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EMERGÊNCIA DE LEITURA BRAILLE RECOMBINATIVA EM PESSOAS COM DEFICIÊNCIA VISUAL

EMERGENCE OF RECOMBINATIVE BRAILLE READING IN VISUALLY IMPAIRED PEOPLE

REGIANE DE SOUZA QUINTEIRO
UNIVERSIDADE FEDERAL DE SÃO CARLOS, BRASIL AND
NATIONAL INSTITUTE OF SCIENCE AND TECHNOLOGY ON BEHAVIOR, COGNITION AND TEACHING (INCT-ECCE)

ELENICE S. HANNA
UNIVERSIDADE DE BBRASÍLIA, BRASIL AND
NATIONAL INSTITUTE OF SCIENCE AND TECHNOLOGY ON BEHAVIOR, COGNITION AND TEACHING (INCT-ECCE)

DEISY DAS GRAÇAS DE SOUZA
UNIVERSIDADE FEDERAL DE SÃO CARLOS, BRASIL AND
NATIONAL INSTITUTE OF SCIENCE AND TECHNOLOGY ON BEHAVIOR, COGNITION AND TEACHING (INCT-ECCE)

RESUMO

O estudo investigou a aquisição de leitura de pseudopalavras em Braille e o desenvolvimento de leitura recombinativa. Quatro adultos alfabetizados, com deficiência visual adquirida, participaram de duas fases com seis ciclos ensino-teste. Cada fase ensinou 12 palavras. A composição das pseudopalavras ensinadas visou potencializar a leitura recombinativa: quatro vogais e quatro consoantes formaram 4 sílabas que ocuparam a posição inicial e final em igual número de palavras dissílabas. Ensinou-se em cada ciclo quatro discriminações condicionais auditivo-táteis entre pseudopalavras ditadas (A) e impressas em alfabeto romano em relevo (B) e duas entre pseudopalavras ditadas e impressas em Braille (C). Testes periódicos avaliaram novas relações de seleção (BC, CB, AC) e a leitura oral das palavras. Os participantes aprenderam as discriminações condicionais e formaram classes de equivalência entre as palavras ditadas e táteis (romano e Braille). Nos testes de seleção com palavras novas os escores foram maiores que 80%. Os participantes apresentaram leitura oral recombinativa acima de 75% de acertos com fonte 90 (Fase 1) e entre 41 e 79% de acertos com a fonte 40 (Fase 2). Os resultados replicaram e estenderam para estímulos em Braille as descobertas prévias de que o controle elementar por unidades intrassilábicas favorece a leitura recombinativa.

Palavras-chave: aquisição de leitura, equivalência de estímulos, leitura recombinativa, Braille, deficiência visual.

ABSTRACT

The present study investigated the acquisition of pseudowords printed in Braille and the development of recombinative reading. Four literate adults with acquired visual impairment participated in two phases composed of six teaching-testing cycles. Each phase taught 12 words. Taught pseudowords were created to strengthen recombinative reading: four vowels and four consonants composed 4 syllables that equally occupied the beginning and end of dissyllable words. In each cycle, four auditory-tactile conditional discriminations were taught between dictated pseudowords (A) and words printed in embossed Roman alphabet (B) and two between dictated pseudowords and words printed in Braille (C). Recurring tests evaluated new selection responses (BC, CB and AC) and oral naming of words. Participants learned all conditional discriminations and formed equivalence classes that included the dictated and tactile (Roman alphabet and Braille) words. Selection tests with new words had scores greater than 80%. On recombinative oral reading tests, participants scored over 75%, with font size 90 (Phase 1), and between 41 and 79% with size 40 (Phase 2). Results replicated and expanded to Braille stimuli previous discoveries that elementary control by within-syllable units promotes recombinative reading.

Key words: reading acquisition, stimulus equivalence, recombinative reading, Braille, blindness.

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Endereço para correspondência: Universidade Federal de São Carlos, Centro de Educação e Ciências Humanas. Laboratório de Estudos do Comportamento Humano (LECH), Rodovia Washington Luís, km 235, CEP: 13565-905, São Carlos, São Paulo – Brasil, Telefone: (16) 33518492. E-mails: resquint@gmail.com, elenicehanna@gmail.com, ddgs@ufscar.br.

Reading is a complex skill that involves a set of discriminated operants (Skinner, 1957). Textual behavior (vocal response under control of a written verbal stimulus) is a discriminated operant which is fundamental in reading, but reading comprehension depends on control from other variables (Skinner, 1957), especially in the formation of stimulus equivalence classes (Sidman, 1971, 1994, 2000), which include figures and events that correspond to textual and auditory stimuli (e.g., dictated words). As well as these two critical components (textual behavior and reading comprehension), the emergence of recombinative reading is another process investigated in the area.

Recombinative generalization refers to *"differential responding to novel combinations of stimulus components that have been included previously in other stimulus contexts"* (Goldstein, 1983, p. 281). For recombinative reading, textual behavior towards new words occurs under control of units previously learned from other words and that are now presented recombined in these new words. Through recombinative processes the reader becomes more and more skilled at learning new texts, without having to learn thousands of words from a given language, one by one (Adams, 1994; de Souza, Hanna, Albuquerque, & Hübner, 2015; Mueller, Olmi, & Saunders, 2000). Readers have fully mastered a language when they are able to abstract (Alessi, 1987; Skinner, 1957) every unit of sound (phonemes) and of text (graphemes) in a language (that is, the alphabet) and relate them to one another (McGuiness, 2004). Once abstraction has been established, the reader may act under control of any given combination between units. For example, in the initial phases of syllabic abstraction, a Brazilian child who has abstracted the syllables BO, CA and LA should be able to display textual behavior for each syllable individually as well as for whole words in which they were combined, such as BOCA (mouth), CABO (cable), CALO (callus), BOLO (cake) and LOBO (wolf).

The behavioral process of reading acquisition has been studied by Brazilian researchers (e.g., Alves, Assis, Kato, & Brino, 2011; Cabral, Assis, & Haydu, 2012; de Rose, de Souza, Rossito, & de Rose, 1989; de Rose, de Souza, & Hanna, 1996; Hübner, Gomes, & McIlvane, 2009; Matos, Avanzi, & McIlvane, 2006; Matos, Hübner, Peres, & Malheiros 1997; Medeiros & Silva, 2002; Melchiori, de Souza, & de Rose, 2000). These researchers have been responsible for advances on the understanding of which variables are important in learning to read taught words, reading comprehension and the emergence of recombinative reading of words that were not directly taught.

A series of studies has searched for empirical evidence for Skinner's (1957) proposition that differential reinforcement contingent to units of stimulus control may have a selective role on smaller units than those directly reinforced; more so, these units may begin to exert discriminative control over behavior, either when isolated or when combined in new compound stimuli (de Rose et al., 1996; Rocha, 1996; Albuquerque, 2001; Matos, Avanzi, & McIlvane, 2006). The general strategy consists of teaching sound-text correspondence by using a set of whole words and of testing the development of control by minimal units by reading new words that include the same syllables as those in the taught words, albeit in different combinations (recombinative reading). Sound-text correspondences are arbitrary relations between stimuli and are usually taught using a matching-to-sample procedure (Cumming & Berryman, 1965).

Results have shown that control by smaller units (letters or syllables) may be developed through an initial control by the larger units (whole words) in which they are contained. However, this depends on a series of variables, such as the number of taught words in which the smaller units repeat themselves (Matos et al., 1997; Hanna et al., 2011); the variation in the position of minimal units, in the beginning as well as in the end of words (Hanna et al., 2011; Rocha, 1996); and the emphasis of smaller units either in auditory stimuli (e.g., in scanning speech; Matos et al., 1997, 2002), textual stimuli (e.g., in tasks that involve copying with a constructed response: de Rose et al., 1996; Matos et al., 2006) or in auditory-visual matching tasks between printed and dictated words (de Souza et al., 2009; Hanna et al., 2010). Hanna et al. (2011), for example, have demonstrated that the development of stimulus control (abstraction) by four isolated syllables was much greater when they were included in 12 disyllable taught words (ensuring that each syllable was equally frequent in the initial and final positions and that each syllable was combined with each of the other three), than when the same four syllables were included in only two words (each syllable was placed in only one position and combined with only one other syllable). Other studies also suggest that within-syllable recombination may be crucial for reading new words (Serejo, Hanna, de Souza, & de Rose, 2007; Hanna et al., 2008; 2011), which confirms and expands similar results obtained when teaching words of the English language (Mueller et al., 2000).

The present study had the objective of investigating whether previous discoveries on recombinative reading (at visual modality) would be replicable when the stimuli are tactile (Braille alphabet). The tactile modality and topography of the stimuli (which has no physical similarities with the Roman alphabet) allows investigation of the course of acquisition of sound-text arbitrary relations and the emergence of (initial and recombinative) textual behavior under control of tactile stimuli. This study is investigating basic learning processes, but has important implications for teaching reading to visually impaired people through the Braille System.

Braille is a tactile system that consists of 63 different combinations of units composed of six raised dots displayed in two columns of three dots each, as shown on Panel a of Figure 1 for the letter J. These six dots constitute what is conventionally called a *Braille cell* (letter) and it is read from top to bottom, starting on the left column (Figure 1, Panel c). This combination enables a representation of alphabet letters, accents, punctuation, numbers, mathematical symbols and even chemical symbols (Larabraille, 2004).

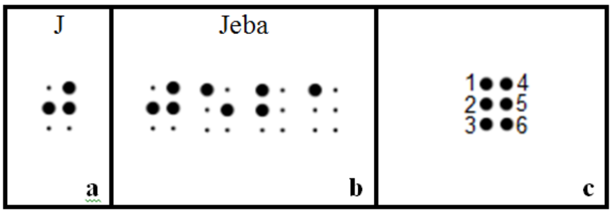

Figure 1. Example of correspondence between Roman alphabet and Braille for the letter J (Panel a) and the word JEBA (Panel b) as well as the conventional order for reading each Braille cell (Panel c).

Recent studies have experimentally investigated the establishment of relationships between letters, syllables or words in auditory (A), visual [text printed in large font (B) and Braille (C)] and tactile modalities [embossed Roman alphabet (D), Braille (E) or plastic (F)] in children and adults, with and without visual impairment (blind and with residual sight). Nascimento (2007) taught illiterate, visually impaired children the auditory-visual relations AD, AE and AF using letters as stimuli. In a study by Toussaint and Tiger (2010), children with degenerative visual impairment were taught tactile-visual relations EB with letters; the children had already mastered relations AB/BA. Two studies (Melo 2012; Vieira, 2012) used syllables and taught relations AD and AE to blind individuals. Feitosa (2009) and Leitão (2009) taught relations AD and AE to blind participants that were fluent in Braille, using words from the English language. Feio (2003) used words in the teaching stages of relations between dictated names and corresponding objects, as well as relations AE, with blind participants. In all studies participants promptly learned the relations taught with letters, syllables or words and tactile stimuli become part of arbitrary relations in the same way as stimuli from other modalities. Moreover, evaluating relations between untaught stimuli from different modalities demonstrated that they became equivalent.

Part of these studies also investigated the development of recombinative reading in tactile stimuli. The study that used words from the Portuguese language (Feio, 2003) showed that temporal spacing of dictated syllables and spatial spacing between syllables written in Braille, when presented in the initial teaching condition, favored recombinative reading of words. Feitosa (2009) and Leitão (2009) used words from the English language, formed in a CVC pattern. As in Mueller et al. (2000), the authors programmed a teaching stage of overlapping stimuli by repeating either the initial letter (onset) or the final letters (rime) for different words. The selected participants had previous experience with reading in Braille. In both studies the emergence of recombinative reading of new words in English occurred. Within-syllable recombination was promptly acquired by the participants, probably due to manipulations (overlapping of initial and final segments) in the composition of the set of directly taught words; however, history of learning Braille was an important additional factor.

A computerized method for teaching how to read in Braille was developed and evaluated with university students (Scheithauer & Tiger, 2012; Scheithauer, Tiger, & Miller, 2013). Stimuli were presented in the visual modality (including the Braille set, represented as a combination of raised black dots). Students were taught to relate 26 printed letters from the Roman alphabet to letters of visual Braille that were presented as the sample, with the evaluation of reading a small text written in visual Braille (Braille passage) before and after teaching stages. Both studies reported learning of all 26 relations taught with letters as well as an increase in the number of words in the text read after the teaching stage, although gains were variable among participants. The procedures' efficiency was not assessed with visually impaired participants in the tactile modality.

In the present study, investigations of acquisition of reading pseudowords (written in Braille and in embossed Roman alphabet) and emergence of recombinative reading in Braille were conducted with people with visual impairment (blindness) acquired at the adult age. They were literate and proficient at reading the Roman alphabet in the visual modality. The main task was to learn new arbitrary relations between dictated and tactile words and evaluate the emergence of new relations that were not directly taught. According to the stimulus equivalence paradigm, learning new relations should result in incorporating these stimuli into previously established classes, which would promote reading comprehension. Simultaneously (according to Skinner, 1957 and to subsequent empirical studies), differential reinforcement in identifying and selecting whole words could also promote development of stimulus control by smaller units (syllables and Braille cells) and favor the emergence of recombinative reading.

To empirically verify these possibilities, the experimental design was based on Experiment 1 from Hanna et al. (2011). The authors investigated, with undergraduate students, the effect of the number of taught pseudowords on the emergence of recombinative reading as well as the effect of teaching words with syllabic combination on the reading of new pseudowords with within-syllable recombination. Using a matching-to-sample procedure, relations involving 12 words (dictated words, words printed in pseudo alphabet and abstract images) were taught in six cycles of teaching and testing; in each cycle, relations between two words were taught and, after reaching the stability criterion, tests of emergent relations were conducted, involving two taught words and two novel words, composed of recombined syllables. When tests for one cycle ended, a new cycle began until all six cycles were completed. The present study used a similar procedure, except for the following aspects: (1) Instead of an invented alphabet, the Roman alphabet and the Braille System were used to compose two sets of tactile stimuli; (2) Two sets of 12 stimuli were used instead of one, therefore, participants were exposed to two phases of teaching, each one with a stimuli set. Also, since this study required a response of touching the stimuli, font size was manipulated for tactile stimuli (Phase 1: size 90 and Phase 2: size 40).

METHOD

Participants

Four adults, aged between 50 and 62 years (three females and one male), participated in this study. All had complete acquired visual impairment (for 5 years, on average) and were students at a specialized treatment institution in a small town in the state of Minas Gerais, Brazil. All participants were literate and indicated by their Braille teacher at the institution and they were considered beginner-level students. The Informed Consent Form was signed by participants at the beginning of the study.

Experimental Setting

Data collection was conducted in a room (6 x 3 m) in the institution attended by the participants, at times in accordance with their permanence in this location. The participant would sit on a chair facing a table. The experimenter would sit on the other side of the table facing the participant and the observer sat to the left of the participant at a distance.

Material and Equipment

The material used in the teaching program was based on a study developed by Hanna et al. (2011), adapted into a version with tactile stimuli, on a table-top based task, with instructions presented by the experimenter on every trial.

Words in Braille in their standard size (6 x 4 mm per letter) were stamped using a pro-60 Juliet printer after using the conversion software Braille Fácil (Easy Braille). Words in Braille (font size 90) were made with small E.V.A. (Etil Vinil Acetato) foam circles (0.5 cm in diameter) that were glued onto the Braille printed letters (3 x 2 cm per letter).

Words in Braille in intermediary font sizes (40 and 70) and words written in Roman alphabet were produced using Thermoform, equipment that embosses PVC film through heat and vacuum. Words in Roman alphabet were written in capital letters, Arial font, sizes 30, 40 and 70. The same words were built with E.V.A. letters in font size 90.

Cardboard (Phase 1) and EVA (Phase 2) were used for the experimental apparatus where the trials were displayed with the tactile stimuli, which were glued to cards and set horizontally on the superior and/or inferior portions of the apparatus.

The reading and selection responses were recorded on paper protocols by the experimenter (Phases 1 and 2) and by the observer (Phase 1).

Tasks conducted in each session were either recorded on video by a portable camcorder (Sony DSC-W380) or the audio was captured by a sound recorder (Panasonic RR-US430) for calculating the reliability index and data analysis. Compliments and arbitrary reinforcement (the sound of marbles dropping on a plastic bowl) indicated the next trial in teaching and test tasks (one marble per trial).

Stimuli

Tactile stimuli that consisted of rectangles with two different textures (vertical stripes and horizontal stripes), circles, stars and triangles were used in the pre-training task (Phase 1). The material was made of EVA foam and felt, glued onto A4 sized cardboard paper.

The teaching program used stimuli in the auditory and tactile modalities, divided into three sets. Set A was composed of auditory stimuli: pseudowords dictated by the experimenter. Tactile stimuli consisted of written pseudowords (hereinafter named just words) with the Roman alphabet (Set B) and the Braille System (Set C). The words were nonsense disyllables formed in a CVCV (consonant-vowel-consonant-vowel) pattern. All 12 words taught in each phase were formed by the combination of four syllables (Phase 1: JE, BA, DO, FI and Phase 2: VI, LE, ZO, TU) with different dimensions in each phase (Phase 1: size 90; Phase 2: size 40); reducing font size in Phase 2 had the objective of approaching stimuli sizes to Braille standard. Another 14 words, used in tests, were composed of the within-syllables recombination of the four syllables. Table 1 displays the words used in the teaching and testing phases for each cycle in both phases of the study.

Dictated words (Set A) were pronounced according to Brazilian language phonemes, with the first tonic syllable and closed sound for the vowels (e.g., jeba = "j**ae**ba", tozu = "t**oe**zu").

Agreement Index

The index, used to assess data reliability, was 99%. The agreement was calculated for 30% of teaching sessions and 100% of partial and final tests. In Phase 1 the agreement compared data between experimenter and observer. In Phase 2 the agreement was between the experimenter's recordings and the audio/video recordings.

Procedure

The study taught relations with two sets of 12 stimuli (presented in Table 1), with the goal of replicating within-subject results for different stimuli. To do so, the procedure was divided into two phases, which were conducted sequentially; Phase 2 began after all procedures from Phase 1 had been completed. The general procedure for both phases was basically the same, except for the new set of stimuli and the reduction of font size (from 90 to 40). Before and after each phase, the participants' repertoire was evaluated in selection tasks and in reading words with meaning in Phase 1 and without meaning in Phase 2. Each phase was divided into six teaching and testing cycles; each cycle began with teaching tasks and ended with tests (named partial tests). For each cycle, auditory-tactile relations were taught; four AB relations (dictated word-word in Roman alphabet) and two AC relations (dictated word-Braille word). Nodules were dictated words and the goal was class formation (four AB classes and two AC classes), each including a spoken word (A), its corresponding word in the embossed Roman alphabet (B) and the same word (only taught words) in Braille (C).

Table 1. Words in Roman alphabet (B) and Braille (C), taught and novel, used in each cycle of Phases 1 and 2.

Cycle	Taught Words		Novel Words		Taught Words		Novel Words	
	B	C	B	C	B	C	B	C
	Phase 1				Phase 2			
1	jeba	⠚⠑⠃⠁	jebi	⠚⠑⠃⠊	vize	⠧⠊⠵⠑	vilu	⠧⠊⠇⠥
	dofi	⠙⠕⠋⠊	fado	⠋⠁⠙⠕	tozu	⠞⠕⠵⠥	zote	⠵⠕⠞⠑
2	fije	⠋⠊⠚⠑	fijo	⠋⠊⠚⠕	levi	⠇⠑⠧⠊	velo	⠧⠑⠇⠕
	bado	⠃⠁⠙⠕	deba	⠙⠑⠃⠁	zuto	⠵⠥⠞⠕	zuti	⠵⠥⠞⠊
3	doba	⠙⠕⠃⠁	bido	⠃⠊⠙⠕	vizu	⠧⠊⠵⠥	vize	⠧⠊⠵⠑
	jefi	⠚⠑⠋⠊	jefa	⠚⠑⠋⠁	tole	⠞⠕⠇⠑	lotu	⠇⠕⠞⠥
4	baje	⠃⠁⠚⠑	bajo	⠃⠁⠚⠕	leto	⠇⠑⠞⠕	teli	⠞⠑⠇⠊
	fido	⠋⠊⠙⠕	defi	⠙⠑⠋⠊	zuvi	⠵⠥⠧⠊	zuvo	⠵⠥⠧⠕
5	jedo	⠚⠑⠙⠕	jedi	⠚⠑⠙⠊	vito	⠧⠊⠞⠕	vite	⠧⠊⠞⠑
	bafi	⠃⠁⠋⠊	foba	⠋⠕⠃⠁	zule	⠵⠥⠇⠑	luzo	⠇⠥⠵⠕
6	doje	⠙⠕⠚⠑	doja	⠙⠕⠚⠁	lezu	⠇⠑⠵⠥	lezi	⠇⠑⠵⠊
	fiba	⠋⠊⠃⠁	befi	⠃⠑⠋⠊	tovi	⠞⠕⠧⠊	votu	⠧⠕⠞⠥
1 a 6[a]			fade	⠋⠁⠙⠑			vilo	⠧⠊⠇⠕
			dija	⠙⠊⠚⠁			tuze	⠞⠥⠵⠑

Note. Stimulus Size: Phase 1=90; Phase 2=40.
[a] Words with recombined elements used in all experimental cicles.

Next, partial equivalence (BC/CB) and recombinative reading (CD – with novel words) tests were conducted. Once the tests were finished, a new teaching cycle of other relations began. After the sixth cycle ended, final tests of emergent relations by equivalence and recombination were conducted.

The sequence of tasks to be accomplished in the teaching program for each cycle of Phase 1 is presented on Table 2. Phase 2 followed the same sequence with a new set of stimuli, shown on Table 1. Each task will be described for Cycle 1. The same description applies to all other cycles in both phases.

Experimental tasks

Matching-to-sample. The procedure for teaching conditional relations was auditory-tactile matching-to-sample (MTS). Each trial began with the presentation of the comparison stimuli on the bottom area of the apparatus. The participant should then emit an observation response of touching the stimuli and describe how many there were. The experimenter would dictate the sample stimulus; the participants' response should be to either point at or say the position of the chosen stimulus.

In conditional discrimination tests with tactile samples, the samples were displayed on the superior portion of the apparatus, simultaneously to the comparison stimuli, which were located on the inferior portion. The participants were instructed to emit first the observation response on the sample and next to touch the available comparison stimuli and choose the one they considered to be correct.

Oral reading (BD/CD). In reading tests of the embossed Roman alphabet (B) or Braille (C) words (taught or recombined), only one tactile stimulus was presented per trial; the participant was instructed to touch the stimulus and name the word that was being displayed.

Consequences

In the teaching phases, the potentially reinforcing consequences (arbitrary and social reinforcements) were presented simultaneously and contingently to correct responses. Incorrect responses were followed by another presentation of the same trial (correction procedure).

During testing, responses did not have any programmed consequences.

Teaching Procedures

The AB relations were taught first, followed by the AC relations.

AB Teaching – matching Roman alphabet words to dictated words. The experimenter presented a trial and the general task's instruction "*For each trial I will say a word and you must find the corresponding embossed written word* (Roman alphabet)". The instruction continued as follows: "*Point to the word [jaeba]*" (throughout trials and cycles, the instruction became simpler, such as "*Which of these words is [jaeba]?*" or "*Where is the word [jaeba]?*").

Teaching was conducted in a block of 60 trials. Relations between four dictated words and four words written in Roman alphabet were taught. Two of these words were later used in AC Teaching and the other two (recombination words) were used in partial and generalization tests of all cycles (Table 1).

Initially, the same sample stimulus was dictated in trials 1 to 6. In the first trial, only the correct comparison stimulus was available; in the next two trials, the number of comparisons increased to two; finally, the next three trials displayed three comparison stimuli simultaneously and the correct stimulus changed positions.

The 54 trials that followed taught the other three relations cumulatively. In order to teach each relation, a trial was presented with the new sample and only its correct comparison stimulus, followed by two trials with the same sample and two comparisons, with the correct stimulus in different positions. Next, trials were programmed with two comparison stimuli and the samples of the relations taught up until then were alternated semi-randomly, with balancing of the correct comparison throughout trials. Afterwards, trials with three comparisons also changed samples and presented, for each sample stimulus, the correct stimulus once in each position. The last 12 trials (49 to 60) were programmed so that three trials for each of the four relations were presented in random order. The teaching words were also used with the negative stimuli in trials with non-corresponding samples.

Table 2. Teaching and testing tasks and number of trials (trials) with taught (T) and novel (N) words of each experimental phase.

Cycle	Function	Task	Stimuli	Trials
Teaching-Testing Cycles with different exemplars				
1	Teaching	1. MTS AB (Roman embossed)	2 T, 2N	60
		2. MTS AC (*Braille*) and	2 T	39
		Oral reading/textual *Braille* (CD)	2 T	8
	Parcial Tests	1. Equivalence (BC/CB)	2 T	12
			2 N	12
		2. Recombinative reading *Braille* (CD)	4 N	8
		3. MTS AC (recombinative)	4 N	8
	Generalization Tests[a]	4. Oral reading /textual *Braille* (CD)	2 T, 4N	6
		5. Oral reading/textual embossed (BD)	2 T, 4N	6
		6. MTS AB (embossed)	2 T, 2N	4
		7. MTS AC (*Braille*)	2 T, 4N	6
2 a 6		Same as in Cycle 1		
Final Tests				
After Cycle 6	Test	1. Equivalence (BC/CB) recombinative	4 N	16
		2. *Braille* oral reading (CD)	12 E	12
		3. *Braille* recombinative oral reading (CD)	14 N	14

Note: Same sequence in Phase 2.
[a]Font = 30

Errors until trial 48 entailed in a correction procedure (repetition of the same trial for a maximum of three times). The learning criterion was 100% correct responses on trials 49 through 60, that is, consecutive correctness in the last 12 trials in the block. If the criterion was not met, the participant was exposed once more to the 12 final trials, which were presented in a different order. If correct response percentage was again less than 100%, the same set of trials was repeated for a third time. If errors persisted, the session was interrupted and the participant would repeat the entire learning session of relation AB of that cycle in the next session. When 100% of correct responses were obtained, the participant would move forward to the next teaching task (Relations AC and CD).

AC and CD Teaching – matching Braille words to dictated words and reading Braille words. In AC teaching, the participant was instructed to choose, among Braille words, one which corresponded to the dictated sample word. The instruction was "*In this task I will dictate a word and you must find the corresponding word in Braille among those available in the trial"*. Negative stimuli of each AC trial had only one letter similar to the positive stimulus placed in the same position (e.g., when **JEBA** was the positive stimulus, negative stimuli were **J**IDO. F**E**DO, DO**B**I, DOF**A**). Comparison stimuli were gradually introduced (from one to three stimuli) and incorrect responses were followed by trial repetition (correction) as described in AB Teaching.

Teaching relations AC and CD was conducted in one 47-trial block of which 39 selection trials (CD) were mixed with eight trials of reading taught words (CD). In one reading trial the word in Braille was presented by itself and correct responses had consequences; if errors occurred in oral reading, the immediately previous sequence of selection trials was repeated (AC) as well as the oral reading trial.

The learning criterion was 100% consecutive correct responses in the 10 final trials, which included six AC type trials and four CD type trials (reading of both words taught in the cycle, two trials per word). If the participant had less than 100% of correct responses, the final AC and CD trials were repeated (up to three times). If even so the participant wasn't able to reach the criterion, the session ended and the next session began with teaching of the same relations again.

At the end of teaching both types of conditional relations (AB and AC), partial tests for the cycle began, in extinction, according to the following description which is summarized on Table 2.

Each partial test used the same two recombination words which were repeated in every cycle (FADE and DIJA on Phase 1; VILO and TUZE on Phase 2) and two words with specific recombinations for each cycle (see Table 1).

Partial Tests

Equivalence test (BC/CB) with taught words. The test was composed of 12 trials that mixed six BC trials and six CB trials (three trials per taught word). The instruction was "*In this task you will identify the word displayed on the superior portion of the paper* (the participant's hand was placed on the sample stimulus) *and then look for the corresponding words from the ones available below*".

The task consisted in choosing the word in Braille that corresponded to the Roman alphabet word (BC) or choosing the word in Roman alphabet that corresponded to the word in Braille (CB).

Equivalence test (BC/CB) with new words (with *recombination).* The test verified the emergence of conditional relations between two novel words (with syllable recombination) printed in Braille (Set C) and embossed Roman alphabet (Set C). The same two words repeated themselves in the partial tests of every cycle. Participants were exposed to 12 mixed trials (six BC and six CB). Each word was also tested in three trials.

Recombinative Reading Test CD. Words in Braille were displayed one at a time. Four new (recombined) words used in the cycle were evaluated, two of which were presented in every cycle and two which were presented specifically in that cycle (Table 1). Each word was tested in two trials (8 in total). The criterion to consider a correct response was emitting a word with precise grapheme-phoneme correspondence. If partial control by parts of the word occurred, the response was recorded as incorrect, but the correct elements were used to analyze correctly pronounced phonemes.

The initial instruction for accomplishing this task was "*On the top of the paper there is a word in Braille. Read it carefully and tell me which word it is*". In the trials that followed the instruction was reduced to "*Which word is this?*" or "*Say which word this is*". Participants that emitted more than one response in a given trial were asked to define what the final response for that trial was.

Receptive-auditory Reading Test (AC) of novel words in Braille. The test of conditional relations between novel dictated words (Set A) and new words in Braille (Set C) used four novel words distributed throughout eight trials (two trials per word): two were specifically from that cycle and two were repeated in every cycle.

Reading generalization and selection Tests. The tasks tested four types of conditional relations, two reading (CD, BD) and two selection (AC, AB), with tactile stimuli from Sets B and C fabricated in font size 30 in order to evaluate stimulus generalization in a smaller size than those taught (see sequence in Table 2). All six words from the cycle (two taught and four new) were used in each test, except for Test AB, which used only four words (two taught words and the two novel words that were constant in each cycle).

Once this sequence of teaching and partial tests ended for a cycle, the same procedures and criteria were used in subsequent cycles (six in total).

Once all six cycle were completed, the final tests were conducted to evaluate retention of what was taught and emergent recombinative repertoires.

Final Tests

Final Recombination Test (BC/CB). This test evaluated the emergence of receptive reading by using four words from the Portuguese language (Phase 1: BIFE, BODE, BAFO, JADE; Phase 2: TULE, LUTO, VOTO, VETO) in Braille and the Roman alphabet, formed by the recombination of letters used in the composition of the taught words. There were two blocks of eight trials each (n=16) that tested one BC relation and one CB relation for each of the words. All trials simultaneously displayed three comparison stimuli: two words with meaning and one nonsense recombination word. Instructions were the same as those in the equivalence and recombination partial tests.

Final Oral Reading Test (CD). All 12 taught words and 14 recombination words were presented in a total of 26 trials (one per word). Taught words and recombination words were interposed. Only responses of naming taught words had consequences (social and arbitrary).

RESULTS

In the initial evaluation two participants had low general scores (between 0% and 40% correct responses) in reading letters and syllables in Braille, while the other two participants read all vowels and 50% of the letters in Braille. Three participants did not read words and one participant read 50% of the words in Braille correctly. In the selection tests, scores for all four participants were above 80%.

Acquisition of relations AB and AC/CD

All participants completed the AB Teaching (matching dictated word-word in embossed Roman alphabet) with practically no errors in all cycles from Phases 1 and 2. Scores varied between 96 and 100% of correct responses throughout the cycles for both phases.

In AC Teaching, participants also learned the relations between dictated and Braille words that were taught, either with no errors or with a maximum of two errors (except for Sony, who made 6 errors in Cycle 1, Phase 1). Scores varied between 88 and 100% correctness throughout the cycles in both phases. Debbie and Dan did not need to conduct the AB and AC teaching sessions for Cycles 2, 3, 5 and 6 from Phase 2 and Mary for Cycle 5 since they had 100% correct responses in the Pre-test.

Equivalence Tests with taught words

The four participants scored in the BC/CB Tests (relations between words written in Roman alphabet and Braille) consistently with the formation of classes with equivalent stimuli in both phases and for all cycles (24 classes in total).

Equivalence Tests with new words, for receptive-auditory reading and oral recombinative reading

Results from Partial and Recombination Tests throughout the cycles for each phase are shown in Figure 2, per participant. These tests measured the emergence of conditional relations between recombination words written with an embossed Roman alphabet and in Braille (BC/CB), the relations between dictated word and word in Braille (AC) and oral reading of words written in Braille (CD).

In Equivalence Tests (Recombination), which evaluated the relations between new words in the Braille and Roman alphabets (BC/CB: open squares), participants obtained 100% scores in practically every cycle of both experimental phases. Sony and Mary had scores that were lower than 100% in some tests, but percentage of correct responses was greater than 80% for Sony and equal to or greater than 65% for Mary.

Most receptive-auditory (AC) Reading Tests had 100% scores for both experimental phases (Figure 2: filled triangles). Out of 24 possible points, only five were lower than 100% (in the first cycle of Phase 2, for Mary; and on the first two cycles of both phases, for Sony).

Recombinative Oral Reading (CD) Tests, represented by the open circle, showed that Debbie and Dan scored between 75 and 100% since the first cycle, in both experimental phases. Mary and Sony scored between 5 and 50% for the first two cycles (after two and four words were taught) of Phase 1 and presented an upward trend in correct response percentages that accompanied the increase in number of taught words. In Phase 2, scores for the first cycle were greater than 60%, except for Mary in the fourth cycle, who obtained only 25% correct responses.

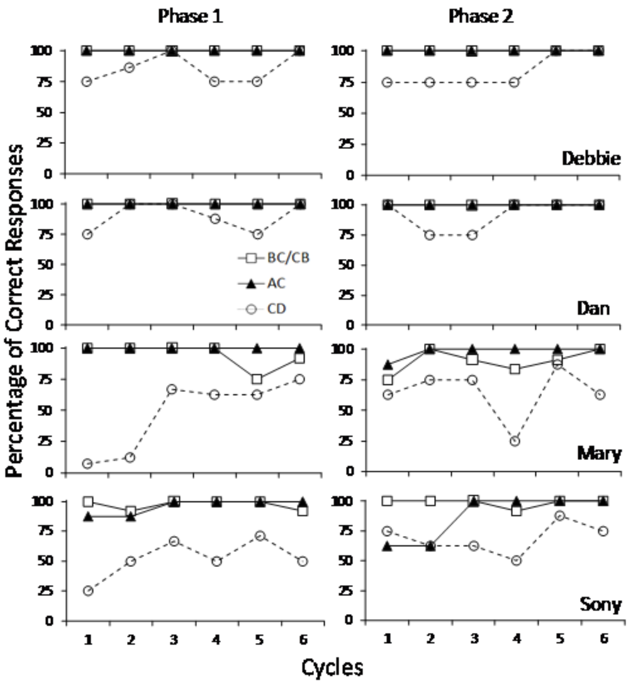

Figure 2. Percentage of correct responses in Partial and Recombination Tests for each cycle of Phases 1 and 2: Receptive-auditory Reading Tests (AC); Recombinative Equivalence Tests (BC/CB); and Recombinative Oral Reading Tests (CD).

Generally, performance in selection tests (BC/CB and AC) was better than indices obtained in oral reading of novel words in Braille (open circles), especially for Mary and Sony.

An analysis of errors in oral reading in Braille throughout cycles shows that Debbie and Dan made sporadic and non-systematic errors, while Sony and Mary, who had made more mistakes, tended to exchange letters and incorrectly spell words during both phases. All four participants presented pronunciation errors (naming "o" and "e" as "open" vowels (i.e. /o/ and /e/) although the pronunciation should be "closed" (i.e. /oe/ and /ae/), and pronouncing the first tonic syllable although all words were oxytone), but these occurrences were not very frequent.

Generalization Tests for oral reading and selection

Selection and oral reading tests with taught and novel stimuli in smaller fonts (size 30) were conducted to evaluate generalization. During the teaching stages of Phase 1, stimuli were font size 90 and in Phase 2 size 40. Debbie and Dan had 100% correct responses in all cycles of the selection tests (AB and AC). Sony and Mary had up to three errors in two cycles of Phase 1; in Phase 2 errors for AC Tests occurred only in the first two cycles, for which percentages of correct responses were between 67 and 86% for Sony and between 67 and 83% for Mary.

Results for the BD (Roman alphabet) and CD (Braille) Oral Reading Tests per cycle are shown in Figure 3 for both taught and recombined words. For each phase, results from the left column refer to taught words and from the right column to novel words.

Scores from oral reading generalization tests with smaller stimuli presented intersubject variability for taught and novel words for both phases although similarity was found with scores from tests with the larger font (compare Figures 2 and 3). Debbie and Dan correctly read all the taught words (100% scores), during BD Tests (filled circles), in at least five cycles from both experimental phases. Sony had 100% correct responses in the first cycle of Phases 1 and 2 and in the third cycle of Phase 2. In the other cycles Sony and Mary had either zero or 50% correct responses in BD trials with taught words for both phases.

Debbie and Dan also had 100% scores when reading words in Braille (CD Test, open circles) taught in Phase 1 in 4 and 5 out of six cycles, respectively. In Phase 2, Debbie obtained 100% correct responses in 5 cycles, but Dan only scored 100% in two cycles and had low scores (0 or 50%) in four out of six cycles. Results for Mary and Sony's oral reading tests in Braille with reduced font varied unsystematically. These participants reached 100% correct responses in only one cycle per phase.

Results for the reading test of novel words with the reduced Roman alphabet were similar to results for reading in Braille for all participants. Debbie and Dan's performance was high (between 75 and 100%) in at least five cycles, Sony's was intermediate (between 50 and 75%) in four cycles and Mary scored zero in three out of five cycles from Phase 1 and two from Phase 2.

Considering Mary and Sony's poor performance in Braille reading tests (CD) with stimuli size 30 in Phase 1, a complementary teaching procedure was prepared with three teaching steps and selection tests and recombinative reading with stimuli from Phase 1. The goal was to expose participants to tactile stimuli that were gradually reduced (sizes 70, 50 and 40) until the size that was used in Phase 2 (40). Both participants had high indices of correctness in the tests conducted during this procedure.

In Phase 2, after being exposed to the complementary procedure, Mary had improved results in oral reading of words taught in Braille in three cycles. Sony and Mary had better results in reading new words compared to Phase 1 in some cycles (Roman: Mary and Sony; Braille: Mary).

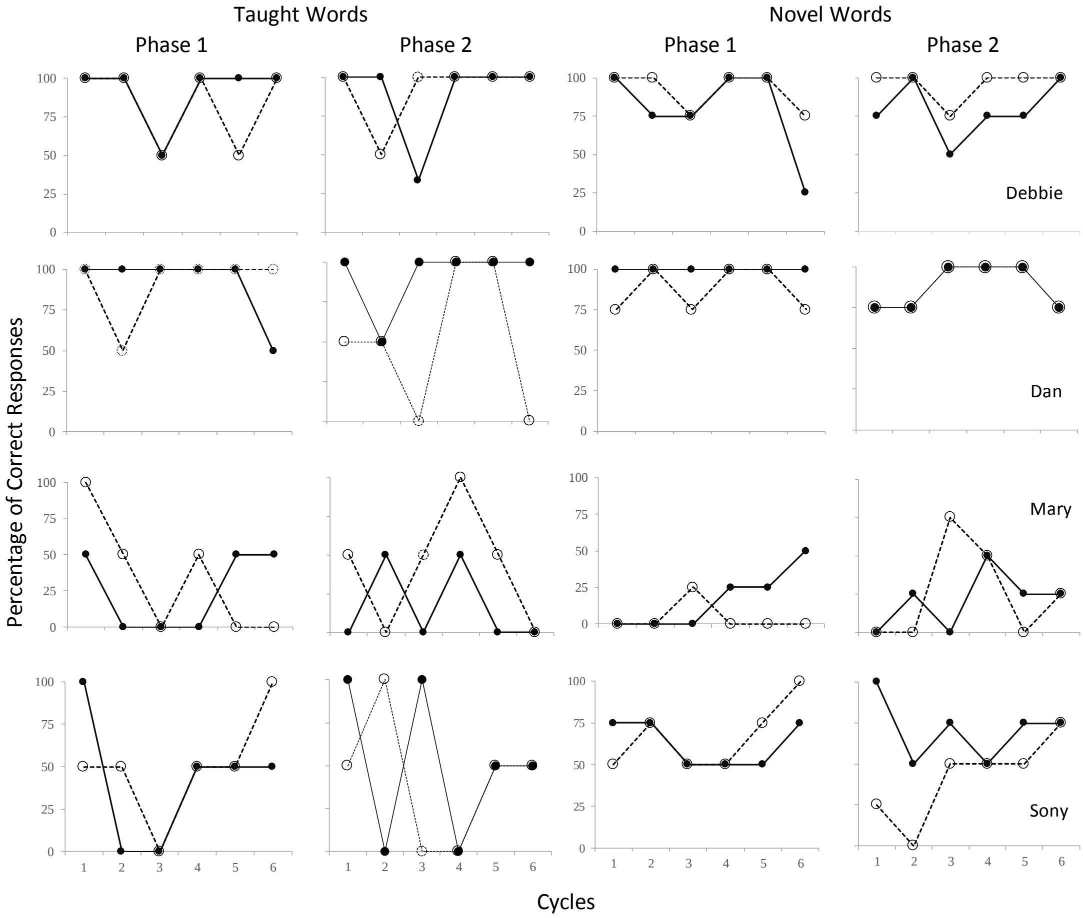

Figure 3. Percentage of correct responses in Oral Reading Generalization Tests (size 30) for taught (left) and novel (right) words in Roman alphabet (BD, filled circles) and Braille (CD, open circles) for both experimental phases.

Final Recombination (BC/CB) and Oral Reading (CD) Tests

At the end of each phase, performance in BC/CB trials with four novel words with meaning and oral reading in Braille (CD) with all taught (12) and tested (14) words for each phase were evaluated. Reading comprehension of words with meaning emerged for all participants who scored 100% in BC and CB type trials. Only Sony made one selection error in a CB trial from Phase 1 (she chose ***f****ade* when the sample was JADE).

Results from oral reading tests conducted at the end of each phase with all words from the teaching program are presented on Figure 4. Graphs to the left show analyses for taught words (black bars) and their respective phonemes (white bars) in each phase; graphs to the right show results for novel words and their respective phonemes in both phases for each participant. In the phoneme analysis, percentages were calculated by adding the number of correctly read phonemes and dividing by the total number of letters that composed the words (48 phonemes in the 12 taught words and 56 in the 14 new words). Correct phonemes were only emitted in the position that corresponded to the word in Braille. If the participant read *"daef****a****"* for the word DEF**I**, three phonemes were considered to be correct; if "***dife***" was read for D**EFI**, then two phonemes were considered correct, and so on. As well as errors from corresponding phonemes, the following were also considered incorrect: (a) tonicity in the second syllable of a given word (e.g., naming *"bi****doe****"* for the word **BI**DO); and (b) open vowel sounds (e.g., *"****de****fi"* instead of *"d****ae****fi"*).

Analysis of reading showed that participants presented performances of over 80% of correct responses (except for Mary and Sony in Phase 2). For novel words, scores were greater than 75% in Phase 1 for all participants; however, there was a decrease in recombinative reading in Phase 2, when the Braille font size was reduced to 40. Considering phoneme analysis, one may observe indices of over 90% of correct responses for taught and novel words in both phases.

DISCUSSION

The main themes discussed in this session result from teaching baseline conditional discriminations, especially those involving words in Braille with tactile stimuli, and the emergence of new repertoires derived from a baseline: forming equivalence classes and recombinative repertoires under control of units smaller than those directly taught.

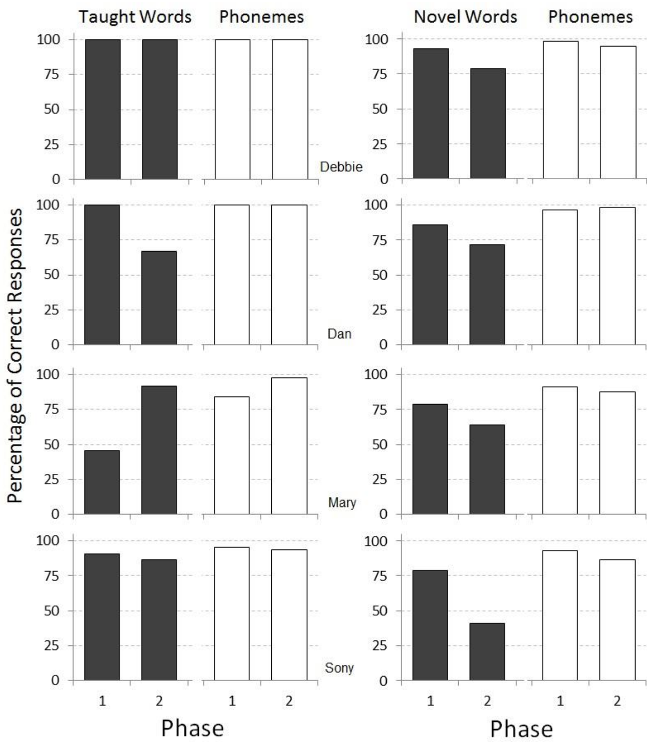

Figure 4. Percentage of correct responses in reading taught and novel words (black bars) and their respective phonemes (white bars) read correctly in the Final Oral Reading Test (CD) in Phases 1 and 2.

The planned teaching procedure established, with proper experimental control, conditional relations between dictated words and words printed in Braille and in embossed Roman alphabet. These relations were the groundwork for developing reading comprehension (with the formation of stimulus equivalence classes) and recombinative reading (by the abstraction of units smaller than words and stimulus control of these units in new words) with the tactile stimuli used in the study.

All participants demonstrated quick acquisition of relations between dictated words and words printed in Braille and in Roman alphabet.

Since participants were literate, learning AB relations probably required only between modality transference (from visual to tactile) of the stimuli presented as comparisons. Results from the teaching phase offer some empirical grounds for this assumption, since more trials were required to reach the learning criteria for dictated word-Braille printed word (AC) matching. Some variables discussed ahead may be related to the longer exposure to AC Teaching trials: familiarization with matching tasks; little previous history with Braille letters; possible deleterious effects of error occurrence; response cost of oral naming required simultaneously with the matching-to-sample task.

All participants had to go through more trials in the initial cycle, especially in Phase 1, suggesting that, at first, they were learning not only conditional discriminations but, simultaneously, how to accomplish the task (paying attention to instructions and to the sample before choosing one of the comparison stimuli, feeling the tactile stimuli with fingers etc). In the cycles that followed the teaching procedure of AB relations, learning occurred promptly, practically with no errors. Therefore, from the task's viewpoint, teaching AC relations, which were introduced right after AB teaching, could also have resulted in fast learning. The inverse result – needing more trials in AC teaching – suggests the presence of another variable: the specific characteristics of the Braille stimuli.

To improve initial learning, the Braille stimuli were used in a much larger size than usual. Even so, these stimuli are very different from the conventional alphabet in regard to individual letters and whole words. Learning discrimination with two words per cycle demanded the students to recognize each word in Braille, discriminate one from another, and learn to relate each written word to its corresponding sound. The greater number of trials in initial cycles and the occurrence of errors even in subsequent cycles, especially by two participants (Sony and Mary), indicate how difficult the task was. The fact that it was harder, however, does not imply that relations between the pseudowords could not be learned – all participants reached 100% scores, which was the criterion to end the teaching stages.

Teaching two words at a time – the smallest number for establishing a discrimination – probably made it easier for students to learn with relatively little trial repetition (which happened after each error and not after a block of trials) in comparison to other studies on acquisition of arbitrary relations. However, the occurrence of many errors in the initial cycle and their persistence in some of the subsequent cycles (at least for Sony and Mary) may characterize what has been pointed out as the deleterious effect of errors (Sidman & Stoddard, 1966; Stoddard & Sidman, 1967; Stoddard, de Rose, & McIlvane, 1986). This kind of interference may make new learning more difficult, but also reduce the accuracy of previously acquired performance by inadvertently installing an irrelevant stimulus control topography, which competes with the control one intends to establish (Dube & McIlvane, 1996; McIlvane & Dube, 2003) and produces variability when testing emergent relations.

Due to the reduced familiarity with Braille, participants presented long latencies in oral naming tasks, sometimes leading to interruptions in the session, which were resumed in the next session. This demanded going back to selection trials and resulted in exposing participants to a greater number of trials, which may have increased response cost and affected motivation for the task.

Despite the greater amount of training necessary to learn relations between printed and spoken words in Braille (AC) than to learn words in the Roman alphabet (AB), it is noteworthy that all participants learned the 12 relations from each phase with a relatively small amount of training, when compared to children from other studies (e.g., Reis, de Souza, & de Rose, 2009). Thus, the study has shown that, even with little experience with Braille, literate participants may learn auditory-tactile relations involving these stimuli. This learning is an important route for forming classes of meaning, which characterizes reading, as demonstrated in the prompt forming of classes that followed learning relations AB and AC. The extension of the results of discriminations for words in Braille and their inclusion in equivalence classes confirm previous results with isolated letters (Nascimento, 2007) and with printed words with separate syllables (Feio, 2003) and separate letters (Feitosa, 2009; Leitão, 2009; Melo, 2012; Vieira, 2012). These increase data generality and reasserting the matching-to-sample procedure as a powerful instrument for teaching conditional discriminations with different types of stimuli, including words in Braille and in pseudo alphabets.

Reading was directly taught by the procedure, which required and reinforced naming of stimuli printed in Braille (textual behavior) after each one was chosen in matching trials. The participants, whom did not read or read very little in the pre-test with Braille words, had high scores (100% for Debbie and Dan and between 80 and 90% for Sony and Mary) throughout the cycles (Figure 2). Scores were also high in the Final Oral Reading Test, which evaluated all 12 words and measured retention of what was learned (Figure 4). These results replicate many previous studies, showing how teaching mainly with selection tasks may improve not only stimulus control, but also response topographies that reproduce the named stimulus (e.g., de Rose et al., 1996; Melchiori et al., 2000). During teaching, the required oral response could only be emitted after a block of matching trials. Replication increases confidence in the robust procedures developed by this area, which may safely be used to teach reading outside the laboratory and, with due adaptations, may be extended to participants with different characteristics or repertoires.

Results of recombinative reading in Braille, especially interesting in this discussion, have shown a systematic increase throughout six cycles (Figure 2) and their maintenance in CD final tests (Figure 4). Two participants had scores between 80 and 95% correct responses and the other two between 50 and 70% in orally reading novel words in Braille in both font sizes (90 and 40).

At the end of each teaching phase, the four syllables (specific for each phase) had been displayed in every position (beginning or end of words) and had been combined between themselves. This systematic manipulation, allied to differential reinforcement for correct and wrong responses in matching spoken word-printed word, may have favored abstraction of all syllables (Skinner, 1957; Alessi, 1987; Hanna et al., 2011). However, the question was whether syllables and letters, when recombined in new printed words, would exert precise control over the corresponding response units (Goldstein, 1983). If, on one hand, the intensive use of only four syllables may have favored abstraction of smaller units, enabling new behavior; on the other, this same parameter could be a source of difficulties in discriminating words which were very similar (and nonsensical, which would eliminate contextual cues that could favor discrimination), especially in matching tasks with recombined stimuli. Therefore, when reading novel words orally, precise responses were a strong indicator that control by elements was effectively developed across teaching phases.

Reading indices obtained have replicated those found for many graduate students in Hanna et al.'s (2011) study, who had to learn a made up alphabet (which could be functionally equivalent to Braille in the present study). However, unlike their study – in which there was variability and some participants did not present recombinative reading –, in this study all participants developed some degree of reading and the participant who read the least, read 50% of words. Nevertheless, the study had few participants, making it premature to generalize an apparent greater efficacy of the procedure for teaching to read in Braille. It would be significant to replicate this study with a greater number of individuals with visual impairment acquired after literacy and with illiterate people, in order to control previous experience with symbolic learning.

Other aspects that need to be analyzed regard the types of reading errors in the tactile modality, their incidence and the possible sources of stimulus control for responses considered incorrect. The highest incidence of errors was swapping one or two letters with other letters that had been taught. Pronunciation errors, in which the vowels E and O were emitted with an open sound (E; O) occurred in Phase 2 when reading new words with smaller font size (30) and in the Final Oral Reading Test. It is possible that the source of control for this type of error is the previous history with some of the words in the Portuguese language in which these vowels are open. The procedure always presented these vowels with a closed sound (AE; OE); however, the stimulus control in the pre-experimental history may have exerted greater control than recent teaching, for words printed in Roman alphabet as well as for those in Braille. Also, but less frequently, participants inverted the position of two letters in the same word, pronounced incorrectly the sound of consonants and emphasized the second syllable (as opposed to the first, which would be the correct response).

In the error analysis, any one of the previously mentioned types of errors led to recording the whole response as incorrect. However, while in some cases there was great lack of control by the textual stimulus; in others it was clear that there was almost complete control by the text, with a point-by-point text-to-sound correspondence that characterizes this behavior (Skinner, 1957). A phoneme by phoneme analysis made it possible to check proximity to the correct response (Figure 4) in the Final CD Tests and in partial tests (results not shown). All participants had higher scores in the phonetic analysis when compared to the whole word analysis. These results indicate responses were under considerable control of textual stimuli; that is, the percentage of partially correct responses was high, with errors occurring in naming of one or two graphemes per word.

In the selection tests with new stimuli (AC, BC and CB), participants had high indices of correct responses in both phases (Figure 2); that is, with two sets of words, one in size 90 and the other in size 40.

Partial tests with reduced stimuli (Roman alphabet size 30 and Braille words in standard size: 6 x 4 mm per letter), conducted with the goal of checking for generalization of control to smaller stimuli, presented a change in demand due to the lack of spacing between the letters that composed a word and the smaller font size. In the reading tests with smaller stimuli, Dan and Sony had low scores for oral naming of words in Braille (CD, smaller or equal to 50%) in four out of six cycles from Phase 1, when compared to reading words in Roman alphabet. The physical resemblance between letters (inverted, mirrored etc.) from the Braille System may make tactile discrimination harder and prolonged; and this difficulty may have been even harder with smaller stimuli, such is the importance of analyzing the types of errors made.

Lack of spacing between letters or syllables in the Braille words (standard size) and Roman alphabet (size 30) may also be a source of difficulty in learning discriminations (simple discrimination between comparison stimuli and conditional discrimination between sample and comparison). In previous studies with tactile stimuli (Feio, 2003; Feitosa, 2009; Leitão, 2009; Melo, 2012; Vieira, 2012), spacing between syllables or letters in taught words were programmed. Feio (2003), for example, manipulated temporal spacing (creating a distance between printed syllables for words in Braille) in order to investigate whether this manipulation would favor recombinative reading. Participants obtained better results in oral naming tests in the spacing condition when compared to the control condition (which did not include spacing). Recombinative reading emerged in Feitosa's (2009) and Leitão's (2009) studies after teaching conditional discriminations of words composed by onset and rime. Melo (2012) and Vieira (2012) demonstrated emergence of orally reading taught and new syllables and emergence of textual reading with comprehension of the words composed of those same syllables.

A gradual decrease of stimuli sizes in the complementary procedure after Phase 1, conducted with the two participants with the worst performance in the phase, had little effect on partial tests with stimuli sized 30 in Phase 2. An alternative could include spacing between letters or syllables that gradually decreased until standard size was reached. In the present study, stimuli in larger (90) Braille, as well as being built with more resistant materials, also presented spacing between letters, while standard sized stimuli were smaller, weren't spaced out and were built with a more delicate material.

Words in size 30 Roman alphabet were also incorrectly named by Sony and Mary despite previous history with Portuguese language words in the visual modality. These results diverge from those reported in studies that used similar stimuli (Feitosa, 2009; Leitão, 2009; Melo, 2012; Vieira, 2012) even though they used smaller font size (26), lowercase and with spacing between letters. Another relevant variable is that participants in such studies had previous experience with tactile stimuli. In Melo's (2012) study, participants were not fluent readers but had previous knowledge of specific letters. Therefore, the degree of difficulty seems to depend on a set of variables, among which are included the effect of previous learning histories on emergent performance. In the present study, control of participants' histories was planned using nonsense words and text in Braille (text in Roman alphabet had histories in their visual correspondents, but text in Braille was relatively new). However, it was not possible to control other aspects of their histories, such as learning sound-letter relations and mastery of the alphabetic principle.

When compared to visual perception, tactile perception may be considered a lesser form of capturing information due to its sequential character (Nunes & Lomônaco, 2008). It would be important to investigate acquisition of the conditional discriminations targeted in this study on participants with and without previous experience with Braille texts. This would allow eliminating the course of learning discrimination of printed letters (the comparison stimuli in teaching tasks) as a variable and would verify only acquisition of conditional sound-text relations.

A fundamental aspect in studies on learning (such as this one) that require many sessions is maintaining participants committed throughout all steps of teaching and testing. In the present study, differential and immediate consequences seem to have been reinforcing enough to guarantee motivation, even when participants had trouble with textual behavior and emitted incorrect responses. This is probably due to the relevance of the skill being taught for adaptation and performance in an environment with new demands from these special needs participants.

Finally, the tactics of using nonsense words for teaching units with syllable manipulation, but not of within-syllable units, was important to eliminate meaning as a possible source of control. In the error analysis for the recombination tests there was a greater frequency of errors in new syllables that involved within-syllable recombination than in directly taught syllables (and recombined with one that involved within-syllable recombination). This raises the question of whether abstraction of units smaller than syllables is harder (e.g., Goswani & Bryant, 1990; Mueller et al., 2000), especially in syllabic languages such as Portuguese (e.g., Bernardino Jr. et al., 2006; Capovilla & Capovilla, 2000); or whether it is due to training that favors syllabic units, such as in the present study and in daily classroom practices. An important test would be to verify the effect of systematic teaching involving manipulation of within-syllable units in the emergence of recombinative reading (not only in Braille, but also in stimuli printed in Roman alphabet).

The present study has aimed to extend the findings in scientific literature by evaluating the necessary conditions to promote reading in Braille for people with visual impairment (blindness) acquired at an adult age. Results have replicated, with a relatively small amount of stimuli, discoveries from previous studies on developing element control as a critical aspect of recombinative reading, even when taught words do not have meaning (e.g., Hanna et al., 2008, 2010, 2011). Results also emphasize the importance of programmed teaching (task subdivision and sequential steps) and stimuli characteristics (size) in creating a generalized repertoire of reading in Braille.

Conducting a study with literate adults with acquired blindness is an important aspect of translational research and shows that functional (reading comprehension) and independent reading (words that were not taught directly) was developed through economical teaching (about 35 sessions per phase). Sight loss during adulthood has a great impact on people's lives, especially at a phase when educational systems are not promptly available to teach new repertoires that would favor adaptation and functionality. Results in this study point towards the possibility of developing viable teaching programs, whose efficacy and efficiency must be empirically validated with extensive programs and a larger sample of participants with different pre-experimental histories.

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