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Computer-Assisted or Instructor-Led Reading Instructions of Portuguese Words with Orthography Difficulties

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Abstract

This article presents the findings of a study comparing a computer-assisted teaching program to traditional instructor-led teaching for elementary school children. The study evaluated reading and writing skills and employed a group design. Results showed that both teaching approaches were effective in improving reading performance, with slightly better gains in the instructor-led version. Both conditions facilitated learning transfer to new words with spelling difficulties, although the computer-assisted condition demonstrated higher generalization in final tests. Motivational and attentional factors, easily addressed by instructors but challenging in computer programs, were highlighted. The instructor-led condition's personalized feedback and differential consequences potentially contributed to the observed differences in learning gains. Individual differences in learners' input and performance were emphasized, suggesting the need for program adaptations. The advantages of computer-assisted teaching, such as scalability and individualized pacing, were discussed, along with the need for further refinements and automation. Strategies for enhancing teaching sequence flexibility and reducing the instructor's decision-making burden were proposed. The study contributes valuable insights into computer-assisted reading instruction for children with spelling difficulties, emphasizing their benefits and areas for improvement. The research underscores the importance of designing effective technology-mediated interventions and provides guidance for future developments in this field.
Key words: computer-assisted teaching, spelling difficulties, reading skills, writing skills, generalization.

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Novelty and Significance

What is already known about the topic?

- Computer-assisted instruction has been widely explored in educational settings to enhance learning outcomes and provide personalized learning experiences for students.
- The application of behavior analysis principles in computer-based instruction has shown promise in improving reading and spelling skills among students, with studies emphasizing the importance of systematic teaching procedures and reinforcement strategies.

What this paper adds?

- The study introduces a unique comparison between computer-based instruction and instructor-led teaching methods, shedding light on their relative effectiveness in improving reading skills among elementary school children.
- The srudy explores the impact of different teaching conditions on children's performance, revealing insights into the role of direct instructor interaction versus computer-based automation in literacy instruction.
- This study presents an innovative approach by examining the potential of a computer program to teach complex reading skills, addressing the need for adaptive teaching sequences and considering individual differences in learners' profiles.

Computerized procedures (software), developed to collect data in studies on reading and/or writing, have been used successfully to teach different repertoires (e.g., Goyos, Souza, Silvares, & Saunders, 2007; Haydu, Zuanazzi, Assis, & Kato, 2015; Hübner,

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Gomes, & McIlvane, 2009; Matos, Avanzi, & McIlvane, 2006; Medeiros, Fernandes, Pimentel, & Simone, 2004; Mueller, Olmi, & Saunders, 2000; Saunders, O'Donnell, Vaidya, & Williams, 2003). Learning benefits have also been reported by studies that have evaluated the effectiveness of computer-assisted instruction to teach reading skills and supplement regular school activities (e.g., Macaruso, Hook, & McCabe, 2006; Nicolson, Fawcett, & Nicolson, 2000; van Daal & Reistman, 2000).

Interactive programs with cartoon-like environments have been used in schools, leading to a decrease in the variability of reading acquisition skills (Layng, Twyman, & Stikeleather, 2003; van Dall & Reistman, 2000). Researchers advocating the importance of phoneme and sound-grapheme correspondence skills have successfully used computer programs to teach these skills (Reitsma & Wesseling, 1998; Underwood, 2000; Wild, 2009; Wise, 1992).

Computer resources, such as educational software and digital books, enrich the teaching-learning process, offer individualized teaching opportunities (Valente, 1989; Underwood, 2000), address specific learning difficulties, and standardize complex procedures.

Alternatively, standardized procedures applied individually by teachers or monitors have shown effectiveness in teaching reading and writing skills to children with learning difficulties (de Rose, de Souza, & Hanna, 1996; de Rose, de Souza, Rossito, & de Rose, 1992; Sudo, Soares, de Souza, & Haydu, 2008). These procedures analyze reading and writing as networks of relations between stimuli and responses, allowing for explicit teaching of relevant relations and the emergence of new verbal relations (Mackay & Sidman, 1984; Sidman, 1971, 1994; Sidman & Cresson, 1973; Stromer, Mackay, & Stoddard, 1992).

Such results of widely replicated experimental studies provided the basis for the development of teaching procedures for the repertoires involved in reading and writing (e.g., de Rose *et alii*, 1992; de Rose *et alii*, 1996). In these studies, teaching contingencies were planned for individualized application and in accordance with the principles of the Personalized Instruction System (Keller, 1968; Skinner, 1968), since they were intended for children who show learning difficulties with other teaching methods. The teaching tasks were programmed in small units, with the opportunity to review what was previously taught, requiring precise performance in each unit before moving on to the next. This allows the learner to carry out the activities at their own pace and to achieve the correct performance (de Souza & de Rose, 2006). The main task was the teaching of relations between written and printed consonant-vowel-consonant-vowel words (e.g., bola), that required an active response of choosing an alternative (the choice of the written word corresponding to the dictated word, presented simultaneously to another written word not corresponding to the dictated word sample). Oral reading (textual behavior) was not required, and yet emerged because of paired learning (cf. Sidman, 1971). In presenting this task, the programming of trials followed the principle of responding by exclusion (Dixon, 1977), between the two words presented for choice: the one considered incorrect was always a word that the student had already learned to read, which increased the probability that they "excluded" this alternative and chose the correct alternative. This "strategy" guaranteed that the student received a high density of feedback for correct responses, an essential variable to strengthen learning and maintain motivation for the task.

While effective, individualized sessions led by instructors have limited scalability due to resource requirements. A computerized version of a program to teach reading of

simple-syllable words was developed (de Rose *et alii*, 1996; Rosa Filho, de Souza, de Rose, Fonseca, & Hanna, 1998), allowing for standardized procedures and automated data recording.

The effectiveness of the computerized version was evaluated in the study by de Souza *et alii* (2009) who, in addition to teaching reading words with regular sequences of consonant-vowel-type syllables, added tasks for teaching conditional discrimination between dictated and printed syllables. The results obtained in the controlled laboratory environment (Study 1) and in the context of public schools (Study 2; see also Reis, de Souza, & de Rose, 2009) replicated those of previous studies that used the instructor version, which presented the task (instructions, stimuli, and consequences). These studies provided empirical evidence of the effectiveness of this alternative for teaching basic repertoires of reading and writing words formed by simple syllables.

A second teaching program was developed by de Rose *et alii* (1992) and by de Souza, de Rose, Fonseca, and Hanna (1999), to investigate processes involved in reading words containing phonetic irregularities and sequences of consonants without vowels, called Portuguese orthographic difficulties or spelling difficulties (e.g., chuva, clima, prato, expresso). In this program, each difficulty is taught in four units, in successive sessions, and in each unit four words are taught and the reading of four new words is evaluated. Only whole words with meaning in Portuguese are used and the exclusion procedure (Dixon, 1977), like that described in the program of words with simple syllables, is used to teach relations between dictated words and printed words. After teaching each difficulty, a generalization test is performed consisting of new 25 words containing orthographic difficulties, only part of which are taught in the program. The results of studies conducted by de Rose *et alii* (1992) and de Souza *et alii* (1999) showed that participants learned to read words with the difficulties taught and that generalizated word reading developed throughout the program, with more accurate performances being observed for participants who previously presented generalized reading simple-syllable words.

The previously described studies demonstrate that properly planned contingencies in reading teaching programs that use whole words, consisting of multiple training of relations between dictated and printed words, result in the emergence of reading of the taught words and in the development of generalized reading of words with simple syllables and with spelling difficulties.

Although the use of modern information technology resources is pointed out to expand access to education for many students at risk in the literacy process, a relevant and recurring question is whether there is a difference in learning to read and write depending on the way of applying the teaching programs: mediated by an instructor or assisted by the computer. Comparative studies usually involve difficulty in interpreting the results, since it is difficult to guarantee experimental control, due to the complexity of the tasks at any stage of the learning process and the difficulty of equating the alternatives to be compared. Despite this, the effort to provide experimental evidence of the effectiveness of computer-student versus instructor-student interactions is important, seeking to achieve experimental control by matching the procedures and tasks used in both forms of application.

The study by Macaruso *et alii* (2006) compared the reading performance of a large first-grade sample using Lexia computer-assisted instruction (CAI) programs with control students who received similar classroom instruction but without Lexia. These programs, created to supplement traditional teaching methods, incorporate a variety of activities

aimed at reinforcing and applying phonic word-attack strategies. These activities operate across different linguistic levels, including letters, words, sentences, and paragraphs. Both groups of students increased their reading skills. However, children with lower baseline scores who were exposed to computer-assisted instruction benefited more from this supplemental program than children in the teacher-mediated instruction group.

The objective of the present study was to evaluate the effectiveness of a computerized version of a program for teaching reading words with spelling difficulties, which has already proved to be efficient (de Souza *et alii*, 1999) in instructor-led version, for individual application. Evidence on the effectiveness of the teaching methodology, when applied with the aid of the computer, opens up new possibilities for research and teaching. For research, the contribution involves greater control of variables, by eliminating components that are difficult to control in situations where procedures require intensive interaction between the participant and the instructor, which makes it possible to refine procedures. For teaching, it is possible to envisage the implementation of computerized programs in schools, when then the role of researchers would consist of supervising and qualifying professionals so that they can conduct the application independently.

While new technologies offer advantages and appeal, their effectiveness in education, including content and teaching procedures, needs empirical verification.

METHOD

Participants

Fourteen children, aged from 7 years to 10 years and 5 months of both genders (see Table 1), attending the second year of Elementary School, participated in the study. Twelve participants were repeating the second year more than once and had low school performance and two, JOR and PAT, had no history of school failure. Eleven children had a history of exposure to the program for teaching words with simple syllables (exceptions JOR, PAT and TAT). Additional information about the performance of these students and the teaching program in which they participated can be obtained from de Rose *et alii* (1996).

This research followed all the human research ethics requirements. The procedures used in this study adhere to the tenets of the Declaration of Helsinki. Informed consent was signed by the institution director and the person responsible for the participating children before starting the experiment.

Setting

A Macintosh computer, Performa 630 model, with a 14-inch monitor, was used for the presentation of the teaching program for words with spelling difficulties developed in HyperTalk language version 2.2 by Divel Porto Lomba. The computer was equipped with an optical pen (PenDirect) that allowed the selection of words on the screen by touch and press. A video camera and a portable recorder, both Sony brand, were used to record images and sounds during the experimental sessions.

In the Instructor Condition, the printed words (format: lowercase, Arial font, size 65) were presented on sheets of white A4 paper organized in document folders with black cover. Protocols were used to record the data and inform the instructor of details about the procedures to be followed in each trial.

Various gifts such as candies, sweets, and small objects (e.g., different school supplies, games, dolls, carts) were organized in the form of a little shop and were obtained by exchanging tokens acquired during each session.

Data collection was carried out in rooms at the University and at an Institution that shelters children and adolescents in the same city. The rooms were approximately 12 m^2, had artificial lighting, and were furnished with two tables and three chairs.

Design

The study employed a group design, wherein participants were divided into two groups of 7 individuals each. Both groups were exposed to an intervention and assessments. One group had the intervention within the *Instructor Condition*, while the other experienced the *Computer Condition*. The intervention consisted of a teaching program with 32 units that taught relations between dictated and printed words with one of eight spelling difficulties. Each spelling difficulty was presented in 4 units. The forth unit was followed by a dictation test of the words with the target difficulty. Diverse Generalized Reading Tests were interspersed between units. Prior to the intervention, participants within each group demonstrated comparable performances as indicated by paired samples analysis, using the assessment of their initial repertoire, as detailed below.

Procedure

The participants' initial repertoire was assessed before the beginning of the study through an oral reading test of 96 words with simple syllables (baseline words, BL) and a reading test with 25 words with spelling difficulties. Table 1 shows the percentage of correct responses in reading word tests. The participants of the two conditions presented similar performances and without significant differences before starting the study (Wilcoxon signed-rank test, $p > .05$, taught simple syllables words $p = .10$ and new simple syllables words $p = .21$; words with spelling difficulties $p = .17$). For participants in both conditions, the percentage of oral reading of 51 taught words composed of simple syllables was high (80% or greater). For simple words not previously taught ($n = 45$), four participants in each condition (the first ones shown in Table 1) also showed high percentage of correct responses (above 50%). For the remaining participants, three of each condition, generalized reading performances were low or null (4% or less). In the test of reading words with spelling difficulties, the performances of the participants of the two conditions were varied: the Computer Condition ranged from 0 to 76% of correct responses (Mean 38.9%) and the Instructor Condition ranged from 0 to 64% ($M = 32.6\%$).

Table 1. Age, Gender, and Scores of Reading Words Composed by Simple Syllables (c-v-c-v) - Taught and New (Generalized), and Words with Orthographic Difficulties for Participants of Each Condition.

Group	Participants	Age	Gender	Taught simple words	New simple words	Words with orthographic difficulties
Computer	XOR	7 y 5 m	M	100	94	72
	TAT	8 y 11 m	F	100	51	48
	PAT	7 y	F	100	89	76
	CRS	8 y 5m	M	94	62	56
	JR	10 y *	M	96	0	20
	RCS	9 y 11 m	F	98	0	0
	WIL	10 y 1m	M	98	2	0
Instructor	ME	9 y 6 m	F	100	91	64
	ELA	9 y	F	100	82	52
	REG	9 y 11 m	F	100	72	56
	RTX	9 y 11 m	M	100	96	44
	AI	10 y	M	94	0	4
	ERI	9 y 11 m	M	90	4	8
	MIL	10 y 5 m	M	82	3	0

Note: Age= Years and months; *= Approximate age, no birth certificate.

Intervention

Initial repertoire assessment. In the intervention both groups were subjected to a personalized teaching program for words with spelling difficulties. The Instructor Group received training with the presence of an experienced instructor, who provided the instructions, presented the trial stimuli on document folders, and recorded data in a form. The Computer Group used an interactive computer program developed for this purpose. Oral reading responses were recorded by the experimenter and an observer in both conditions. Both groups underwent individual teaching sessions, with a frequency of three times a week.

The teaching program consisted of teaching the conditional relations between dictated words and printed words using matching-to-sample with exclusion (Dixon, 1977). The words contained one of eight specific spelling difficulties. The teaching was divided into 32 teaching units, with four units for each target difficulty. Table 2 presents the sequence of tests and teaching units conducted for words with the first taught orthographic difficulty (vowel-R-consonant) and examples of words. Other target difficulties of the Portuguese language of the following teaching units were: vowel-S-consonant (escova, casca); vowel-N-consonant (pingo, bengala); vowel-L-consonant (palma, soldado); QUE/QUI (queijo, quibe); consonant-R-vowel (prato, cabrito); consonant-L-vowel (dupla, bloco); and X with Z phonics (exato, exílio).

Table 2. Sequence of tests and teaching units conducted for words with the orthographic difficulty of vowel-R-consonant present in the taught words.

Procedure	Spelling Difficulty	Word Examples		
		Teaching	Generalization	Baseline
Diverse Generalization Reading Test 1	25		perna, mosca, pingo, balde	tatu, tomate, fivela, bolo
Teaching Unit 1 - VRC	**Vowel-R-Consonant**	[illegible]	[illegible]	[illegible]
Teaching Unit 2 - VRC	**Vowel-R-Consonant**	[illegible]	[illegible]	[illegible]
Diverse Generalization Reading Test 2	25		avião, muro, terra, osso	bolo, mala, tubo, aluno
Teaching Unit 3 - VRC	**Vowel-R-Consonant**	[illegible]	[illegible]	[illegible]
Teaching Unit 4 - VRC	**Vowel-R-Consonant**	[illegible]	[illegible]	[illegible]
Dictation Test - VRC	Vowel-R-Consonant	all 16 words	all 16 words	

Note: The same sequence was used for seven other orthographic difficulties: VSC, VNC, VLC, QUE/QUI, CRV, CLV, and X with Z phonics. Each Teaching Unit included a retention test, a pre-test, exclusion training, and a post-test structure.

Teaching Units. All teaching units were constructed with 48 trials according to the Pre-test, Exclusion Training and Post-test structure. Every trial programmed an MTS task and a reading task (Figure 1). The first 12 trials were characterized as an initial assessment and consisted of four trials to evaluate retention of the words taught in the previous unit (or words with simple syllables, in the first unit of the first difficulty taught), and eight pre-test trials. The final eight trials were planned as a final assessment or Post-test. In the Pre-test and Post-test, the reading of four Teaching Words (TR) and four Generalization Words (GN) was requested, without differential consequences for correct and incorrect responses. The teaching of the four words of each unit was carried out in 28 trials (7 trials per word) of exclusion and novelty control inserted between the Pre- and Post-test (Figure 1).

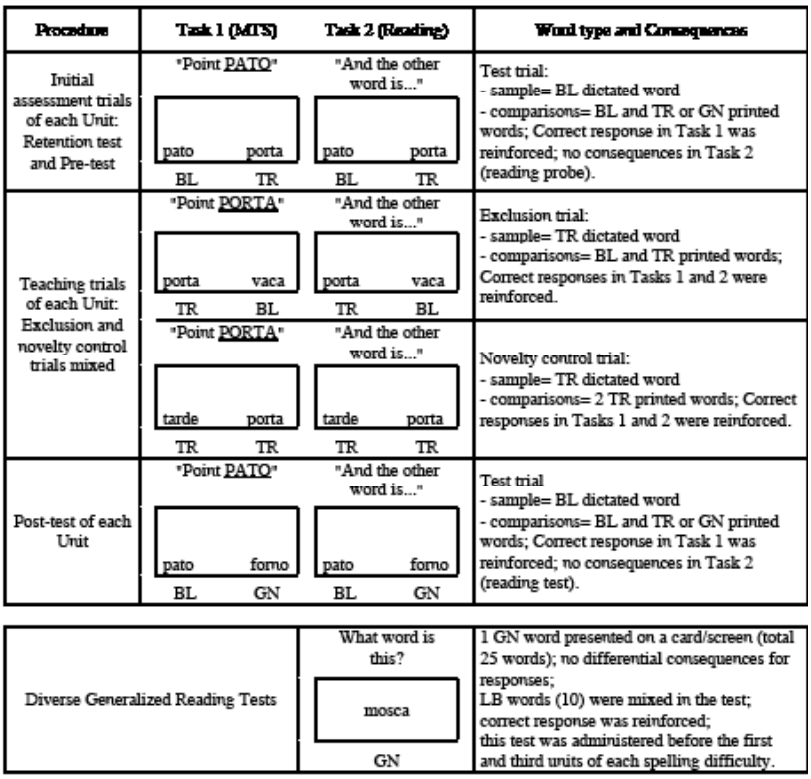

Figure 1. Scheme of Different Trials Used in Each Part of Teaching Units and in the Diverse Generalized Reading Test.

In the initial 12 trials (retention and Pre-test) and the final eight trials (Post-test) of each teaching unit, one of the comparison stimuli was a baseline word and the other a teaching or generalization word. The dictated word always matched the baseline word. After correcting the selection response, the naming of the other printed word was requested (which characterized a reading probe). Errors in selecting the printed word corresponding to the dictated word resulted in the omission of reinforcement and the next trial was presented.

In the training trials, two words printed on the computer screen or at the bottom of the A4 sheet (in landscape layout) were presented as comparison stimuli: a baseline word (composed of simple syllables, see examples in Table 2) and a teaching word that contained the target difficulty of that unit. The first training trials presented the dictated teaching stimulus as sample and allowed the selection by exclusion of the known word (baseline). Novelty control trials (where the dictated word was the baseline or already trained one) followed the exclusion trials to avoid selection based on novelty and were also employed as reading probes with reinforcement. After the correct selection, the experimenter asked the participant to name the new other (not selected) word.

In training trials, selection responses and correct readings were followed by social reinforcement and tokens that could be exchanged for gifts at the end of the session. Choice errors produced the question "Are you sure?" and the experimenter or the computer waited for a new answer. Errors in the reading were followed by the presentation of the next trial.

The learning criterion for each teaching unit was 100% accuracy in reading the four teaching words in the Post-test, eight final trials. In case of error, the unit was repeated in the next session.

Six Instructor Condition participants (ELA, ERI, ME, RTR, MIL and AL) were exposed to all teaching units, regardless of performance in the first 12 test trials. For the other participants, the teaching units were performed only in case of error, in the Pre-test, in reading the training words for which the unit had been planned. In case of 100% correct responses in the teaching words, the session was interrupted, and the participant was exposed to the next programmed unit.

Procedure for maintaining the baseline repertoire. For the Computer Condition, a Pre-test of the baseline simple syllable words used in each teaching unit was included, followed by a retraining of the incorrectly read words, also using the exclusion procedure, before moving on to the Computer Condition. In the Instructor Condition, if errors occurred in baseline words (BL), the special retraining unit was also performed, with the same structure as that used in the Computer Condition, except that this was done after the teaching unit.

Assessments

Dictation Tests. At the end of training the fourth unit of each target difficulty, a dictation test was performed with paper and pencil of all the training and generalization words used in the four units of that target difficulty. Each emission of a response (correct or incorrect) was followed by a token and then, by the dictation of the next word.

Diverse Generalized Reading Tests. The aim of the diversified generalized reading tests was to assess the reading of new words with spelling difficulties, same and different from those taught throughout the teaching program. The task consisted of requesting the reading of each printed word presented individually on white cards (Instructor Condition) or in the center of the monitor screen (Computer Condition).

Each generalized reading test consisted of 25 printed words, each of which had a different difficulty. Among the words, 8 contained the target difficulties of the teaching program; the others presented difficulties not taught, such as those underlined in the examples between parentheses (ninho, milho, torre, missa), words that involved the same sound that could be represented by two or more letters depending on the context (e.g., "azulejo", where the Z corresponds to the same sound as S, in words like "casa"; "caixa", where the X has the same sound as CH; "exame", where the X can correspond to the same sound as S or Z), words with M or N preceded by the letter a, which become nasalized ("cama", "piano"), word with R between vowels (e.g., parede), whose sound is different from the initial R (e.g., rato), words accented by tilde (balão, avelã), and a word that contained more than one spelling difficulty (e.g., mosquito, esguicho). Responses in this task were followed by tokens, regardless of success or failure. Ten baseline words that the participants had previously learned to name were mixed into the 25 difficult words, and their correct naming was followed by both social reinforcement and tokens.

For two participants in the Instructor Condition (ELA and ERI) the diverse generalized reading test was performed before the first exposure to each teaching unit. For the other participants, the tests were performed before exposure to the first and third units of each difficulty.

Data and material availability

Data deposition will be in Research Gate of the first author's account, with private access conditional to authors authorization. The original program was written in HyperCard in 1994 and does not work on current Windows and OS systems and therefore cannot be shared. However, the teaching program used in the study was introduced on a new platform (GEIC-Gerenciador de Ensino Individualizado por Computador) which can be accessed at the link http://geic.ufscar.br:8080/site/.

RESULTS

The results of the study were analyzed based on the participants' performance in teaching units, reading assessments (Pre- and Post-tests), dictation assessments, and diverse generalized reading tests.

Table 3 presents the minimum, maximum and average number of exposures to the teaching units of each difficulty, for participants in each condition, and the respective standard deviations. Each value presented in the table was calculated based on the data of the seven participants of each condition, considering the four units of each difficulty. The minimum value could be zero, since if the participant read correctly in the Pre-test the words that were going to be taught in the unit, the training was not carried out. If the participant performed at least one training of each difficulty unit, the value would be four; the number of units repeated because criteria were unattained was also counted.

Regarding the teaching units, participants in the Computer Condition were exposed to the units of each difficulty more times compared to those in the Instructor Condition, except for the CRV difficulty. The variability among participants in the number of exposures was also greater in the Computer Condition, except for the QUE/

Table 3. Minimum and Maximum Values, Average and Standard Deviation of the Number of Exposures to Teaching Steps of each Orthographic Difficulty for Instructor and Computer Conditions.

Orthografic	Min-Max		Average		*SD*	
Difficulty	C	I	C	I	C	I
VRC	1-21	1-6	6.7	4.3	7.5	1.7
VSC	0-11	0-5	4.7	2.7	3.6	2.4
VNC	1-11	2-6	6.7	4.4	3.9	1.4
VLC	2-12	3-7	7.3	5.1	4.3	1.6
QUE/I	3-9	1-10	6.0	5.3	2.3	2.8
CRV	0-10	0-8	4.4	4.7	4.0	2.9
CLV	0-22	4-10	9.4	6.4	7.9	2.4
X(Z)	9-23	5-15	15.3	9.4	5.8	3.7
General	0-23	0-15	7.6	5.3	2.0	0.8

Notes: C= Computer; I= Instructor.

QUI difficulty. The difference in the number of exposures between the two conditions was statistically significant (analysis with results of each participant in the different spelling difficulties, n= 48 for each condition, t-test, p= .012).

The oral reading of the words with the taught difficulties was monitored through the Pre- and Post-tests carried out in the teaching units. Figure 2 presents the percentage of correct responses (averages) in the Pre- and Post-tests for each participant in the Computer (graphs on the left in Figure 2) and Instructor (graphs on the right) Conditions. The analysis used the Pre-test of the first exposure to the teaching units and all the Post-tests of the teaching units since the scores in the Post-test of the last exposure to the units were always 100% correct (criterion) for the teaching words. For the taught stimuli (upper graphs), there is a significant increase (Wilcoxon signed-rank test, p <.05) in reading from the Pre-test to the Post-test for all participants in the Instructor Condition and for six of the seven participants of the Computer Condition (except for PAT, which already had high scores in the Pre-tests for most spelling difficulties). The scores of all participants in the Post-test of taught words were greater than 75% of

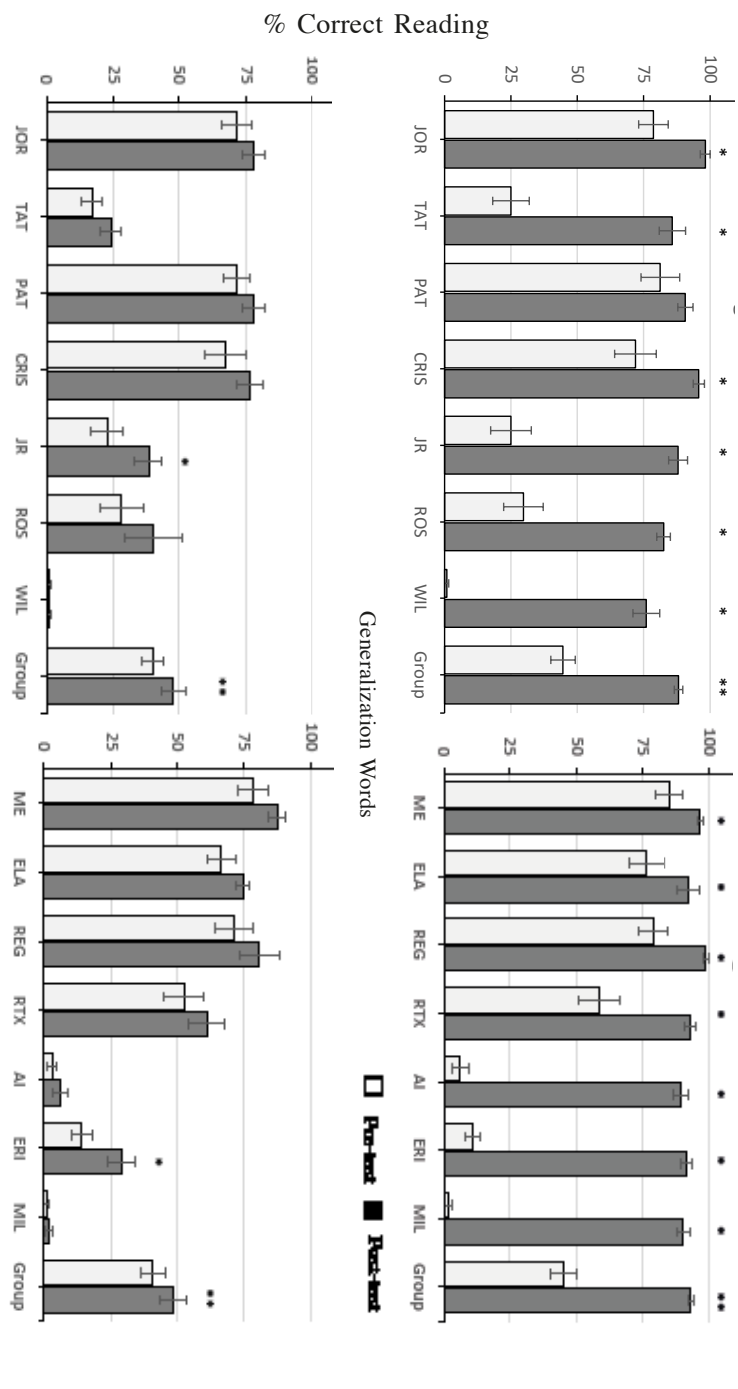

Figure 2. Percentage of Correct Responses in Pre- and Post-tests of Reading for each Participant of Conditions Computer and Instructor. (*Wilcoxon sign rank test, $p < .05$; **Student's t-test $p < .05$)

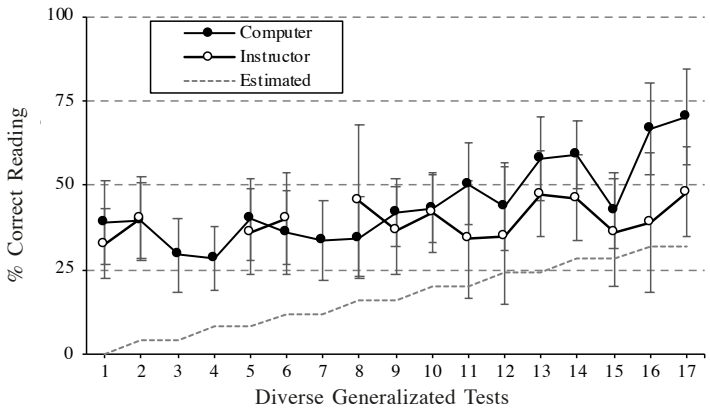

Figure 3. Percentage of Correct Responses in Diverse Generalization Reading Tests for Each Condition (Mean and Standard Error).

correct responses. For the untaught words with the target spelling difficulties (lower graph, generalization words), increases in the Post-test also occurred, but they were small, not significant and varied between participants.

The difference between Pre- and Post-test scores for each condition, shown by the mean in the bars to the right of each graph, was statistically significant for both conditions and both types of words (*t*-test, $p < .01$). Comparisons between conditions showed a significant difference (*t*-test, $p < .01$) only between the Post-tests with taught words: the Instructor group had a higher score (93.3%) than the Computer group (87.7%).

Figure 3 shows the percentage of correct responses, for each condition (Computer, black circle; Instructor, white circle), in the diverse generalized reading tests, which evaluated the reading of words not taught for each of the 25 spelling difficulties throughout the teaching program. The dashed line indicates the estimated percentage of correct responses if the student correctly read only the words with target difficulties taught up to that test.

In the first test (before starting teaching), the scores of the two conditions were very close and below 50% of correct responses. For both conditions, an increasing trend was observed in the percentage of correct responses throughout exposure to the teaching program. The scores for the two conditions were similar up to the tenth test, when words with four different target difficulties had been taught. From Test 11 onwards, the scores of the Computer Condition were higher than those of the Instructor Condition. Due to the high variability of the data (standard error shown by the vertical lines) and the small sample of the two conditions (7), the differences between the conditions in tests 11 to 17 were not significant (Wilcoxon signed-rank test, $p > .05$). The performance was above the estimated curve of correct responses for words with difficulties taught for both conditions.

Figure 4 shows, for the two conditions (Computer in the left column and Instructor in the right column) the percentages of correct responses in the reading and dictation tests of teaching words (upper graphs) and new words (lower graphs) for each target difficulty. The analysis used results from the dictation tests performed after the fourth teaching unit of each difficulty. For reading, the post-tests of all the teaching units that the child performed (including those in which the learning criterion was not met) were used.

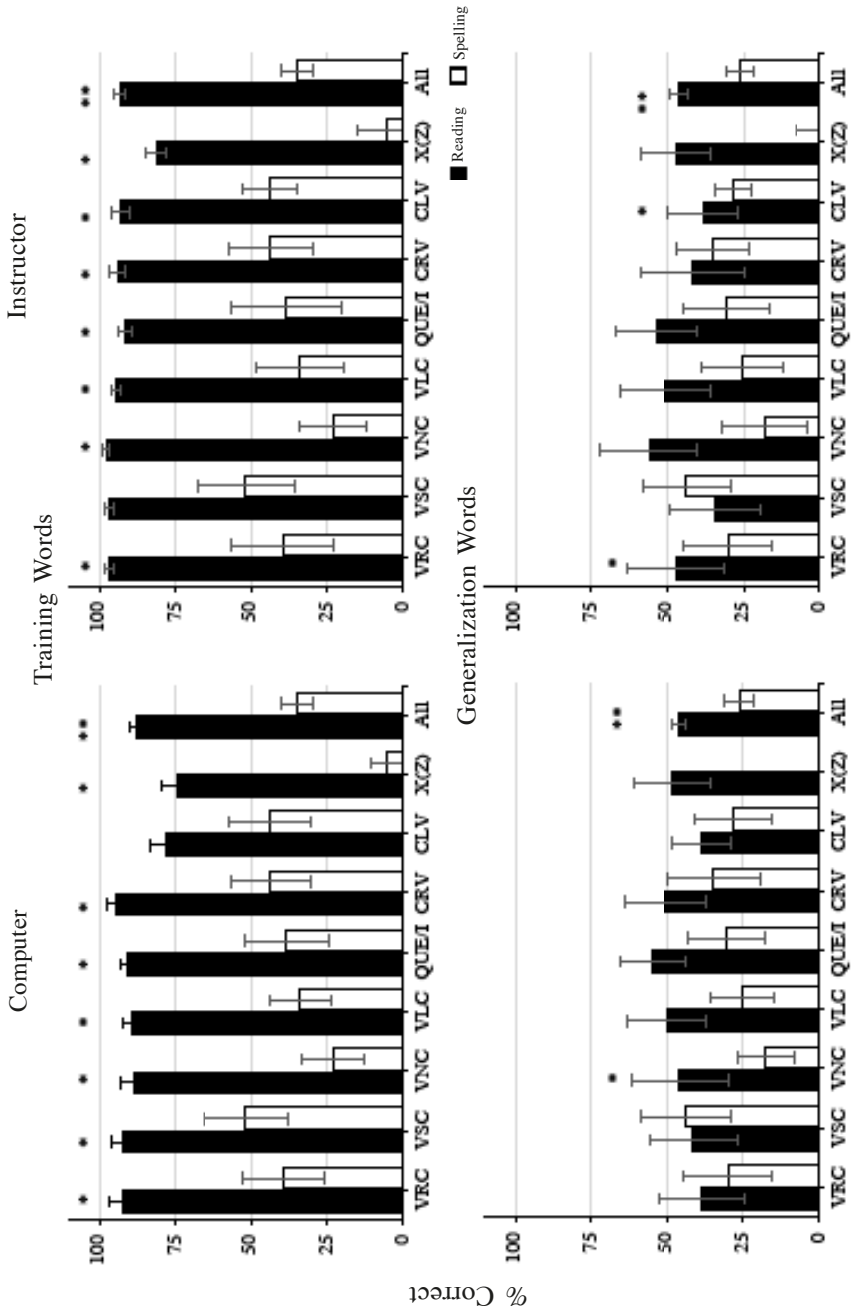

Figure 4. Comparison Between Reading and Spelling Scores (% Correct) for Training and Generalization Words with each Orthographic Difficulty for each Condition. (*Wilcoxon sign rank test, $p < .05$; **Student's *t*-test $p < .05$).

In both conditions, the percentages of correct reading of taught words (upper graphs) were significantly higher (Wilcoxon signed-rank test, $p > .05$) than in writing in seven of the eight spelling difficulties (except for VLC in the Computer Condition and VSC in the Instructor Condition). For generalization words (lower graphs), the differences between reading and writing were smaller and the variability in each spelling difficulty was greater. There were only three cases of significant differences (Wilcoxon signed-rank test, $p < .05$): VNC for the Computer Condition and VRC and CRV for the Instructor Condition. Both in reading and in dictation, the percentages of correct responses were higher for teaching words than for generalization. The comparison between reading and writing considering all spelling difficulties (All) showed significant differences (Student's test, $p < .05$) for Teaching and Generalizing Words for both conditions. The differences between the means of the two experimental conditions were not statistically significant for reading and writing of taught and generalization words (Wilcoxon signed-rank test, $p > .05$).

Discussion

The present study compared the effectiveness of a teaching program delivered by an instructor and by a computer in teaching words with spelling difficulties to elementary school children. The results showed that both conditions were effective in producing high percentages of correct responses in reading taught words, with slightly greater gains observed in the Instructor Condition. The study also found that both conditions led to generalization, but at varying levels, in both reading and writing new words with spelling difficulties. The Computer Condition showed higher levels of generalization in the last general tests.

The differences in the amount of exposure to teaching units between the conditions may be attributed to the flexibility and adaptability of the instructor in providing differential consequences and addressing attentional variables. The computer-based program lacked the ability to address attention and motivation issues or modify contingencies based on performance. This may have influenced the participants' engagement and the number of repetitions required to reach the learning criterion. In the Computer Condition, consequences remained unchanged even when systematic errors occurred. The first correct response after consecutive errors did not result in any changes to the consequences. In contrast, in the Instructor Condition where direct interaction between the instructor and the child took place, there was more flexibility in programming differential consequences. For example, if the same unit was repeated with successive incorrect responses, the literacy teacher would often modify the social consequence for the first correct response to highlight the child's progress, using a supportive tone and encouraging words. In situations where error frequency was high, reinforcement magnitude might be intensified to enhance task engagement and promote correct responses.

Another example pertains to attentional variables, where the participant may not look at the presented stimuli or do so for an insufficient period according to the instructor. In such cases, the instructor would commonly repeat the instruction or ask the child to look at the stimuli, pointing and prompting them to touch them. Only after ensuring eye contact with the stimuli would the participant's response be required and followed by consequences. However, the program used in the Computer Condition did not allow for the evaluation of gaze responses or planned contingencies for attention and motivation issues. Although the instructor could request the repetition of an "inattentive" reading response by pressing a function key (F1), once reading was required and the

participant interacted solely with the computer, the antecedent events became predictable. Consequences for pointing and naming responses were programmed independently of the duration and manner of contact with the stimuli presented on the screen.

The findings of the study align with previous research that has shown the effectiveness of computer-assisted procedures in teaching other reading skills. Computer instruction has been found to be comparable or even superior to instructor-assisted procedures in skills relevant to read (Mitchell & Fox, 2001; Underwood, 2000) and in reading tests (Macaruso *et alii*, 2006; Nicolson *et alii*, 2000; van Dall & Reistman, 2000). The engagement, attention, and enthusiasm generated by computer-based activities, as well as the variation of activities, have been identified as contributing factors to the positive outcomes (van Dall & Reistman, 2000). The Computer Condition of the present study used different words in each teaching unit, however the training and test trials had a similar structure and with little or no variation between sessions, which may have affected the performance of the participants, who repeated more tasks until reaching the learning criterion.

The study also highlighted the importance of generalization in the learning process. Participants were able to read not only the words explicitly taught but also new words with similar and new spelling difficulties. However, reading entirely new words that did not contain the taught difficulties relied on partial or total correspondence with spoken words in the participants' community. The findings emphasize the need to consider individual differences and develop teaching programs that address specific needs and promote generalized reading skills.

During the teaching program, participants surpassed explicitly taught performances by reading not only the words taught through the exclusion procedure, but also new words with similar difficulties. These findings confirm previous research by de Rose *et alii* (1992) and de Souza *et alii* (2009), showing that teaching relations between dictated and printed words can develop word unit control and reading abilities with letter recombination. Generalized reading of words containing target difficulties depends on discriminative control by minimal textual units and unit recombination (de Souza *et alii*, 1999). For instance, after learning to select "banda" and "pimenta," the child can read new words like "anjo" and "catinga" with different target units (vowel-N-consonant) in different positions. Explicit teaching of word units with varied spelling difficulties resulted in generalized reading, like studies teaching words with simple syllables (de Souza *et alii*, 2009; Reis *et alii*, 2009). However, reading entirely new words with untaught difficulties involves generalization and reliance on the listener's repertoire, including correspondence with spoken words in their community (Blok, Oostdam, Otter, & Overmaat 2002; Skinner, 1957). At this stage, the student may make mistakes, but "success" in "discovering" meaningful parts of words strengthens performance and develops generalized reading as a second-order operant. It's worth noting that reading scores for new words were lower than previously taught words, consistent with studies teaching simple words (de Rose *et alii*, 1996) and rudiments of music reading (Hanna, Huber, & Natalino, 2016; Perez & de Rose, 2010).

There was variability among participants regarding generalization in the input repertoire (Table 1) and after teaching words with spelling difficulties (Figures 2 to 4, generalization words). Two participants (WIL and MIL), one for each condition, showed very low scores (less than 20% correct) in both dictation and diversified reading tests, even after exposure to 32 teaching units. These results suggest that the teaching program may not equally meet the needs of all students and should be revised using new procedures developed to accelerate recombinative reading. Direct teaching of syllables

and the systematic use of units (letters and syllables) in different positions within taught words have shown to benefit reading and writing of new words containing those units (e.g., Hübner *et alii*, 2009; Matos *et alii*, 2006; Serejo, Hanna, de Souza, & de Rose, 2007), referred to as generalized reading or recombinative generalization (Goldstein, 1983; Hanna *et alii*, 2011; Mueller *et alii*, 2000).

In a few cases, difficulties were identified for most participants in reading and writing words with certain spelling complexities, even after they were taught (mainly, CLV and X(Z)). Although it may seem that the problem lies in the spelling itself, other explanations are possible: (a) patterns of behavior may be strongly established by modeling and differentiation by the verbal community in which children are inserted and these are inconsistent with the required responses (e.g., change the "L" for "R" in words like CLIMA, CLAVE); (b) equivalence classes can be improperly formed when different stimuli are conditionally discriminative to the same sample (e.g., S, Z, or X, for the sound of Z); and (c) stimulus characteristics can control a combination of multiple repertoires. The experimental analysis of these possibilities will provide bases for teaching programming with corrective and, mainly, preventive purposes.

The study evaluated a teaching program constructed from empirically supported procedures, adaptable for use with conventional materials or computers. Matching-to-sample tasks (e.g., Cumming & Berryman, 1965), exclusion procedure (Dixon, 1977), oral reading and dictation tasks, and trained instructors ensured similar and consistent experiences for students. This controlled variables when comparing computer and instructor-led applications, allowing for result replication, and enhancing generalizability of computer-mediated teaching data. Prior review research (e.g., Blok *et alii*, 2002; MacArthur, Ferretti, Okolo, & Cavalier, 2001) has emphasized the importance of design and detailed information about computer-assisted interventions. This study addressed these concerns by providing procedure details, including a control group, pre- and post-test measurements, and transfer of learning assessments for both taught (reading) and untaught (writing) skills. The program taught relations between dictated and printed words, focusing on eight spelling difficulties. Similar construction of matching-to-sample trials (MTS), instructions, and consequences occurred for both instructor and computer-based instruction. Measures included taught relation learning, reading of taught and untaught words with spelling difficulties, and dictation tests to assess effects on writing and compare reading and writing performances.

The use of computers in teaching, as demonstrated in this study, offers several advantages. Firstly, it enables the expansion of access to and benefits from teaching programs, reaching a larger number of students. Secondly, it allows for the utilization of technology within schools and institutions, enabling students to work independently at their own pace. However, the Computer Condition would benefit from further improvements, such as a fully automated version powered by a more efficient program. Methodological adaptations are also necessary, as the current approach was effective for a specific profile of participants. Strategies should be developed to enhance flexibility in teaching sequences to accommodate individual differences in input repertoires and performance throughout the program. For instance, supplementary units could be incorporated to teach a greater number of words with single syllables to children who struggle with generalization. Additionally, the number of teaching units for a specific difficulty could be adjusted based on each student's performance. It is essential to create resources that automate the procedure further, reducing the need for individual decision-making by the instructor, particularly in tasks and recording naming and dictation responses. This

would enable the application of the program by teachers in the school context and promote independent computer-based learning.

In conclusion, the study highlights the potential of computer-assisted teaching programs in enhancing reading skills, while acknowledging the importance of individual differences, flexibility in programming, and ongoing improvements in methodology and resources. The computer serves as a tool (Skinner, 1968) that can support effective teaching programs but does not replace the role of instructors in managing contingencies and fostering engagement and motivation in students.

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