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Emergent Reading via Stimulus Pairing with Orientation Response

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Abstract
Matching-to-sample (MTS) is a widely used instrumental procedure for teaching reading and writing skills to beginning readers, in particular across stimulus equivalence research. Recent works suggests that stimulus-stimulus (S-S) pairing procedures incorporating orienting responses (SOresp) may also establish equivalence classes effectively. In brief, the "SOresp" involves sequences of S-S pairs following an orienting requirement (clicking on a fixation-cross that signals location of stimulus onsets). We investigated the efficacy of the SOresp using printed words (C) linked with referent pictures (B) with four children with reading deficits. Stimuli included six printed words (C1, C2 . . . C6) and their corresponding pictures (B1, B2 . . . B6) divided into two sets of three S-S pairs (Set 1: C1-B1, C2-B2, C3-B3; Set 2: C4-B4, C5-B5, C6-B6). For each stimulus set, the sequence was organized in 36-trial blocks (12 trials for each stimulus pair), repeated three to four times (108–144 trials per stimulus set). Training trials involved participants clicking on a fixation-cross presented in one of the four corners of the screen, followed by the presentation of a C-B sequence from one of three pairs (e.g., the printed word "LUA"—an image of the moon). Probe trials provided evidence for reading acquisition, and partial or total retention of the emergent reading, across all children, after a maximum of 144 teaching trials per set. A second experiment replicated and extended these findings with two additional children using a multiple probe design and three stimulus sets. These results have significant implications for educational interventions based on relational learning.

Keywords Stimulus pairing · Stimulus equivalence · Reading · Orientation response · Children

The matching-to-sample procedure (MTS) has been widely used to teach behavior regarded as *symbolic* (e.g., Ferster, 1964; Hively, 1962; Rocha e Silva & Ferster, 1966). Subsequent work by Sidman and colleagues (Sidman, 1971, 1986, 1994; Sidman & Cresson, 1973; Sidman & Tailby, 1982) showed that the MTS procedure teaches relations between stimuli, and these directly taught relations can yield *emergent* relations. Based on these findings, Sidman and Tailby proposed a behavioral conceptualization of what *symbolic* means, specifying criteria to determine when relations between stimuli are *equivalence relations*, so that stimuli can be substituted for each other. These criteria are based on the generation of emergent stimulus relations that document the mathematical properties of symmetry and transitivity.[1]

This generative potential of equivalence relations, and the ensuing efficiency and economy of teaching, have provided the foundation for what has been called equivalence-based

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[1] The conceptualization of stimulus equivalence by Sidman and Tailby (1982) also required the property of reflexivity, in accordance with the mathematical definition of equivalence. However, recent studies about stimulus equivalence seldom include tests for reflexivity. The reason, at least in part, may be the argument of Saunders and Green (1992), who argued that typical reflexivity tests are inherently confused with generalized identity matching and therefore cannot prove the reflexivity of the stimulus relations. Symmetry is defined as sample-comparison reversibility, i.e., emergence of BA after training of AB. Transitivity is defined as an emergent relation between TWO stimuli related to a common stimulus, i.e., emergence of AC after training AB and BC. Transitive relations are also expected to be symmetrical, so CA should also emerge after training of AB and BC.

instruction (EBI; see Pilgrim, 2019, for a comprehensive review). The hallmark of EBI is the teaching of only a subset of the stimulus relations that constitute a specific symbolic repertoire (conceived, therefore, as a relational network), so that teaching a subset of the relations generates the complete relational network.

The studies of Sidman (1971) and Sidman and Cresson (1973) are typical examples of EBI. These studies were based on the relational network diagrammed in Fig. 1a. In this diagram, A, B, and C are sets of stimuli, and D is the oral production of the names of stimuli. The solid lines represent relations taught directly to young men with severe intellectual deficiency. The line connecting the dictated words (A) to the pictures (B) represents the relation AB, i.e., given one of the 20 dictated words as sample, selecting its corresponding picture will produce a reinforcing consequence. Similarly, the line connecting the dictated (A) to the printed words (C) represents the relation AC: given a dictated word, select its corresponding printed word (C). After participants learned these two relations, all the relations represented by dotted lines emerged: BC (picture-samples to printed-word-comparisons), CB (printed-word-samples to picture-comparisons), and oral naming[2] of pictures (BD) and reading the printed words (CD). These emergent relations led the researchers to conclude that the participants showed reading, with comprehension, of the set of 20 words (see Pilgrim, 2019; Sidman, 1994; Sidman & Tailby, 1982, for more extended treatments of stimulus equivalence and symbolic relations).

Research on stimulus equivalence as well as most EBI studies use MTS to establish stimulus relations that then generate emergent relations (cf., Pilgrim, 2019). However, other procedures were reported to be effective to establish stimulus relations and generate emergent relations. Among such procedures are the go/no-go procedure (e.g., Canovas, Queiroz, Debert, & Hubner, 2019; Debert, Matos, & McIlvane, 2007), and the respondent-type training procedure (Leader & Barnes-Holmes, 2001; Leader, Barnes-Holmes, & Smeets, 1996, 2000). The respondent-type procedure presents visual stimuli in pairs, one at a time, with no response requirement. Stimulus pairs alternate across a sequence of trials, and the temporal parameters (the duration of each stimulus presentation and the within-pair- and between-pair-delays) are critical for the procedure's efficacy. Emergent relations are then tested, usually with the standard MTS procedure.

Amd and colleagues (Amd, de Almeida, de Rose, Silveira, & Pompermaier, 2017; Amd, de Oliveira, Passarelli, Balog, & de Rose, 2018) reported a modified respondent-type procedure,

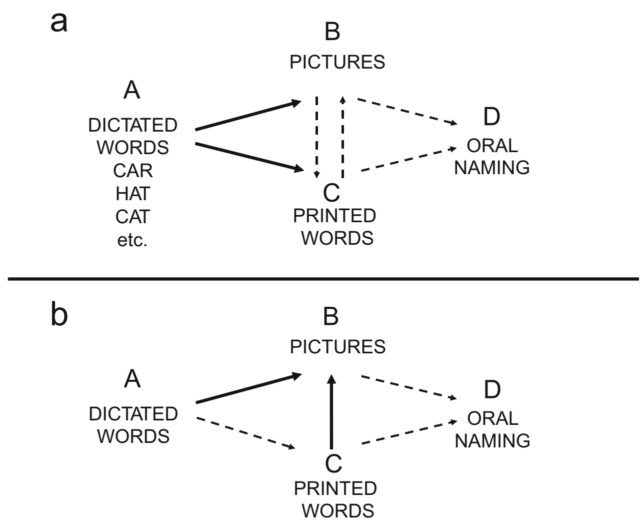


Fig. 1 The upper panel (a) shows a schematic diagram of relations trained and tested in the Experiments of Sidman (1971) and Sidman and Cresson (1973), and the lower panel (b) shows a diagram of relations trained and tested in the present experiment. Solid lines represent directly trained relations and dotted lines represent emergent relations. In the present experiment participants already could name pictures (AB), but this relation was trained to assure that the name given by all participants corresponded to the printed words (C stimuli)

that included an orientation response requirement (SOresp), to increase the probability of participants attending to the stimuli. In this procedure, each acquisition trial began with a fixation cross presented inside a square located at one of the four quadrants of the screen. Clicking on the cross caused its removal, followed by the successive presentation, in the same quadrant, of two abstract stimuli separated by a time interval ranging from 500 to 1500 ms. Based on the finding that orienting (versus observing; see Wyckoff, 1952) responses favor acquisition of S-S relations, the position of the cross (and the paired stimuli) was varied across trials. Those authors paired stimuli A and B (A1B1, A2B2, A3B3), and B and C (B1C1, B2C2, B3C3), followed by a card sorting test for the emergent A-C relation, that documents transitivity of the trained relations. Transitivity was confirmed following sorting of stimuli in pairs correspondent with training histories (A1C1, A2C2, A3C3). The SOresp appears to be at least as effective in establishing stimulus relations as MTS (Amd et al., 2017, 2018).

The success of the SOresp procedure of Amd et al. (2017, 2018) in establishing relations between arbitrary stimuli suggests that such procedure may be also effective in teaching relations between stimuli such as printed words and corresponding pictures. The present study was designed to explore this possibility of an educational application of the SOresp procedure. Because the SOresp procedure requires just clicking on a fixation point and looking, it may provide an alternative for students that do not learn well with MTS.

Figure 1b outlines the procedure of the present study, with directly trained relations represented by solid lines and

[2] Note that "naming" is used here to designate instances of what Skinner (1957) called *tact*, or *tacting,* which may be loosely defined as naming a stimulus, action, or property of a stimulus or action. This is not the more specific sense as defined by Horne and Lowe (1996), in which *naming* is not just *tacting,* but is defined by a set of emergent relations: after learning to *tact* a stimulus, responding as listener to its name (e.g., finding the object that has this name), and after learning to respond to a name as a listener, tacting (producing the name) the corresponding object.

emergent relations represented by dotted lines. The procedure is also based on the relational network depicted in Fig. 1a, with a change, however, in the trained relations. Sidman (1971) and Sidman and Cresson (1973) trained the auditory-visual relations AB and AC. This was also the approach of subsequent EBI studies on rudimentary reading skills (Bernardo & Dounavi, 2011; de Rose, de Souza, & Hanna, 1996; de Rose, de Souza, Rossito, & de Rose, 1992; de Souza et al., 2009; Matos, Avanzi, & McIlvane, 2006; Matos & Hubner, 1992; Mueller, Olmi, & Saunders, 2000). To use the SOresp procedure, however, it was necessary to train a visual-visual relation. Therefore, relation CB was chosen for direct training. Relations CB (directly taught using the SOresp procedure) and AB (already in the children's repertoire, but trained to ensure standard naming) should together generate the other relations and should also generate emergent reading.

Experiment 1

Method

Participants

Participants were four typically developing children aged 6–7 years, three boys and one girl. Participants' characteristics are summarized in Table 1. All children were enrolled in the first grade of a public elementary school in the city of São Carlos (SP), Brazil. Participants were selected based on a preliminary assessment test in which they failed to read and spell a list of simple words (not used in the experimental tasks). Children were asked to read orally words presented one by one on a computer screen and to spell those words to dictation. No feedback was given for correct or incorrect responses during assessment. Participants with scores below 50% correct in reading, and 20% correct in spelling were included in the study. The study was approved by the Ethics Committee of Universidade Federal de São Carlos (CAAE: 94796818.0.0000.5504), and children's participation began after their parents signed a consent form.

Table 1 Participants Age, Gender, Schooling, and Preexperimental Reading and Writing Performance in Experiment 1

Participant	Age (years/months)	Gender	School year (elementary school)	Initial performance (%)	
				Reading	Writing
P1	6y7m	Male	1st	0	0
P2	7y0m	Female	1st	33	0
P3	6y6m	Male	1st	0	0
P4	6y10m	Male	1st	0	0

Equipment and Materials

Tasks were performed on a Dell Inspiron I14-3443-B40t microcomputer equipped with a monitor and mouse. The software Match-to-Sample Program III (Dube & Wallace, 2003) and the E-Prime platform (Schneider, Eschman, & Zuccolotto, 2002) were used to present the stimuli and record the responses, respectively, in the MTS and stimulus pairing with orientation response tasks. The recording of participants' responses in the reading task was done using data sheets and an audio recorder device. The audios were evaluated by an independent observer for reliability checking. Children could choose among several toys, such as puzzle games, modeling clay, or dominoes, to play after the experimental tasks.

Stimuli and Responses

Two sets with stimuli divided into three categories were used: dictated words (A), pictures (B), and printed words (C). The dictated words were recorded in a male voice and were presented by the computer's speaker. The printed words had three letters and were displayed on the computer screen in font Arial 64 black in capital letters. Words were dictated and printed in Portuguese. The pictures and printed words were inserted into squares of approximately 5cm x 5cm on a white background. Figure 2 shows the experimental stimuli for each of the sets, which also included three printed words that were used as a control in the reading probes. We designated as D the responses of naming the stimulus. Therefore, BD referred to picture naming, and CD referred to reading the printed words. Note that we use "naming" as merely saying orally the name of the thing represented in a picture, and "reading" as merely saying orally a printed word (respectively, tact and textual behavior; Skinner, 1957).

Setting

The children were transported every weekday from their school to the laboratory by specialized school transportation. Experimental sessions were conducted individually, once a day, and lasted approximately 20 min. In each session, the participant was asked to sit on a chair in front of a computer in a quiet room. The experimenter provided task instructions and remained in the room beside the child until the end of the session. After completing the experimental tasks, the participant engaged in a preferred play activity for approximately 5 min.

Procedure

Overview Figure 3 shows a flowchart of the procedure, which was divided into two phases. Phase 1 evaluated the repertoire of reading the words and naming the pictures to be used as

Fig. 2 Experimental and control stimuli used in the Experiment 1. A = dictated words; B = pictures; C = printed words

Stimulus function \ Stimuli	Set 1			Set 2		
	A	B	C	A	B	C
Experimental	*"lua"*		LUA	*"uva"*		UVA
	"rei"		REI	*"pia"*		PIA
	"boi"		BOI	*"sol"*		SOL
Control	-	-	RIO	-	-	RUA
	-	-	LUZ	-	-	AVE
	-	-	ASA	-	-	PAU

experimental stimuli. Phase 2 implemented the printed word-picture pairings with orientation response. Blocks of pairing trials were preceded and followed by oral reading (CD, or textual behavior) and matching printed words to dictated words (AC) tests. Phase 2 was repeated three times with stimuli from Set 1. At the end of the last AC test with Set-1 stimuli, Phase 1 was initiated with Set-2 stimuli. The experiment was terminated when the student finished the final Phase-2 test with the stimuli of Set 2. The specific procedures for each phase are described below.

Phase 1. Initial Repertoire Assessment

This phase evaluated students' ability to read words and identify their corresponding pictures. This included a reading test, a sequence of conditional discriminations between dictated words and pictures, and a naming test of the pictures. These procedures were carried out in a single session.

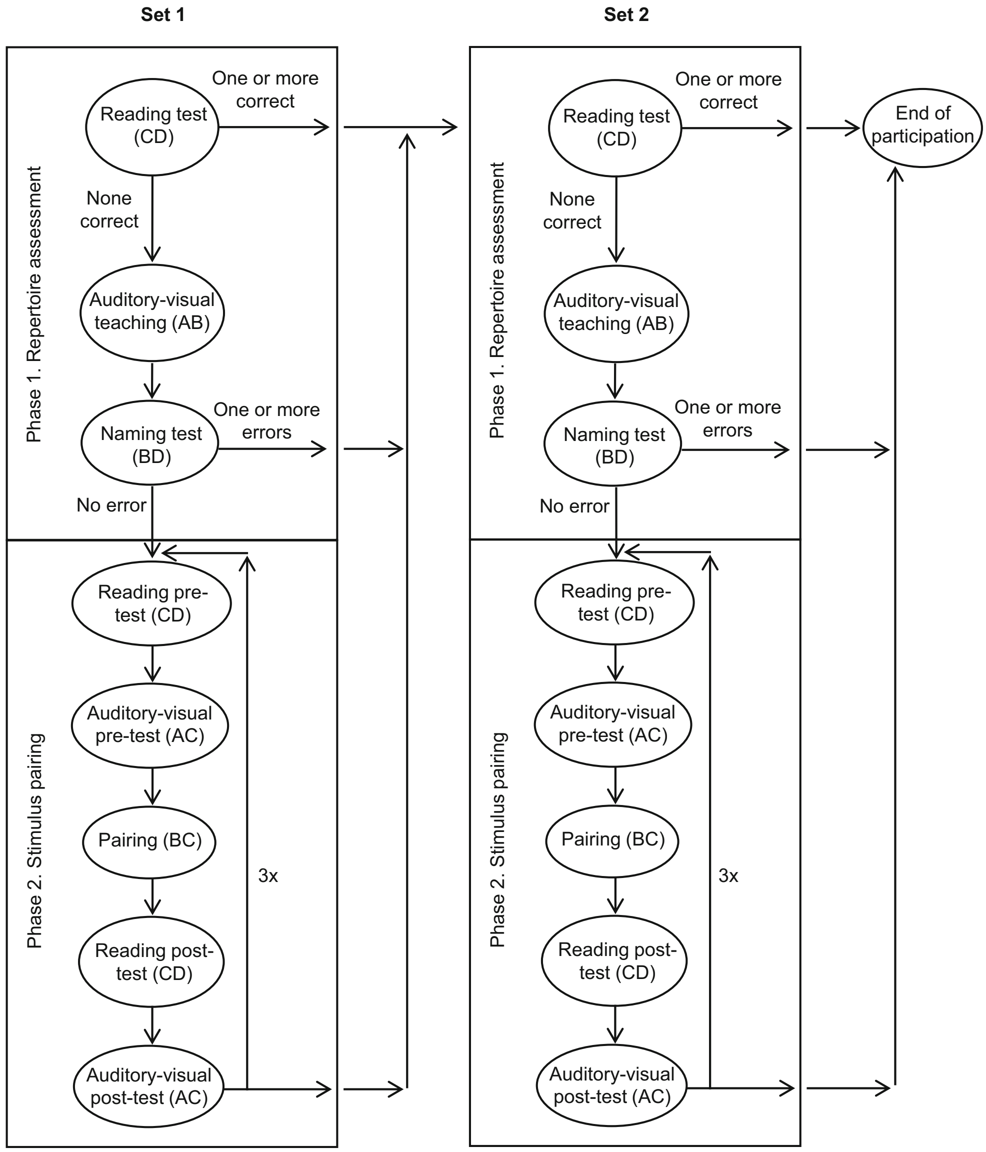
Reading Test (CD) The following instruction was spoken by the experimenter: "I'll show you some words here on the computer and ask you to read. If you do not know how to read the word there is no problem, just say that you do not know the word. If you do not understand what you have to do, you can ask me."

After the instruction, the experimental words were presented successively on the screen, in random order, interspersed with three control words. For Set 1 the experimental words were "LUA," "REI," and "BOI," and the control words were "RIO," "LUZ," and "ASA." For Set 2 the experimental words were "UVA," "PIA," and "SOL," and the controls were "RUA," "AVE," and "PAU." Each word was presented once and the experimenter asked the participant what word was being presented. If the participant read any experimental word from Set 1, they advanced to Phase 1 of Set 2. Participation was terminated if the participant read any experimental word from Set 2 in this phase. There were no programmed differential consequences for correct or incorrect responses.

Teaching of Auditory–Visual Relations (AB) Although students had already a tact repertory, it was necessary to ensure that they could tact the pictures used in the experiment with the vocal topography required. MTS trials between dictated word samples (A) and pictures (B) were conducted for this purpose. Because pictures were not used with control words, the AB relations included only the experimental words. Each trial began with the presentation of the picture of a loudspeaker on a white square on the center of the computer screen. When the participant clicked on the speaker, it was removed from the screen and one of the three words of the set was dictated by the computer's loudspeaker together with the presentation of the three pictures on the bottom of the monitor (left, center, and right). Clicking on the picture corresponding to the dictated word produced stars flashing on the monitor and a sequence of tones, followed by an intertrial interval (ITI) of 1 s. The choice of an incorrect picture was followed only by the ITI. Each dictated word was presented six times, in a random order, totaling 18 trials. A picture naming (tact) test followed, regardless of the number of correct matching responses in these AB trials.

Naming Test (BD) Each trial presented one of the pictures (B) on the center of the screen and the experimenter instructed the participant to say the name of the picture (D). There were no differential consequences programmed for correct or incorrect responses. The test block had three trials, one for each picture.

Fig. 3 Flowchart of experiment steps. The arrows indicate the transition to the next step conditionally or not to a specified criterion



The criterion for completing this step was a block with 100% of correct responses. If the criterion was not met, the block was repeated once and, if the participant still made any error, the procedure advanced to the Phase 1 with Set 2.

Phase 2. Stimulus Pairing with Orientation Response

Reading Pretest (CD) The purpose of this step was to reevaluate the reading repertoire of the set's words before the beginning of the pairings. The procedures used were identical to those of the reading test of Phase 1.

Auditory-Visual Pretest (AC) The relations between the dictated words (A) and the corresponding written words (C) were tested in a block of MTS trials. At each trial, the picture of a loudspeaker was displayed on the center of the screen and clicking on it produced one of the three dictated words together with three comparison stimuli. Two comparisons were experimental words, one of which corresponded to the dictated word (S+). The remaining comparison was a control word; control words were used only as S-comparisons. There were no differential consequences for correct or incorrect responses. The block had 18 trials presented in a semi-random order, with six trials with each experimental word dictated as sample.

Pairing of Printed Words and Pictures with Orientation Response (CB) The following instruction was presented by the experimenter: "Now a cross will appear on the screen and you must click on it. After you click, you will see pictures. When the pictures disappear, the cross will appear somewhere else and you have to click on it again."

At each trial, a black fixation cross was presented on a white square located at one of the four quadrants of the screen. Clicking on the cross caused its removal, followed by the presentation, on the same square, of one of the words (C) of the set being taught, for 1,000 ms. Next, the word was removed and only the empty square was presented during an interstimulus interval (ISI) ranging from 500 to 750 ms. After the ISI the picture (B) corresponding to the printed word was presented on the square for 1,000 ms, followed by an ITI of 1,000 ms. Each CB pair was presented 12 times for a total of 36 trials. Control words were not presented during this procedure. The location of the square and the pair of stimuli to be paired changed from trial to trial in accordance to a randomized sequence.

Reading Posttest (CD) This test aimed to evaluate the emergence of reading after the pairings between pictures and printed words. The procedure was identical to the reading pretest.

Auditory-Visual Posttest (AC) The AC relations were again tested after the pairings using the same procedure used in the auditory-visual pretest.

The participants performed three times the sequence of procedures of this second phase for each set of stimuli. Each sequence was performed in a different session.

Interobserver Agreement

An independent observer unaware of which words were experimental or control assessed participants' responses in 50% (150) of the reading tests trials. Experimenters and the independent observer agreed on 91% of the 75 trials involving experimental words and 99% of the 75 trials involving control words.

Results

Reading Repertoire Before and After Pairing with Orientation Response

Figure 4 shows the number of correct responses of each participant in the reading pre- and posttests for each set of words used in the pairing procedure. No participant read the words in the first pretest with Set 1. Reading accuracy in the posttests increased across the three sessions, and all children read correctly the three training words at the posttest of the third session. Pretest accuracy also increased across sessions, showing that reading acquired in one session was partially maintained at the beginning of the following session or was totally maintained at times. Therefore, after two or three exposures to the pairing procedure, all children read the three experimental words from Set 1.

With Set 2, two participants performed four (rather than three) pairing sessions due to an experimental error, whereas P4 performed only two, due to the end of the school semester. In general, data replicated the trends observed with Set 1: participants started the procedure without reading the words in the pretest, except for P3, who read one word. Accuracy increased in the subsequent pretests and posttests. The results were somewhat less regular than with Set 1, because both P1 and P2 showed occasional decreases in accuracy in the posttest, and P2 scored only two correct responses in the posttest of the last session.

In summary, for both sets there was an increase in the number of words read in both the pretests and the posttests ACROSS SESSIONS. (except for an error of participants P1 and P2 in the third block for Set 2). All the students reached 100% correct responses in the posttests for the two sets. The number of sessions needed to achieve this score varied among participants. Also, in Set 2 P2 reached 100% accuracy in the posttest of the second session, but did not maintain this score in the posttest of the third session, in which the participant made one error.

The participants presented very low accuracy for the control words. P1 and P2 did not read control words of either set. P3 read correctly the word "RUA" in the first session with Set 2, and the word "AVE" in the second session with this set. P4 read only the word "RIO" in a posttest of Set 1 and did not read any of the control words in Set 2 tests.

Auditory-Visual Conditional Discrimination Repertoire Before and After Pairing with Orientation Response

Table 2 shows the number of correct responses (out of 18 trials) for each participant in the pre-and posttest of auditory-visual conditional discrimination (AC). For P1, P3, and P4 the tests started in the second session of Set 1. In Set 2, posttests from the first and second sessions were not recorded for P4 and P3, respectively, due to an experimental error. The number of correct responses in the pretest sessions was high since the participants' first exposure to the task and remained at this level until the completion of Set 1. The same performance pattern was obtained with Set 2.

Discussion

Participants did not read the words in the initial pretests (except for a child who read one word in the pretest for Set 2). The pairing procedure resulted in an increase in accurate textual behavior (i.e., naming the printed words), with all participants reaching 100% correct after the third block of pairing trials with Set 1. The number of correct responses in the posttests was always higher or equal to the number in the pretests of the same sessions, indicating an improvement of the performance after the pairings. These results were repeated with Set 2, with the difference that one participant who had 100%

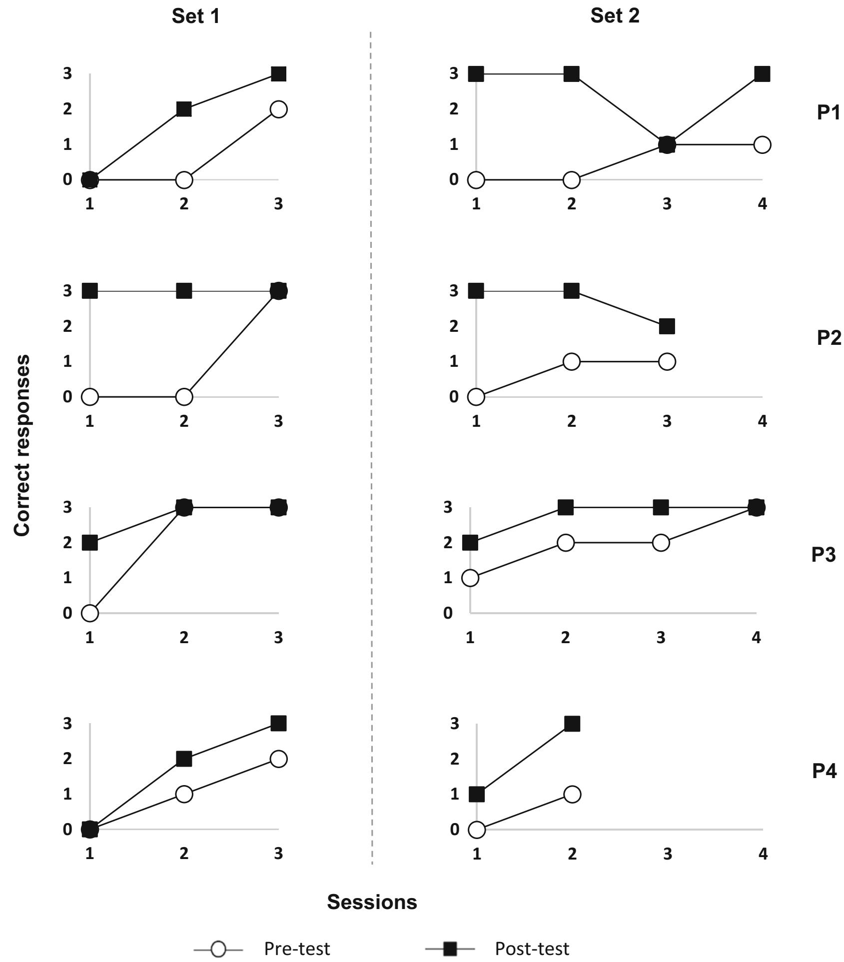


Fig. 4. Number of correct reading responses in pre- and posttests for each pairing block (session) with Stimulus Sets 1 (left) and 2 (right) in Experiment 1. The maximum of correct responses was three, one for each experimental word

accuracy after the second block presented one error in the posttest after the third block.

Performance in pretests typically increased along sessions. This was expected: because participants learned to read new words after the pairings, they could read at least some of these words in the pretest for the following block. This indicates a maintenance or retention of the reading gains after each successive pairing block.

High scores in control words reading tests would indicate that variables other than the pairings could be responsible for the outcomes obtained with the experimental words. However, accuracy in reading the control words was low.

Table 2 Number of Correct Responses (out of 18) in the Auditory-Visual (AC) Pre- and Posttests per Participant in Each Session of Experiment 1

Participants	Sessions													
	Set 1						Set 2							
	1		2		3		1		2		3		4	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
P1	-	-	16	16	17	16	15	18	11	17	16	18	18	18
P2	12	15	17	16	13	16	18	16	17	18	14	15	-	-
P3	-	-	15	14	18	16	17	17	18	-	18	17	17	18
P4	-	-	14	16	16	17	17	-	18	18	-	-	-	-

Note. Dashes indicate that the tests were not conducted. For P1, P3, and P4 the tests were introduced in the second session of Set 1. In Set 2, posttests from the first and second sessions were not recorded for P4 and P3, respectively, due to an experimental error

There were only three correct responses (two of P3 and one of P4), which was not maintained in subsequent sessions. Because only the words paired with pictures had high reading scores and were maintained across sessions, it is assumed that the SOresp procedure was the relevant variable to establish reading.

Participants showed accuracies above chance level in the AC tests in the first sessions for both sets. This suggests that the participants had no difficulties in identifying the printed word corresponding to the dictated word (word recognition) and in discriminating among the three comparison words, even when they could not read these words.

Despite the evidence showing that the SOresp produced the emergence of equivalence relations among printed and spoken words resulting in the reading of the former, some methodological issues might limit the conclusions that can be drawn from this experiment. First, no baselines and reading maintenance measures were used to assess reading performance before the pairing's introduction and after all pairing sessions. Second, P1 and P2 showed decreases in accuracy along the Set 2 and failed to replicate the data obtained in the Set 1 sessions. Also, P4 completed only two sessions from Set 2. To overcome these limitations and test the replicability of the data, a second experiment was conducted with new participants, using a multiple probe across three stimulus sets.

Experiment 2

Method

Participants

Participants were two typically developing boys, 7 (P5) and 6 years old (P6), with low-level performances in reading and writing repertoires as presented in Table 3.

Equipment, Materials, and Stimuli

Equipment and materials were the same from Experiment 1. Three stimulus sets containing dictated words (A), pictures (B), and printed words (C) were used. Figure 5 shows the experimental and control stimuli and the sets in which they were allocated for each participant.

Procedure

Overview Like in Experiment 1, pairing sessions involved a sequence of reading pretest, AC pretest, CB pairing, reading posttest, and AC posttest. Three sessions were conducted for each stimulus set. Reading probes and AC probes employing all stimuli preceded and followed the three pairing sessions of each set. The trial configurations of the reading probes and tests, as well as the configurations of AC probes and tests trials, were the same as those from reading tests and AC tests from Experiment 1, respectively.

Reading Probes (CD) All experimental and control printed words from all sets were presented once in the same block, totaling 15 trials (9 experimental and 6 control). There were no programmed consequences for correct or incorrect responses.

Auditory-Visual Probes (AC) The block had 27 trials presented in a semi-random order and without programmed consequences for correct or incorrect responses. Each experimental dictated word (A) was presented in three trials as sample and each trial included two experimental and one control printed word (C) as comparisons.

Picture Naming Test (BD) and Auditory-Visual Teaching (AB) Before the beginning of the pairing sessions, naming tests were carried out using the pictures of the set to be taught. Configuration, number of trials, and criteria were the same from Experiment 1. If the participant failed to name correctly one or more pictures, a block to teach auditory-visual (AB) relations was administered in the same format as in Experiment 1.

Reading Pretest and Posttest (CD) Reading tests were conducted before and after the pairing blocks. The three experimental and two control words of the set being taught were presented once per block (for a total of five trials) in random order. There were no programmed differential consequences for correct or incorrect responses.

Auditory-Visual Pretest and Posttest (AC) These tests were conducted after every reading test. Configuration and number of trials were the same as from Experiment 1.

Pairing of Printed Words and Pictures with Orientation Response (CB) Pairings were identical to those conducted in Experiment 1. Clicking on a fixation cross caused its removal, followed by the sequence of a word (C) and its corresponding picture (B). CB pairs were presented 12 times each, totaling 36 trials per stimulus set.

Interobserver Agreement

As in Experiment 1, an independent observer assessed participants' responses in 65% (205) of the reading tests trials; the percentage of agreement with the experimenters' records were 95% of the 123 trials involving experimental words, and 98% of the 82 trials involving control words.

Table 3 Participants Age, Gender, Schooling, and Preexperimental Reading and Writing Performance in Experiment 2

Participant	Age (years/months)	Gender	School year (elementary school)	Initial performance (%)	
				Reading	Writing
P5	7y10m	Male	1st	0	0
P6	6y4m	Male	1st	0	0

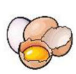
Stimulus function	Stimuli A	Stimuli B	Stimuli C	Participants' sets P5	Participants' sets P6
Experimental	"boi"		BOI	Set 1	-
	"rei"		REI	Set 1	Set 1
	"lua"		LUA	Set 1	Set 1
	"asa"		ASA	-	Set 1
	"uva"		UVA	Set 2	-
	"pia"		PIA	Set 2	Set 2
	"sol"		SOL	Set 2	Set 2
	"oca"		OCA	-	Set 2
	"ovo"		OVO	Set 3	-
	"mel"		MEL	Set 3	Set 3
	"van"		VAN	Set 3	Set 3
	"uno"		UNO	-	Set 3
Control	-	-	AVE	Set 1	-
	-	-	TIA	Set 1	Set 1
	-	-	COR	-	Set 1
	-	-	GIZ	Set 2	-
	-	-	EMA	Set 2	Set 2
	-	-	BAR	-	Set 2
	-	-	FIO	Set 3	Set 3
	-	-	DOR	Set 3	Set 3

Fig. 5 Experimental and control stimuli used in the Experiment 2 and the sets into which they were allocated for the two participants. A = dictated words; B = pictures; C = printed words

Results

Reading Probes and Tests

The performances of P5 and P6 in reading probes and tests for the three stimulus sets are shown in Figs. 6 and 7, respectively. Participants did not read any experimental words in the first probe. After the first pairing session, P5 read correctly all words from Set 1 in the posttest, whereas P6 read one word. Pretests of the second session showed reading maintenance of two words for P5 and one word for P6, and both participants read all words after the pairings in the same session. In the pretest and posttests of the third pairing session, both participants demonstrated maintenance of the reading acquired in the previous session. In the second probe the participants could read all words from Set 1, but none from Set 2 and Set 3.

A similar pattern of reading acquisition occurred for Set 2. Participants read all words after the first pairing session and maintained this performance to the end of the third session. The third probes showed the maintenance of reading for all words from Sets 1 and 2 and no correct responses for Set 3. After the third probe, P5 had a school break and experimental sessions were interrupted for 34 days. A new probe was administered to P5 after the break, and the participant demonstrated reading maintenance of all words from Set 1, two from Set 2, and acquisition of one word from Set 3.

Along the Set 3 sessions, P5 showed acquisition and a gradual maintenance of the two words he had not read in the preceding probe. In the last probe, the participant did read all words from all stimulus sets. P6 read the three words from Set 3 in all the posttests, but failed to maintain this performance in each subsequent pretest. In the last probe, P6 read all words from Set 1 and Set 2, but only one word from Set 3, which is consistent with the lack of maintenance demonstrated in his previous pretests.

No participant read correctly the control words in any session of this experiment.

Auditory-Visual Probes and Tests

Percentages of correct responses in auditory-visual (AC) probes and tests are depicted in Fig. 8 (P5) and Fig. 9 (P6). An experimental error precluded recording the first probe data of P5. In the first pairing session of Set 1, the participant

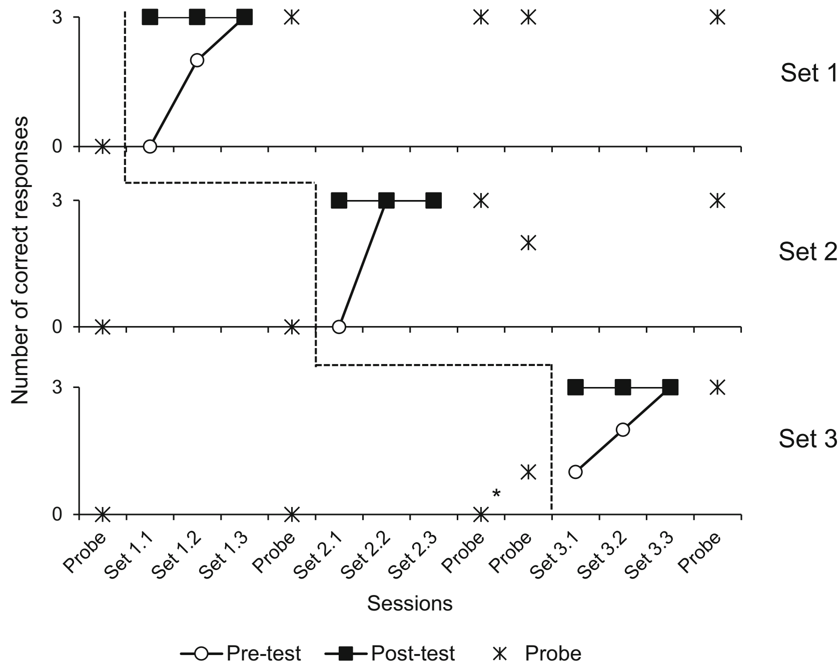


Fig. 6 Number of correct responses in reading tests and probes (CD) and in each stimulus set per session for P5. The dashed line indicates when the pairing blocks were introduced for each stimulus set. Asterisk indicates that sessions were interrupted for 34 days between the third and the fourth probe due to a school break

changed from a near chance level (33%) of correct responses in the pretest to 100% in the posttest. This high percentage was maintained in the following tests of the set. The second probe showed a high percentage of correct responses for Set 1 and percentages below 50% for Set 2 and Set 3. However, in the first pretest of Set 2 the participant responded correctly in almost all trials, and his score remained high in all the remaining tests of this set. The third probe demonstrated the maintenance of the performance in Sets 1 and 2, and the increase of correct responses in trials from Set 3. The percentage of correct responses was the same in third and fourth probes for all sets, even with a 34 days interval between these sessions. Set 3 pretests and posttests had high scores in all sessions, as well as the subsequent probes for all sets.

As shown in Fig. 9, in the first probe P6 had a high score for Set 1 and intermediate scores for Sets 2 and 3. A decrease in the percentage of correct responses is observed from the first probe to the first session of Set 1, but the following two sessions showed a reacquisition and maintenance of high scores. Scores increased to near perfect performances in the

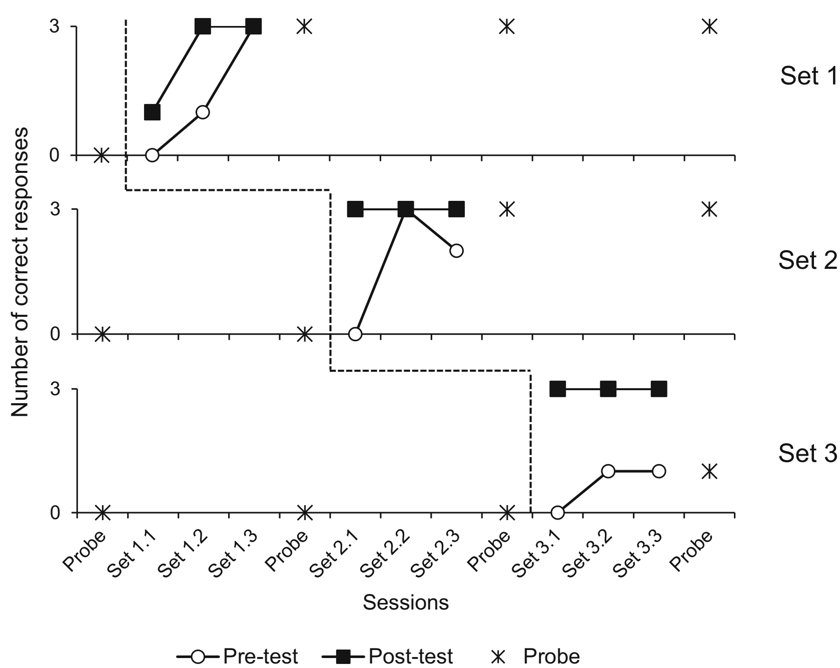


Fig. 7 Number of correct responses in reading tests and probes (CD) and in each stimulus set per session for P6. The dashed line indicates when the pairing blocks were introduced for each stimulus set

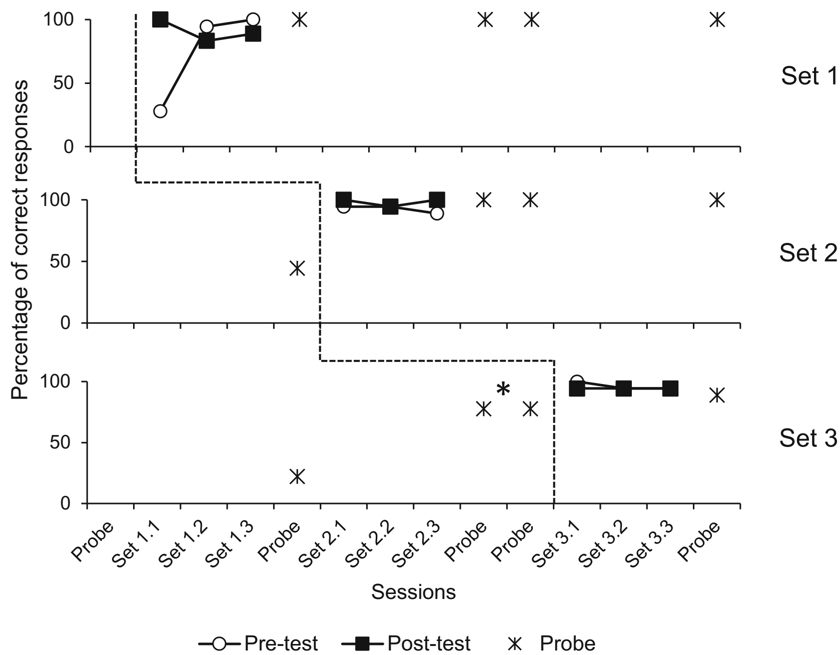


Fig. 8 Percentage of correct responses in auditory-visual tests and probes (AC) and in each stimulus set per session for P5. The dashed line indicates when the pairing blocks were introduced for each stimulus set. Asterisk indicates that sessions were interrupted for 34 days between the third and the fourth probe due to a school break

second probe for all sets comparatively to the first probe. The participant had high percentages of correct responses in all tests along Set 2 sessions. No probes were conducted after the last Set 2 session due to an experimental error. In the first session for Set 3, the participant responded correctly in about 50% of the trials in the pretest and the posttest. In the next session, the percentage increased to above 80% and was maintained at this level in the last session. The last probe showed near perfect performances for all sets.

Discussion

Results of Experiment 2 confirm that SOresp can generate equivalence classes including spoken words, pictures, and printed words, and produce emergent reading behavior. Scores in reading probes increased with the pairing sessions for each word set. Also, as in Experiment 1, the number of correct responses in the pretests and posttests increased across the pairing sessions of each set and the participants did not read the control words in any experimental session.

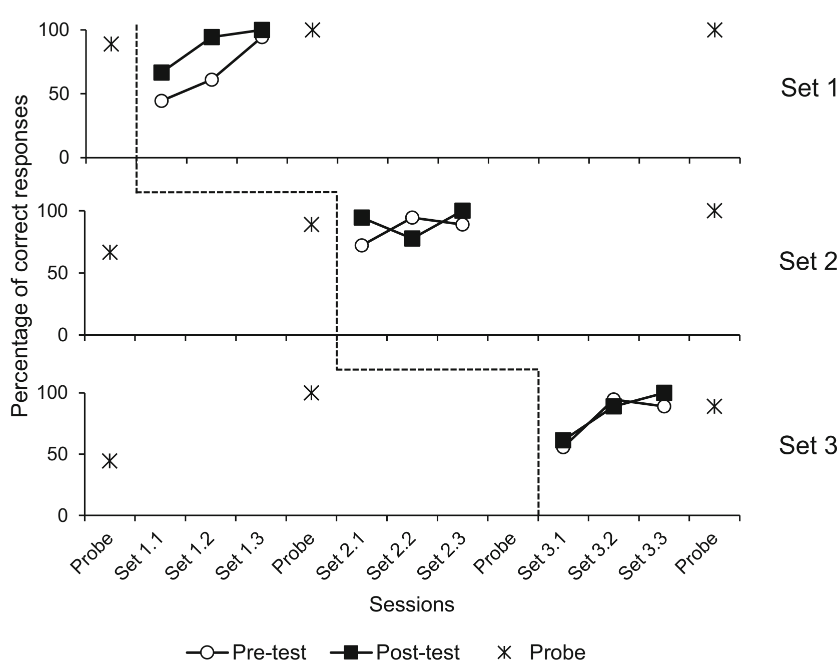


Fig. 9 Percentage of correct responses in auditory-visual tests and probes (AC) and in each stimulus set per session for P6. The dashed line indicates when the pairing blocks were introduced for each stimulus set

P5 read one word from Set 3 in the probe that anteceded the introduction of the SOresp for this set. Because this probe was conducted after several days of school break, it is likely that P5 learned to read this word outside the experimental context. Even so, P5 acquired the remaining words from Set 3 only after the pairing sessions.

Both participants demonstrated maintenance of reading in the probes that were conducted after the pairing sessions. The only exception was the last probe performed by P6 for Set 3. The participant failed to read two words even after reading the three words in the posttests of the preceding sessions. Also, P6 read one word in the second and third pretests of the Set 3, indicating a lack of reading maintenance for this set.

Results in AC probes and tests were similar to those from Experiment 1. In general, the percentage of correct responses in the probes was high before the introduction of the pairings, suggesting that this performance was acquired before or during the experimental sessions independently of the stimulus pairings.

General Discussion

The present study showed that the SOresp procedure was effective for generating oral reading of the printed words. In both experiments, children that initially could not read three-letter printed words underwent a stimulus-pairing procedure with orientation response (SOresp) between the printed words and their corresponding pictures. Tests and probes showed the acquisition of reading of all paired words whereas scores for reading control words (not paired with the corresponding pictures) remained very low.

The study by Amd et al. (2017) compared three pairing procedures, using nonsense trigrams, to generate transitive relations (AC) after pairing AB and BC stimuli. One was a simple stimulus pairing (SP) in which stimuli were presented successively on the center of the screen, as in the studies of Leader et al. (1996, 2000). The other pairing procedure (SPresp) required a response to the fixation cross to produce the stimuli, but the fixation cross and the paired stimuli appeared always on the center of the screen. The SOresp procedure, by contrast, presented the fixation cross and the paired stimuli on different quadrants of the screen, in accordance to a randomized sequence (within a trial the cross and the paired stimuli appeared in the same quadrant). Therefore, participants were required to orient to a stimulus that could appear on different locations. Amd et al. showed that the SOresp procedure was significantly superior in yielding transitive relations. The present study did not compare the SOresp procedure with other pairing procedures. Based on the results of Amd et al., we might assume that other pairing procedures would be less effective, but this assumption remains to be confirmed by future research.

The present study substituted educational, meaningful stimuli for the nonsense trigrams used by Amd et al. (2017). The successful preliminary results suggest that it is possible to carry out EBI without requiring a response other than the orienting response. It suggests also that participants may learn stimulus relations and show emergent relations without reinforcement for responses to the paired stimuli. The only response explicitly reinforced in the present study was the mouse click on the fixation cross.

MTS will probably continue to be the procedure of choice in EBI. However, it is interesting to explore alternative procedures for cases where MTS is not efficient to teach the target behavior. For example, participants who do not consistently respond to differential reinforcement nevertheless orient toward sudden shifts across their perceptual arrays, because orientation is (generally) elicited rather than emitted (Wyckoff, 1952). Thus, future works could attempt to lessen response demands and enhance the likelihood of attentional capture by manipulating stimulus displays (e.g., a flashing sample).

In EBI studies, such as those of de Rose et al. (1992, 1996) and de Souza et al. (2009), participants had already acquired the AB relation before the experiment began, and learned the AC relation with a MTS procedure. This training generated ABC equivalence classes and reading of the printed words (CD). In the present study, the participants had similar entry repertoires, and the trained relation was CB with a pairing procedure (AB and BD were, respectively, trained and tested, with the purpose of standardizing the names given for each picture). The other tests performed were AC and CD. A thorough demonstration of equivalence class formation would require additional tests. First, it would be necessary to verify if pairing C to B actually yielded the CB relation. Also, it would be necessary to verify the symmetrical relation, BC. We may presume that the emergence of reading (CD) is an indirect evidence that relations CB and BC were established, but future research should attempt a more direct testing.

The AC relation, however, was assessed before and after the pairing procedure for all sets of words. Participants typically performed with high accuracy in this relation before the beginning of pairing sessions. There are two possible reasons for these surprising results. We may assume that the AC relation had been established before the study, whereas the CB and BC relations had not. Thus, teaching CB resulted in the emergence of BC, establishing the equivalence classes ABC and yielding emergent naming of the words. However, this is not likely, because many studies have already found that AB and AC are sufficient for the emergence of all the network, including oral reading. It seems more likely, therefore, that the choices during the AC tests were controlled by fragments of the written words rather than the words as a whole. Anecdotal observations indicated that participants sometimes selected control words whose initial letters were the same as the experimental word dictated as the sample stimulus (e.g., “LUA” and "LUZ," "PIA" and "PAU"). However, in the reading test, relying solely on the first letter would be insufficient for correct responding, which is consistent with the very low reading scores in all of the initial pretests.

The EBI programs by de Rose, de Souza, and colleagues (e.g., de Rose et al., 1996) increased progressively the word reading repertoire of the students, up to around 50 words. As the repertoire expanded, children began to read untrained words, formed by recombination of the textual units of the trained words. Further refinements in the program increased the probability of recombination (de Souza et al., 2009; Reis, de Souza, & de Rose, 2009), so that children developed a generalized reading repertoire. The present study stopped at a very small number of words, much smaller than the number usually necessary to promote recombination of textual units. Further research should also determine whether an expanded EBI program based on pairing, involving an increased number of words and/or words with more syllables, would also generate recombination and generalized reading.

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Compliance with ethical standards

Conflict of Interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the Ethics Committee of Universidade Federal de São Carlos (CAAE: 94796818.0.0000.5504) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Availability of Data and Materials The data that support the findings of this study are available from the corresponding author upon reasonable request.

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