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Article

Teaching a Child with Cochlear Implant to Read Words with Orthographic Difficulties

Felipe Augusto Monteiro Cravo[1,*]
Orcid.org/0000-0002-5572-4239
Ana Claudia Moreira Almeida-Verdu[1]
Orcid.org/0000-0001-5202-0263
Fernando Del Mando Lucchesi[2]
Orcid.org/0000-0001-8381-2212
Leandra Tabanez do Nascimento Silva[3]
Orcid.org/0000-0002-2472-4180
Adriane Lima Mortari Moret[4]
Orcid.org/0000-0002-1776-9209

[1]*Universidade Estadual Paulista Júlio de Mesquita Filho, Bauru, SP, Brasil*
[2]*Universidade Federal de São Carlos, São Carlos, SP, Brasil*
[3]*Hospital de Reabilitação de Anomalias Craniofaciais, Bauru, SP, Brasil*
[4]*Universidade de São Paulo, São Paulo, SP, Brasil*

Abstract

Considering the effects of reading on the accuracy of the speech of deaf and hard and hearing children and cochlear implants presented in the scientific literature, the main aim of this study was to evaluate the effects of Module 2 of the ALEPP software regarding teaching words with orthographic difficulties to a cochlear implanted child. The participant was a girl, had nine years of age, with profound bilateral and sensorineural hearing loss. The program aims to teach contingencies of the selection of printed words and syllables conditioned to dictated words and syllables of six different stimuli sets; each set contained 16 words, with a total of 96 teaching words and 64 control words. Probes of 160 words were interspersed with the teaching steps according to the multiple probe design. The participant learned to read the 96 taught words, controlled by the words' minimal units. She presented maintenance of performance and reading generalization of the control words. The number of speech accuracy errors only decreased after

* Mailing address: Rua Luiz Ricardo Maffei, nº 1278, Sorocaba, SP, Brazil 18076-320. E-mail: felipeamcravo@gmail.com and ana.verdu@unesp.br
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the teaching intervention. The results replicated those of previous studies with orthographically easier words and future studies may explore the different types of training provided by the ALEPP and its effects on the accuracy of the speech of cochlear implanted children.

Keywords: Reading teaching, speech accuracy, cochlear implant.

Ensino de Leitura de Palavras com Dificuldades Ortográficas para uma Criança com de Implante Coclear

Resumo

Considerando os efeitos do ensino de leitura sobre a precisão da fala de crianças com deficiência auditiva e implante coclear apresentados na literatura, o objetivo deste estudo foi verificar os efeitos do Módulo 2 do ALEPP® sobre a precisão da fala em leitura de palavras com dificuldades ortográficas a uma criança usuária de implante coclear. A participante tinha nove anos, com deficiência auditiva profunda, bilateral e sensorioneural. O programa expôs a contingências de ensino de seleção de palavras e sílabas impressas condicionalmente a palavras e sílabas ditadas com seis conjuntos de estímulos (ç, lh, ch, vLc, vNc e vRc); cada conjunto era composto por 16 palavras, totalizando 96 palavras de ensino; outras 64 palavras funcionaram como controle. Testes das 160 palavras intercalaram o ensino de acordo com o delineamento de múltiplas sondas. A participante aprendeu a ler as 96 palavras-alvo de ensino, com estabelecimento de controle pelas unidades mínimas alvo, manutenção de desempenho e generalização na leitura de palavras controle. Erros na precisão da fala diminuíram somente após o ensino. Os resultados replicam estudos anteriores com palavras simples e futuras investigações podem isolar os tipos de treino do ALEPP® e explorar seus efeitos sobre a precisão da fala e sobre o controle pelas unidades mínimas.

Palavras-chave: Ensino de leitura, precisão da fala, implante coclear.

Enseñanza de Lectura de Palabras con Dificultades Ortográficas para Niña Usuaria con Implante Coclear

Resumen

Considerando los efectos de la enseñanza de lectura sobre la precisión del habla en niños con deficiencia auditiva e implante coclear presentados en la literatura, el objetivo de este estudio fue verificar los efectos del Módulo 2 de ALEPP® sobre la enseñanza de lectura de palabras con dificultades ortográficas a una niña usuaria de implante coclear. La participante tenía nueve años, deficiencia auditiva profunda, bilateral y neurossensorial. El programa exposu a contingencias de enseñanza de selecciòn de palabras y silabas impresas condicionalmente a las palabras y silabas dictadas con seis conjuntos de estímulos; cada conjunto estaba compuesto por 16 palabras, totalizando 96 palabras de enseñanza; otras 64 palabras funcionaron como control. Las pruebas de las 160 palabras intercalaron la enseñanza de acuerdo con el delineamiento de múltiples sondas. La participante aprendió a leer las 96 palabras objetivo de enseñanza, con establecimiento de control por las unidades mínimas, mantenimiento de desempeño y generalización en la lectura de palabras control. Los errores en la precisión del habla disminuyeron sólo después de la inserción de la enseñanza. Los resultados replican estudios anteriores con palabras sin dificultades ortográficas y futuras investigaciones pueden explorar los efectos de los tipos de entrenamientos ofrecidos por el ALEPP® y sus efectos sobre la precisión del habla y el control por las unidades mínimas.

Palabras clave: Enseñanza de lectura, precisión del habla, implante coclear.

Cochlear implants are effective devices to promote hearing, especially in children with severe or profound, sensorineural, bilateral, and pre-lingual hearing impairment (Svirsky, 2017). Cochlear implant activation establishes auditory detection and provides learning conditions for listening with comprehension and accurate speaking under naturalistic conditions, however, some implant users require exposure to systematized teaching procedures (Lucchesi, Almeida-Verdu, Buffa, & Bevilacqua, 2015; Lund & Douglas, 2016; Lund & Schuele, 2014; Miller, Lederberg, & Easterbrooks, 2013; Tucci, Trussel, & Easterbrooks, 2014). Both Speech Therapy and Behavior Analysis studies field have identified difficulties in a portion of this population regarding reading comprehension and writing skills (Lederberg, Miller, Easterbrooks, & Connor, 2014; Lund & Schuele, 2014), picture naming (Lucchesi et al., 2015; Lund & Schuele, 2014), and oral reading of words and picture naming (Anastácio-Pessan, Almeida-Verdu, Bevilacqua, & de Souza, 2015; Messier & Wood, 2015), especially with respect to accuracy of the oral production in these activities, that is, point-to-point correspondence with the conventions of the verbal community.

Technical-scientific interactions between Behavior Analysis and Speech Therapy have documented the applied extensions of the equivalence paradigm (Sidman, 2000; Sidman & Tailby, 1982) for the development of the behavior of listening with comprehension through the establishment of conditional relations between visual, textual and auditory stimuli (Almeida-Verdu et al., 2008; da Silva et al., 2006). The extensions of the use of the paradigm to improve the production of accurate speech by establishing relationships between stimuli and responses considering oral reading and picture naming has also been verified (Anastácio-Pessan et al., 2015; Lucchesi, de Souza, & Almeida-Verdu, 2018).

According to de Rose (2005) equivalence-based teaching is effective in establishing word reading repertoires. When there is a precise vocal topography already established for pictures, there is a transfer of stimulus control to textual stimuli, improving the speech in reading tasks as showed by de Souza, Hanna, de Rose, Pereira, and Sallorenzo (1997) in listening children. A similar process has been observed in deaf and hard of hearing children with and cochlear implants, however, in the opposite direction to that observed with listeners. The speech of children using cochlear implants is marked by distortions when presented with pictorial stimuli; however when presented with textual stimuli, this tends to occur more precisely, since each grapheme controls the emission of a phoneme (Almeida-Verdu & Golfeto, 2016; de Rose, 2005). After establishing the vocal topography in reading tasks, the control exerted by the textual stimuli can then be transferred to the pictorial stimuli (Almeida-Verdu & Golfeto, 2016; Hollis, Futon, & Larson, 1986).

Recent studies have shown that after Equivalence-Based Instruction (EBI) students have increased comprehension and understanding of different content, such as inferential statistics (Fienup & Critchifield, 2011), visual inspection of charts (Blair et al., 2019) and neuroanatomy (Pytte & Fienup, 2012). In all the studies, relations emerged between stimuli that participated in the teaching contingencies, however, that had not yet been directly related to each other; and stimulus-controlled responses came to be controlled by all other stimuli that composed the equivalence class (Sidman, 2000). When applied to children with cochlear implants, Equivalence-Based Instruction programs have produced improvements in the accuracy of the speech in picture naming tasks representing nouns (Anastácio-Pessan et al., 2015; Lucchesi et al., 2015) or action figures (Neves, Almeida-Verdu, Assis, Silva, & Moret, 2018; Silva, Neves, & Almeida-Verdu, 2017). Studies with deaf and hard of hearing and cochlear implant have replicated the potential of EBI programs to promote the transfer of control between stimuli producing the same response regardless of what baseline the children presented before being exposed to the teaching activities: from naming to reading (de Rose, de Souza, & Hanna, 1996; Reis, de Souza, & de Rose, 2009), from copying to dictation (Almeida-Verdu & Oliveira, 2014; Reis, Postalli, & de Souza, 2013) and from

reading to naming, considering the accuracy of the speech (Almeida-Verdu & Golfeto, 2016). The ALEPP® (*Aprendendo a Ler e Escrever em Pequenos Passos* - Learning to Read and Write in Small Steps) is an example of an equivalence-based program, in which the generality for people with deaf and hard of hearing has been studied as a way to address gaps in stimulus control between printed words, the minimal textual units of each word (letters and syllables), pictures and the speech itself. The ALEPP is a systematic and computerized program for the teaching of reading and writing, being the result of more than two decades of research in Brazil on symbolic functioning (Orlando et al., 2016). This software consists of three teaching modules actually; Module 1 teaches 51 words without orthographic difficulties, consisting of two and three syllables formed by consonant-vowel (simple words); Module 2 teaches 160 words with orthographic difficulties as consonant digraphs (e.g. *chave*/key; *galinha*/chicken), consonant encounters (e.g. *salto*/jump; *corpo*/ body), homonymous phonemes (e.g. ç with sond of /s/ as *laço*/loop; *taça*/cup); and Module 3 teaches reading of children's books formed by larger units such as sentences (de Souza & de Rose, 2006). The application of the program has shown consistent results in the establishment of reading and writing in hearers (de Souza & de Rose, 2006; Reis et al., 2009) as well as in children using cochlear implants (Lucchesi et al., 2015; Lucchesi et al., 2018).

Lucchesi et al. (2015) demonstrated that exposure to the ALEPP® Module 1 tasks can teach word reading and increase picture naming accuracy. Interspersed with the teaching units, the researchers applied multiple probes of pictures naming and observed improved speech accuracy as a function of the exposures to the teaching units. The study by Lucchesi et al. (2015) highlighted the need to investigate the potential of data generalization with more participants and the applicability of this teaching program using Module 2 with more complex textual stimuli such as words with orthographic difficulties.

The aim of this study was to verify whether exposure to Module 2 of the ALEPP® would teach oral reading of complex words observing the accuracy in the oral production of orthographic difficult named here as target minimum textual units through; this is a difficulty by the discrepancies between grapheme and phoneme. In addition, the study aimed to verify whether there would be modifications in the types of errors in the reading tasks during the teaching.

Method

Participant

Julia (fictitious name), female, nine years and five months of age, with deaf and hard and hearing sensorineural, bilateral, prelingual, severe (right side) and profound (left side) of unknown etiology. Julia used a cochlear implant on the left side and a hearing aid on the right side and was enrolled in the 3rd year of elementary education in a public school in the state of São Paulo. To expand the characterization of the participant, (1) a cognitive assessment was performed, in which she presented a low-average Age Deviation Score (ADS = 84) according to the Columbia Mental Maturity Scale (Burgmeister, Blum, & Lorge, 2001), (2) the initial school repertoire was investigated, in which the participant presented a low Total Gross Score (TGS = 22) in academic performance according to the School Performance Test (Stein, 1994), and (3) receptive language was evaluated, with result indicating auditory age corresponding to three years of age according to the Peabody Picture Verbal Test (Dunn & Dunn, 1981). In the medical record at the time of the study, the participant was in hearing category 5 (on a scale that goes up to 6), that is, she could identify the word through the recognition of consonants (Bevilacqua, Delgado, & Moret, 1996); and in language category 4 (on a scale that goes up to 5), that is, she could construct sentences of four to five words and started using connective words such as pronouns, prepositions and articles (Geers, 1994). The participant had

eight months of experience with the cochlear implant at the time of the first collection phase (August to October 2016) and one year and three months at the second collection phase (March to June 2017). Prior to this study, the participant had already undergone intervention with the ALEPP® Module 1, having experience with the matching-to-sample procedure. At the time she completed the first Module with the learning of 51 simple words. Julia did not present accuracy in the reading of printed words with orthographic difficulties, reading the printed words such as "*TAÇA*", "*BICHO*", "*BOLHA*", "*CALDO*", as "ta*C*a", "bi*CIG*o", "bo*LIG*a" and "caLIdo" respectively.

Instruments and Materials

An ACER notebook equipped with speakers was used for the data collection, on which Module 2 of the ALEPP® was installed and presented at volume intensity 5. The stimuli used by the ALEPP® Module 2 are syllables and printed words and syllables and dictated words. Table 1 presents the 160 words, corresponding to the auditory and textual stimuli used; of these, 96 were teaching targets and the other 64 words formed the control set. Therefore the units taught had words composed of the minimum target units ç, *lh*, *ch*, v*Lc* (lê-se: éle [L]) between vowel (v) and consonant (c), vRc and vNc; the other units of which the words were not taught worked as the control set and were composed of *nh*, v*S*c, *Ge/Gi* and *Ce/Ci*. Each unit had four teaching steps and each step taught 4 words, totaling 16 words per teaching unit. The present study added a reading probe that included all the 160 words of Module 2 of the ALEPP, presented in two blocks of 80 trials each.

Data Collection Procedures

The performance of the project was approved by the Research Ethics Committee (CAAE: 59810216.7.0000.5398) and all other ethical precautions were followed, with those legally responsible for the participants signing the consent form and the participant signing an assent form.

Data collection took place at the regular school during the participants' time in the Multifunctional Resource Room, in sessions lasting 30 to 40 minutes, two to three times a week, totaling 31 sessions. Only the researcher interacted with the participant during the scheduled activities. Stickers and activities in the park were used as generalized reinforcing consequences after the sessions, regardless of the performance in the tasks.

In a staggered way the participant was exposed to six teaching units of the ALEPP Module 2, corresponding to six orthographic difficulties (ç, *lh* /ʎ/, *ch* , v*L*c /û/, v*N*c and v*R*c), which included four steps per unit. The teaching took place using the matching-to-sample (MTS) procedure, which consisted of presenting a model stimulus (e.g., a dictated word or syllable, word and printed word or syllable) and two or more comparison stimuli; the answer required was the selection of the stimulus experimentally corresponding to the model. A variation on the MTS is the constructed-response-matching-to-sample (CRMTS), in which an auditory (dictation task) or textual (copy task) model is presented and the learner has to select from a list of letters, those of which their sequence corresponds to the model (Mackay, 1985). In the lower right corner of Figure 1 is a representation of the types of scheduled tasks of Module 2.

One Module 2 teaching step consisted of seven teaching blocks and five test blocks, presented to learners according to their performance; as the learning criteria are met, new tasks are presented to the learner, implying the learner's progress in the blocks of a teaching step. A teaching step began with a pretest that assessed the conditional relations between the dictated word and written word selection (AC) through MTS and between the dictated word and the construction of the written word (AE) through CRMTS of the four teaching target words of the step and of generalization words[1].

1 The generalization words were composed of a recombination of syllables and letters from the teaching words. In none of the training/teaching

Table 1
Teaching Words of Module 2 of the ALEPP®. The Units and Words in Gray were Only used as the Controls in the Present Study. The First Word is in Portuguese and the Second Word is in English

Units	Steps			
	1	2	3	4
Ç	*Roça*/farm	*Moça*/girl	*Babaçu*/babassu	*Caniço*/reed
	Taça/cup	*Fuça*/sneak	*Cabeça*/head	*Paçoca*/peanut candy
	Maço/pack	*Laço*/loop	*Sumiço*/disappearance	*Roçado*/mowed
	Poço/well	*Baço*/spleen	*Laçada*/loop	*Bagaço*/bagasse
Lh	*Bolha*/bubble	*Abelha*/bee	*Medalha*/medal	*Velho*/old
	Galho/branch	*Bilhete*/admit one	*Novilha*/heifer	*Pilha*/battery
	Filha/daughter	*Telhado*/roof	*Repolho*/cabbage	*Julho*/July
	Molho/sauce	*Detalhe*/detail	*Folheto*/flyer	*Folha*/leaf
Ch	*Bicho*/worm	*Chave*/key	*Boliche*/bowling	*Cochilo*/nap
	Cacho/bunch	*Ducha*/shower	*Chicote*/whip	*Fachada*/facade
	Chapa/plate	*Ficha*/card	*Chupeta*/pacifier	*Machado*/axe
	Chute/kick	*Mecha*/wick	*Mochila*/backpack	*Rochedo*/rock
vLc	*Caldo*/broth	*Revolta*/revolt	*Papel*/paper	*Funil*/funnel
	Palco/stage	*Culpado*/guilty	*Salto*/jump	*Filme*/movie
	Canil/kennel	*Soldado*/soldier	*Selva*/jungle	*Culto*/cult
	Multa/penalty	*Futebol*/soccer	*Polvo*/octopus	*Golpe*/scam
vNc	*Banda*/band	*Bandeja*/tray	*Mundo*/world	*Fazenda*/farm
	Fonte/source	*Domingo*/Sunday	*Ninja*/ninja	*Pancada*/blow
	Junta/joint	*Pingado*/dripped	*Ponte*/bridge	*Redondo*/round
	Linda/beautiful	*Sanfona*/accordion	*Bingo*/bingo	*Jumento*/donkey
vRc	*Barco*/boat	*Caderno*/notebook	*Forca*/force	*Martelo*/hammer
	Curva/curve	*Bordado*/embroidery	*Surfe*/surf	*Retorno*/return
	Corpo/glass	*Formiga*/ant	*Norte*/north	*Gargalo*/neck
	Garfo/fork	*Lagarta*/grub	*Torno*/lathe	*Cortina*/curtain
vSc	*Casca*/bark	*Bisnaga*/tube	*Vespa*/wasp	*Cascudo*/husky
	Fusca/fusca	*Castelo*/castle	*Susto*/scare	*Escada*/stair
	Festa/prty	*Desfile*/parade	*Poste*/post	*Nevasca*/blizzard
	Mosca/fly	*Mascote*/mascot	*Gosto*/taste	*Revista*/magazine
Nh	*Vinho*/wine	*Minhoca*/earthworm	*Rinha*/frog	*Cunhado*/brother in law
	Senha/pass	*Rebanho*/flock	*Linho*/linen	*Gatinho*/little cat
	Manha/ruse	*Tamanho*/length	*Lenha*/firewood	*Ninhada*/brooding
	Linha/line	*Galinha*/chicken	*Sonho*/dream	*Canhoto*/left
Ge/Gi	*Gelo*/ice	*Tigela*/bowl	*Gelatina*/jelly	*Mágico*/magician
	Gema/Yolk	*Gemido*/groan	*Gemada*/flip	*Relógio*/watch
	Gibi/comic book	*Mugido*/moo	*Sigilo*/secrecy	*Geada*/frost
	Bugio/howler monkey	*Gelado*/iced	*Regina*/Regina	*Geleia*/jam
Ce/Ci	*Cego*/blindness	*Vacina*/vaccine	*Tecido*/fabric	*Cigano*/gypsy
	Doce/sweet	*Cebola*/onion	*Vacilo*/waver	*Bacilo*/bacillus
	Coice/kick	*Cidade*/city	*Cevada*/barley	*Cinema*/cinema
	Saci/Saci	*Macete*/trick	*Recibo*/receipt	*Cilada*/trap

Figure 1 presents a flowchart with the routes to which a student could be exposed within a teaching step, depending on the performance in the trial blocks. If the participant's performance was accurate, the program automatically proceeded to the pretest of the words from the next step (see Figure 1, gray line linking the pretest of step 1 to the pretest of step 2); if the performance was not accurate, the program would start teaching words for that step through different types of training: multiple differences, critical differences, and discrimination training (see Figure 1, gray line linking the pretest in step 1 to the multiple differences training).

As shown in the flowchart of Figure 1, the participant proceeds to the blocks on the right (black arrows) when getting 100% correct responses in a teaching block; and goes to the blocks below (gray arrows) when the number of errors is greater than 1 (error > 1). If at the end of an AC/AE post-test block the learner did not get 100% correct responses s/he is exposed to the beginning of this step again.

Also in Figure 1, the names of the teaching blocks refer to their formal characteristics or functions. The tasks of the "discrimination training" block presented conditional discriminations in which the learner has to select the words learned in the step, having the same teaching target words as the comparison words. This is called "multiple differences" training when the comparison stimuli do not share any similarities (e.g., S+ *BOLHA*, S-*TOCO*, S- *VELA*). When the comparison stimuli are very similar to each other, the training is called "critical differences" (e.g., S+ *BOLHA*, S-POLHA, S- *BOLA*; Birnie-Selwyn & Guerin, 1997).

Design

This study used an experimental multiple probes design, characteristic of the behavioral sciences. Multiple probes are adopted when the aim is to verify not only the effect of the teaching procedure, but whether other behaviors are affected by the procedure. This method has been recommended to verify whether the teaching procedures adopted can support evidence-based practices in language disorders (Byiers, Reichle, & Symons, 2012). The block of probes with the 160 printed words of the program, presented in discrete trials, elaborated for this study, was presented interchangeably with the teaching units, in repeated probes and it was verified how the teaching affected the reading of words of the teaching step and words of other steps not yet taught (see Table 1).

Dependent Variable and Independent Variable

The dependent variable was the oral reading of words. Word reading is understood as oral production controlled by the textual stimulus corresponding to that of the verbal community, including the accurate emission of the minimum textual unit target taught (words composed with ç, *ch*, *lh*, v*L*c, v*N*c and v*R*c). As the independent variable, the curriculum of the ALEPP®, Module 2 computer program, consisting of tasks of the selection of printed words (AC) and construction of syllables (AE) when words ware dictated in conditions of critical and multiple differences with matching-to-sample tasks and constructed-response-matching-to-sample tasks, respectively.

Data Analysis Procedures

The vocal responses in the reading probes were audio recorded for later transcription and evaluation through phonemic analysis. The transcribed phonemes were compared with the target phonemes agreed upon by the verbal community and the percentage of correctly issued phonemes was calculated (e.g. if the target response was: "*bicho*", and the response emitted was: "*bico*" this was considered a 75% correct response; the error was related to the target minimum textual unit, "*ch*" the sound of which was "*x*"). Overlapping the phonemic analysis of the words of a unit, the percentage of

blocks were these words displayed; only in the test blocks, which aimed to investigate the generative character of the teaching.

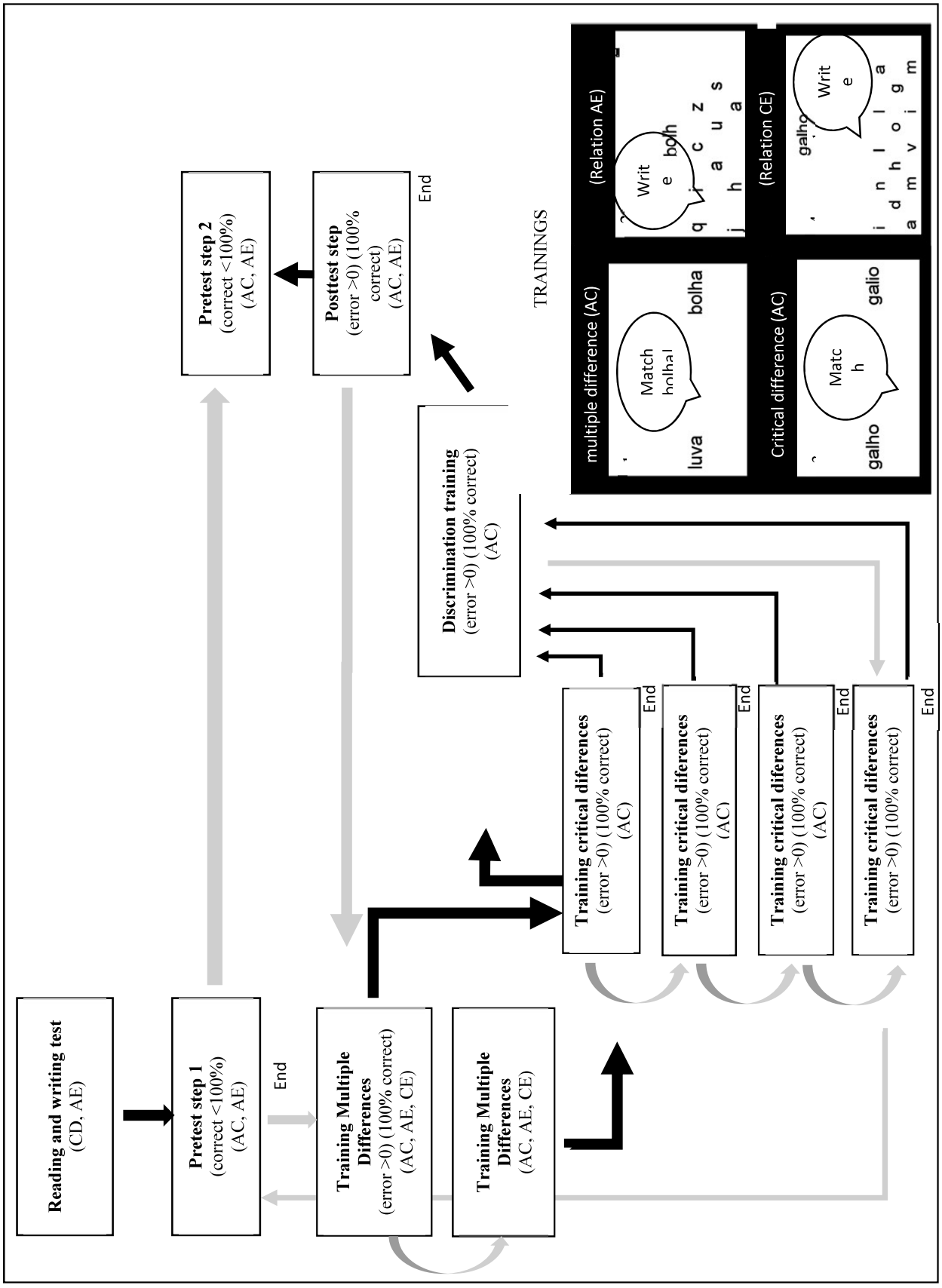

Figure 1. Flowchart of a teaching step according to correct responses and errors by the participant, and example of the tasks of the ALEPP® Module 2 (left and below corner).

correct responses in the target minimum textual units was calculated. Another measure, taken from the ALEPP® database, was the number of exposures to the teaching blocks required until accuracy of responses was achieved.

Finally, the amount and types of oral production errors issued in the evaluation tasks were analyzed. The error categories were selected based on research by Lucchesi et al., (2015) and were: addition – addition of a phoneme; omission – suppression of a phoneme; and exchange – replacement of a correct phoneme with an incorrect one. To complement the analysis of the errors the Microsoft Visual Basic software developed by E.S. Hanna (2015) was used and the percentage of correct responses in bigrams[2], vowels and consonants throughout the teaching units was verified.

The concordance analysis consisted of presenting the audio recordings of 80% of the word reading sessions to an independent researcher who verified whether there was congruence or not with the transcripts and categorizations that the principal researcher had established. The agreement index between the observers was 95.9% according to the criteria of Kazdin (2010).

Results

Figure 2 presents the percentage of the participant's correct answers in reading tasks monitored by the multiple probes that were interspersed with the teaching units. The bars correspond to the percentage of correct responses in the whole word according to the point-to-point correspondence (e.g. in the presence of the word CACHO, read "*cacho*"), the dots represent the correct responses in the target minimum unit – TMU (e.g. producing or not of the sound corresponding to "*ch*", /ʃ/). The light gray bars and black markers represent the results before the intervention in the respective teaching units; the dark gray bars and white markers represent the successive tests after the teaching unit. The dashed line denotes a break in activities and a resumption of activities after the school holidays.

According to Figure 2 the participant demonstrated a percentage of correct answers higher than 75% in all the reading pre-tests (bars) of all the teaching units; the errors were concentrated in the phonemes corresponding to the TMUs (dots) and were not accurately produced. For the target words "*roça*", "*golpe*", "*chave*" or "*bolha*", each representing different groups of orthographic difficulties, the participant read only the simple syllables; she used her own strategies to read the orthographic difficulties such as "ro*c*a" (ignoring the ç), "go*l*ipe" (syllablizing the vLc), "*c*ave" (ignoring the "h"), "bo*l*iga" (reading the "h" in its "agá" form)[3].

As the participant was exposed to the six teaching units (ç, *lh* /ʎ/, *ch* , v*L*c /û/, v*N*c and v*R*c) for all units there was a change in the percentage of correct responses: in the units ç and *ch* the percentage of correct responses was 100%; in the units *lh* and *vRc* the percentage of correct responses was 56%; in the v*L*c unit, the percentage of correct responses was 75%. These results remained high and stable during the follow-up probes conducted after the teaching. Some TMUs suffered the effect of the teaching of units with similar spelling difficulties; for example, "*nh*" was issued accurately after teaching the *ch* and *lh* units; *vNc* and *vSc* were issued more accurately after teaching the *vLc* unit.

Figure 3 shows the types of errors emitted in the word vocalizations before and after teaching for the 96 words taught. Errors of omission (white bars), exchange (gray bars) and addition (black bars) were observed in all the teaching units, with the addition errors being the most frequent.

2 The number of bigrams was counted from the decomposition of the word into adjacent overlapping word pairs (Lee & Sanderson, 1987); given the word "palco" one would have: -p, -pa, al-, lc, -co, -o, accounting for six bigrams.

3 In this study correct reading is understood as that which corresponds point-to-point to the conventions of the verbal community regarding the grapheme-phoneme relationship in Portuguese.

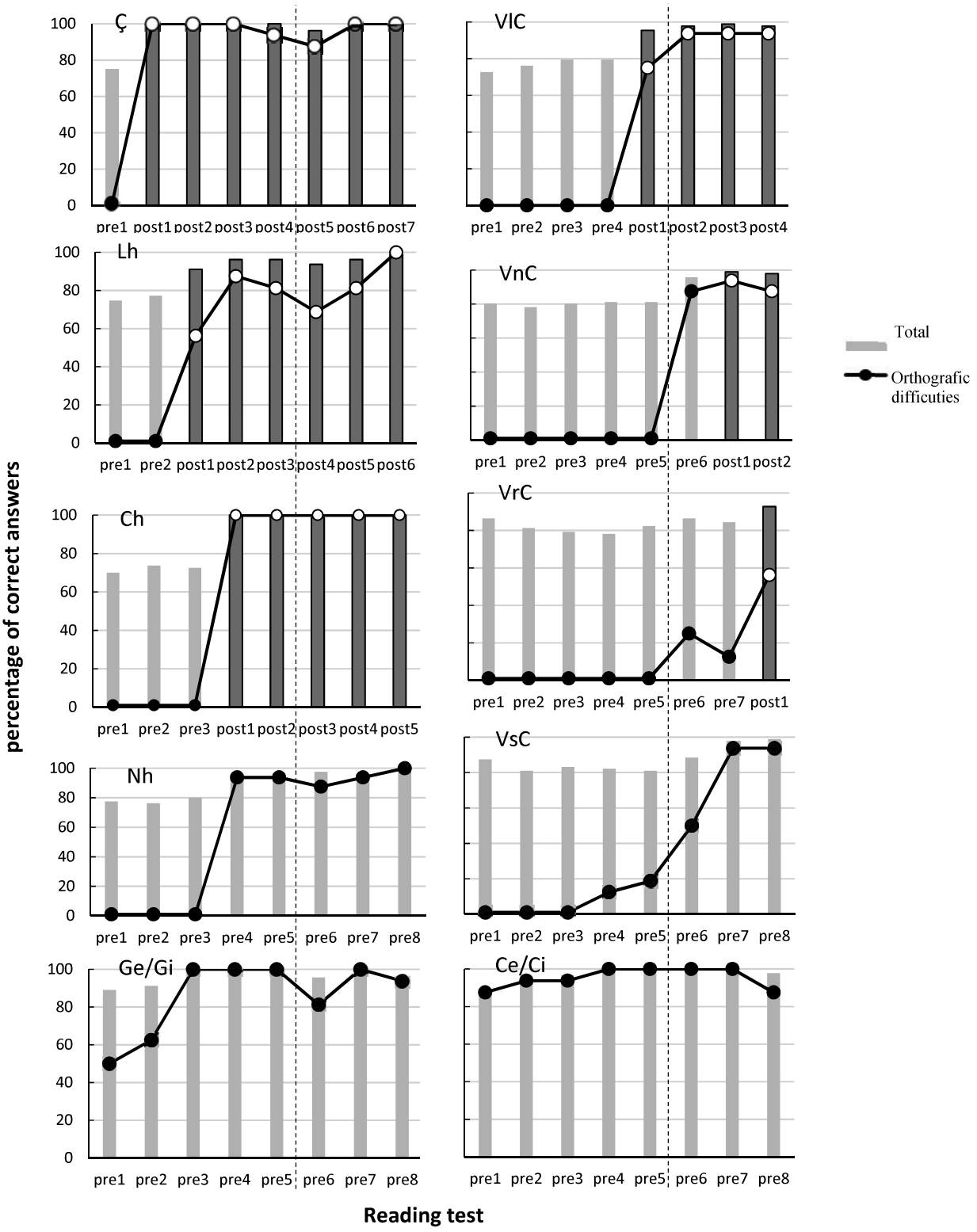

Figure 2. Reading of words with orthographic difficulties and analysis of the accuracy of the speech in minimum units. The bars represent the participant's performance in the emission of the phonemes of the word, while the dots represent the performance in the emission of the phonemes with difficulties (TMUs). The dashed line represents the pause in the activities.

After the teaching (marked by the dashed line), there was a marked decrease in the occurrence of all types of errors in all units teaching. In the "ç" unit the most frequent type of error was exchange (e.g. instead of producing the sound of /s/ - e.g., roça, caça) the participant vocalized "c"

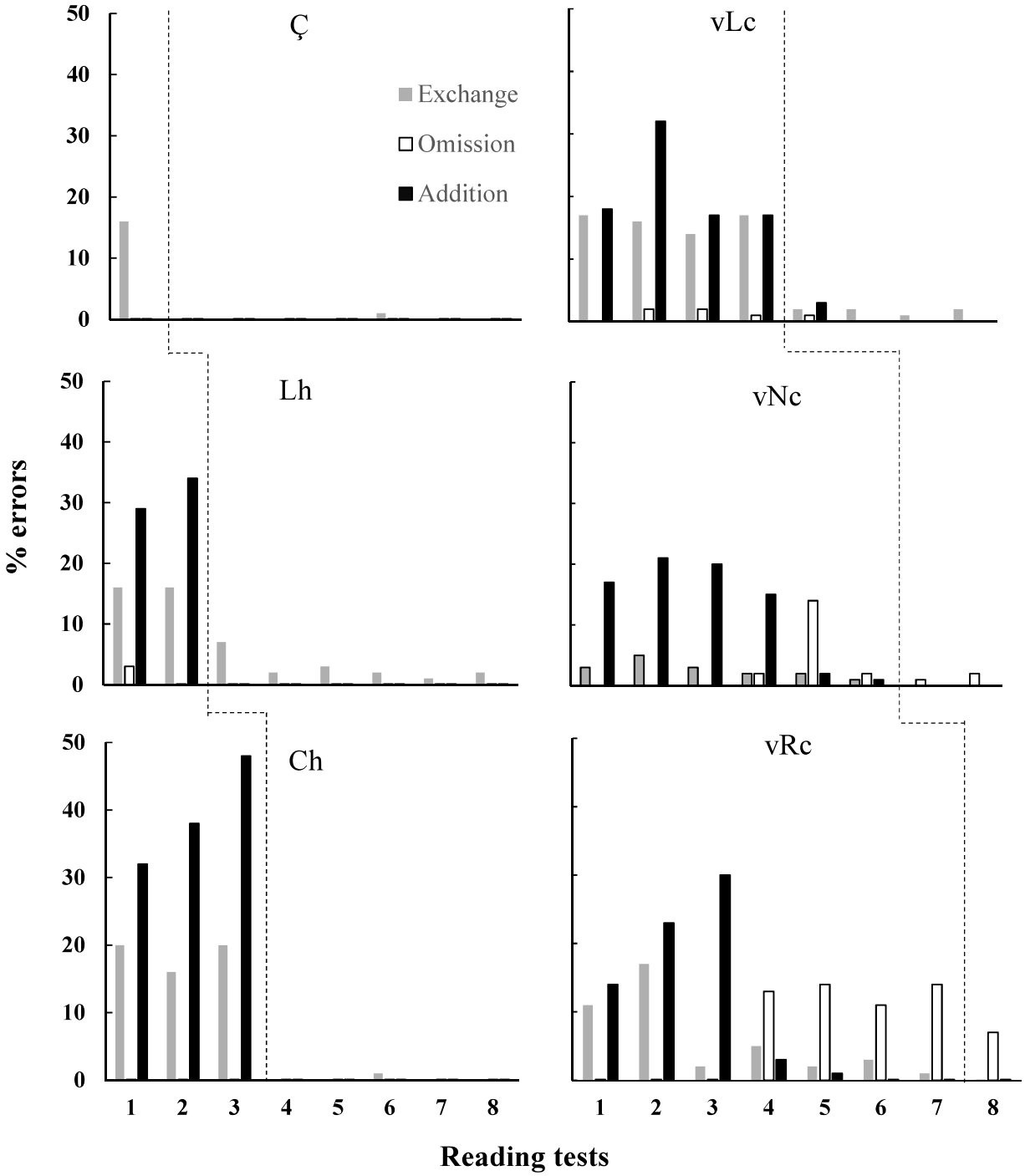

Figure 3. Percentage of errors in the oral reading probes between units. The bars represent the amount of errors made by the participant. The errors observed were exchange (light gray bar), omission (white bar) and addition (black bar). The dashed line represents the insertion of the teaching corresponding to each teaching unit and the continuous black line the follow-up.

with sound of /k/ (e.g., roca, caca). In the "lh" and "ch" units the addition error was the most characteristic, which increased throughout the repeated probes and reduced only after exposure to the teaching. In these words she added the phoneme "i" after the letter l or c, and in place of the letter "h" (agá) the syllable "gui/gue/ga/go" (eg, bicho = bicigou; bolha = bo*lig*a).

Table 2 presents the number of correct answers in vowels, consonants and bigrams during the multiple probes, with these analyses generated by the Visual Basic program (Hanna,

2015). The line that cuts the table marks the insertion of the teaching units. For each of the teaching units (gray cells) and the means, in the last row of the table, it can be seen that before the exposure to the teaching the participant expressively responded correctly in the vowels; while the percentage of correct responses in the consonants and bigrams increased and approached accuracy only after the teaching (dark gray cells).

The number of repetitions required for the participant to achieve the correct response criterion, by type of training (multiple differences and critical differences) and teaching unit is presented in Figure 4. Although the participant achieved the correct response criterion in all types of training and in all the units, there were more exposures to the teaching in the first four units; in these four units there were more repetitions in the critical difference training than in the multiple difference training.

Discussion

Overall, the participant's exposure to Module 2 of the ALEPP promoted the establishment of the reading of words with orthographic difficulties, including the target minimum units (TMUs). In this study, the results replicate data from the literature on the applicability and effectiveness of computerized and systematic, equivalence-based teaching programs in establishing the reading repertoire with other populations, such as children with learning disabilities (de Rose et al., 1996), visual impairment (Quinteiro, Hanna, & de Souza, 2014), Down syndrome (Benitez & Domeniconi, 2012), illiterate adults (Calcagno, Barros, Ferrari, & de Souza, 2016) and children with hearing impairments and cochlear implants, in the teaching of simple words (Lucchesi et al., 2015; Rique, Almeida-Verdu, Silva, Buffa, & Moret, 2017). The results regarding the possibility of programs based on the equivalence relations paradigm to promote learning to read complex words in children using cochlear implants add to this class of research.

The results related to the efficacy of a teaching program are in line with the considerations made by Lund and Douglas (2016) and Petursdottir and Mellor (2017) regarding the need for systematic planning of the teaching of reading and writing for the with deaf and hard and hearing population that, considering some variables (e.g., length of hearing loss, hearing aid experience and gender), do not attain good receptive repertoires, even with the use of hearing aids. The relationship between behavioral teaching technologies and therapeutic procedures of Educational Audiology and Speech Therapy has been shown to be a fruitful interaction in the establishment

Table 2
Correct Responses in Vowels, Consonants and Bigrams in the Pre- and Post-Intervention Probes

	1			2			3			4			5			6			7		
	vg.	*cs.*	*bi.*	*vg.*	*cs.*	*bi.*	*vg.*	*cs.*	*bi.*	*vg.*	*cs.*	*bi.*	*vg.*	*cs.*	*bi.*	*vg.*	*cs.*	*bi.*	*vg.*	*cs.*	*bi.*
Ç	100	55	63	100	100	100	100	100	100	100	100	100	100	100	99	100	100	100	97.5	100	100
lh	95	52	57	100	47	58	100	80	83	97	90	90	100	87	90	100	92.7	99.1	97.5	94.5	100
ch	98	67	64	100	67	67	100	65	65	100	100	100	100	100	100	100	100	100	100	100	100
vLc	100	84	71	100	71	67	97	94	78	100	76	70	97	98	93	100	98.1	100	100	96.1	100
vNc	100	94	82	100	91	78	100	96	83	100	89	80	100	71	69	100	98.2	99.1	100	96.4	98.2
vRc	100	94	80	97	96	82	100	96	82	100	66	65	97	73	69	100	73.2	87.5	100	87.5	93.7
mean	98.8	74.3	69.5	99.5	78.7	75.3	99.5	88.5	81.8	99.5	86.8	84.2	99.0	88.2	86.7	100.0	93.7	97.6	99.2	95.8	98.7

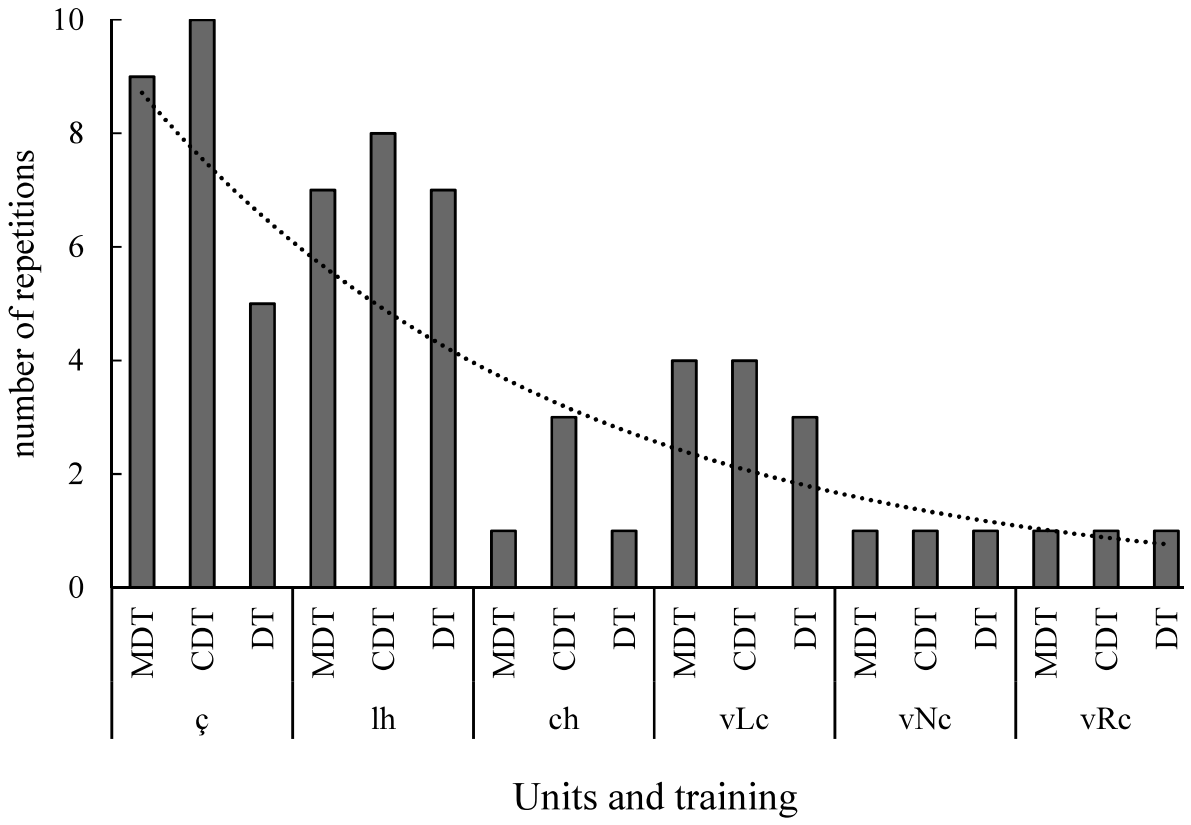

Figure 4. Number of repetitions in the teaching blocks to advance between the units. Legend: MDT (multiple difference training); CDT (critical difference training), DT (discrimination training). The black dashed line represents the downward trend in exposure to the teaching blocks.

of expressive repertoires for children with hearing impairments and cochlear implants when they need therapeutic/educational support complementary to the use/experience with the CI (Almeida-Verdu & Golfeto, 2016).

The higher repetition rate of the blocks at the beginning of the exposure to the program, and the gradual decrease in this rate, suggest a possible learning set effect, a discriminative ability to learn to solve problems in situations similar to those previously learned, according to Harlow (1949). The learning set effect was also found in Menzori's (2016) study of children in the Multifunctional Resource Room with Module 1 of the ALEPP, with simple words.

The data observed from the multiple probe design (Horner & Baer, 1978) show that (1) the participant already presented reading accuracy above 75% of correct phonemic responses, however without adequate speech of the target minimum units in the pre-test, (2) she remained at baseline levels even after successive opportunities for inter-unit probe responses and (3) she achieved accuracy in the TMUs either after exposure to direct teaching or after exposure to examples of similar orthographic difficulties.

Regarding the improvement in performance during the baseline condition, such as *nh* after teaching units *lh* and *ch*, and also as *vNc* and *vSc* after teaching *vLc*, this may have been due to learning to read units with similar characteristics, favoring the generality of behaviors. According to Hanna et al. (2011) the recombinative and generative effect of a teaching program based on auditory-visual conditional relations training is a function of the number of exposures to multiple examples of phoneme-grapheme relations. Furthermore, these examples are presented in different places of the word, creating conditions for generalizations from the relations taught. Generality is a dimension of Applied Behavior

Analysis (Baer, Wolf, & Risley, 1968) and multiple example training is a technology implicit in generalization (Stokers & Baer, 1977).

The probes performed after the teaching registered an increase of over 60% of correct responses in the reading of the target minimum units. Although variability was observed in the follow-up probes, it can be noted that the TMU reading scores did not return to baseline levels after the inclusion of other training, demonstrating consistency of the teaching methodology and program used (de Rose, 2005; de Souza & de Rose, 2006).

Concerning the errors that occurred in the TMUs during the probes, it is understood that, in a few cases in Portuguese, there is a point-to-point correspondence between graphemes, the name of the letter and the expected phonemes in their production in one word. Correspondence occurs with vowels (e.g., a = *a*; e = *e*), however, not with consonants (b = *bê*; c = *cê*) and there are very complex cases (e.g., h = *agá*; l = éle), with the expressive amount of exchanges and additions observed in the oral production of the words of the teaching units "*ch*" and "*lh*" being understandable. The decrease in errors after insertion of systematic teaching replicates the results of previous studies (Lucchesi et al., 2015; Rique et al., 2017) in which the modification in the characteristics of the errors in the oral production of children with implants is observed, based on the progress in the teaching steps.

One of the shortcomings of this study is the lack of pictures to verify whether the precise speech to the printed stimulus could occur when presented with them. Although this training presented with pictures is not important for generalized reading (Hanna et al., 2011), previous studies with children using cochlear implants have shown that this population emits more accurate speech to textual stimuli than pictorial stimuli and that, after the formation of classes between dictated words and syllables, printed words and syllables and pictorial stimuli transfer the control exerted by the printed word to the picture (Almeida-Verdu & Golfeto, 2016; Anastácio-Pessan et al., 2015; Lucchesi et al., 2015; Rique et al., 2017). Future research can verify the effects of the teaching of a selection of words and pictures on naming tasks by including pictures in the relation between dictated word-picture and picture naming in Module 2 of the ALEPP® in deaf and hard and hearing children.

Another fact that deserves investigation concerns the amount of repetitions needed for the different types of teaching of each teaching unit. In this study, the type of teaching that required the most exposures until the correct response criterion was achieved was the critical differences training, with these results being similar to those observed by Birnie-Selwyn and Guerin (1997). According to the study by Birnie-Selwyn and Guerin (1997), the greater number of exposures to blocks with critical differences may be due to the complexity of the required discrimination task, which resulted in better results in the dictation tasks evaluated after the teaching. Future studies should isolate this variable and balance the number of blocks with critical differences and multiple differences.

Authors' Contributions

Substantial contribution in the concept and design of the study: Felipe A. M. Cravo, Ana C. M. Almeida-Verdu, Fernando Del Mando Lucchesi, Leandra T. N. Silva, Adriane L. M. Moret.

Contribution to data collection: Felipe A. M. Cravo, Fernando D. M. Lucchesi.

Contribution to data analysis and interpretation: Felipe A. M. Cravo, Ana C. M. Almeida-Verdu, Fernando D. M. Lucchesi, Leandra T. N. Silva, Adriane L. M. Moret.

Contribution to manuscript preparation: Felipe Augusto Monteiro Cravo, Ana C. M. Almeida-Verdu, Fernando D. M. Lucchesi.

Contribution to critical revision, adding intelectual content: Felipe A. M. Cravo, Ana C. M. Almeida-Verdu, Fernando D. M. Lucchesi, Leandra T. N. Silva, Adriane L. M. Moret.

Conflicts of interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

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