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Rudimentary Reading Repertoires via Stimulus Equivalence and Recombination of Minimal Verbal Units

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We report a study with sixteen low-SES Brazilian children that sought to establish a repertoire of relations involving dictated words, printed words, and corresponding pictures. Children were taught: (1) in response to dictated words, to select corresponding pictures; (2) in response to syllables presented in both visual and auditory formats, to select words which contained a corresponding syllable in either the first or the last position; (3) in response to dictated-word samples, to "construct" corresponding printed words via arranging their constituent syllabic components; and (4) in response to printed word samples, to construct identical printed words by arranging their syllabic constituents. After training on the first two types of tasks, children were given tests for potentially emergent relations involving printed words and pictures. Almost all exhibited relations consistent with stimulus equivalence. They also displayed emergent naming performances—not only with training words but also with new words that were recombinations of their constituent syllables. The present work was inspired by Sidman's stimulus equivalence paradigm and by Skinner's functional analysis of verbal relations, particularly as applied to conceptions of minimal behavioral units and creativity (i.e., behavioral flexibility) in the analytical units applied to verbal relations.

Key words: Rudimentary reading, stimulus equivalence, minimal verbal units, unit recombination.

MARIA AMELIA MATOS: A REMEMBRANCE AND APPRECIATION*
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On May 17, 2005, our field suffered the heartbreakingly premature loss of Dr. Maria Amelia Matos, who influenced generations of behavior analysts in Brazil and elsewhere. Her loss was all the more devastating in that it came

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The software used in this experiment was a modified version of the EQUIV program, submitted by Pimentel (1996) in partial completion of the requirements for a Master's degree at the Universidad Mackenzie, São Paulo.

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rapidly upon the heels of a long, brave, seemingly successful battle against metastatic cancer. As the accompanying article suggests ("Rudimentary Reading Repertoires via Stimulus Equivalence and Recombination of Minimal Verbal Units"), however, Dr. Matos continued exemplary professional activity even during her battle and the too-short remission that followed. She was an inspiration to her many colleagues, students, and friends throughout the world.

Dr. Matos was born in Birigui, a city in the state of São Paulo, on the 14th of April, 1939. She left Birigui in December of 1957 to initiate coursework leading to a degree in psychology at the Universidade Federal de São Paulo (USP). In 1961, she met Dr. Fred Keller, who had secured leave from Columbia to serve as a visiting professor at USP. With that powerful stimulus, she resolved to attend graduate school at Columbia, matriculating into the Experimental Analysis of Behavior/Experimental Psychology program and graduating in 1969. There, Dr. Matos had the privilege of working not only with Dr. Keller but also with Dr. William "Nat" Schoenfeld—mentorship that was a source of great personal pride and inspiration throughout the remainder of her life. The influence of these distinguished teachers was obvious in her subsequent work, which showed singular dedication to quality of thought, procedural rigor, and ongoing application of research principles to problems in education. Many health and education scientists have come only recently to understand and voice appreciation for "research translation" efforts in which basic and applied scientific interests are intermingled within the same career path. It is noteworthy that Dr. Matos followed such a path through a career spanning more than five decades, for example, continuing the tradition of principle-based programmed instruction that was inspired by Drs. Keller and Skinner.

Following her graduation from Columbia, Dr. Matos returned to USP and initiated a distinguished career in teaching and research. She rapidly developed a reputation as an unusually demanding but also an unusually generous teacher. She spent extraordinary time in careful lesson planning and arranging appropriate contingencies to promote student progress, achievement, and excellence. With respect to graduate training, Dr. Matos supervised more than sixty master's and doctoral theses, and a number of her students are now acknowledged leaders in the experimental analysis of behavior in Brazil.

Her goal as a teacher was obvious—to assure that the benefits of her training and experience would be passed on effectively and completely to the next generations. In particular, Dr. Matos was known as a builder of critical thinking skills. As a proponent of programmed instruction, she was committed to the proposition that all well-motivated students had the capacity to learn and to think critically if their teachers were similarly motivated to teach effectively—as she so plainly and obviously was.

Dr. Matos was highly instrumental in developing the USP program and in placing it on course for national and international prominence. In concert with other like-minded USP colleagues, she developed and maintained the graduate program in Experimental Psychology, and she maintained one of the first laboratories in Brazil for conducting research in the experimental analysis of behavior. Among her many contributions was influential work in aversive control, stimulus control processes, verbal behavior, and rule-governance. More recently and illustrated in the accompanying article, she pursued a long-term program of research seeking effective, scientifically based methods for teaching reading skills to disadvantaged children who might not acquire them otherwise.

More generally, Dr. Matos was among the pioneers of scientific psychology in Brazil. Her influence on the form of psychology programs throughout that country is now and likely will remain substantial for years to come. While still a student, she was an articulate voice regarding maintenance of program quality and professional standards in concert with her mentor, Dr. Carolina Bori. These outstanding scholars maintained a close professional friendship that sustained them both, perhaps especially during the later years of their careers. For example, they seemed to delight in each other's presence during the recent international meeting of the Association for Behavior Analysis in Campinas, BR, at which it appeared to all that Dr. Matos had recovered her health, sadly only briefly as it turned out. It may not be mere coincidence that Dr. Matos's health took a turn for the worse following Dr. Bori's unexpected death shortly thereafter.

Dr. Matos's service as a national leader was both exemplary and important for the development of behavioral science in Brazil. She was active in scientific societies, especially the Sociedade Brasileira de Psicologia (SBP). She was instrumental in transforming SBP from a regional to a national conference, forever leaving her imprint on that increasingly important scientific society. Dr. Matos distinguished herself also as an editor and reviewer for many scholarly publications, extending her mentorship to many colleagues and students within and outside Brazil.

The loss of Dr. Matos leaves a noteworthy vacuum in behavior analysis in Brazil. Like other accomplished leaders, she has left a legacy of dedicated, well-trained students to fill it. No one, however, will be able fill the emotional void left in those of us who had the gift of knowing her personally, who owe her so much, and who suffered her premature loss so greatly.

Thank you for everything, Maria Amelia.

* * *

In *Verbal Behavior* (1957), Skinner articulated a novel taxonomy of verbal relations that re-defined many of the relevant environment-behavior relationships in terms of their functional antecedent and consequential controlling relations. Intended to advance basic scientific understanding of verbal relations, Skinner's taxonomy stood as a complementary alternative to the structural analyses emphasized in information-processing approaches. Whereas Skinner's analysis was primarily conceptual in nature, its functional emphasis lends itself naturally to the design and analysis of pedagogical techniques for establishing verbal relations. Applications of functional analysis appear particularly useful in learners who do not acquire verbal relations via the educational experiences that suffice for other learners (Sundberg & Partington, 1998).

Our interest has been in defining and teaching the set of functional relations that comprise an effective reading repertoire. The failure of traditional techniques of reading instruction is a global problem, especially in developing nations that can invest comparatively few resources in teacher training. We believe that a well-defined technology of teaching inspired by Skinner's functional analysis of verbal behavior and application of other more recent advances in behavior analytic science has the potential to make a major contribution toward solving this problem.

Many of the functional relations articulated within Skinner's analysis of verbal behavior map directly onto the tasks that are the major challenges in reading instruction. *Textual* behavior, for example, is demonstrated by the ability to discriminate and produce (i.e. name) printed words that the learner has not encountered before, including words that merely resemble structurally those defined as meaningful by a given verbal community. For example, accomplished readers have no difficulty naming the so-called *nonsense* words (e.g., CUG, ZID, VEK) which have been used in research on verbal learning(e.g., Postman, 1975) and, more recently, in behavior analytic research on relational learning (e.g., McIlvane, Kledaras, Munson, King, de Rose, & Stoddard, 1987).

A counterpart within the auditory domain is *echoic* behavior in which the learner reproduces, typically orally, the behavior of a model. As in textual behavior, an echoic does not necessarily reflect established meaning defined within a verbal community (e.g., one can repeat orally the nonsense words just exemplified). The ability to exhibit purely textual and echoic behavior is probably essential to skilled reading, however. In describing these functional relationships, Skinner anticipated the current interest in so-called *phonological awareness* (i.e., behavior that indicates certain established relationships between textual units and corresponding speech sounds) that has recently assumed central importance in the analysis of skilled reading repertoires (Torgensen, Morgan, & Davis, 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 (de Rose, de Souza, Rossito, & de Rose, 1992; de Rose, de Souza, & Hannah, 1996) and is applicable also within cognitive analyses of reading repertoires (cf. Blachman, 1997). To illustrate the approach, research on so-called recombinative generalization has shown that teaching behavior appropriate to, for example, the word pairs BLUE HAT and RED CHAIR may render the learner able to behave appropriately with respect to the pairs RED HAT and BLUE CHAIR without explicit teaching (cf. Goldstein, 1993). Units are thus recombined in novel and appropriate ways. This recombinative minimal unit approach can also be extended to individual words. Research has shown, for example, that when direct teaching that establishes appropriate oral naming of words comprised of separable units within the highly phonetic Portuguese language (e.g., BOLA, LOCA), that learning may be accompanied by emergent naming of recombinations of the constituent units (i.e., LOLA, CABO) (de Rose et al., 1992, 1996; Matos, Hübner, Serra, Basaglia, & Avanzi, 2002).

By themselves, textual and echoic behaviors do not constitute the full range of functional relations that comprise a functional reading repertoire. The learner must also acquire a variety of other functional relations that have traditionally been subsumed under the rubric of "meaning." Among the most important of these functional relations is the *tact*. When shown a picture of a four-legged animal with whiskers, pointed ear, feline eyes, and so on, emitting the spoken word "cat" could function to tact (i.e., name) the picture. Similarly, when shown the printed word CAT, emitting the spoken word "cat" could also function in the manner of a tact, through stimulus equivalence, but it could also be a textual response (e.g., mere phonetic naming by a learner with an appropriate textual repertoire).[1] Further tests are necessary to determine whether or not "cat" does or could function in the manner of a tact.

Evidence to support an inference of true tact functional capability may be obtained using the Sidman (1971) stimulus equivalence paradigm. Within a matching-to-sample paradigm, a learner may be taught to select a comparison picture of a cat in the presence of a sample dictated word "cat." S/he may also be taught to select a comparison printed word CAT 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—bi-directional matching of the picture with the printed word without further training. Moreover, one may find additionally that the learner who has never done so before will spontaneously say "cat" when shown the printed word CAT. In this case, a reasonable inference is that the learner may be capable of tacting that printed word in a manner that is conventionally reinforced by the verbal community of English speakers.

In recent and ongoing applied research, a number of behavior analysts in Brazil have sought to develop reliable methodology for teaching rudimentary reading to the many children from 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, 1996; Matos & Hübner-D'Oliveira, 1992). The work has been inspired in part by Skinner's analysis of verbal behavior (particularly the concept of minimal units) and by Sidman's analysis of equivalence relations. An overarching goal of this research program has been to develop methodology that incorporates within it procedures for establishing the range of functional relations that constitute the basis for a functional reading repertoire. The present study exemplifies this ongoing effort and reports methodology that has proven reliably effective in teaching rudimentary reading to preschool children. The methodology has evolved over a number of years of research that has progressively refined the techniques (e.g., Matos & Hübner-D'Oliveira, 1992; Matos, Hübner, & Peres, 1997; Matos, Peres, Hübner, & Malheiros, 1999; Matos, Hübner, Serra, Basaglia, & Avanzi, 2002). Methodology reported here represents a more comprehensive implementation of contingencies to instantiate a number of the functional relations defined in *Verbal Behavior* within the context of an effective program to teach rudimentary reading.

Method

Participants

Participants were sixteen children aged from

[1] In technical language, of course, a tact is defined as verbal response to a nonverbal stimulus, and the printed word CAT may appear obviously verbal in nature. That status, however, must be acknowledged as an inference— the validity of which depends critically on the topography of stimulus control (cf. McIlvane & Dube, 2003). To illustrate the relevant issue, consider the status of the familiar McDonald's trademark. For an adult, the famous golden arches comprise a capital M which is classifiable as a verbal stimulus. What is the status of the M, however, for a child who has not yet learned letter recognition? For him/her, the McDonald's trademark is arguably as "nonverbal" in nature as the cheeseburger it predicts. Verbal responses to it that may be classified as tacts, however, can come about via stimulus equivalence and related transformation of functions.

Table 1
Stimulus sets used during the study.

Set Name	Elements	Presentation Media
Colors-PA	Color patches: yellow, blue, green, red	Computer screen
Colors-PB	Dictated words corresponding to Colors-PA	Experimenter's voice
Pictures-PC	Pictures (colored): train, airplane, and snail	Color prints
A	Dictated words: boca, cabo, bolo, lobo	Experimenter's voice
B	Line Drawings corresponding to Set A	Computer screen
C	Printed words corresponding to Set A	Computer screen
A‘	Dictated words: lolo, bobo, loca, calo	Experimenter's voice
B‘	Line Drawings corresponding to Set A‘	Computer screen
C‘	Printed words corresponding to Set A‘	Computer screen
A“	Dictated words: bola, bala, coca, caco	Experimenter's voice
B“	Line Drawings corresponding to Set A“	Computer screen
C“	Printed words corresponding to Set A“	Computer screen
C“‘	Printed words:coco, cola, lola, loba, loco, boba, colo, cala	Computer screen
S1	Printed syllables: BO, LO, CA	Computer screen
S2	Printed syllables: BA, LA, CO	Computer screen
S3	Printed syllables: BO, LO, CA, MA, TA	Wood blocks
S4	Printed syllables: BO, BA, LO, LA, CA, CO, MA, TA	Wood blocks
AN C	Printed words corresponding to Set A	Wood blocks
AN C‘	Printed words corresponding to Set A‘	Wood blocks
AN C“	Printed words corresponding to Set A“	Wood blocks

5-6 (years-months) to 6-2 at the start of the study. All came from low-SES families. Their parents were on welfare or were unskilled workers (e.g., domestics, laborers, etc.). No parent had finished elementary school. All children attended a public preschool in São Paulo, Brazil that provided no instruction in literacy skills.

Setting and Materials

Participants were seen individually in 25-30 minute sessions, typically twice per week. The children sat at a table on which rested a Pentium computer and a touchscreen-equipped monitor that presented all stimuli and recorded the data. Experimental operations were controlled by a software program written to support research of this type (see Acknowledgements). Nearby was another table that contained the reinforcers, toys, and edibles. The experimenter sat behind the participant during the sessions.

Discriminative stimuli. Table 1 shows the 20 sets of stimuli that were use in the course of the study. Stimuli were of five types: (1) color patches presented on the computer screen, (2) words dictated by the experimenter, (3) pictures presented on the screen, (4) written syllables, and (5) written words. The latter two stimulus types were presented in two formats, on the computer screen and on wooden blocks. Each of the words was composed of two consonant-vowel syllables (the first accented) and was meaningful in Portuguese. Words from Sets C and C‘ had the vowel O pronounced as a closed O (as in *slope*), Sets C“ and C“‘ had words with a closed O and other words with an open O (as in *ball*).

All screen-presented visual stimuli were presented within 5.0 x 6.0 cm rectangles (“windows”), displayed on a black background. Matching-to-sample trials presented five windows. One window was centered at the bottom of the screen; this window was used to display the sample. Centered above the bottom window were the other four windows, displayed in a 2 x 2 array; these were used to present comparison stimuli. Naming trials displayed stimuli within a single window at the bottom of the screen.

When a color stimulus was presented, it filled the entire window in which it was displayed. Pictures were multicolored, and printed words were printed in 36-point black Arial capital letters; both types of stimuli were presented on yellow backgrounds.

Wooden blocks presenting syllables were 3.0 x 1.5 x 1.0 cm; those presenting complete words were 5.5 x 1.5 x 1.0 cm. The former could be presented singly or as two together to display a two-syllable word.

Reinforcing consequences were a brief computer-generated musical phrase, verbal praise from the experimenter, and a hand-delivered token. Tokens could be exchanged after sessions for items selected from an assortment of food items and little toys; these items had different "prices" and they were varied every three weeks to maintain their efficacy as reinforcers.

During training, every correct response was followed by reinforcing consequences; incorrect responses were followed by .5 s intertrial interval. During that interval, the screen was dark. No stimuli were present on the screen until the next trial began. During testing, no reinforcing consequences followed any trial. Instead, children were told that their choices were being recorded and that the number of tokens corresponding to their correct selections would be given to them at the end of the session. In addition, they were told that extra reinforcers were available for paying attention and performing well. These latter procedures were incorporated to maintain the children's motivation during the test sessions.

Sequence and Characteristics of Training and Test Procedures

Children were first introduced to the token reinforcement system. Thereafter, all of the stimuli that were drawings or were made up of printed letter s (i.e., those from Sets B, C, B', C', B", and C") were presented individually in an unsystematic order, and the child was asked to name each one orally. Each stimulus appeared on three such oral naming pretest trials. Where pictures were involved, one could infer that the naming responses were tacts, that is, responses that had been previously established and reinforced by the child's verbal community; as such, all correct responses were followed by reinforcing consequences. Where stimuli were comprised of printed letters, the minimum required was a textual response, but positive test outcomes were not expected in these children, who had little or no prior reading instruction. Indeed, we included a child in the study only if s/he failed to name *any* written word correctly; as such, no reinforcing consequences followed any such trial.

Pretests and subsequent preliminary training (described below) were needed to verify performances that were prerequisite for subsequent training and testing. For example, the logic of the procedures to be implemented required that the child give a familiar, culturally appropriate name for each drawing (i.e., to tact the pictures). If the child did not know that name or did not recognize the picture on its first presentation, the experimenter spoke that name herself and told the child a brief story to put the name of the picture in context. On subsequent trials, stories were omitted, and all trials were followed merely by differential consequences. For any child who required instructions in naming the drawings, another block of trials composed of Sets B, B', and B" was presented. Such trial blocks were repeated until the child responded to all trials without error.

Further training was conducted to establish the simultaneous matching-to-sample baselines that would be needed to implement the experimental procedures. Identity matching-to-sample on the computer screen was established first (Pretraining A). Sample and comparison stimuli were four color patches (see Table 1, Colors-PA), presented twice each, within a block of eight trials. These stimuli were displayed at the bottom of the screen, and children were to touch the sample before selecting a comparison stimulus above it. In this part of pretraining, the number of comparison stimuli presented was initially one (identical to the sample); all selections of comparison stimuli that matched the sample in this and all subsequent pretraining were followed by reinforcing consequences. When the child made 8 of 8 correct comparison selections in the one-comparison format, the following identity-matching block presented two comparison stimuli (one identical and one nonidentical); in these and all subsequent matching-to-sample procedures, the position of correct and incorrect comparison stimuli varied unsystematically across trials. When the 100% criterion was met, the number of comparisons was increased, first to three and then to four.

Table 2
Sequence of experimental phases, including prestests and pretraining.

Phases	Tasks
Pretest	Test oral naming, Sets C, C‘, and C“; Teach oral naming, Sets B, B‘, and B“
Pretraining A	Teach identity matching-to-sample with Set Colors-PA
Pretraining B	Teach arbitrary matching-to-sample, Set Colors-PA and Set Colors-PB
Pretraining C	Teach correct use of “begin” and “end” with Set Pictures-PC
I	Teach feature matching — printed words to Set S1 (initial position)
II	Teach feature matching — printed words to Set S1 (final position)
III	Teach arbitrary matching — Set B to Set A
IV	Test/teach constructed response identity matching — Set S3 to Set AN C
V	Test/teach constructed response arbitrary matching — Set S3 to Set A
VI	Test arbitrary matching — Set B to Set C and Set C to Set B
VII	Teach arbitrary matching — Set B‘ to Set A‘
VIII	Test arbitrary matching — Set B‘ to Set C‘ and Set C‘ to Set B‘
IX	Test/teach constructed response identity matching — Set S3 to Set AN C‘
X	Test/teach constructed response arbitrary matching — Set S3 to Set A‘
XI	Teach feature matching — printed words to Set S2 (initial position)
XII	Teach feature matching — printed words to Set S2 (final position)
XIII	Teach arbitrary matching — Set B“ to Set A“
XIV	Test arbitrary matching — Set B“ to Set C“ and Set C“ to Set B“
XV	Test/teach constructed response identity matching — Set S4 to Set AN C“
XVI	Test/teach constructed response arbitrary matching — Set S4 to Set A“
XVII	Test oral naming — Sets C, C‘, C“, and C‘“

In the next part (Pretraining B), arbitrary matching-to-sample was established. Comparison stimuli were the same four colors that had appeared on identity-matching trials during Pretraining A, and the samples were experimenter-dictated names corresponding to those colors (Colors-PB, Table 1). Criterion for advancing was 100% accuracy on an 8-trial block that presented each of the four samples twice. No visual sample stimulus was displayed on any of the arbitrary-matching trials.

In the last part (Pretraining C), the children were shown picture stimuli (an airplane, a train, and a snail, Pictures-PC, Table 1) three time each, and they were instructed to indicate where the pictures “began” (i.e., by pointing to the front portion of the pictured items) and “ended” (i.e., by pointing to its rear portion). If a child did not immediately give a correct answer, s/he was told a brief story about the picture and its function, and then the task was presented once again. This pretraining was necessary to prepare the children for responding to the beginning or end of a word, as they did not generally understand “left” vs. “right” relationships that would be relevant later in training.

Table 2 summarizes the subsequent experimental procedures. In total, there were 17 phases, some of which replicated the procedures of earlier phases with different stimulus sets. What follows will summarize the details of and rationale for the various phases.

Teaching feature matching (syllable topography). Phases I and II (using Set 1 [(BO, LO, CA]) and Phases XI and XII (using Set 2 [BA, LA, CO]) were conducted to establish discrimination of stimulus elements (syllables) that would later be combined to form printed words. On every trial during these phases, the sample stimulus was one of the syllables (wood blocks). The experimenter dictated the syllable orally, required the child to repeat it (thus verifying echoic response capability) and then to touch one of four comparison stimuli. The comparison stimuli were four printed words (used only for training purposes and not shown in Table 1); the positive stimulus contained the same syllable as the sample. As Table 2 shows, in Phases I and XI, the matching syllable was presented at the beginning of the word; in Phases II and XII, the matching syllable was presented at the end of the correct comparison stimulus. For convenience in exposition, we will use the terms "training position" to describe the position that was the focus of training (i.e., at the beginning vs. the end of the word) and "other position" to describe the one that was not on a given trial.

To minimize errors, the differences between the sample and the incorrect comparison stimuli were initially large, and those differences were reduced systematically over steps. In the first step of each phase, none of the incorrect comparison stimuli contained the same consonant as the sample; shared vowels were always placed in the other position. Phase I will be used to exemplify this and all subsequent steps in the trial series (e.g., sample: BO, correct comparison: BOCA; incorrect comparisons: LAMA, CERA, FIG*O*). In Step 2, one incorrect comparison shared a consonant in the training position (e.g., sample: BO; correct comparison: BODE; incorrect comparisons: *B*ATE, MESA, TATU). In Step 3, one incorrect comparison shared a vowel in the training position and a consonant in the other position (e.g., sample: BO; correct comparison: BOTO; incorrect comparisons: C*O*LA, TA*B*A, NAVE). In Step 4, the sample and one incorrect comparison stimulus shared a consonant-vowel combination, the latter in the other position (e.g., sample: BO; correct comparison: BOTE; incorrect comparisons: CA*B*O, PERU, MOLA). In Step 5, one incorrect comparison reversed the syllables of the correct comparison and the others had less complete overlapping letters (e.g., sample: BO, correct comparison: BORA; incorrect comparisons: *RABO*, COPA, BELA). Words selected for training in this and subsequent were typically in common usage, and it is likely that children were familiar with them prior to training.

During Steps 1, 4, and 5, training with each syllable (see Table 1) was done initially in a separate 6-trial block; all three syllables were then combined in a fourth 12-trial training block. During Steps 2 and 3 training, all three syllables were presented only in the combined 6-trial training block, since pilot studies showed that training with separate 6-trial blocks was not necessary at this point (i.e., no errors occurred). Advancement criterion for each block was errorless performance. If one or more errors occurred within a given block, then it was repeated. During the fourth block on Steps 1, 4 and 5, participants had to exhibit 100% correct responses prior to moving on. If not, the block was repeated.

Auditory-visual arbitrary matching (Sets B to Sets A). In Phases III, VII, and XIII, the children learned to match computer-displayed pictures to words dictated by the experimenter. At the beginning of each trial, the experimenter dictated the sample name and required the child to repeat it before selecting one of four comparison stimuli that were displayed. This auditory-visual learning provided behavioral prerequisites for subsequent tests of stimulus equivalence that would be used to verify comprehension of the textual stimuli.

Constructed response identity matching to sample (CRMTS-ID): Wooden-block word sample and wooden-block syllable comparison stimuli. During Phases IV, IX, and XV, children learned to combine/recombine syllables such that they were identical to two-syllable sample stimuli (analogous to the so-called "anagram" procedure of Mackay [1985]). Both the sample and comparison stimuli were comprised of wooden blocks on which letters were embossed. From this array of comparison stimuli, the child was required to choose, in succession and in left-to-right order, the two syllables that comprised the sample block. Three trials with each sample stimulus were presented in every block of constructed-response trials. Sample stimuli in these phases were selected to contain the same syllabic stimuli as the words from sets that would be used during later training of reading comprehension (termed Sets AN C, AN C‘, and AN C“ stimuli in Table 2). The intent of using these stimuli was to isolate the syllabic components such that their selection would be analogous to the textual behavior of copying.

Trials began when the experimenter displayed a wooden-block sample containing a word and required the child to name it. If the child did not give the correct name, the experimenter dictated it and the child was required to repeat it. Thereafter, the wooden-block comparison stimuli containing syllables were displayed. From this array, the child was required to select the syllables that matched the wooden-block sample; the comparison stimuli were always those from the set that was the focus of training (see Tables 1 and 2). Prior to selecting each wooden-block syllable, the child was required to say its name (i.e., to say "BO" prior to selecting the BO wooden block); if s/he did not say the name of the block prior to selecting it, corrective instructional feedback was provided. The child was also required to select the syllable-blocks in the same left-to-right order that appeared in the wooden block sample. Finally, when the word was constructed, the child was required to say its corresponding name once again.

If the appropriate reading repertoire had emerged as a product of prior training, it was possible that the child could accomplish the performance just described without training (i.e., the first trial can be viewed as a test of the skill being targeted). If the child did not exhibit accurate matching to the sample independently, verbal and/or other prompts were provided to occasion the correct behavior, and the trial was scored as an "error." Prompts were eliminated gradually over trials, beginning with the last step in the construction sequence (analogous to a backward chaining procedure).

During all three phases of CRMTS-ID, the number of stimuli available in the choice pool was larger than the required syllables, because there were (a) opportunities to construct comparison stimuli in which the first syllable and the last were identical, e.g., BOBO, see Tables 1 and 2), and (b) other syllables that were not appropriate selections for the displayed samples. As training progressed, the child's baseline expanded. In Phase IX, for example, trials were presented not only with newly introduced stimuli (Set AN C‘) but also those previously mastered (Set AN C); similarly, Phase XV included both the new Set AN C“ and the old Set AN C‘.

The constructed-response matching-to-sample baseline training provided essential behavioral prerequisites for subsequent phases (V, X and XVI) in which syllables were combined to "write" words that corresponded to dictated words (see Dube et al., 1991 for detailed discussion of the development of this procedure and its potential benefits for establishing reading comprehension). In addition, the child was required to produce the name of each sample before selecting a comparison stimulus—a potentially helpful step towards learning the relation between the printed words and its corresponding auditory counterpart.

Constructed response arbitrary matching to sample: Dictated word samples and wooden-block syllable comparison stimuli (CRMTS-ARB). During Phases V, X, and XVI, the child was required to construct printed words (i.e., select the appropriate wood block) that matched samples dictated by the experimenter. Procedures were like those in the CRMTS-ID phases just described, except that the sample stimulus was dictated rather than visually presented. The child was required to repeat the dictated word before constructing the comparison stimuli. Also as before, the first trial with every dictated word-constructed word pair constituted a test of whether the prior training had led the child to learn the critical relations between these two stimulus types. If the child did not construct comparison stimuli that matched the sample stimuli, however, the correct sequence of construction was prompted by the experimenter in the manner described above.

Tests for emergent equivalence relations. The objective of Phases VI, VIII, and XIV was to test for the emergence of reading with comprehension—relations between picture samples and printed word comparisons (BC) and *vice-versa* (CB). The procedures were a systematic replication of the study reported by Sidman (1971). All performances during these phases were tested in the standard matching-to-sample format in which the child merely touched a comparison stimulus on each trial (i.e., did not respond via construction).

Prior to Phase VI, the child had received both identity and arbitrary constructed-response matching training. It was logically possible, therefore, for children to have learned directly to relate the printed words to corresponding dictated words (therefore facilitating the emergence of AC performance), and thus to relate the printed words with the pictures on the basis of stimulus equivalence. By contrast, however, tests conducted in Phases VIII and XIV occurred prior to, rather than after, the constructed response matching. Accurate printed word-picture matching, therefore, could occur only if the children were able to read with comprehension via recombination of syllables that had appeared in different orders during earlier training.

The BC and CB equivalence tests were embedded within a baseline of trials that evaluated directly the AB and AC performances that were prerequisite for the emergent equivalence relations; as in prior auditory-visual matching performance the child was required to repeat the dictated sample prior to selecting a comparison stimulus. Tests were conducted in 20-

Table 3
*Results of training phases in relation to the minimum number of trials necessary to meet criterion.**

				Syllable Topography				CRMTS-IDAV			MTS-ARB			CRMTS-ARB
Phase	PtA	PtB	PtC	I	II	XI	XII	IV	IX	XV	III	VII	XIII	V
Min. Trials	44	12	15	102	102	102	102	12	24	24	16	16	16	12
Part. No.														
P8	52	12	15	124	116	102	104	12	24	24	16	16	16	12
P9	52	12	15	156	128	122	110	24	24	24	16	16	16	12
P10	56	12	15	114	144	112	132	24	24	24	16	16	16	12
P11	44	24	15	124	124	112	124	12	24	24	16	16	16	12
P12	44	12	15	128	128	126	140	60	24	24	32	16	16	24
P13	44	12	15	144	104	126	104	24	24	24	16	16	16	12
P14	44	12	15	114	104	102	104	12	24	24	16	16	16	12
P15	44	12	15	106	104	110	122	36	24	24	32	16	16	24
P17	44	12	15	104	114	104	102	24	24	24	16	16	16	12
P18	44	12	15	108	102	104	114	12	24	24	16	16	16	12
P19	52	12	15	124	112	102	126	24	24	24	16	16	16	12
P20	44	24	15	106	118	110	110	24	24	24	16	16	16	12
P21	44	12	15	118	108	104	122	12	24	24	16	16	16	12
P22	44	36	15	116	132	102	102	12	24	24	16	16	16	12
P23	44	12	15	200	132	102	116	12	24	24	16	16	16	12
Mean	46	15	15	126	118	109	116	22	24	24	18	16	16	14

* Data from P16 were excluded from analysis (see text).

trial blocks (12 trials of either the BC or the CB relations and 4 trials each of the AB and AC relations, with all trials presented in an unsystematic order) presented twice. All trials were conducted without differential consequences; whether consistent or inconsistent with experimenter-defined equivalence relations, every matching selection during this phase was followed merely by the intertrial interval and the next trial.

Note that the AC matching relation in the standard format was necessarily the product of prior training in the CRMTS format. Standard-format AC trials had never been the focus of explicit discrimination training and no differential consequences were provided during these tests. Positive results on the AC matching tests would provide further confirmation that these relations had been learned during prior direct training on related performances (i.e., CRMTS).

In Phase VI only, any performances on the BC and CB tests that did not meet a criterion of at least 95% resulted in a return to CRMTS before the BC and CB relations were re-tested. Results will be shown only for the first test of BC and CB relations, however.

Test of oral naming of printed words. These tests were conducted with Sets C, C‘, C“, and C“‘ (the last of which tested naming of unit recombinations that had never appeared on MTS trials, thus constituting a "pure" test of textual responding). Whereas prior performances had emphasized selection of stimuli in response to dictated words and pictures, it was possible also that oral naming of printed words might emerge either as a response to the textual stimuli themselves and/or as a consequence of equivalence class formation. Each of 20 words was presented successively on the computer screen, and the child was asked to name it. Words from Sets C and C‘ were presented once each. Words from Set C“ and Set C“‘ were presented two and three times each, respectively.

RESULTS AND DISCUSSION

Pretests and preliminary training were completed within a single session for every child. Overall, the children made few errors during the pretraining procedures. Data in the leftmost columns of Table 3 show that children, on average, completed these steps in a total of about 77 trials (results of Pretraining A, B, and C combined). Not shown for these and all subsequent tasks are data for one child (P16), who exhibited much "off-task" behavior during the sessions (e.g., leaving the test setting, repeatedly attempting to engage the experimenter in irrelevant conversation, etc.), thus suggesting inadequate motivational support in and/or insufficient pre-experimental adaptation to the experimental setting). For all other children, however, the typically high accuracy during pretesting and pretraining demonstrated that they had the behavioral prerequisites necessary to proceed to the experimental phases.

Feature matching (syllable topography). Phases I and II (using Set 1 [(BO, LO, CA]) and Phases XI and XII (using Set 2 [BA, LA, CO]) were conducted to establish discrimination of stimulus elements (syllables) that would later be combined to form printed words. For each phase, the minimum number of trials programmed was 102. Table 3 shows that there were differences between the number of training trials required to meet criterion in the initial (i.e., I and XI) vs. the final positions (II and XII, compare the fifth and seventh column to the sixth and eighth). These differences were small, however, and, in general, the training was effective without generating numerous errors by the children. Training times for each of these phases varied across children. Ranges were approximately 25-90 minutes (Phase I), 25-60 minutes (Phase II), 25-60 minutes (Phase XI), and 12-60 minutes (Phase XII). Training time for the entire set of these syllable topography tasks ranged from approximately 100-263 minutes (mean =150 minutes) across participants.

Auditory-visual arbitrary matching (AVMTS-ARB, Phases III, VII, XIII). In these phases, children were taught to match dictated words to corresponding pictures (to be used in subsequent reading comprehension tests). Training progressed rapidly. Only two children needed more than the minimum programmed number of trials (16). In Phases III and VII, average training time ranged from approximately 8-30 minutes. For Phase XIII, the range was 8-13 minutes.

Constructed response identity matching to sample (CRMTS-ID, Phases IV, IX, XV): Wooden-block sample and comparison stimuli. During the first CRMTS-ID Phase (IV), Table 3 shows that only seven children achieved perfect scores initially (i.e., the 12 trial minimum). Thus, the prior training of syllable topography was not sufficient by itself to establish recombinative identity matching. Further training was needed. Most children required only one additional block of 12 trials to demonstrate mastery, but some children required more (see Table 3). Once established initially, however, substantial transfer of the CRMTS-ID training was evident. No child required more than the minimum number of trials (24) to achieve the mastery criterion in Phases IX and XV. Not surprisingly given the accuracy scores, training time during these phases was minimal (range: 8-30 minutes in Phase IV; 8-15 minutes in Phases IX and XV).

Constructed response arbitrary matching to sample (CRMTS-ARB, Phases V, X, XVI). Dictated samples and wooden-block comparison stimuli. All children met criterion very rapidly. Only two required more than the minimum number of trials (12) in Phase V (see Table 3), and none did in the two subsequent phases (data not shown). Clearly, there was substantial transfer of training from preceding phases. Indeed, the fact that children performed perfectly in Phases X and XIV is very strong evidence that these performances were accomplished via spontaneous recombination of minimal units that had been established in prior discrimination training.

Tests for emergent equivalence relations (reading comprehension, Phases VI, VIII, XIV). Tests of BC and CB relations constituted a test for the emergence of reading with comprehension. Also tested were AC matching relations, which (a) could emerge as a product of the prior CRMTS training and (b) were logically prerequisite for the emergence of BC and CB relations. Data for the 24 trials of the initial test are shown in Table 4.

Overall, results on the BC and CB tests were consistent with the formation of equivalence classes. Even though the tests were conducted without differential reinforcement, a great majority of children's scores exceeded 90% con-

Table 4
Results of tests (% consistent with stimulus equivalence) for potentially emergent matching-to-sample relations. N/R = data not recorded due to a technical problem with the apparatus.

	Phase VI		Phase VIII		Phase XIV	
Part. No.	BC/CB	AC	BC/CB	AC	BC/CB	AC
P8	75	100	88	100	100	100
P9	100	98	100	98	100	98
P10	100	100	88	98	88	88
P11	75	75	94	98	94	75
P12	56	73	63	96	94	67
P13	100	98	100	100	100	100
P14	100	100	100	85	100	98
P15	94	92	100	98	100	88
P17	100	98	100	100	100	98
P18	100	93	100	98	94	98
P19	100	91	100	100	100	83
P20	100	100	100	100	100	100
P21	88	100	94	100	100	100
P22	75	97	100	97	87	97
P23	94	97	N/R	100	87	83

sistent with such relations. Low scores were rare, and only 1 of the 45 scores arguably even approached the so-called "chance" range (typically defined as scores from 15%-35% on a four-comparison task). Performance was comparable on the AC trials, providing evidence of substantial transfer from prior training and including recombinative generalization of the minimal units established via direct training.

The generally accurate transfer performances by the children were especially impressive in that the performances tested in Phase VIII and XIV were necessarily a result of (a) spontaneous recombination of minimal units and (b) the children's tact repertoire which was verified (and experimentally defined) by the training contingencies. Surely, achieving such transfer is a critical step in developing a competent repertoire of generalized reading, even at a rudimentary level.

Notwithstanding the high levels of performance overall, there are curious features to certain aspects of the data. Note the few instances in Table 4 in which accuracy on BC/CB trials was not accompanied by comparable accuracy on AC trials and *vice versa*. While these disparities typically were not great, they do present a challenge to an analysis based on simple stimulus equivalence relations. If all of the stimuli within a given class were equivalent, why the disparities? Thus far, there have been few attempts to understand these minor but puzzling difficulties. One exception may be found in stimulus control topography (SCTCT) coherence theory (McIlvane et al., 2000; McIlvane & Dube, 2003). The SCTCT analysis accounts for such finding in terms of across-trial competition of more than one equivalence relation; those relations not in accordance with the teacher/experimenter's definition of the relevant stimulus relations are scored as "errors," thus reducing the overall accuracy score. The SCTCT analysis was developed in part to help understand the "gradual emergence" of equivalence relations that is sometimes observed in equivalence studies; over trials, performance improves, even if the tests are conducted in extinction.

It seems possible that some of our findings may be related to the gradual emergence phenomena. Note in Table 4 that AC scores were higher in Phase VIII than in the other two test phases (VI and XIV). Perhaps these higher scores resulted at least in part from the repeated exposure to the syllables (i.e., those of Phase VI, but presented in different combinations). According to the SCTCT analysis, such exposures could reduce competition from competing stimulus control relations (cf. Dube & McIlvane, 1996). While the SCTCT analysis

Table 5
Results of tests (% consistent with experimenter-specified equivalence relations) for potentially emergent naming performances.

Part. #	Set C (N=4)	Set C‘ (N=4)	Set C“ (N=8)	Set C“‘ (N=24)
P8	100	100	100	100
P9	100	100	100	100
P10	100	100	100	88
P11	100	100	100	96
P12	100	100	100	44
P13	100	100	100	100
P14	100	100	100	100
P15	100	100	100	100
P17	100	100	100	88
P18	100	100	100	100
P19	100	100	100	88
P20	100	100	100	83
P21	100	100	100	88
P22	100	100	100	100
P23	75	50	75	63

has some empirical support in studies of simple discrimination learning (e.g., McIlvane et al., 2002), it has yet to be explicitly evaluated in the context of a stimulus equivalence experiment. Thus, we cannot presently account with any certainty for differences in BC/CB and AC accuracy levels.

Two minor problems were noted during procedures. First, the testing was apparently insufficient to prepare the children for completely accurate recombination of syllabic units. There were certain minor mismatches in the pronunciation of certain syllabic units (e.g., an open “O” as in COCA vs. a closed “O”). In earlier training, they had learned pronunciations with the latter. Had we preceded the stimulus equivalence and recombination tests with CRMTS (as in Phase VI), it seems likely that such problems could have been avoided. Second, and of somewhat greater concern was the tendency of some children to produce one syllable after the other with a slight pause in between them (see Phase IV). When they did this, children did not always detect that the two syllables combined to form a word (e.g., BO . . . LO). If they repeated the syllables a bit faster, either spontaneously of after brief experimenter prompting, they rapidly detected the relationship of interest—a finding that is fully consistent with past research in the area of “precision teaching” (Lindsley, 1992).

Oral naming of printed words. Table 5 shows the results for these tests (Phase XVII), which were conducted after all of the other procedures. Four findings seem particularly worthy of note.

1. All but one child exhibited highly accurate naming of stimuli from Sets C, C‘ and C“. This finding is consistent with much data reported in the equivalence literature since its earliest days (e.g., Sidman, 1971).
2. In marked contrast, one child exhibited fairly low scores on naming tests despite generally high scores on tests for stimulus equivalence and recombination of syllabic units. Such findings occur with some frequency in the equivalence literature, leading to the assertion that coincident naming is neither necessary for nor sufficient to produce emergent behavior and vice versa (cf. Sidman et al., 1986). In *Verbal Behavior* terms, one’s repertoires as a speaker and listener may be independent of one another (cf. Lee, 1981).
3. Data on naming of stimuli from Set C“‘ showed greater across-participant variability than the other sets. In general, naming of syllable recombinations was accurate, suggesting development of a true textual repertoire and perhaps the beginnings of phonological awareness. As Table 5 shows, however, not all children exhibited accurate textual behavior. For some children at least, the other aspects of our procedures may be important to allow them to exhibit accurate syllabic recombination.
4. Some of the children’s behavior suggested that certain of our stimulus selections may not have been considered sufficiently in advance of our experimental work. For example, the combination CALA (the sole word that was not a noun but a verb) tended to occasion errors. Several children responded to this word by saying “Carla,” which was the name of another child in their class (parenthetically a demonstration of SCTCT-like competition). Another combination was LOLA, which is a woman’s name of Spanish origin; it appeared that most children were not familiar with it. These observations suggest that coherence with extraexperimental experience may be

an important variable in producing emergent behavior that is consistent with the teacher/experimenter's objectives.

Results summary. Despite a few minor problems, it appears that the procedures reported here are effective in establishing stimulus equivalence, recombination of syllabic units, and rudimentary reading repertoires in children who have had no prior reading instruction. These results were achieved with all of the children within a fairly short time frame. The entire procedure required an average of only 11 sessions (range: 9-14), requiring only 4-7 hours. These procedures seem to be a substantial improvement of those reported in our earlier articles (Matos et al., 1999, 2002) (see below).

GENERAL DISCUSSION

Implicit in our design of the procedures reported here was the assumption that functional, generative rudimentary reading repertoires could be encouraged by establishing three types of verbal relations: tacts, echoics, and textual responses. Critical behavioral prerequisites for establishing these relations were provided not only by matching-to-sample procedures like those used by Sidman (1971) but also via constructed-response matching to sample, a variant of MTS first reported by Mackay and Sidman (1984), and supplemental procedural features that were added to encourage verbal responding. What follows will summarize these critical behavioral prerequisites in relation to the taxonomic categories articulated by Skinner (1957).

1. When children spoke culturally-appropriate names in the presence of pictures, tact function was a reasonable inference. When training established the basis for equivalence relations involving those pictures and printed words, it is reasonable also to infer that children became capable of tacting the latter—not merely exhibiting textual responses to the printed stimuli.
2. Echoic responses were essential in order to verify that each child could (a) discriminate dictated words from others that were presented and (b) reproduce those dictated words orally, a behavior prerequisite for accurate oral tacting of both pictures and printed words. It is not clear from the present results, however whether the echoic repertoire had other functional significance. Horne and Lowe (1996) have argued, for example, that emergent stimulus equivalence reflects so-called "behavioral fusion" of the repertoires of the speaker and the listener. If such fusion is indeed involved in the manner they specify, the procedures reported here clearly encouraged it. For example, echoics were explicitly required in the presence of stimuli that were to be related to the dictated words, that is, to repeat the sample before selecting a comparison stimulus on matching-to-sample trials. Subsequent experimentation will be needed to determine whether establishing echoics outside the context of the matching-to-sample relations will prove similarly effective in encouraging the development of functional reading repertoires. Research thus far has been limited (e.g., Matos et al., 2002), but the data thus far collected suggest that the "package" of procedures reported in the present study—and not isolated training on various verbal operants—provides the training critical to reliable emergence of recombinative generative reading in a high proportion of children.
3. Textual responses were likely essential for recombinative generalization involving the minimal syllabic units that made up the printed words used in the study. Relating our work to cognitive analyses of reading skills, phonological awareness clearly involves phonological and textual units of a type consistent with Skinner's (1957) analysis. For example, the child who learns to select and to produce the spoken syllable "bo" in the presence of the printed syllable BO does so in the absence of any tact relationship defined by the verbal community (i.e.,"bo" is not independently meaningful in Portuguese).

A question for further study is whether textual responses reflect equivalence relations involving spoken and printed syllables. A relationship of this nature is consistent with the logic of the stimulus equivalence paradigm and the recombinative generalization that has been demonstrated in behavior analytic studies of procedures for teaching rudimentary reading to persons with developmental limitations (e.g., Saunders, O'Donnell, Vaidya, & Williams, 2003). It is also consistent with Sidman's (2000) recent theoretical analysis of the relationship between the various elements of the reinforcement contingency. Related analyses that have focused primarily on ordinal stimulus relations (e.g., Mackay, Kotlarchyk, & Stromer, 1997; Holcomb, Stromer, & Mackay, 1997) may also prove relevant to the analysis of textual responding in the syllabic recombination that may result in generative reading.

Verbal behavior analyses of stimulus equivalence. Analysis of emergent equivalence relations within a framework of verbal relations as defined by Skinner (1957) may help to respond to an issue identified many years ago by McIlvane, Kledaras, Dube, Iennaco, and Stoddard (1989). These authors noted that stimulus equivalence was then (and continues to be) promoted as the behavior analytic counterpart to "meaning" as defined by the layman and in psycholinguistics. Yet, most equivalence experiments appear remarkably devoid of "meaning" as conventionally defined in other branches of behavioral science (e.g., psycholinguistics). For purposes of experimental control, typical laboratory studies define potential equivalence relationships among sets of arbitrary, inherently meaningless stimuli (e.g., nonrepresentational forms, nonsense syllables, etc.). Positive outcomes are shown when participants exhibit equivalence relations among these stimuli in a manner that is consistent with experimenter-arranged contingency relationships. The question identified by McIlvane and colleagues can be posed as follows: *While members of a given equivalence class may have the same meaning, what is it that they mean?* They concluded that the empirically demonstrated "meaning" in typical experimental preparations was merely a statement of contingency relations—the contextual determinants of reinforcement. As such, their analysis was consistent with the common view among behavior analysts that verbal behavior is not different in kind from other forms of behavior, however complex and generative the former may appear to be.

Viewed from a verbal behavior perspective, the equivalence relations in typical laboratory studies appear analogous to the behaviors established within the present study—behaviors that permitted textual responding and syllable recombination. That is, when a child is taught that the printed syllable BO is to be related to the dictated syllable "bo," the "meaning" is merely a procedurally defined relationship—an experimentally defined tact. That is, oral naming of BO as "bo" is established and reinforced initially within the context of the experiment. That relationship may prove useful not only within its confines (i.e., permitting potentially reinforceable recombinative responding) but also later as those experimentally defined tacts provide the behavioral prerequisites for subsequent textual responding in other contexts.

By implication, the behavioral relations involved in cognitive analysis of recombinative processes involved in reading repertoires may submit to analysis in terms of verbal equivalence relations. For example, spontaneous recombination of minimal units involving differing initial consonants and identical vowel-consonant pairs (e.g., rhymes such as B-AT, C-AT, H-AT, M-AT, etc.) may involve the same or similar behavioral processes as those involved in syllabic recombination (see also Skinner's [1957], p. 336, discussion of autoclitic frames and Chapter 11, "New Combinations of Fragmentary Responses").

Component analyses of verbal behavior relations in rudimentary reading instruction. Although our study was inspired by Skinner's analysis of verbal relations and Sidman's stimulus equivalence paradigm, our primary interest has been defining an effective set of contingencies for establishing rudimentary reading repertoires. The population of primary interest has been the large group of children with low SES who are at risk for school failure due to limited educational opportunities. As such, we made no effort to control all of the variables that might be involved in a comprehensive analysis of the behavioral prerequisites for rudimentary reading. That acknowledged, the larger program that preceded the present study has explored a number of variations that presented various program components in different arrangements. In the study by Matos and colleagues (2002), for example, a training package that presented components in a different, somewhat more isolated fashion led to emergent matching-to-sample relations but not spontaneous recombinative performances with new words in a large majority of similar children.

Given that we have defined a very effective set of training contingencies, a logical next step is a more comprehensive component analysis of the contingencies to determine which features are truly essential and which (if any) steps can be simplified or even omitted. Because the contingencies reported here evolved over a number of prior studies, it is possible to make informal comparisons among them to develop hypotheses that may be tested in subsequent formal comparison studies. There are also procedural aspects that require closer examination. For example, we typically required that the children meet a very high accuracy criterion (often 100%) before moving from phase to phase. Might applying a less stringent criterion permit even faster progress through the program or might doing so undermine its effectiveness?

Another consideration is whether the procedures can be fully automated. In the present case, the procedures were semi-automated, involving a teacher in certain aspects (e.g., during pretraining, presenting the wood blocks, etc.). On its face, it would seem preferable to provide a program that is fully computer-implemented and/or computer-managed. Doing so could provide the basis for effective individualized instruction. Given the age of the children involved, however, it seems likely that some dimension of social motivational support would remain important even in highly automated procedures. Moreover, practical realities of typical classrooms dictate that most or all instruction must be provided in group situations, often involving paraprofessionals and/or parent volunteers. We are hopeful that our work will assist educators in designing applied behavior analytic procedures in which instruction can be delivered in a manner that maximizes both effective resource implementation and student achievement.

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