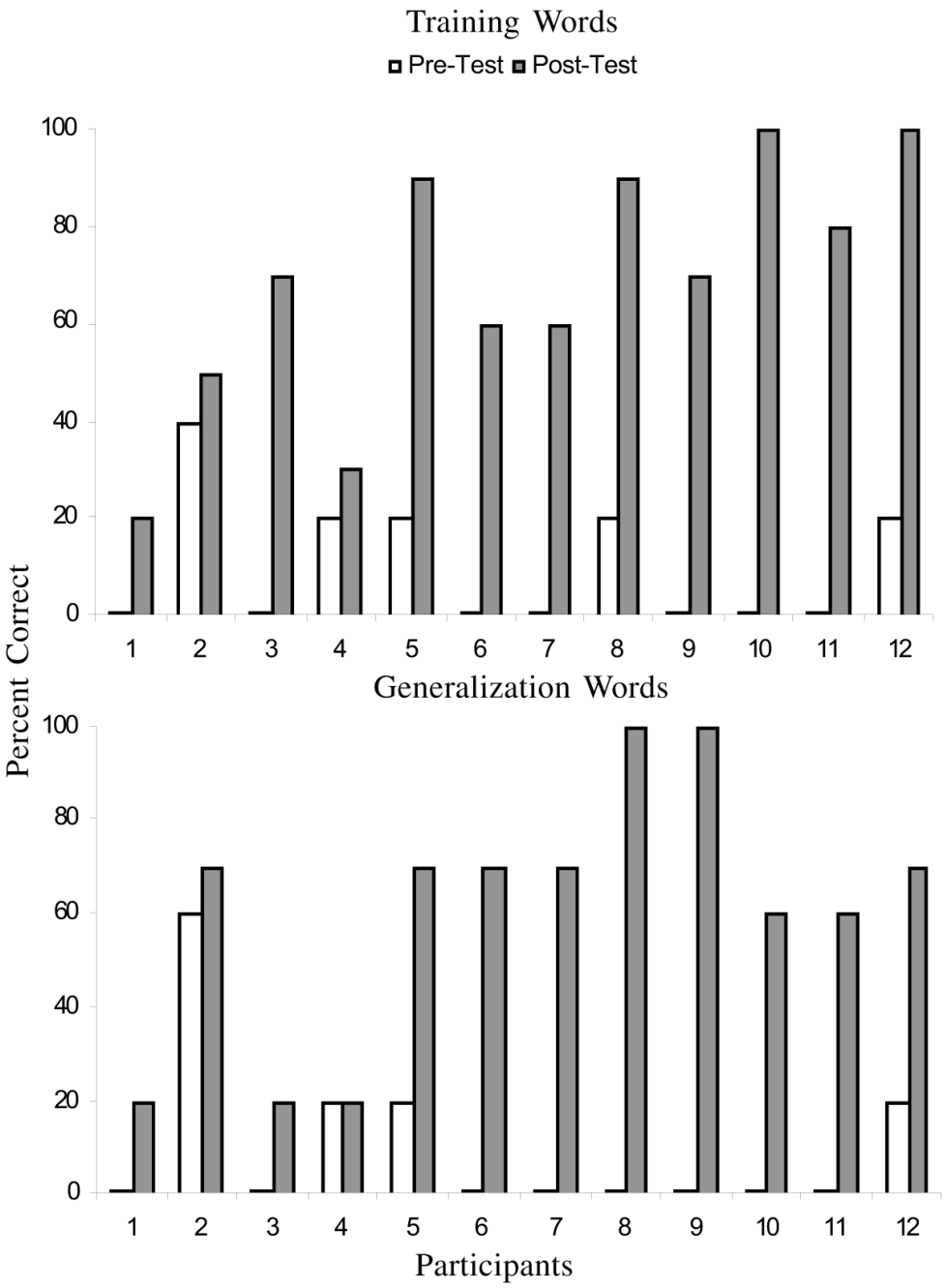

Figure 4.
Results of the spelling to dictation tests conducted in the cursive writing format in Study 1.

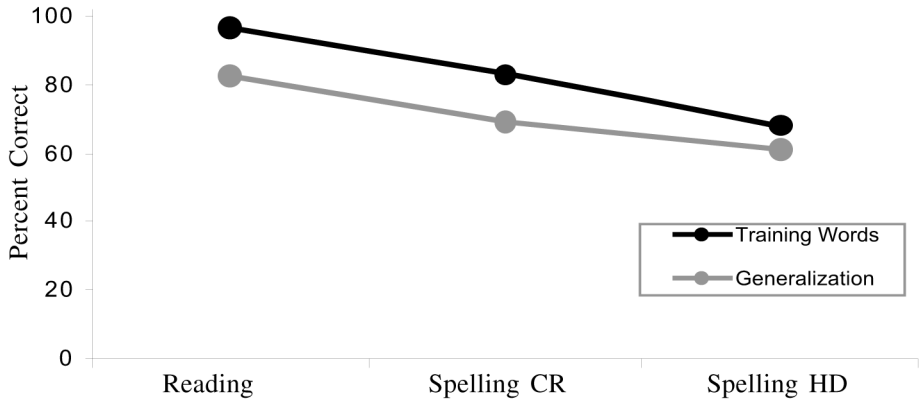

Figure 5.
Group summary data for oral reading and spelling to dictation from Study 1.

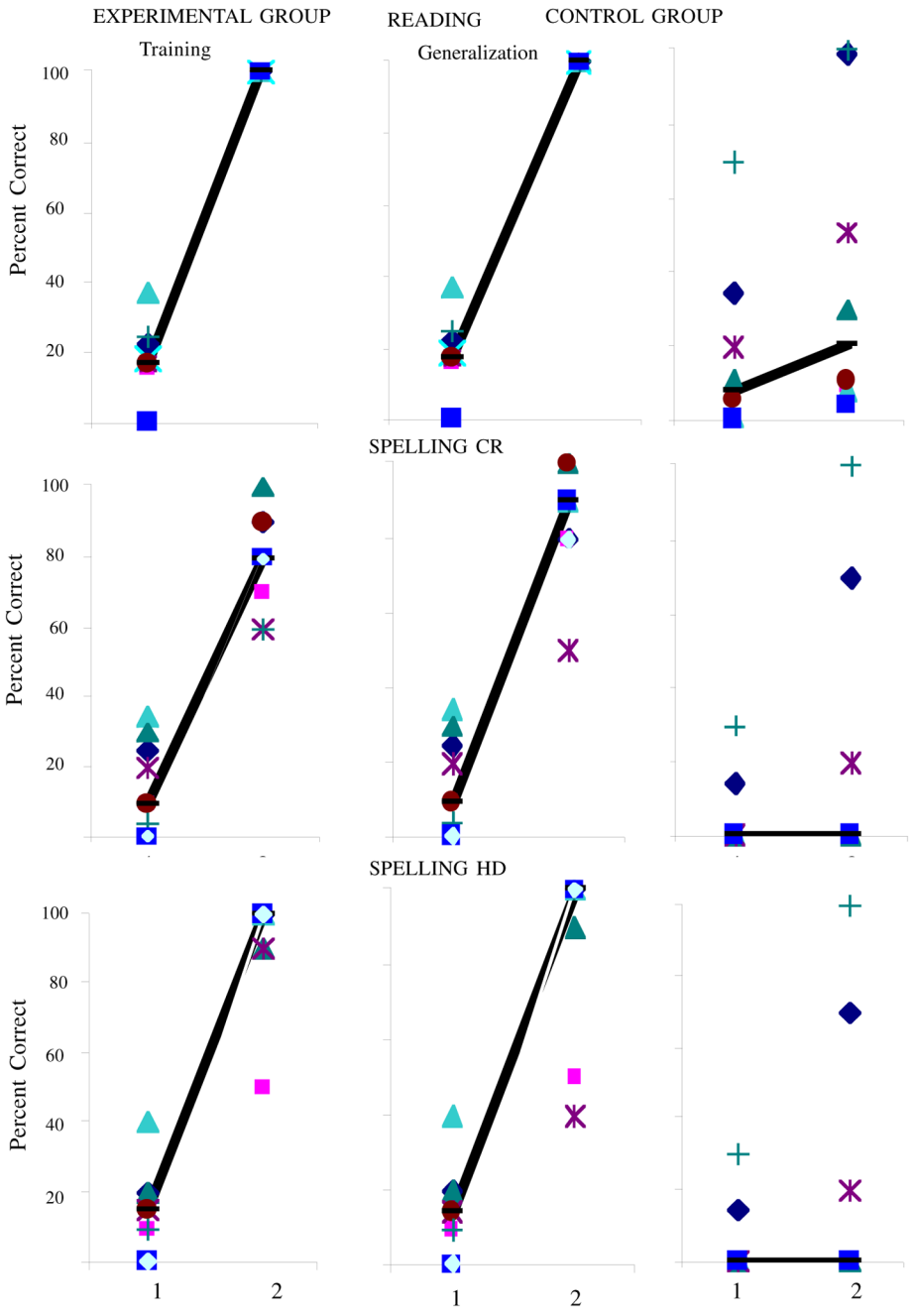

Figure 6.
Individual scores (isolated points) on pre- and post-tests for oral reading of generalization words in Study 2. Solid lines indicate group medians.

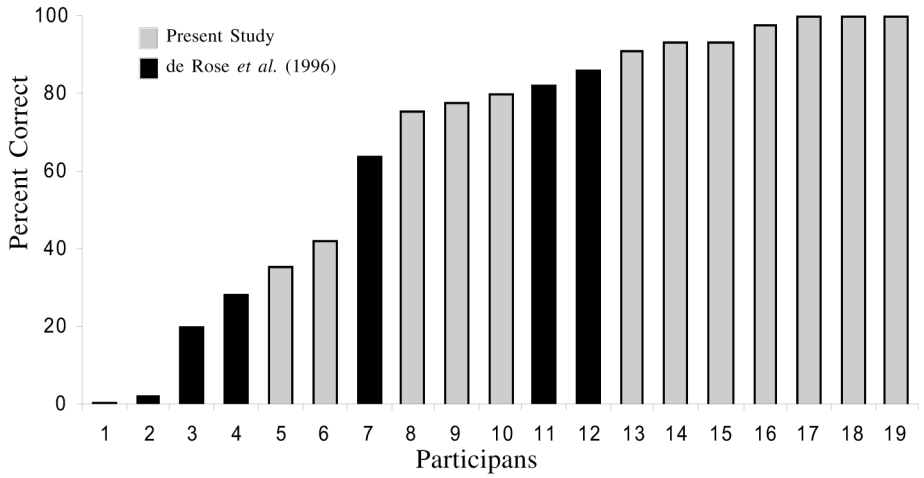

Figure 7.
Individual scores on tests for oral reading of generalization words in Study 1 and from the study published by de Rose and colleagues (1996).

Table 1

Sequence of Teaching and Assessment Units: Function of Each Unit, and Number of Training and Generalization Words Presented in Each Unit.

Unit(s)	Function	Words		
		Training	Generalization	
			Common	Pseudo
1	Initial Assessment	15	5	0
2	Pre-test – Set 1	15	8	4
3	Teaching (baseline)	3		
4–7	Teaching: exclusion 2–5	3		
8	Post-test– Set 1	15	8	4
9	Pre-test– Set 2	12	8	4
10–13	Teaching: exclusion 6–9	3		
14	Post-test– Set 2	12	8	4
15	Mid -Curriculum Tests	27	13	2
16	Pre-test– Set 3	12	8	4
17–20	Teaching: exclusion 10–13	3		
21	Post-test– Set 3	12	8	4
22	Pre-test– Set 4	12	8	4
23–26	Teaching: exclusion 14–17	3		
27	Post-test– Set 4	12	8	4
28	Comprehensive Final Tests	51	25	4
29	Final Assessment	15	5	0

Note: Pre- and post-tests for each set of teaching units included the same training words, and 12 generalization words (8 common words and 4 pseudo-words) not included in any other tests. Comprehensive tests in Unit 28 presented all 51 words from previous units, plus generalization words (25 common words and 4 pseudo-words) not included in any other unit.

Table 2

Trial Types Included in the Pre-and Post-Tests for Each Set of Teaching Units.

	Trial Types[a]													
	Training Words							Generalization Words						
								Common						Pseudo
Function	**AB**	**BD**	**CC**	**BC**	**CB**	**CD**	**AE**	**AB**	**BD**	**BC**	**CB**	**CD**	**AE**	**CD**
Pre-test [b]	◆	◆	◆	◆	◆	◆		◆	◆	◆	◆			
Post-test 1[c]				◆	◆	◆				◆	◆			
Post-test 2						◆	◆					◆	◆	◆

[a] Tasks involved three stimulus types (A= Dictated Words; B= Pictures; C= Printed Words) and two response types (D: Naming; E= Constructed Response). Task were: AB= Matching pictures to dictated words; BD= Naming Pictures; CC= Matching printed words to printed words (Identity matching); CD= Naming printed words (Textual behavior); BC= Matching printed words to pictures; C B= Matching pictures to printed words; AE= Spelling to dictation.

[b] Relations AB, BD and CC were trained to criterion, along with relation AC which was tested indirectly via oral reading tests; all other trial types were probe trials.

[c] In the post-test, there were two blocks of CD trials with training words; the student had to achieve 100% accuracy in the first to pass to a second CD block that mixed training, generalization and pseudo-words; Spelling on dictation (AE) was conducted only after the second block of reading probes.