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RECOMBINATIVE READING DERIVED FROM PSEUDOWORD INSTRUCTION IN A MINIATURE LINGUISTIC SYSTEM

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A miniature linguistic system was used to study acquisition of recombinative symbolic behavior. Three studies evaluated the teaching conditions of conditional discriminations with printed and spoken pseudowords that could potentially generate recombinative reading. Fifty-four college students across all studies learned to match 12 printed pseudowords to 12 spoken pseudowords. Some also matched pictures to the same spoken words. Each two-syllable pseudoword was formed by symbols from an arbitrarily created alphabet composed of four vowels and four consonants. Letters had univocal correspondence with phonemes. Recombinative receptive reading, comprehensive reading, and textual responding to pseudowords were periodically assessed. Experiment 1 (n = 20) showed that recombinative reading increased as the number of trained words composed of the same symbols increased. Experiment 2 (n = 14) showed that overtraining the same two words did not produce recombinative reading for most participants. Experiment 3 (n = 20), in which training with pictures was omitted, showed that elemental control by within-syllable units can develop even when the trained pseudowords are meaningless (not related to pictures). The present results support the utility of the miniature linguistic system methodology for identifying and controlling environmental determinants of rudimentary reading skills.

Key words: reading, recombination of behavioral units, stimulus equivalence, textual behavior, miniature linguistic system, college students, button presses

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In *Verbal Behavior* (1957), Skinner provided what he termed an ''exercise in interpretation,'' endeavoring to relate various communication repertoires (listening, speaking, reading, writing, etc.) to fundamental processes that were originally defined in basic research with laboratory animals. For some years, this exercise did not seem to inspire much theoretical extension or empirical analysis, but that is no longer true. For example, stimulus equivalence (Sidman, 1994) is one behavioral process that was perhaps implicit in *Verbal Behavior* and is clearly necessary for the analysis of verbal relations. That topic has inspired voluminous research that (1) has led to fundamental insights about complex human behavior (e.g., Hayes, Barnes-Holmes, & Roche, 2001) and (2) has come to be recognized through basic studies as a fundamental behavioral process (Catania, 2001; Sidman, 2000). Equivalence class formation has thus become a standard process-level answer to the historical criticism that behavior analysis could not explain the emergence of novel behavior.

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Another behavioral process that was clearly explicit in *Verbal Behavior* was emergent recombination of behavioral units to form new units. Unit recombination also results in the emergence of novel performances, thus adding another important process-level answer to the historical criticism. In this light, it is surprising that there have been virtually no basic research studies exploring recombinative processes in behavioral journals. We know of only one such study (Goldstein, 1983), and none have appeared in *JEAB* (stimulus substitutability in sequence classes, e.g., Wulfert & Hayes, 1988, seems to be the closest related topic).

Some unit recombination research has been done by behavior analysts interested in acquisition of rudimentary reading repertoires and other relations established conventionally by the verbal community (e.g., de Rose, de Souza, & Hanna, 1996; de Souza, de Rose, Faleiros, Bortoloti, Hanna, & McIlvane, 2009a; Hübner, Gomes, & McIlvane, 2009; Matos, Avanzi, & McIlvane, 2006; Mueller, Olmi, & Saunders, 2000). Valuable as these studies are, they do not constitute basic research in the usual sense—exactly because they are concerned with conventional relations that participants may have encountered in some form before. This same problem, of course, had to be dealt with in stimulus equivalence research. After a few initial studies with conventional relations (e.g., Sidman, 1971), basic stimulus equivalence research studies have come to use arbitrary stimuli that are unrecognizable as verbal stimuli and which are virtually impossible to name or sometimes even to describe. Goldstein (1983) seems to be alone in using that approach to study unit recombination, usually called *recombinative generalization*[1] (Goldstein, 1993; Suchowierska, 2006).

Notably, other branches of behavioral science (e.g., psycholinguistics) have been interested in the same issues of experimental control that have inspired the current stimulus selection practices in stimulus equivalence research. Moreover, they have applied them to study recombinative processes. One common, longstanding solution has been to employ what have been termed *miniature linguistic systems* or *miniature artificial languages* (Berko, 1958; Braine, Brody, Brooks, Sudhalter, Ross, Catalano & Fisch, 1990; Esper, 1925; Foss, 1968; MacWhinney, 1983).

A miniature linguistic system consists of a set of stimuli especially created for research purposes that may vary along one or more dimensions (e.g., shape, position) and a set of specific responses to be made in the presence of those stimuli (Foss, 1968). Use of stimuli with no extraexperimental history allows one to do well-controlled basic studies of recombinative processes with language-experienced participant populations such as college students and verbal children.

This article describes the use of a miniature linguistic system to study acquisition of behavioral unit recombination in college students. Our object was to model experimentally naturally occurring unit recombination in conventional reading, writing and other symbolic communication tasks. A series of systematic replications with minor variations was set to allow potentially informative post hoc comparisons of the results of these studies.

A pseudoalphabet of eight ''letters'' was created, four corresponding to vowels and four to consonants. Tests of recombinative ''reading'' of pseudowords (constructed from these letters) were alternated with training sessions of basic relations between spoken words and abstract pictures (AB) and between spoken words and printed words (AC). As the number of trained relations increased, new AC relations, pseudoword comprehension (BC/CB), and oral textual responding (CD) to novel pseudowords were tested.

The first experiment examined the acquisition process and the emergence of recombinative performances and pseudoword naming as the amount of training with new pseudowords increased. The second experiment evaluated whether effects of the teaching procedure would be maintained when the same two pseudowords were overtrained instead of adding new combinations. The third experiment omitted the history of matching pictures to spoken words, and evaluated the amount of behavioral unit recombination that emerged when only spoken word–printed word relations were taught.

[1] Since the use of the word *generalization* is controversial in the context of *discriminative control by elements* (Alessi, 1987), verbal or nonverbal, the terms *recombinative reading* and *emergent textual behavior* will be preferred in this paper.

EXPERIMENT 1

Translational and applied studies of recombinative generalization showed that recombination increases with amount of training and with the number of relations mastered by the student (e.g., de Rose et al., 1996; Goldstein, 1983; Hanna, de Souza, de Rose & Fonseca, 2004; Matos et al., 2006; Mueller et al., 2000). The goal of this experiment was to take advantage of the experimental control allowed by the miniature linguistic system to study this effect. The number of trained relations increased along six cycles of training and testing conditions. Each cycle was designed to yield equivalence classes consisting of two spoken words and the corresponding pictures and printed words, as well as textual responses to the printed words (i.e., oral reading of these words). Recombination was probed after each cycle. The experiment also aimed to investigate whether training with syllabic recombination would produce reading of novel pseudowords with within-syllable recombination.

Method

Participants

Twenty undergraduate students (11 males), enrolled in Introductory Psychology classes, volunteered to participate. Their ages ranged between 18 and 24 years (mean 20), and their native language was Portuguese. Half of them were students of Natural Sciences and Engineering and the other half were students of Health or Social Sciences. Participants had two or three periods of 30 min per week available for the sessions. They read and signed an informed consent form, which stated that the aim of the research was to investigate symbolic behavior, that participation was voluntary, and that they could withdraw at any time. Students earned course credits for research participation that could increase their Introductory Psychology grades up to 5%.

Setting and Apparatus

A sound-attenuated room of 9 m^2 housed a Macintosh Performa 6230 computer that programmed reinforcement contingencies and recorded data through the MTS 11.6.7 software (Dube, 1991). Participants selected stimuli using the computer's mouse. The experimenter sat to the right of the participant, with the keyboard in front. An independent observer sat at the right diagonal corner of the room. Experimenter and observer were present during all sessions and recorded oral responses on response forms. They could not see each other's recorded observations. An audio recorder and tapes also recorded oral responses.

Stimuli

Stimuli were spoken pseudowords (A), pictures (B), and printed pseudowords (C). All spoken pseudowords were formed by two consonant–vowel (CV) syllables (e.g., FALE), therefore consisting of four phonemes. Spoken words were pronounced with stress on the last syllable (e.g., |falɛ′|), different from the Portuguese language in which most words have stress on the penultimate syllable. Recorded male and female voices were produced by two external computer loudspeakers. Twelve pseudowords were used in training, each formed by two of the four possible syllables NI, BO, FA and LE (e.g., NIBO and FALE). Fourteen two-syllable words, formed by new combinations of the letters, were used for testing (e.g., BENA and LOFI). The pictures were ambiguous forms that resembled animals and toys, all selected from a stimulus library (Dube, 1991). Printed words were written with letters from an invented alphabet whose characters resembled Greek letters. Letters had a univocal correspondence with B, F, L, N, A, E, I and O and their respective phonemes in the Portuguese language. None of the words had meaning in Portuguese. Figure 1 shows all visual stimuli and phonetic transcriptions of auditory stimuli.

Stimuli used for training sessions combined syllables NI, BO, FA and LE, so that all syllables were used once in each cycle (see Figure 1). In AC relations (match printed word to spoken word sample), the correct comparison was the printed word that corresponded to the spoken word according the rules of the miniature linguistic system. Incorrect comparisons were also two-syllable words which had only one common letter and in the same position as the correct word (S+). The other three letters of the S− did not occur in the S+. In Cycle 1, for example, when the sample was |falɛ′|, the printed word FALE was the S+ and *F*BO, B*A*NI, NO*L*I or BIN*E* could be S− (all stimuli were written with the pseudoword alphabet). The choice of S− pseudowords was designed

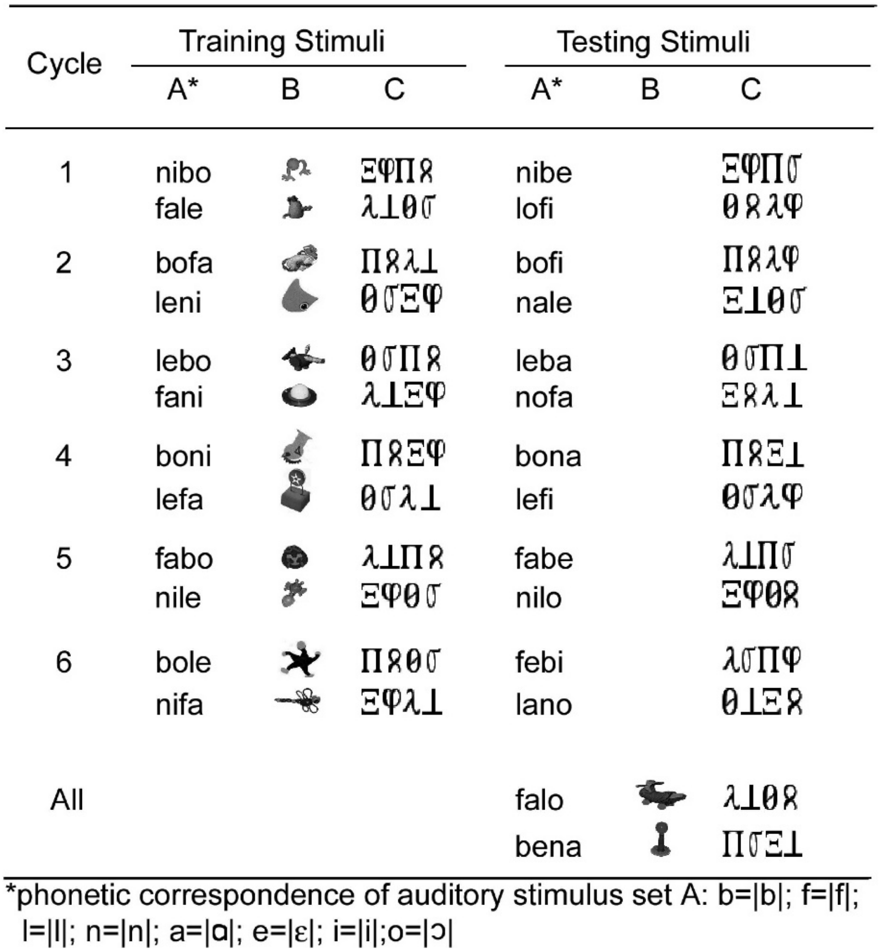

Fig. 1. Spoken pseudowords (A), pictures (B), and written pseudowords with the invented alphabet (C) used as training and testing stimuli in each cycle of Experiment 1.

to prevent restricted control by one of the letters in one location.

Interobserver Agreement Measures

Interobserver agreement checks were conducted for oral textual responses during training and tests. Two independent observers (including the experimenter) recorded oral responses. Each of these responses was considered a unit and scored as an agreement or disagreement. Interobserver agreement was obtained using a point-by-point formula (Kazdin, 1982): the total number of agreements was divided by agreements plus disagreements and multiplied by 100. Agreement scores were obtained for 3578 responses (98% of the total), and agreement was 96.7%. For most disagreements, listening to the audiotape of the session made clear which responses should be included in the data analysis.

Procedure

All participants initially learned to match two patterns to two related geometric forms, as pretraining for the arbitrary matching procedure.

Table 1 shows the procedures and order of conditions of Study 1. For each set of words, training and testing followed a sequence of tasks consisting of a *cycle*, as exemplified in Table 1. Six cycles were conducted. In each cycle, participants learned stimulus relations AB (matching picture to spoken-word sample) and AC (matching printed-word to spoken-

Table 1

Sequence of training and test conditions of Experiment 1.

Condition[a]	Task	Stimuli	Example[b]
Training conditions of each cycle			
1	Matching Pictures to Spoken Words (AB)	4 words/cycle	NIBO, FALE, FALO, BENA[c]
2	Matching Printed to Spoken Words and Textual Responding (AC/CD)	2 words/cycle	NIBO, FALE
Tests of each cycle			
3	*Assessment of Equivalence Classes*: Picture-Printed Word and Printed Word-Picture MTS (BC/CB)	2 training words/cycle	NIBO, FALE
4	*Recombinative Reading Comprehension*: Picture-Printed Word and Printed Word-Picture MTS (BC/CB)	2 test words/cycle	FALO, BENA
5	*Recombinative Oral Reading*: Textual responding (CD)	4 test words/cycle	NIBE, LOFI, FALO, BENA
6	*Recombinative Receptive Reading*: Printed to Spoken Word MTS (AC)	4 test words/cycle	NIBE, LOFI, FALO, BENA
Final Test			
7	Textual Responding (CD)	12 training words 14 test words	see Figure 1

[a] Conditions 1 to 6 comprise an Experimental Cycle. Six Experimental Cycles were performed with training of two different pseudowords in each cycle.

[b] Example based on Cycle 1; see Figure 1 for other cycles.

[c] FALO and BENA were test stimuli for recombinative reading. The teaching of relations between these spoken words and pictures allowed for testing recombinative reading comprehension in Condition 4.

word sample), as well as textual responding (CD - oral reading) of two printed words until criterion was reached. Cycles ended with tests for (1) emergence of equivalence classes (BC and CB matching with trained words) or word comprehension, (2) recombinative reading comprehension (BC and CB matching with novel words), (3) recombinative oral reading (textual responses for novel words), and (4) recombinative receptive reading (AC matching with novel printed pseudowords).

AB and AC relations with two different two-syllable words were taught in each cycle. Tests used the words FALO and BENA in all cycles (''constant'' testing words) that were composed of elements of the training stimuli. Participants were never explicitly taught to relate these printed words to the respective spoken words. Students learned, however, to relate these words, in spoken form, to pictures, to allow for testing of the relation of the corresponding printed words to the respective pictures (recombinative reading comprehension). Each cycle tested recombinative performances of two additional words which were different in each cycle (e.g., NIBE and LOFI in Cycle 1; see Figure 1). This permitted a test in each cycle of recombinative reading of words that were completely new. Note that these new words had not been related to pictures, so they had no ''meaning'' in this invented system and, therefore, it was not possible to test reading comprehension of these words.

AB training – matching pictures to spoken pseudowords. AB training consisted of 60 matching trials to establish relations between four pictures and four corresponding spoken words (see Table 1). Two of these words (called training words) were later used in AC training, and the other two (called testing words) were used later to test recombinative reading comprehension. Cycles that followed the first one did not include review trials with training words from previous cycles. Testing words were repeated every cycle.

Instructions, presented on the screen at the beginning of each session, consisted of a Portuguese version of: ''Listen and click on the black square presented in the center of the screen and then choose one of the pictures presented in the bottom. If you get it right, the computer will show stars or the word 'Correct' on the screen''.

Matching trials began with the presentation of the sample stimulus: A black square was displayed on the center key of the screen monitor and a word was spoken and repeated every 15 s. A mouse click on the black square displayed pictures on the bottom keys. The spoken word continued to repeat until the participant selected one of the comparison stimuli. A 1-s display of flashing stars accompanied by a series of computer-generated chimes or the presentation of the printed word ''Correct'' and a beep followed correct key selection. Incorrect responses were followed by 3 s of black screen and the repetition of the trial. The correct choice stimulus did not appear in the same position on more than two consecutive trials. The intertrial interval (ITI) was 1.5 s.

Training trials were distributed across 15 successive blocks that gradually increased the number of samples and comparisons. Table 2 shows the sequence of training blocks. A single AB relation was trained initially, with the same sample displayed on successive trials. The number of comparisons increased from one to three over successive trials (blocks 1 to 3, Table 2). Two errors within blocks of two or three comparison stimuli led to a decrease in the number of choices (backup procedure). After training two relations, samples were randomly alternated with two- and three-comparison stimuli. Once all relations had been presented with three comparison stimuli, the cumulative final block of trials (block 15) presented three trials of each sample with the correct comparison stimulus once in each position. Training in a particular cycle ended if the participant scored 100% in the final block, otherwise the cumulative block could be repeated up to two additional times. If the criterion was not reached after the third presentation of the cumulative block, the session ended and the training was repeated from the beginning in the next session.

AC/CD training – matching printed to spoken pseudowords and textual responding. AC Training was similar to AB training, with the differences that only two AC relations were trained in each cycle, rather than four relations (as in AB training), and that probes verifying textual behavior to the printed pseudowords (CD) were interspersed within matching blocks. Table 2 shows the sequence of training blocks. Training in the first cycle illustrates the training procedures, which repeated with different words in all other cycles. Relation A1C1 was trained first, beginning with only the correct comparison stimulus and increasing the number of comparisons to two and three in subsequent trials. Two probe trials then verified oral reading (CD) of the printed word C1. If reading was not correct, the experimenter said the correct pseudoword and the A1C1 training trials with three comparisons were repeated until the participant read C1 correctly in oral reading trials. Subsequent trials taught the A2C2 relation, starting with only the correct comparison and increasing the number of comparisons to two. Subsequent trials alternated samples A1 and A2, starting with two comparisons and increasing to three. A2C2 trials with three comparisons were presented twice as often as A1C1. Two trials then verified reading of C2. Any reading error repeated these AC trials, alternating again samples A1 and A2 with three comparison stimuli. AC training ended with a final block of six trials with A1 and A2 samples in a mixed sequence (Block 10), followed by a block of four textual responding trials (Block 11), two with each word, in a mixed sequence. Errors in either of those two blocks (10 and 11) repeated the matching-trial block (Block 10) until 100% correct performance was achieved before the final block of textual responding trials was presented (Table 2). The return to the matching block could occur up to three times. If an error was made in the third block, the session ended and training was repeated from the beginning in the following session. If all responses were correct, session ended.

On textual responding (CD) trials, a single printed pseudoword was displayed in the center-bottom key. On the first trial, the experimenter asked ''What are those symbols?'' A drawing of a male face with open mouth above the word signaled the request of an oral response. The experimenter (as well as the observer) recorded the participant's utterance and pressed previously defined keys on the keyboard for a correct or an incorrect response for providing feedback to the participant. In a few cases participants changed a response immediately after it was made, before the experimenter operated the keyboard to provide response consequences. In these cases, both responses were recorded but the last was considered for feedback and analysis. The correct model spoken by the experimenter followed incorrect responses. The partici-

Table 2

Structure of AB Training and AC/CD Training: trial type, number of trials with each sample, positive comparison (S+), number of negative comparisons (number of S−), learning criterion to move to the next block (criterion max error) and number of the block to back up when the criterion was not met (back up block) for each block.

Block	Trial type	Number of trials	Sample	S+	Number of S−	Criterion max error	Back up block
AB Training							
1	AB	1	A1	B1	0	-	-
2	AB	2	A1	B1	1	1	1
3	AB	3	A1	B1	2	1	2
4	AB	1	A2	B2	0	-	-
5	AB	2	A2	B2	1	1	4
6	AB	2	A1	B1	1	1	5
		2	A2	B2	1		
7	AB	3	A1	B1	2	1	6
		3	A2	B2	2		
8	AB	1	A3	B3	0	-	-
9	AB	2	A3	B3	1	1	8
10	AB	2	A3	B3	1	1	9
		2	A2	B2	1		
		2	A1	B1	1		
11	AB	3	A3	B3	2	1	10
		3	A2	B2	2		
		3	A1	B1	2		
12	AB	1	A4	B4	0	-	-
13	AB	2	A4	B4	1	1	12
14	AB	2	A4	B4	1	1	13
		2	A3	B3	1		
		2	A2	B2	1		
		2	A1	B1	1		
15	AB	3	A4	B4	2	1	15*
		3	A3	B3	2		
		3	A2	B2	2		
		3	A1	B1	2		
1	AC	1	A1	C1	0	-	-
2	AC	4	A1	C1	1	1	1
3	AC	6	A1	C1	2	1	2
4	CD	2	C1	-	-	0	3
5	AC	1	A2	C2	0	-	-
6	AC	4	A2	C2	1	1	5
7	AC	4	A2	C2	1	1	6
		4	A1	C1	1		
8	AC	6	A2	C2	2	1	7
		3	A1	C1	2		
9	CD	2	C2	-	-	0	8
10	AC	3	A2	C2	2	1	10[a]
		3	A1	C1	2		
11	CD	2	C1	-	-	0	10
		2	C2	-	-		

Note. Within a block, trials with different samples were mixed.
[a] If errors persisted after two repetitions, training repeated from Block 1 in a new session.

pant was not asked to make a corrected response at that point. Correct textual responses were followed by the same consequences described for matching trials. The minimum number of AC/CD training trials in each cycle was 40 matching trials and 8 textual response trials.

The next session started with a cumulative block of matching trials with differential reinforcement programmed in all trials (Block 10, Table 2). A second block with the same trials in a different order programmed intermittent feedback for correct or incorrect responses (every third trial, on average). This block could be repeated three times if an error occurred. After the third repetition, the session was interrupted and training was resumed in the next session, beginning with Block 1. Tests began after 100% correct responding on the training block with intermittent reinforcement.

Testing equivalence classes and recombinative reading. In each cycle, after participants mastered the AB, AC and CD relations, the cycle ended with tests of stimulus equivalence and three tests with novel recombined words.

BC and CB relations with training stimuli were tested in blocks of 12 trials (3 with each sample). The two types of trials were mixed in a quasirandom order, with no more than two consecutive trials of the same type. Three blocks of trials were programmed but testing could end earlier if the participant scored 100% correct on the first or second block (responses consistent with equivalence were considered correct).

The first recombination test with novel stimuli evaluated the reading comprehension (BC/CB) of the ''constant'' recombination words, FALO and BENA. Twelve trials verified matching of printed words to pictures and matching of pictures to printed words with these two pseudowords. The two types of trials were mixed in a quasirandom order, with no more than two consecutive trials of the same type. During this test new ambiguous forms were used as S−, since the use of training pictures could artificially inflate scores by ''exclusion'' of the trained pictures (e.g., Dixon, 1977; McIlvane & Stoddard, 1981). The second eight-trial recombinative test assessed textual responding (oral reading – CD) of the two constant and the two variable novel pseudowords. The third recombination test programmed eight matching trials of printed words to spoken words (AC relations) with the two constant and the two variable recombination words used in each cycle. In these matching trials, three comparison stimuli were displayed on all trials.

Instructions were presented on the screen at the beginning of each test and consisted of the Portuguese version of: ''Look/listen and click on the black square, picture or sequence of symbols presented in the center of the screen. Then choose one of the stimuli presented in the bottom. *The computer will not tell you when your response is right*''.

After the sixth cycle, a general textual responding test was conducted with all 12 training words and 14 recombination words (one trial for each printed word). Tests had no programmed consequences for correct or incorrect responses.

Results and Discussion

Few or no errors occurred during training of matching abstract pictures to spoken pseudowords. With few exceptions, the number of trials to criterion in this condition was close to the minimum of 60 programmed trials (median 62 and range 60–105).

In general, few or no errors (median 0 and range 0–6) occurred during training of matching printed to spoken pseudowords and in textual responding to printed pseudowords. Trials to criterion and interparticipant variability decreased across cycles. In the sixth cycle all participants ended the training with 47–49 trials, with only 4 showing errors. For some participants, however, the number of errors was higher than in AB training. A procedure of fading-in the incorrect comparison stimuli in blocks of trials with the same sample proved effective such that few errors occurred in training.

Matching printed words to pictures and viceversa (equivalence or reading comprehension) emerged for all participants in all cycles. Ten students scored 100% correct on both trial types of all cycles. The remaining 10 scored less than 100% correct in only one cycle. Thus, the training conditions were sufficient to establish the equivalence between 12 pictures, 12 spoken and 12 printed words. These results replicate previous studies with pseudoalphabets used with literate and preschool children (Albuquerque, Hanna & Ribeiro, 1998) and those employing meaningful Portuguese words (e.g., de Rose et al., 1996; Matos et al., 2006; Matos, Hübner, & Peres, 1997; Matos, Hübner, Serra, Basaglia, & Avanzi, 2003) and English words (e.g., Sidman, 1971).

Figure 2 shows accuracy on tests that evaluated three types of performances with new words, formed by recombining elements of training words, conducted after training on each cycle: equivalence or reading comprehension, listening comprehension, and pseudoword textual responding. Mean percentage of correct responses for the group of participants was calculated for tests of matching

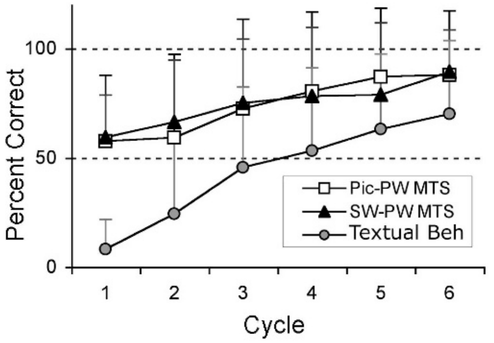

Fig. 2. Percentage of correct selection responses (group mean) in tests of recombinative reading in each experimental cycle of Experiment 1: matching printed words to spoken word (SW–PW MTS, triangles), matching pictures to printed word and printed words to picture (Pic–PW/PW–Pic MTS, squares) and textual responding to printed word (Textual Beh, circles). Vertical lines show one standard deviation from the mean.

pictures to printed words and vice-versa (BC/CB), for tests of matching printed to spoken words, and for emergent pseudoword naming or textual responding (CD) tests. Accuracy in all tests increased across successive cycles. Mean scores for matching performances were higher than those for textual responding; large standard deviations (vertical line) indicate interparticipant variability, however. These results indicated that the number of instructional trials was an important factor in the development of recombinative reading. The words used in each cycle contained the same four syllables (NI, BO, LE, FA). The small number of letters (8) and the repeated exposure to the same syllables in different words and in different positions within a word (the first or the last) allowed for development of control by textual units smaller than the whole words used in training. Thus, these results support Skinner's assertion that control by minimal units may develop from exposure to larger units (Skinner, 1957); once the stimulus control is established, the stimulus unit continues to control the corresponding response unit even when recombined with other stimulus units (Alessi, 1987).

Most participants showed some degree of recombinative reading after training with six words (third cycle) when each of the four syllables had been presented in three different words and in the two possible positions. Group analysis (Figure 2) shows that for textual behavior, larger changes on recombination scores occurred in the first three cycles than in the last three, although there was an increasing trend in accuracy until the last cycle. After 12 words had been trained, 18 out of 20 participants read at least one new word in the recombination test of the sixth cycle.

An analysis of recombinative textual responding (not shown) revealed higher scores for the constant words than for the different words in all cycles. These differences could be due to the repeated exposure but also to the participants' history in the AB training, in which the constant words were related to pictures. Subsequent study sought to clarify this difference.

Figure 3 shows individual scores on the final test of textual responding to printed pseudowords (oral reading), conducted at the end of the study with all words. Scores for training (upper panel) and recombined (lower panel) words were similar for all participants. Thirteen students correctly named more than 50% of the 12 training words and more than 75% of the 14 recombined words. For the 7 remaining participants, scores were less than 20% correct for training and recombined words. Thus, scores for training and novel words were highly correlated and high accuracy was found for 65% of the participants in tests of recombinative reading.

Control by within-syllable units developed gradually after participants learned conditional relations between pictures and spoken words, and between printed and spoken words. Characteristics of the miniature language system may have facilitated the development of control by within-syllable textual units and these units continued to exert accurate control when recombined in novel stimuli. The few elements to discriminate, systematic manipulation of the syllables' position within training words (so that each syllable was trained the same number of trials as the first and as the last component of a whole word), and the univocal correspondence between letters and phonemes may have been important aspects of the discriminative training which helped to establish correspondence between syllables and their related sounds as well as the emergence of relations between printed letters and phonemes. The demonstration of recombinative reading on the level of printed letters and

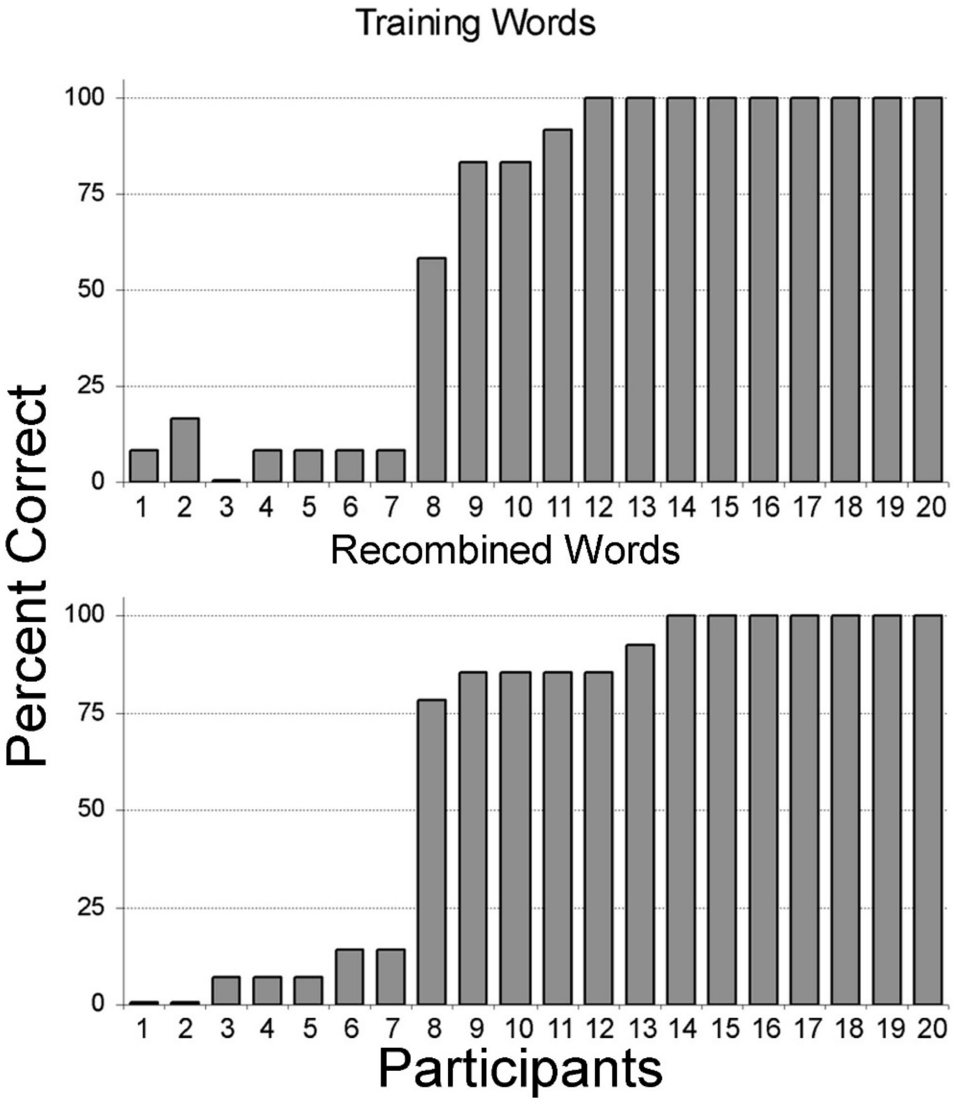

Fig. 3. Individual scores (percent correct) in the final test of textual responding to training (upper panel) and recombined pseudowords (lower panel) of Experiment 1.

phonemes is a robust and additional demonstration (e.g., de Rose et al., 1996; Mueller et al., 2000) that minimal units not presented independently in a contingency of reinforcement can develop from larger units (Skinner, 1957).

However, 7 students did not show recombination of repertoires even after the training with 12 words. It is possible that these participants would show recombination if they had been exposed to additional training, since participants showed individual differences in the amount of training needed for recombination. The 12 training words, however, exhausted all the possible combinations of the four syllables into different two-syllable words, so that increasing the amount of training would require the use of three-syllable words or the use of a larger number of syllables.

Each cycle in this study was independent and taught specific words. This facilitated learning of the conditional relations but retention in the final test of naming printed words (textual behavior) was low for the participants who showed inaccurate recombination. These results contrast with previous studies with Portuguese words (e.g., de Rose et al., 1996; de Souza et al., 2009a) that used a cumulative training in which words learned in previous cycles continued to be trained as baseline words. Although some participants in the de Rose et al. study showed poor recombination scores, they all showed high scores for training words, presumably due to the cumulative training. Because these studies used stimuli with which the participants had extra-experimental histories, it was not possible to ascertain whether the high scores on training words were a joint product of the instruction and past experience. In the present study, by contrast, the miniature linguistic system methods eliminated concerns about previous history with all stimuli in determining the results (although it is conceivable that a history of abstraction in one language may influence acquisition in another or in a contrived one).

EXPERIMENT 2

The results of Experiment 1 showed that recombinative reading increased across cycles as the number of trained words increased. In each cycle, participants learned to match and read two different words formed by different combinations of the same four syllables. The position of the syllables was varied between cycles. This procedure included two aspects that should be evaluated for their importance in explaining recombinative reading: (1) behavior in the presence of the same four syllables was reinforced during training of all six cycles; and (2) stimulus elements (syllables) were recombined to form new words and new responses controlled by these training words were established in each cycle. It is possible, however, that mere exposure to training with these syllables in the same position could produce recombinative reading. Thus, Experiment 2 also used six cycles, but the procedures trained the same two words in every cycle. In this study the syllabic units were trained the same number of times as in Experiment 1 and behavior was reinforced in the presence of the four syllables during training of six cycles. However, participants were not exposed to stimuli that placed the syllables in different positions.

Method

Participants

Participants were 14 undergraduate students aged 17 to 24 years (M = 20.5), 7 male and 7 female. Half of them were from Natural Sciences and Engineering and the other half were enrolled in Health and Social Sciences courses.

Setting and Apparatus

Setting, apparatus, stimuli, and interobserver agreement measures were the same as in Experiment 1. Agreement scores were obtained for 1572 responses (99% of the total), and agreement was 98.4%.

Procedure

The procedure was the same described for Experiment 1, except that the words (spoken and printed) used in training conditions of all cycles were always NIBO and FALE. The training conditions of Cycles 2 to 6 were the same as Cycle 1.

Six participants were exposed to all training trials in every cycle (Participants 24, 28, 29, 30, 31 and 34). For the remaining 8 participants training trials were reduced for Cycles 2 to 6: AB Training from 60 to 12 trials and AC/CD Training from 47 to 20 trials. The reduction was in response to participant complaints about the repetitive, boring nature of the task. For these 8 students, the final cumulative blocks were conducted twice (block 15 of AB Training and blocks 10 and 11 of AC/CD Training). For all participants a score of 100% correct in the cumulative block was required to end the session. Correction procedures were the same as those described in Experiment 1.

Results and Discussion

This study evaluated whether effects of the teaching procedure would be maintained when the same two pseudowords were overtrained instead of adding words with recombination of the syllables. Each syllable was present once in every cycle, as in Experiment 1, but a syllable never changed position (beginning or ending of the word) and always belonged to a single word. Performance in the first cycle was similar to Experiment 1. Average number of trials to criterion in matching pictures to spoken words was 76.3, ranging from 62 to 162. In matching printed to spoken words and textual responding to printed words, average number of trials to criterion in Cycle 1 was 50.5, ranging from 47 to 55.

For 6 participants the following cycles (2 through 6) overtrained these tasks with the same number of trials and the others were trained in the cumulative block until criterion was reached. None of the participants made more than one error in one cycle and many made no errors at all. All 14 participants scored 100% correct across the six cycles that tested matching printed words and pictures and vice-versa with training stimuli, showing that, for training words, equivalence between printed words, spoken words, and pictures already emerged in the first cycle.

Results of the recombinative tests are shown in Figure 4. The percentage of correct selections averaged for all participants during the three tests of recombinative reading conducted in each cycle (reading comprehension, listening comprehension and emergent oral reading or textual responding) was similar to that of Experiment 1 in the first cycle. In the following cycles, contrary to what was found in Experiment 1, there was no increase in matching accuracy and there was only a moderate increase in textual responding accuracy along the first three cycles. As in Experiment 1, the analysis of recombinative textual responding (not shown) revealed higher scores for the constant words than for the different words in all cycles. These differences could be due to the repeated exposure, but also to the participants' history in the AB training, in which these words were related to pictures.

Only 4 of the 14 participants scored higher than 50% correct in the final test of textual responding to novel pseudowords (Figure 5). Participants 31 and 34 had the same number of training trials as in Study 1, and the other 2 (Participants 32 and 33) were exposed to the reduced training. Although students read correctly the two training words in this final test (except Participants 21 and 22), the training with only two words did not produce recombinative reading for the majority of the participants. Thus, these lower scores in this study cannot be attributed merely to the reduced training, since some participants exposed to the regular and some exposed to the reduced training produced similarly low scores (respectively, 4 and 6 participants),

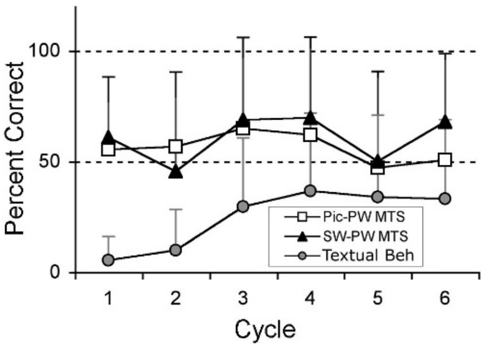

Fig. 4. Percentage of correct selection responses (group mean) in tests of recombinative reading in each experimental cycle of Experiment 2: matching printed words to spoken word (SW–PW MTS, triangles), matching pictures to printed word and printed words to picture (Pic–PW/PW–Pic MTS, squares) and textual responding to printed word (Textual Beh, circles). Vertical lines show one standard deviation from the mean.

while others presented similarly high scores (2 participants under the reduced training and 2 participants under the regular training).

The results of Experiment 1 (but not of Experiment 2) systematically replicated, with two-syllable pseudowords, the results of Mueller et al. (2000) with English one-syllable words. The stimuli in both studies were whole words (dictated and printed words), but the procedures manipulated the within-word components (syllables or onset and rhymes) by systematically varying sets of words with overlapping syllables (Experiment 1) or letters (Mueller et al.). This overlapping of components was missing in Experiment 2. Since the overtraining with the same components did not prove sufficient for generating recombinative reading, the results suggest that the recombination of elements of the training stimuli is a critical factor in recombinative reading. This finding is consistent with studies showing that multiple exemplars varying elemental position appear critical for abstraction of novel words (e.g., de Rose et al., 1996; Mueller et al.). In some previous studies, this variable was confounded with number of words, which also employed components of different words included in training, although the recombinations were not as systematic as those planned in Experiment 1 or in the study of Mueller et al. For example, de Rose et al. taught the words SELO and BOLO (present-

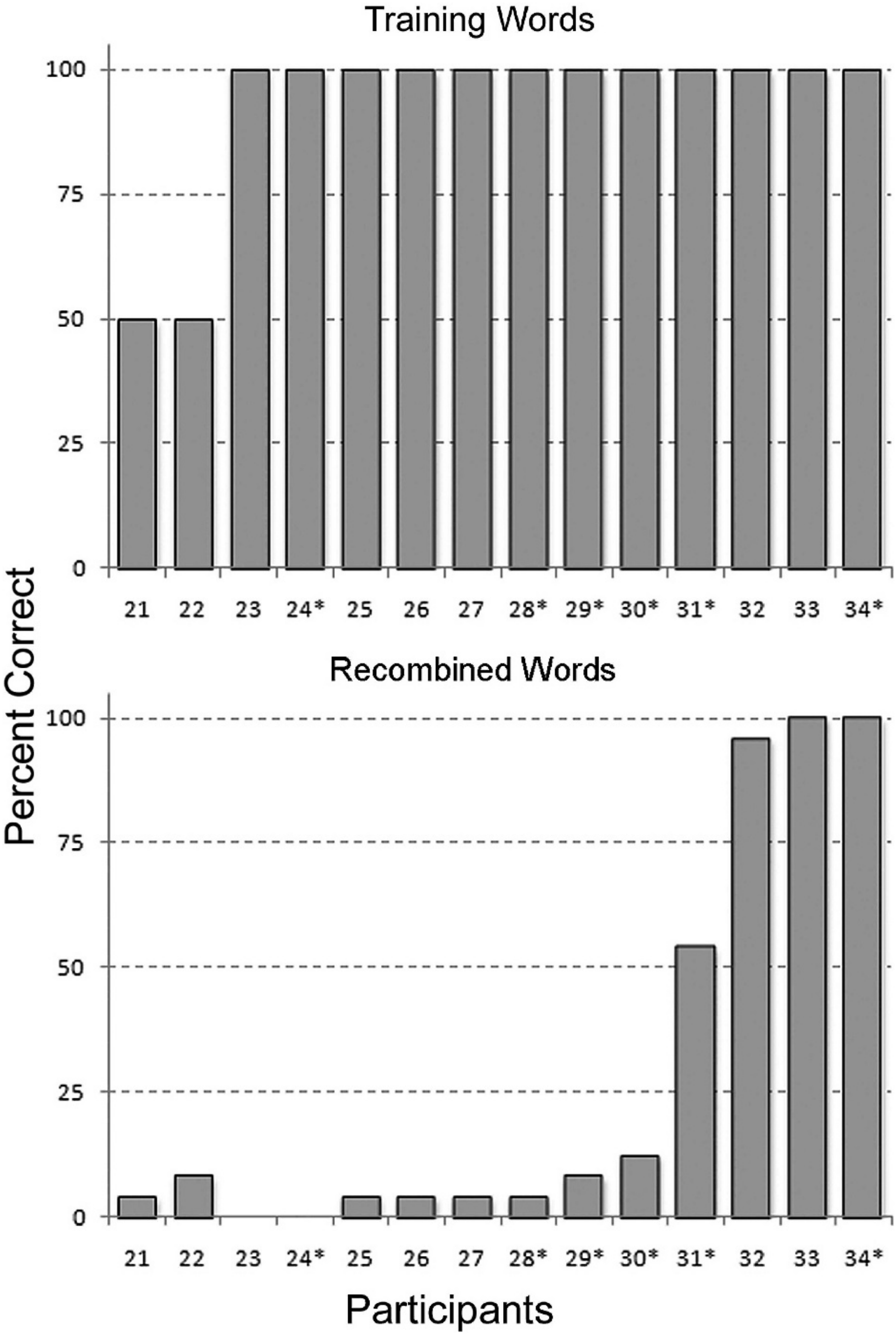

Fig. 5. Individual scores (percent correct) in the final test of textual responding to training (upper panel) and recombined pseudowords (lower panel) of Experiment 2. Participants with reduced training are marked with asterisks.

ing the syllable LO in two different words); VACA and CAVALO (thus presenting the syllables VA and CA in different words and in different positions within the words; and training the syllable LO in one more word); such examples increased as the study progressed. In light of the results of Experiment 2 (i.e., the lack of recombinative performances), one could infer that the use of recombined stimuli during training (and not merely the increase in the number of training words) was a critical aspect in those previous studies. Future investigation could evaluate whether the mere increase in the number of trained words without recombining any word elements would result in recombinative reading of trained elements presented only in tests. However, the robust effects in Experiment 1, combined with those of Mueller et al., strongly suggest that the experience with repeatable units in different words and word positions is a necessary condition for (1) the establishment of abstraction of those units, and for (2) the integrity of the accurate stimulus control that they exert when inserted within or recombined with other stimuli (see Goldstein, 1983; Striefel, Wetherby, & Karlan, 1976; Wetherby & Striefel, 1978, for similar processes with other verbal behaviors).

EXPERIMENT 3

Experiments 1 and 2 were based on the stimulus equivalence paradigm: Baseline relations (AB and AC) were taught and emergence of other relations was tested. Previous reports showed that once an individual learns to select both a picture and a printed word upon hearing the corresponding spoken word, s/he will also select the picture upon seeing the printed word and vice-versa, performances that have been considered to be a rudimentary form of reading comprehension (Sidman, 1971). Textual responses to novel pseudowords, which require the recombination of linguistic units, are not necessarily meaningful (e.g., many Portuguese-speaking persons can name words in Latin even when they do not know the meaning of these words). In this study, we evaluated the importance of learning to match pictures to spoken words for the acquisition of recombinative textual responses, given that the crucial prerequisite seems to be stimulus control by textual units over the production of speech sounds. Do equivalence classes formed by combinations of pictures, spoken words and printed words promote the development of the control by smaller linguistic units?

To address this question, Experiment 3 used a procedure similar to Experiment 1, but we omitted the training of conditional relations between pictures and spoken words. The textual-response test with recombined words was programmed after training printed-pseudoword-to-spoken-word matching in each cycle of the study. The number of participants who developed recombinative reading with this procedure was thus available for comparison with Experiment 1. If substantially fewer participants exhibited recombinative reading, then that outcome would support the conclusion that teaching spoken word–picture matching could facilitate recombinative reading. If not, then it would appear that recombinative reading could emerge merely from the teaching relations involving spoken and printed pseudowords.

Method

Participants

Twenty undergraduate students (10 male and 10 female) ranging in age from 17 to 30 years (mean 20.8) participated. Half were from Natural Sciences and Engineering and the other half were from Health and Social Sciences courses.

Setting and Apparatus

Setting, apparatus, stimuli and interobserver agreement measures were the same as in Experiment 1. Agreement scores were obtained for 3642 responses (99% of the total), and agreement was 97.5%.

Procedure

The procedures were similar to those of Experiment 1 with the omission of training (Condition 1 in Table 1) and testing with pictures (Conditions 3 and 4 of Table 1).

Six independent cycles of training and testing conditions were programmed. A cycle started with training of two conditional relations between printed and spoken words (AC) and textual responding of the two printed pseudowords (CD). Two tests of recombinative reading ended the cycles: (1) Oral textual responding of four test printed pseudowords; and (2) matching printed to spoken pseudowords with test words. The AC/CD Training was conducted with different words in each cycle (Figure 1) as in Experiment 1. A general textual responding test with all training and novel pseudowords was conducted at the end of the study.

Results and Discussion

This experiment omitted the history of matching pictures to spoken pseudowords, and evaluated the amount of behavioral unit recombination that emerged when only spoken–printed pseudoword relations were taught.

The number of trials to learn conditional discriminations between printed and spoken pseudowords in each cycle was higher than the minimum, due to errors that required repetition of blocks; however, number of trials decreased across cycles. In general, training of Cycles 1 to 3 was somewhat longer than that for participants of Experiment 1 (where matching pictures to spoken words preceded training of matching printed pseudowords to spoken words). Group mean decreased from 78.8 to 51.3 trials from the first to the sixth cycle, and all participants ended training of the last three cycles with no more than one error.

In this experiment, the reading comprehension tests were omitted. Although recent studies have suggested that one need not teach the picture–print–spoken word relations (e.g., Greer & Speckman, 2009; Leite & Hübner, 2009), this would apply only to cases in which the child already learned to relate specific pictures to the corresponding words as was the case in the first study by Sidman (1971). When the child has a tact for a ''picture'' as a result of a naming experience, training can be reduced by omitting the teaching of AB relations. In this study, although the college student participants had an extensive repertoire of naming, it was not functional in the context of pseudowords, and reading comprehension required the learning of picture–spoken word matching and/or picture tacting.

Figure 6 shows mean results from the two recombination tests conducted in each cycle after mastering the baseline relations: (1) matching novel printed to spoken pseudowords and (2) emergent oral reading of novel pseudowords (textual responding). Increasing trends were found for both measures of recombinative performances. The score for textual responding in the first cycle was very low (3.8%) and gradually increased through Cycle 4 (50%). There was no further increase in the group mean in the last two cycles, and intersubject variability was high (see vertical

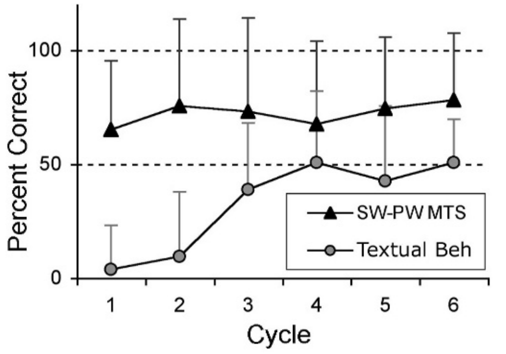

Fig. 6. Percentage of correct selection responses (group mean) in tests of recombinative reading in each experimental cycle of Experiment 3: matching printed words to spoken word (SW–PW MTS, triangles), matching pictures to printed word and printed words to picture (Pic–PW/PW–Pic MTS, squares) and textual responding to printed word (Textual Beh, circles). Vertical lines show one standard deviation from the mean.

bars in Figure 6 for standard deviations). Percentages were higher for matching (i.e., listener responding) than for textual responding (i.e., speaker responding).

The increases from Cycle 1 to Cycle 6 were smaller in the present study than those found in Experiment 1. In both studies, scores on the two measures of recombinative repertoires increased as the number of trained words increased, but the gains were higher for participants of Experiment 1, who had a history of spoken word–picture matching training. These results can be interpreted as evidence of a facilitative effect of a history of matching pictures to spoken pseudowords on recombinative repertoires such as receptive reading (AC) and textual behavior (CD). But why should establishing picture–word relations facilitate recombinative repertoires that they are not dependent upon?

This difference may be related to an aspect of the procedure. In Experiment 1, AB training included two dictated word–picture relations of testing stimuli in recombination assessments (FALO and BENA, Figure 1). Results of recombinative tests showed higher scores for the constant words than for words that differed in every cycle. This difference was not found in Experiment 3. An analysis of recombinative textual responding across cycles (not shown) revealed similar scores for the constant words and for the different words in all cycles. Experiment 1 has, however, two

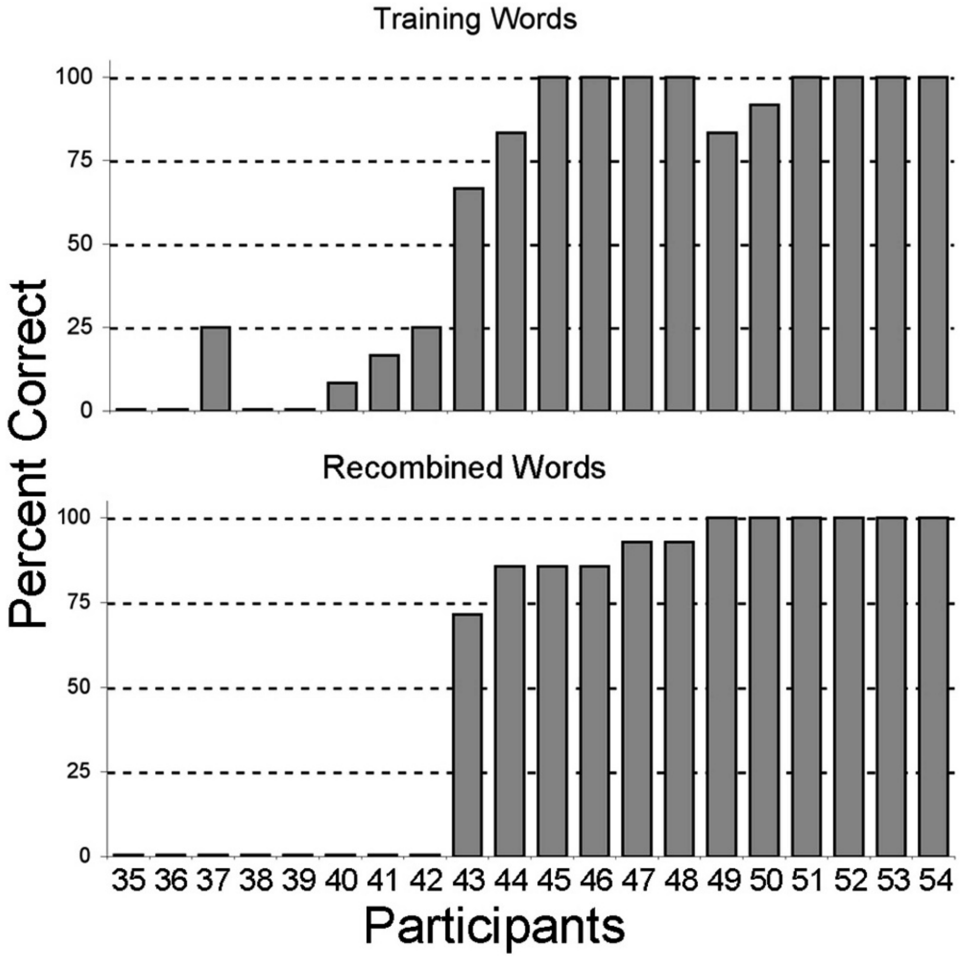

Fig. 7. Individual scores (percent correct) in the final test of textual responding to training (upper panel) and recombined pseudowords (lower panel) of Experiment 3.

confounding variables: (1) exposure to the same textual and auditory stimuli during testing conditions of every cycle; and (2) additional teaching of AB relations (pictures were related to spoken words in every cycle). In Experiment 3, by contrast, there was no AB training but the constant words were presented in the recombination tests of all cycles. Repeated exposure to the words in several tests was not sufficient, therefore, to produce higher scores of oral reading of these words. Higher scores of recombinative textual behavior and receptive reading appear to be related to the additional exposure to some of the testing stimuli during AB training.

Figure 7 shows individual scores in the final oral reading test (textual responding) for training (upper panel) and recombined pseudowords (lower panel). Twelve of the 20 participants scored 70% correct or higher for both types of words. The remaining 8 students showed 25% or lower scores to training words and no correct textual responses to novel printed words. Scores for training pseudowords and for novel pseudowords were almost perfectly correlated: If participants read training words accurately, then they also read recombined words accurately; the others did not read any words accurately. These results suggest a shared underlying process in the emergence of reading training and novel pseudowords. Participants who developed pseudoword reading abstracted sound–print relations that were smaller than the whole words during the matching trials. When those units were represented in other words, they continued to exert accurate stimulus control on vocal responses to text (Alessi, 1987; Skinner, 1957).

The proportion of participants who showed recombinative reading in Experiment 3 (12 of 20) was comparable to that of Experiment 1 (13 of 20) and much higher than that in Experiment 2 (4 of 14). Thus, recombinative reading in a miniature language system does not appear to depend upon (although it may benefit from) relating words to pictures. Rather, Experiment 3 developed true or ''pure'' textual behavior, isolating it from the comprehension component of reading. Although students did not relate the pseudowords to pictures, they apparently could sound out the words and recognize their similarity to words dictated to them.

GENERAL DISCUSSION

Three studies showed recombinative reading of novel pseudowords with a miniature language system using three different behavior measures that assessed listener and speaker responding: matching printed to spoken pseudowords, textual responding, and picture to printed pseudowords (reading comprehension).

Emergent Textual Responding and Recombinative Reading

In Experiment 1, 65% of the participants responded textually to recombined letters embedded in new printed pseudowords after forming 12 classes of equivalent stimuli composed of pictures, spoken and printed pseudowords.

In Experiment 2, only two classes of stimuli were established with no variation of the syllables' position in different training pseudowords and no overlapping syllables. This procedure was significantly less effective; recombinative scores of 50% or greater were achieved by only 28% of the participants. In Experiment 3, no equivalence classes were established between printed and spoken pseudowords and pictures. Instead, students acquired 12 conditional discriminations between spoken and printed pseudowords in which the positions of syllables varied in different training pseudowords, as in Experiment 1, ensuring training with overlapping syllables and experience with recombined stimuli. Sixty percent of participants achieved textual responding scores above 50% correct, comparable to the proportion of participants who did so in Experiment 1.

Overall, this sequence of three demonstration studies showed that learning the phonemic sounds in a miniature language system led to abstracted or derived textual responding of novel arrangements of the originally taught print–sound relations. Moreover, teaching more print–sound relations was correlated with more emergent responses.

The accurate control by single sound–print relations over elements of responses to novel stimuli, derived from the whole word training conditions, systematically replicates and extends results reported by Mueller et al. (2000). In Experiments 1 and 3 participants were exposed to all possible pairs of combinations with the syllables BO, FA, LE, and NI (e.g., NIBO, BOFA, FALE; LENI, etc); this ensured that (1) each syllable was presented in the first and in the last position of a word; (2) each syllable participated in a compound with all the other syllables: and (3) each syllable participated as a compound in the same number of pseudowords (six). When tests evaluated textual behavior to pseudowords with within-syllable recombination, most participants showed recombinative reading. These results were not replicated in Experiment 2, in which participants learned only two pseudowords, NIBO and FALE; although these pseudowords contained all the elementary units (the same four consonants and four vowels) and were presented in all cycles, the training lacked the overlapping feature of Experiments 1 and 3. Thus, it seems that experience with the recombination of elements during training is a necessary condition for the development of abstraction (cf. Goldstein, 1983; Mueller et al., 2000; Striefel et al., 1976; Wetherby & Striefel, 1976).

Results of the present studies taken together also suggest that, although the history of matching picture to spoken pseudoword was not a necessary condition (Experiment 3), it did influence the recombinative performance (Experiment 1), increasing scores of reading words that were previously related to pictures (meaningful words). Experimental history with picture-matching might select a set of responses that are emitted more often in a related context (Hanna, Kohlsdorf, Quinteiro, Fava, de Souza, & de Rose, 2008). When partial stimulus control is also established in that context, efficient performance can result under the control of new stimuli (correct recombinative reading).

In summary, the difference in the number of participants who recombined textual elements across the three studies suggests that: (1) The critical variable in fostering element recombination is not the number of training trials overall, but rather the number of exemplars of recombinations encountered during training, (2) establishing equivalence classes involving pictures and pseudowords (spoken and printed) is not necessary for generating recombinative performances, and (3) development of recombinative unit-based instructional technology (de Souza et al., 2009a; Mueller et al., 2000) is effective in bypassing the challenge of teaching word attack skills or textual responses to individuals who formerly lacked them.

The present studies add evidence that multiple exemplar instruction promotes the development of abstracted stimulus control of verbal operants (cf., Becker, 1992; Greer, Stolfi, Chavez-Brown, & Rivera-Valdez, 2005a; Greer, Yuan, & Gautreaux, 2005b; Striefel et al., 1976), extending previous findings to word-element abstraction.

Reading Comprehension

Identifying the critical variables that allow the recombination of units—especially emergent textual behavior—is important for the understanding of this component of a reading repertoire also. Clearly, a key component of skilled reading is the speaker response as it relates to print stimuli (i.e., textual responding). Other processes are likely to be important also. There is increasing evidence, for example, that the relation between the textual response and the speaker acting as listener of his/her own productions (Skinner, 1957) is likely to be a key component in reading comprehension (de Rose, 2005; de Souza, de Rose & Domeniconi, 2009; Greer & Ross, 2008; Greer & Speckman, 2009). The special observing responses (listener responses) and production responses (speaker responses) found in verbal behavior may be established independently (e.g., Greer, Stolfi, et al., 2005; Lee & Pegler, 1982; Skinner, 1957). In a skilled reader repertoire, however, these otherwise independent verbal operants become interrelated in a network of relations, and formation of equivalence relations may be the mechanism underlying the interdependence development (e.g., de Rose et al., 1996; Sidman, 1994; Stromer, Mackay & Stoddard, 1992). Reading comprehension was demonstrated in the first two studies by the emergence of matching pictures to printed pseudowords and vice-versa (not directly trained), thus replicating the effects first described by Sidman (1971) with pseudowords and abstract pictures. Although an initial observational experience can be the source of comprehension, where a child with a repertoire of other verbal relations need not have a picture MTS experience (e.g., Greer & Speckman, 2009), when using a MLS system, picture MTS could be useful in establishing the comprehension component in reading. In Experiment 3, this component was absent, supporting the assertion that responding to print was purely textual behavior (under the control of print–sounds relations) and not reading with comprehension.

Methodological Aspects

The present series of studies could have been reported as a single experiment that varied between groups (1) the amount of trained relations, (2) the occurrence of overlapping elements in the training stimuli and (3) the occurrence of AB training. Although the participants were all college students and their behavioral histories were apparently similar, we did not (1) equate participant numbers across the studies, (2) match precisely for participant variables (chronological age, intellectual functioning, etc.), (3) equate every detail of training, and (4) analyze the data statistically, as is customary in formal matched-group studies. Rather, we conducted the studies as a series of systematic replications (Sidman, 1960). This tactic did allow us to demonstrate, however, replications and generalization of an important behavioral phenomenon (the emergence of recombinative repertoires) among conditions that suggested a role for apparently critical variables or conditions (e.g., amount of exemplars and overlapping stimuli on recombinative reading, the role of class formation in reading comprehension, etc.).

The robust findings of the present studies suggest that a miniature linguistic system may prove useful in analyzing the role of ''hearing'' phonemic sounds in deriving textual responding. They permit precisely controlled, fine-grained analyses that trace teaching conditions step by step. One can thus examine the variables that determine the first instances of emergence of novel behavior with respect to specific printed stimuli. The miniature system certainly adds to the evidence of research done in conventional languages such as English and Portuguese.

By limiting the number of letters, phonemes, and trained syllables, by inventing pseudowords with convenient configurations (e.g., the regularity in the sound–print correspondences), by specifying some pseudowords to be nonsense, and by providing a similar history with other ''meaningful'' pseudowords prior to testing, we identified a favorable context to advance the comprehension of trained and emergent verbal skills. This methodology permits simulation of reading acquisition with participants who have already learned to read in their native language. Thus, it may be possible via this procedure to conduct systematic investigation of variables with readers that may be important also in reading acquisition by nonreaders.

Considering the network of verbal relations involved in reading and writing, one would predict that an individual who learns phonemic sounds for letters may have the behavioral prerequisites for spelling given that s/he has derived relations between speaking and writing (e.g., de Rose et al., 1996; de Souza, de Rose, Faleiros et al., 2009). Future research with a miniature linguistic system could evaluate whether the accuracy of emergent written spelling would be a function of the accuracy of control by the speech sounds, in line with results reported by Greer, Yuan et al. (2005) in a study using English words. The present studies also have implications for the teaching methodologies of future research. MTS procedures that gradually introduced choice stimuli across successive trials were used to establish numerous conditional discriminations with few or no errors. Minimizing errors will likely help to minimize multiple teaching failures in stimulus equivalence studies that teach many baseline relations (e.g., Fields, Matneja, Varelas, Belanich, Fitzer, & Shamoun, 2002) and perhaps to develop baselines for stimulus control studies that are less contaminated by undesirable competing stimulus control topographies (McIlvane & Dube, 2003).

The methodology used in the present study may be effective also in guiding translations and applications of the research findings, as it has been in other fields (e.g., second language instruction, MacWhinney, 1983). Moreover, as in the theoretical analysis of stimulus equivalence (Hayes et al., 2001; McIlvane & Dube, 2003), basic studies of the variables that determine the circumstances under which recombination of behavioral units occurs (or not) have importance for theoretical understanding and/or interpretation of complex human behavior.

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