Audiofonologia
Tom XXIV 2003

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Recombinative generalization in teaching spelling of three-letter words pre-school children

Generalizacja rekombinacyjna w uczeniu ortografii dzieci w wieku przedszkolnym

Key words: letter-sound correspondence, spelling, writing, reading, generalization, children.
Słowa kluczowe: relacje litera–dźwięk, ortografia, pisanie, czytanie, generalizacja, dzieci.

Summary

Recombinative generalization is the demonstration of novel recombinations of previously established linguistic units. Several studies have shown recombination of whole words, but novel spelling requires recombination of units that are smaller than words (i.e., syllables or units within a syllable). This paper presents data on recombinative generalization of within-syllable units in a spelling task performed by three pre-school children. It also provides data on the accuracy of the participants' printed word naming before and after the spelling intervention. The children were trained and tested using a computer with a touch-sensitive monitor. They spelled words by touching individual letters on the screen. All words were consonant-vowel-consonant (CVC) words. These words were divided into six sets, presented consecutively. Within sets, the spelling words had overlapping onsets (initial consonant) (e.g., fed-fog) or rimes (vowel-consonant ending) (e.g., fed-led). Across sets, the words had overlapping rimes (e.g., bed-med). Each set contained three training words and three untrained words. Tests for recombinative generalization determined whether children spelled correctly novel words that were constructed by recombining onsets and rimes in ways that had not been directly trained. One child showed perfect recombinative generalization after two training sets. Two other children showed partial recombinative generalization after two and three training sets, respectively. All three children demonstrated higher percentage of printed words named correctly following the spelling intervention. These findings are a promising step in the development of a computerized technology for teaching basic literacy skills.

Streszczenie

Ortografia odgrywa ważną rolę przy komunikowaniu się w formie pisemnej i przy nauce czytania [Ehri 1987; Okyere (et al.) 1997]. Jest ona zatem również istotnym elementem kompletnego programu nauki języka [Buswinka (et al.) 1996]. Niestety, wiele dzieci ma problemy z ortografią [Scott 2000]. Gettinger [1993] sugeruje, że problemy te wynikają z mało efektywnych metod nauczania. Wielu naukowców zaleca, aby metody uczenia ortografii były oparte na wynikach dokładnych badań eksperymentalnych [np. Scott 2000; Templeton 1991]. Paradygmat analizy zachowania oferuje efektywne sposoby uczenia ortografii, które właśnie wywodzą się z badań eksperymentalnych [Heron (et al.) 1991]. Ograniczeniem tych badań jest jednakże fakt, że skupiły się one na nauczaniu poprawnej ortografii znikomej liczby słów. Tylko w kilku projektach doswiadczalnych poddano badaniom zagadnienia generalizacji poprawnej pisowni lub przedstawiono wyjaśnienie takiej generalizacji w odniesieniu do procesów behawioralnych [np. de Rose (et al.) 1996; Kinney (et al.) 2003]. Behawioryści zainteresowani generalizacją w ortografii sugerują, że abstrahowanie i generalizacja rekombinacyjna odgrywają ważną rolę przy poprawnej pisowni słów, których bezpośrednio nie uczono [np. Mueller (et al.) 2000].

Generalizacja rekombinacyjna została zdefiniowana jako „zróżnicowane zachowania się wobec nowych połączeń elementów bodźca, które poprzednio były przedstawiane w nowym układzie" [Goldstein 1983 s. 281]. Jeżeli połączone inaczej znane już bodźce spowodują odpowiednią zmianę zachowań, to znaczy, że nastąpiła generalizacja rekombinacyjna. Jeśli chodzi o umiejętność czytania i pisania, generalizacja rekombinacyjna polega na poprawnej reakcji na nowe połączenia wynikające z poprzednio nauczonych elementów lingwistycznych [Goldstein 1993]. W kilku eksperymentach wykazano rekombinację całych słów [np. Striefel (et al.) 1976; 1978], ale generalizacja rekombinacyjna w ortografii wymaga połączeń elementów mniejszych niż słowa (sylab, ich elementów składowych lub liter) [np. de Rose (et al.) 1996; Goswami 1986; 1990; Mueller (et al.) 2000; Saunders (et al.) 2003].

Przedstawiane badania dotyczą generalizacji rekombinacyjnej elementów sylab przy nauce ortografii dzieci w wieku przedszkolnym – z użyciem treningu matrycowego (opisanego poniżej). Badania te prezentują również dane o porawności czytania przed nauką pisania słów użytych w eksperymencie i po niej. Troje dzieci uczono ortografii, a wyniki nauki testowano przy użyciu komputera z ekranem dotykowym. Dzieci tworzyły słowa przez dotykanie poszczególnych liter na ekranie. Każde z 26 słów użytych w eksperymencie składało się z trzech liter (spółgłoska – samogłoska – spółgłoska). Słowa te były podzielone na 6 grup (niektóre słowa występowały w dwóch grupach). Każda grupa zawierała trzy słowa bazowe i trzy słowa utworzone przez rekombinację. Trening matrycowy polegał na systematycznym ułożeniu słów do nauki i słów do generalizacji. W zestawie słów bazowych dwa słowa miały te same litery początkowe (np. FED i FOG), a w dwóch słowach występowały te same części końcowe (np. FED i LED). Zadaniem dzieci było poprawne napisanie słów (bez poprzedniego bezpośredniego nauczania tych słów) utworzonych przez połączenie liter początkowych i części końcowych słów bazowych. Wyniki pokazały, że jedno dziecko zademonstrowało prawie pełną rekombinację po nauczeniu się pięciu słów bazowych; to dziecko utworzyło poprawnie pozostałych 21 słów bez dodatkowego nauczania. Dwoje dzieci demonstrowało częściową rekombinację – po nauczeniu się sześciu lub ośmiu słów bazowych dzieci te utworzyły poprawnie 2/3 pozostałych słów (odpowiednio 13 i 12 słów). Wszystkie dzieci przeczytały poprawnie więcej słów po zakończeniu treningu pisania.

Opisany eksperyment dostarcza dowodów świadczących o tym, że trening matrycowy zwiększa prawdopodobieństwo efektywnej rekombinacji przy nauce ortografii. Eksperyment ten jest też jednym z niewielu projektów poświęconych generalizacji rekombinacyjnej elementów składowych sylab. Badania te mogą być zaliczane do badań łączących eksperymentalną i stosowaną analizę zachowania. Wyniki badań przyczyniają się do lepszego zrozumienia procesów biorących udział w nauce pisania i czytania oraz w planowaniu efektywnych metod nauczania ortografii. Dalsze badania nad generalizacją rekombinacyjną w ortografii rozszerzą zastosowanie tego procesu w nauce pisania.

1. INTRODUCTION

1.1. Overview

Spelling is a complex skill that involves the „translation" or „conversion" of speech forms into standard written forms [Simok, 1976; Snow, Burns, Griffin, 1998; Templeton, Morris, 2000]. Spelling is important in written communication and is interrelated with learning to read [Ehri, 1987; Okyere, Heron, Goddard, 1997]. It is also an essential component of a total language arts curriculum [Buswinka et al., 1996]. Unfortunately, spelling is an area of difficulty for many students [Scott, 2000]. Gettinger [1993] suggests that poor spelling ability might be attributed, in part, to instructional factors. Several authors assert that the traditional method of requiring students to memorize spelling of 10-20 words a week is not effective for many learners [e.g., Gill, Scharer, 1996]. The efficacy of commercially available materials for teaching spelling and of allowing students to discover correct spelling via reading and writing is also questionable [Schlagal, Schlagal, 1992]. Finally, the research basis supporting the traditional educational practices for teaching spelling is fraught with inadequacies in design and measures [Greer, 1992]. Thus, many researchers advocate the need for effective and systematic spelling instruction based on rigorous, experimental research [e.g., Scott, 2000; Templeton, 1991].

Behavior analytic (BA) research in spelling has been both rigorous and effective [Heron, Okyere, Miller, 1991]. However, a limitation of behavior analytic studies is that they have focused on teaching the rote spelling of a limited number of words. Very few projects have examined how children come to spell novel words correctly [e.g., de Rose, de Souza, Hanna, 1996; Kinney, Vedora, Stromer, 2003]. Additionally, those studies that do investigate novel spelling do not offer process-level explanations for this performance. Graham [1999] writes that this criticism can also be applied to traditional spelling research, despite the fact that there are more studies in the education literature reporting data on spelling of novel words [e.g., Berninger et al., 1998; Davidson, Jenkins, 1994; Qi, O'Connor, 2000]. This paper will generally not rely on those studies because they do not provide information about the proportion of individuals who master the spelling tasks as a result of an intervention and they rarely investigate the precise conditions under which generalization occurs.

The present study stemmed from behavior analytic research on teaching spelling as well as from research on the development of the alphabetic principle and word naming skills. In the latter studies, the concepts of abstraction and recombinative generalization have been suggested to play a role in correct spelling of words that have not been previously encountered by the learner [e.g., Mueller, Olmi, and Saunders, 2000]. Thus, the purpose of this introduction is three-fold. First, I will review behavior analytic strategies for teaching spelling. Second, I will discuss the role of abstraction in the development of early literacy skills. Third, I will elaborate on the role of recombinative generalization in spelling and in naming novel printed words.

1.2. Behavior Analytic Strategies for Teaching Spelling

The essence of a behavior analytic approach for teaching any academic skill, including spelling, entails the following components: (1) reliance on precise, measurable, behavioral units, (2) frequent measurement of the target behavior of each individual learner, (3) the notion of a temporal relationship between the antecedent stimulus, the target behavior, and the consequence (a three-term contingency), (4) provision of many opportunities to respond correctly, (5) acknowledgment of the role of reinforcement rate, and (6) reliance on strengthening successive approximations of the target behavior [Edgar, Sulzbacher, 1992]. All of the studies reviewed in this section included the first two components. Regarding the three-term contingency, some researchers manipulated variables to learn how specific antecedent stimuli evoke correct spelling while others investigated the role of immediate consequences in spelling. Many studies, especially those investigating instructional packages, included several of these behavioral components. This review will present the studies in clusters based on either common research questions or common procedures. I will discuss only one study per cluster, the one that is most convincing, according to the Baer, Wolf, and Risley's [1968, 1987] criteria for behavior-analytic research.

Researchers have used delayed-prompt and match-to-sample procedures to look at the transfer of stimulus control in spelling from copying a written word to the spoken word. In a delayed-prompt procedure, a teacher asks a student to spell a new word and simultaneously presents this word in written form for the student to copy [e.g., Kinney, Stevens, Schuster, 1988; Stevens, Schuster, 1987]. During successive trials, the teacher delays showing the word, giving the student a chance to respond independently. Stevens, Blackhurst, and Bott-Slaton [1991] taught 18 spelling words to five students with learning disabilities. A computer delivered the requests, the models, and praise for correct spelling. When students made a mistake, they were shown the correct spelling and the same request was repeated until the word was spelled correctly. The authors reported that the students learned to spell new words quickly and with few errors. However, independent and prompted correct spellings had been reinforced in the same way, so the precise cause of the transfer of stimulus control from the written prompt to the spoken word was not clear. Possibly, the increased reinforcement rate when a response preceded a prompt facilitated such transfer [as argued by Touchette, Howard, 1984].

Transfer of stimulus control in spelling from a written prompt to spoken words or pictures, using a „constructed" response, has also been investigated by Mackay and colleagues [e.g., Mackay, 1985; Stromer, Mackay, 1992a, 1992b). A constructed-response match-to-sample procedure (CRMTS) involves matching individual letters to written words, in the correct order from left to right. Dube, McDonald, McIlvane, and Mackay [1991] used a computerized version of CRMTS to teach two participants to spell several words. The participants were asked by a computer to spell a word in response to a presented picture. Initially, they saw on the computer screen the picture and the corresponding printed word to serve as a model. The transfer of stimulus control from the written word to the picture alone was achieved by gradually fading the letters of the written word. Correct spelling was differentially reinforced. The CRMTS training produced substantial spelling improvements. However, the researchers taught only a few words to two participants and did not present any follow-up data, so the generality and maintenance of the results remains unknown.

Positive reinforcement was used in the earliest behavior-analytic procedures to teach spelling [e.g., McLaughlin, Malaby, 1971; Sulzer, Hunt, Ashby, Koniarski, Krams, 1971]. For example, Chadwick and Day [1971] looked at the effects of a reinforcement package on 25 students' spelling accuracy. Students earned points for correct spelling and exchanged them for a variety of items or activities. When the teacher implemented the point system and praised the students contingent on correct spelling, students' spelling accuracy increased substantially as compared to baseline. When the point system was discontinued, but the teacher still praised correct spelling, students' performance remained high and stable. Despite several methodological problems [e.g., potential „carry-over"), this study's results and the results of many other studies convincingly show effects of positive reinforcement on increasing spelling accuracy.

The use of overcorrection, in which students repeatedly practice the correct spelling if an error occurs, also emphasizes the role of consequences [e.g., Matson, Esveldt-Dawson, Kazdin, 1982]. In Ollendick, Matson, Esveldt-Dawson, and Shapiro's [1980] study, for each misspelled word, the participants had to listen to the word, say it, say each letter of it, and write it correctly. This sequence was repeated five times. When the researchers compared overcorrection alone, overcorrection with praise for correctly spelled words, and a no-teaching control procedure, the results showed that both overcorrection alone and with praise increased spelling accuracy. The latter resulted in slightly more rapid learning. A comparison of overcorrection with praise to a traditional corrective procedure (teacher circled the mistake and wrote the correct spelling) with and without praise revealed that overcorrection with praise produced perfect performance much more rapidly than the other two procedures.

Instructional packages such as Classwide Peer Tutoring (CWPT) [e.g., Delquadri, Greenwood, Stretton, Hall, 1983] and Direct Instruction (DI) [e.g., Kinder, Carnine, 1991] have also been used to teach spelling. CWPT involves pairs of students. The procedure uses reciprocal and highly structured tutoring interactions, group contingencies for „competing" teams, organization of the material to be learned into daily and weekly units, frequent testing to evaluate learning, and it programs many opportunities to respond [Arreaga-Mayer, Terry, Greenwood, 1998; Reddy et al., 1999]. Sideridis et al. [1997], for example, looked at the effects of CWPT on the spelling achievement of six students with and without disabilities. The tutor was to read aloud from a weekly list of spelling words, to provide feedback to the tutee, and to correct tutee errors. The tutee was to spell orally and to write down the dictated word. If the spelling was correct, the tutor awarded two points to the tutee. If the spelling was incorrect, the tutor read the correct spelling aloud, and the tutee wrote the correct spelling three times to earn one point. At the end of the week, individual points were summed for each team, and the class praised the winning team. The results showed that CWPT increased spelling accuracy for all students, but the effects were more pronounced for the students with disabilities. However, since the typical students sometimes reached the ceiling of their spelling performance, this difference might have been underestimated.

Direct Instruction (DI) is characterized by careful-sequencing of the material to be taught, using scripted instructions by the teachers, brisk pacing of questions, reinforcement of correct responding, and specific correction procedures [Engelmann, Becker, Carnine, Gersten, 1988]. Children work with the teacher in small groups, respond in unison at the signal of the teacher, and have ample opportunities to respond correctly. There are many studies investigating effectiveness of DI for teaching basic academic skills, including spelling [e.g., Becker, Engelmann, 1978]. The most comprehensive evaluation of DI was during Project Follow Through. The data show that DI achieved the best outcomes in teaching basic skills although the Behavior Analysis model also was very successful at improving students' spelling performance [Stebbins, Pierre, Proper, Anderson,Cerva, 1977]. Other analyses of the data confirmed that the instructional methods used in DI were most effective in teaching spelling and other basic literacy skills [Kennedy, 1978].

The role of reinforcement rate might be seen in studies that investigated interspersing words that the participants knew how to spell with words they did not know how to spell [e.g., Koegel, Koegel, 1986]. Neef, Iwata, and Page [1980] compared the spelling performance of three students across three conditions: in baseline (participants were to spell 10 unknown words), during interspersal training (participants were to spell 10 unknown words and 10 known words), and in a third condition (participants were to spell 10 unknown words but also received 10 additional praise statements not contingent on their spelling). All participants mastered 10-20 more words, learned those words more rapidly, and maintained correct spelling of the words longer, for the words taught in the interspersal condition. Although the mechanisms responsible for the superiority of the interspersal condition are unclear, the frequent reinforcement for correct spelling in this condition could have facilitated attending to all training stimuli.

To summarize, behavior analysts have developed several strategies that have been successfully used to teach spelling. They include: manipulation of antecedent stimuli to evoke correct spelling, systematic fading of prompts, use of positive reinforcement to maintain correct spelling, provision of many opportunities to respond correctly, and use of effective correction procedures and efficient reinforcement rates. Despite the effectiveness of these procedures, a limitation of past research is that it did not investigate specifically conditions that facilitate correct spelling of novel words. The issue of generalization in spelling is important from both applied and conceptual perspectives. For an educator, the emergence of correct spelling of untrained words is beneficial because it may increase the number of spelling words learned and potentially free teaching time for other skills [Dixon, 1991]. For a researcher, the emergence of correct novel spelling indicates that minimal units that have not been presented independently can develop from larger units [Skinner, 1957]. The latter issue has been experimentally investigated in terms of abstraction and recombinative generalization, which will be discussed next.

1.3. Abstraction and Early Literacy

„Abstraction is a discrimination based on a single property of a stimulus, independent of other properties; thus, generalization to other stimuli with that property" [Catania, 1998, p. 250]. Abstraction is demonstrated when an individual correctly identifies the property of interest in untrained stimuli [e.g., if the property is „redness," abstraction is shown when a child identifies a ball as being red the first time the child sees the red ball). In the context of spelling, abstraction is involved in the alphabetic principle, which refers to „useable knowledge of the fact that phonemes can be represented by letters, such that whenever a particular phoneme occurs in a word, and in whatever position, it can be represented by the same letter" [Byrne, 1989, p. 313]. Thus, the alphabetic principle involves: 1] a visual abstraction: discriminating printed letters or letter combinations within printed words, 2] an auditory abstraction: discriminating specific phonemes or phoneme combinations within spoken words, and 3] relating specific letters or letter combinations to specific phonemes or phoneme combinations within words [Saunders, 2002]. In other words, the alphabetic principle is synonymous with generalized sound-letter relations.

The next section will discuss the role of abstraction in early literacy (reading and spelling) skills, especially in the development of the alphabetic principle. Experimental studies on word naming and spelling have been combined for this review because of the integrated and interrelated nature of those repertoires [Ehri, 1989; Ehri, Wilce, 1987; Lee, Pegler, 1982].

1.4. Visual abstraction

The visual abstraction component of the alphabetic principle involves recognizing individual printed letters or letter combinations within complex, whole word stimuli [Saunders, Johnston, Brady, 2000]. For example, a student is shown the printed word „six" and taught to select printed words that begin with the same letter [e.g., „sat, sick, set" and not „pat, pick, pet"). If, on a test, when presented with the task again, the student independently selects the untrained words „simple, sage, sill" and not „pimple, page, pill," the student would demonstrate visual abstraction of the printed letter „s." When investigating the acquisition of the alphabetic principle, the visual part, as compared to the auditory part, of the letter-sound relation has received relatively little attention from practitioners and scientists [Saunders et al., 2000]. One reason for this might be that teachers and researchers assume that students who discriminate printed letters presented in isolation can also focus on individual letters or letter combinations within whole words. However, that is sometimes not the case, especially with young prereaders or individuals with mental retardation [Saunders, 2001; Snow, et al., 1998].

Saunders and colleagues [2000] reported that typically developing pre-readers showed at least 90% accuracy in matching individual letters. In contrast, their accuracy on matching consonant-vowel-consonant (CVC) words that differed only in the initial letter was sometimes at chance levels. The children's responding did not indicate that they visually abstracted the initial consonant, that is, made a discrimination based on this property of the written stimuli. The authors concluded that failing to isolate individual letters embedded in words could compromise linking appropriate phonemes to those letters, and thus demonstrating the alphabetic principle.

Similarly, McCandliss and colleagues [2003] suggested that procedures that focus attention on each individual letter within a word may play an important role in learning to name and identify novel words. The authors supported their assertion by investigating the effectiveness of an instructional program that taught children with reading difficulties to form and read words by manipulating a single letter in a previously constructed word. A child was, for example, taught to change „sat" to „sap" to „tap" to „top," etc and to name those words. The dependent measures were: naming of pseudowords, naming of sight words, phonemic awareness measures, and reading comprehension. The scores for the experimental group were compared with the scores of the control group, which received no intervention. The authors attributed the improvements in scores across measures for the experimental group, in part, to the fact that the program trained the children to attend to each letter and link it to the appropriate phoneme. However, this study did not provide empirical evidence for this claim because the authors did not evaluate specifically the role of visual abstraction.

Finally, Byrne [1992] investigated the differences in learning to name printed words that were visually more similar [e.g., rat, ran, rag) or less similar [e.g., two, boo, you). The results showed that the participants learned the visually less-similar words more readily and with fewer mistakes. The authors concluded that the difficulties in naming similarly spelled words might have been related to the visual, not auditory resemblance and, potentially, to the children's lack of skill in focusing on individual letters. That is, if children do not abstract individual letters within a word, they might not read similarly spelled words correctly. Byrne's conclusion can be supported by the results of Birnie-Selwyn and Guerin [1997]. Those researches showed that six typically developing children spelled more words correctly following spoken-to-printed word match-to-sample training that involved visually similar comparisons [e.g., if „snow" was the sample, „slow" and „snap" were the comparisons) as compared to training involving visually dissimilar comparisons [e.g., if „snow" was the sample, „nice" and „rest" were the comparisons). The authors concluded that the finer discrimination training at the level of single letters led to improved spelling performance. Presumably, such finer discrimination training facilitated visual abstraction of individual letters, which in turn led to better spelling accuracy.

In summary, visual abstraction is a component of learning the alphabetic principle. Although there are few studies on the role of visual abstraction relative to the number of studies on auditory abstraction, this skill seems to be logically necessary for learning the alphabetic principle and spelling of novel words [Snow et al., 1998]. However, it is not sufficient. Visual abstraction must be accompanied by auditory abstraction if children are to master early literacy skills [Byrne, 1992].

1.5. Auditory Abstraction

Auditory abstraction involves recognizing individual sounds or sound combinations within a spoken word [Saunders, 2002]. For example, a student is taught that the spoken words „mat, milk, mouth" start with the same /m/ sound and that „sat, silly, sandwich" all start with the same /s/ sound. If, on the test, the student responds correctly to the question: „Which word starts with the same sound as 'mat,' is it 'mum' or 'sum'?" the student would demonstrate auditory abstraction of the sound /m/. Thus, following Catania's [1998] definition of abstraction, auditory abstraction is a discrimination based on a single phoneme or a phoneme combination in a word, independent of other phonemes, thus, generalization to other words with that phoneme or phoneme combination [Saunders]. In terms of spelling, if children learn to break spoken words into smaller units, to relate those units to printed letters, and to sequence the letters correctly, they will be successful in spelling novel, phonetically regular words.

Traditionally, individual phonemes have been the starting point in teaching children to read and spell [e.g., Buchanan, 1973]. More recently, however, researchers have shown that larger sound segments [e.g., onset and rime] might be abstracted by children earlier than individual phonemes [Treiman, 1992; Treiman, Zukowski, 1996]. In a syllable, the term „onset" refers to the initial consonant or consonant cluster and „rime" to the vowel and subsequent consonants, if any [Bernstein, Treiman, 2003]. For example, in „run," „r" is the onset and „un" is the rime and in „shop," „sh" is the onset and „op" is the rime. It might be easier for students to learn naming or spelling of onset/rime units because of the more reliable correspondence between written rime units and their sounds than between individual letters and their sounds [Goswami, Bryant, 1992; Treiman, 1992]. For example, the sound of the letter „i" differs in the words „rim" and „rime," but the rime units „im" and „ime" almost always correspond to the same sound [e.g., dim, dime). Some researchers have suggested that teaching basic word naming and spelling should start with onset and rime units before progressing to individual phonemes (other than the onset) [Goswami, 1999].

Byrne and Fielding-Barnsley have conducted a series of experiments investigating the conditions necessary for mastery of the alphabetic principle [1989, 1990, 1991, 1993, 1995]. They mainly investigated the onset sounds. In the 1989 study, for example, the researchers first taught 12 typically developing pre-schoolers to name two written words („mat" and „sat"). Then, the researchers administered segment identity training, which consisted of teaching each child that a testing word (e.g., „mum") has the same onset as the training word (e.g., „mat") (segment identity involves auditory abstraction and, for clarity, I will refer to segment identity as auditory abstraction from this point on). Five children mastered the auditory abstraction task, but none performed correctly on the generalization test (answering the question: „Does this say 'sum' or 'mum'?" when presented with the written word „mum"). Finally, the children were trained on letter-sound relations. That is, they were taught that the letter „m" corresponds to the sound /m/ and the letter „s" to the sound /s/. All 12 children learned to say /m/ when they saw „m" and /s/ when they saw „s." During the next transfer test, six children performed correctly on the generalization task. Five of those children mastered both the auditory abstraction and letter-sound correspondence training. From this and other studies in the series [e.g., 1990; 1991], the authors concluded that the two skills necessary for the development of the alphabetic principle were auditory abstraction and letter-sound relation.

Auditory abstraction training taught the children to isolate the onset from the rest of the word, discriminate among words based on their onsets, and to generalize among words with the same onsets. The reported studies also showed that once children demonstrate auditory abstraction for a particular phoneme in a particular position, they are likely to demonstrate abstraction of other phonemes in other positions [Byrne, Fielding-Barnsley, 1990, 1991]. However, it appears that auditory abstraction is not sufficient for mastery of the alphabetic principle. It needs to be supplemented by direct letter-sound training [Fielding-Barnsley, 1997]. Both skills in combination seem to promote acquisition of the alphabetic principle and early literacy skills.

A piece of evidence regarding auditory abstraction and spelling accuracy comes from a study conducted by Byrne and Fielding-Barnsley [1993]. The researchers compared, at the end of kindergarten, spelling scores of children who at the end of preschool were successful at the auditory abstraction task (the „passers") with scores of children who failed that task (the „failers"). Both groups demonstrated knowledge of letter-sound correspondences at the end of kindergarten. The results showed that the „passers" spelled correctly more words than the „failers," especially when it came to phonetically regular real words and pseudowords. Thus, auditory abstraction seems to be an important component of learning to spell correctly. Saunders [2001] also examined conditions necessary to establish the alphabetic principle. Regarding onset abstraction, Saunders taught five typically developing kindergartners and three adults with mental retardation (MR) to select the printed letters „m" or „s" corresponding to the onset sound of several spoken CVC words beginning with those letters. Essentially, the researchers trained auditory abstraction and letter-sound correspondence at the same time. All of the children and two adults with MR readily selected the letter corresponding to the onset sound of words they had not been trained on while one adult with MR required some additional training before generalization was shown [Vaidya, Saunders, 2000]. Those results clearly indicate abstracted stimulus control by the onset sound, which is a component of the alphabetic principle.

To summarize this section, abstraction is a process involved in generalized reading and spelling of phonetically regular words. If a student learns to isolate letters or letter units within written words and sound or sound units within spoken words, as well as to relate those letters and sounds to one another, the student will have mastered the alphabetic principle. The alphabetic principle is crucial for naming and spelling novel words. However, as Byrne and Fielding-Barnsley [1989] point out, mastery of the alphabetic principle might not be enough to produce novel reading and spelling performances. „An assembly routine" (p. 313) might be necessary. Behavior analysts have conceptualized the assembly routine in terms of recombinative generalization [Saunders, 2001]. The role of recombinative generalization in early literacy is discussed next.

1.6. Recombinative Generalization and Early Literacy

Recombinative generalization has been defined as „differential responding to novel combinations of stimulus components that have been included previously in other stimulus contexts" [Goldstein, 1983, p. 281]. When familiar stimuli are recombined in novel ways and stimulus elements continue to exert precise and appropriate control over corresponding portions of the response, recombinative generalization has occurred [Goldstein, Mousetis, 1989]. In the context of language and early literacy skills, recombinative generalization refers to demonstration of novel arrangements of previously established linguistic units [Goldstein, 1993]. The early recombinative generalization studies originated from Esper's [1925] work on a „miniature linguistic system" [as reported by Wetherby, 1978, p. 401]. In this system, the referential stimuli (i.e., words) are arranged in a pattern that includes all possible combinations of the dimensions of interest. For example, if the dimensions of interest are color and shape, the words representing different colors are placed in rows and the words representing different shapes are placed in columns. Thus, a matrix is formed in which separate cells, the intersections of each row and column, contain a two-word utterance referring to a color-shape combination [e.g., green square) (see Figure 1). Within the whole matrix, there is an overlap between the two-word utterances because each color is paired with each shape (e.g., green square, green circle, green triangle).

Colors

Shapes	SQUARE	CIRCLE	TRIANGLE	HEART	RECTANGLE	OVAL
RED	red square	red circle	red triangle	red heart	red rectangle	red oval
GREEN	green square	green circle	green triangle	green heart	green rectangle	green oval
BLUE	blue square	blue circle	blue triangle	blue heart	blue rectangle	blue oval
YELLOW	yellow square	yellow circle	yellow triangle	yellow heart	yellow rectangle	yellow oval
PINK	pink square	pink circle	pink triangle	pink heart	pink rectangle	pink oval
BLACK	black square	black circle	black triangle	black heart	black rectangle	black oval

Figure 1. An example of a matrix. The words representing different colors are placed in rows and the words representing different shapes are placed in columns. The intersections of each row and column contain a two-word utterance referring to a color-shape combination [e.g., green square]

Studies subsequent to Ester's clearly delineated the training conditions necessary for recombinative generalization to occur. Foss [1968a,b], Striefel, Bryan, and Aikins [1974], Striefel and Wetherby [1973], and Striefel, Wetherby, and Karlan [1976] distinguished between diagonal and stepwise training, which differed in the selection of training items. In diagonal training, the participants were trained on labels that did not have an element in common [e.g., red circle, yellow triangle, blue square] (see Figure 2). Stepwise training, in contrast, provided an overlap among the stimulus components [e.g., red circle, red triangle, yellow triangle, yellow square, blue square, blue heart] (see Figure 3). The combined results of several studies showed that only the stepwise training resulted in correct labeling of the untrained stimuli, presumably by establishing stimulus control of both elements in each two-word utterance [e.g., Striefel et al., 1976]. Thus, overlap among stimulus components is vital because it facilitates subjects making the discriminations necessary to demonstrate recombinative generalization. The stepwise training is also called matrix training. All of the studies described in the rest of this section involve matrix training and overlapping stimulus components.

Colors

Shapes	SQUARE	CIRCLE	TRIANGLE	HEART	RECTANGLE	OVAL
RED	red square	red circle	red triangle	red heart	red rectangle	red oval
GREEN	green square	green circle	green triangle	green heart	green rectangle	green oval
BLUE	blue square	blue circle	blue triangle	blue heart	blue rectangle	blue oval
YELLOW	yellow square	yellow circle	yellow triangle	yellow heart	yellow rectangle	yellow oval
PINK	pink square	pink circle	pink triangle	pink heart	pink rectangle	pink oval
BLACK	black square	black circle	black triangle	black heart	black rectangle	black oval

Figure 2. An example of diagonal training. The two-word labels selected for training do not contain an overlap [e.g., red circle, yellow triangle, blue square]

Colors

Shapes	SQUARE	CIRCLE	TRIANGLE	HEART	RECTANGLE	OVAL
RED	red square	red circle	red triangle	red heart	red rectangle	red oval
GREEN	green square	green circle	green triangle	green heart	green rectangle	green oval
BLUE	blue square	blue circle	blue triangle	blue heart	blue rectangle	blue oval
YELLOW	yellow square	yellow circle	yellow triangle	yellow heart	yellow rectangle	yellow oval
PINK	pink square	pink circle	pink triangle	pink heart	pink rectangle	pink oval
BLACK	black square	black circle	black triangle	black heart	black rectangle	black oval

Figure 3. An example of stepwise training. The two-word labels selected for training contain an overlap among the stimulus components [e.g., red circle, red triangle, yellow triangle, yellow square, blue square, blue heart].

Although early recombinative generalization research focused on recombination of two-and three-word phases [e.g., Striefel, Wetherby, Karlan, 1976, 1978] or simple sentences [e.g., Lutzker, Sherman, 1974], more recent studies have investigated recombinative generalization of units that are smaller than words (i.e., syllables or onset/rime units) [e.g., de Rose et al., 1996; Goswami, 1986, 1990; Mueller et al., 2000; Saunders, O'Donnell, Vaidya, Williams, 2003]. Recombination of within-word units is particularly relevant to the acquisition of novel word reading and spelling.

de Rose and colleagues [1996] taught seven first-grade Brazilian children to read 51 words that consisted of two or three syllables. The teaching procedures consisted of matching printed to dictated words, copying printed words with movable letters, and naming words. Upon reaching mastery criterion on reading the 51 words, the children were asked to name 45 untrained words. The untrained words were constructed by rearranging the syllables of the training words (e.g. if the trained Portuguese words were „bolo" and „vaca," the generalization word was „boca"). Three of the seven children named correctly at least 65% of the untrained words. Additionally, those three children spelled correctly at least 60% of the untrained words. Thus, correct performance on the reading generalization task indicated that the children learned that spoken words consist of syllables (i.e., auditory abstraction) and that those syllables correspond to specific letter combinations no matter in which word they occur or in what position. The three children's performance demonstrated the alphabetic principle. Moreover, the children understood that they could spell novel words by rearranging the small units comprising the trained words. The results of de Rose et al. [1996] were replicated by Melchiori, de Souza, de Rose [2000].

Mueller et al. [2000] investigated recombinative generalization of within-syllable units (i.e., onsets and rimes) using matrix training. Three kindergartners were taught, using a match-to-sample procedure, to select several printed words containing overlapping onsets and rimes [e.g., mat/sat/sop/sug) upon hearing those words. The researchers were interested in whether the children would correctly select untrained printed words formed by rearranging letters of the trained words [e.g., mop/mug]. The three participants demonstrated generalization after little training (on one or two word sets out of six). This performance indicates the abstraction of onset and rime units and the recombination of those units. The researchers also asked the participants to name the 21 words used in the study before and after the match-to-sample training. None of the children read any of the words at the beginning of the study. At the end, the participants read 65%, 0%, and 20% of the words. The word naming results for the first participant suggest the development of control by units smaller than onsets and rimes (individual phonemes). Because there was a considerable overlap in letters among the study words [e.g., „mop" and „map"], the first participant's word naming was most likely under the control of all of the letters. Such performance is not common in beginning readers as they often name words based on the first letter only [Ehri, 1992]. The results of Mueller et al. [2000], especially those pertaining to selection of novel printed words, were reproduced using adults with mental retardation by Saunders et al. [2003].

Finally, Goswami [1993] showed that when young prereaders were taught to read a „clue" word [e.g., „bug"], they were more likely to read correctly untrained words with a rime that overlapped with the „clue" word [e.g., „rug"]. However, the generalization results were modest, potentially due to a lack of prerequisite skills for complete generalization (i.e., cue words containing the initial consonants were not taught). Goswami [1986] referred to the children's performance as reading by analogy, but the participants' performance was clearly an example of abstraction and recombination. The positive results on abstraction and recombinative generalization shown in the studies done by Saunders and colleagues as well as Goswami, along with the interrelated nature of reading and spelling, suggest that generalized spelling skills might also be promoted by matrix training.

In summary, behavior analysts have pointed to abstraction and recombinative generalization as processes involved in generative responding in early literacy skills. However, the research on those processes is still at its beginnings. Especially, there are very few studies that examined and programmed for recombinative generalization of within-word units in spelling [e.g., Kinney et al., 2003]. The main purpose of the present study was to determine whether a matrix training strategy could be used to demonstrate recombinative generalization in spelling three-letter words. Additionally, we investigated the relation between the children's spelling and printed word naming accuracy of the words included in the present study. Finally, we examined the effectiveness of the visual prompt fading procedure for teaching spelling of three-letter words.

2. GENERAL METHOD

2.1. Participants

Three typically developing girls – Ella, Connie, and Molly – participated. They were 53-, 60-, and 59-months-old, respectively. Their age equivalents of the Peabody Picture Vocabulary test were 100-, 109, and 89-months, respectively. The participants attended a university-based preschool. The parents were professionals and at least one in each family worked at the university. We selected participants who named correctly at least 8 of the 11 letters used in the study and who had some rudimentary reading skills. The descriptions of how the relevant skills were assessed and trained, if needed, are provided in the „Study Phases – Method and Results" section.

The three participants were receiving individualized reading instruction in their preschool using Sullivan's Programmed Reading Series [Buchanan, 1988]. This series teaches letter-sound correspondences and blending of sounds. All three participants were just beginning the series. Molly was in the Primer and Ella and Connie were in Book 1A. There are 23 books in the series. The participants had been introduced to two vowel sounds (/a/, /i/) and nine consonant sounds (/p/, /m/, /n/, /f/, /c/, /s/, /t/, /th/, /l/). They also started learning to read a few three-letter words [e.g., mat, pin]. The approximation of grade level reading was the very beginning of Grade 1 (i.e., first month). Throughout the course of the study the girls were not introduced to additional letter sounds. They were at approximately the same place in the reading curriculum at the end of the study as at its beginning.

2.2. Apparatus

Sessions were conducted in a small room equipped with a child-sized table, two chairs, and a one-way mirror. All sessions were programmed on a Macintosh computer with a touch-sensitive monitor. The child sat in front of the computer, which was placed on the table, and the experimenter sat to the right of the participant. Session events were controlled and data were recorded by software written by Dube et al. [1991]. Visual stimuli (pictures, words, or letters) were presented on the computer screen and auditory stimuli (recorded female voice) were presented via external speakers.

2.3. General Procedure

We usually conducted two sessions per day with a 3-5 minute break in between them. Each session consisted of 12 trials. Sessions took place at approximately the same time of day and were conducted on average four times a week, depending on the participants' availability and willingness to participate. From the very first to the very last session in the study, the time span was 18 weeks for Ella (nine weeks of actual participation with a 3-month summer-break between the seventh and the eighth week), seven weeks for Connie, and 11 weeks for Molly.

2.4. The Five Session Formats

This section provides a general description of the five types of sessions used in the study: table-top tutoring, matching-to-sample, constructed-response copying, constructed-response spelling, and letter- and word-naming. Table-top tutoring and matching-to-sample sessions were used only in the Pretraining Phase (Phase 1). With the exception of table-top tutoring, all teaching and testing sessions were computerized. The same font was used across these sessions. The font was SPELLFont size 70.

Table-top tutoring. These sessions were used to teach the prerequisite skills (i.e., letter and printed word naming), if necessary, and to establish rapport with the participants. Table-top sessions usually did not last longer than 5-7 minutes. The stimuli used were flashcards with either individual lowercase letters or three-letter words written on them. The experimenter used modeling and prompting to evoke correct responses. The consequence for correct answers was social praise. The consequence for incorrect answers was „No" said by the experimenter, a correct answer provided by the experimenter, and a repetition of the trial. After the end of each tutoring session, the participant and the experimenter engaged in a playful activity of the participant's choice [e.g., doing a puzzle, playing with Barbies, etc.].

Matching-to-sample sessions (MTS). During the Pretraining phase, the participants were assessed and trained, if necessary, using the MTS procedures. Visual stimuli were presented on a computer screen in five touch-sensitive zones, one located in the center of the screen and one in each of the four corners. Each trial began with a presentation of a sample stimulus in the center of the screen. Touching it was followed by a presentation of two comparison stimuli in two of the four corners of the screen; the two other corners were blank. The sample remained present, and further touches to it had no programmed consequences. One comparison, S+, was identical to the sample, and the other, S-, was different. A touch to S+ was followed by a 1-s flashing screen display and melodic tones, and social praise provided by the experimenter. A touch to any of the other three corner squares (S- or a blank) was incorrect, and was followed by 3-s blackout of the screen. The experimenter did not provide any feedback contingent on incorrect responding. A 3-s intertrial interval, during which the screen was blank, followed either form of feedback. Touching the blank screen reinstated the 3-s interval.

Constructed-response copying sessions (CRC). CRC sessions involved constructing a word by copying the model (i.e., written word) letter by letter. The screen display used for the CRC sessions is presented in Figure 4a. It consisted of two white rectangles on a white background and two buttons (START OVER and DONE). The sample display area and the construction area were in the upper rectangle, and the choice pool area was in the lower rectangle. The START OVER button was in the upper left corner and the DONE button in the upper right corner. CRC involved constructing the word that was displayed in the sample area (Figure 4b). A touch to the sample produced an array of individual letters in the choice pool area. As the participant touched the choice pool letters, a „copy" of each letter moved up into the construction area, resulting in a constant number of letters in the choice pool. Pressing the START OVER button erased all the letters in the construction area, allowing the participants to construct the word again. After the participant constructed the word, she touched the DONE button. The consequences were the same as during the MTS sessions.

Constructed-response spelling sessions (CRS). CRS sessions involved constructing a word in response to this word being spoken by the computer. For these spoken-to printed-word constructed-response sessions, the screen display was the same as in the CRC sessions. Trials began with the presentation of a spoken word corresponding to the word to be constructed, and 11 letters in the choice pool (Figure 5). The participant repeated the word to be spelled to ascertain that she heard the right word. In the CRS sessions, the participants constructed their responses in the same way as in the identity CRC sessions. The consequences for correct or incorrect responding were the same as well.

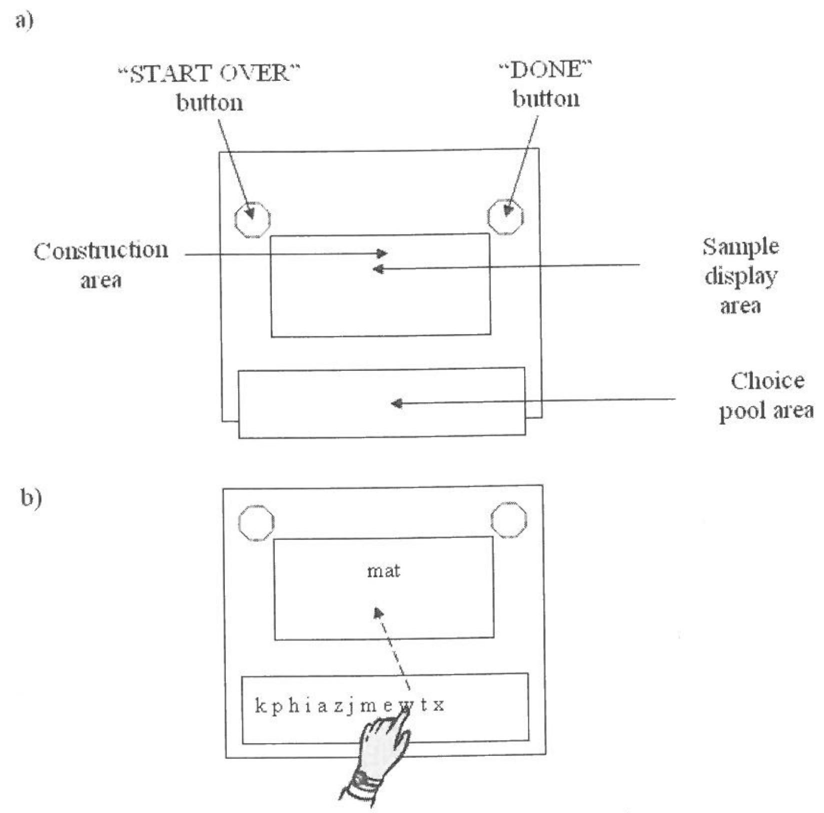

Figure 4. Two graphics representing the screen display used for constructed-response copying (CRC) sessions (a) and a mechanism for constructing words during CRC sessions (b)

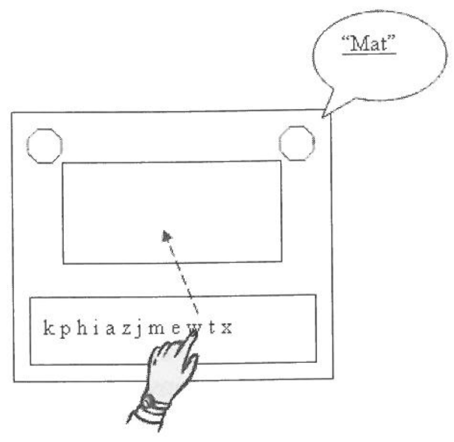

Figure 5. A graphic representing the screen display used for constructed-response spelling (CRS) sessions and a mechanism for constructing words during CRS sessions.

Sessions using any of the three computerized teaching procedures were sometimes presented without feedback. In sessions designated as „without feedback," responses produced only the intertrial interval (i.e., there were no consequences for correct or incorrect responses). Before the start of the session, the participants were told, „This time the computer will not tell you how you are doing. It will not make sounds, but I want you to do your best." The participants received small trinkets after each training and testing session regardless of performance.

Letter- and word-naming sessions. These sessions were used to test the participants' letter- and printed word-naming skills. The computer display consisted of a white screen in the middle of which individual, lower case letters or three-letter words written in lower case appeared. The experimenter initiated and ended each trial by pressing the „Enter" button on the keyboard. She manually scored accuracy of letter- and word-naming using the keyboard. The word naming sessions were audio taped for future calculations of reliability. The audiotaped sessions were put in random order and were given to an independent observer to score. The scores of the independent observer and the experimenter were compared on trial-by-trial basis for at least 40% of the word-naming sessions for each participant.

2.5. Overview of Phases

The experiment consisted of four phases. The order of the phases and the procedures included in each phase are depicted in Figure 6. The specific methods for testing and training the children in each phase as well as the results for each phase are described in the „Study Phases – Methods and Results" section.

2.6. Word Sets

The dependent measure of primary interest was the participants' accuracy on spelling of the 26 words used in the study. From this point onward, we will refer to those words as study words. The 26 words were arranged into 6 sets, as shown in Table 1. There were six words in each word set. A word set contained all possible combinations of two onsets and four rimes. For example, in Set 1, the onsets were „f" and „l" and the rimes were „ed," „og," „eg," and „od." Within each set, three words were designated as exemplar words and three other words were designated as generalization words. Within the generalization words, one word was called an onset/rime recombination word, and two were called within-rime recombination words. For example, in Set 1, the exemplar words were „fed, led, fog" the onset/rime recombination word was „log", and the within-rime recombination words were „leg, fod". The onset/rime recombination word was formed by combining one of the onsets from the exemplar words with one of the rimes from the exemplar words. This word served as one of the exemplar words in subsequent sets. The within-rime recombination words were formed by combining one of the onsets

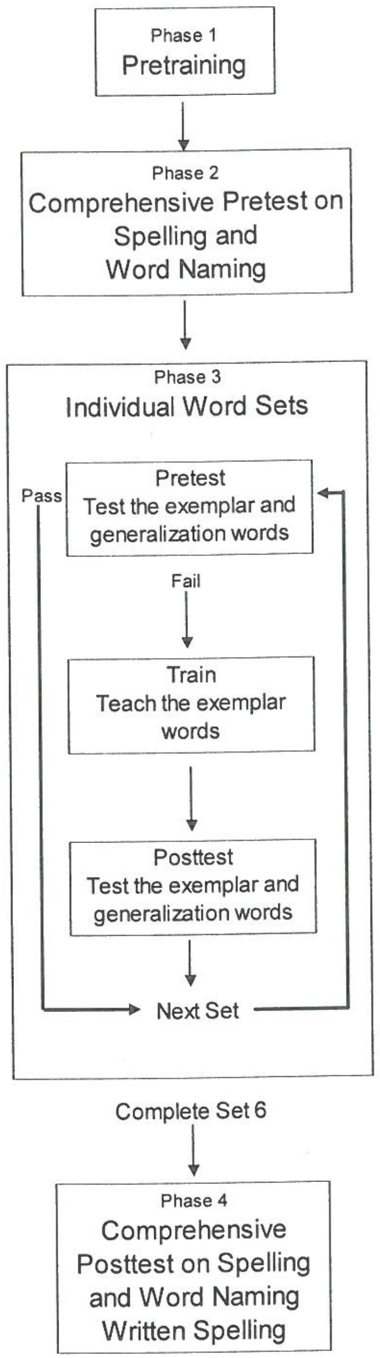

Figure 6. A graphic representing the order of the four phases of the experiment and the procedures included in each phase.

from the exemplar words with a rime that is a recombination of the exemplar rimes. These words were not included in subsequent sets. The exemplar words incorporated all of the components needed to form the generalization words.

3. STUDY PHASES – METHOD AND RESULTS

3.1. Phase 1: Pretraining

3.1.1. Method

We conducted six types of pretraining sessions (naming letters, naming words, auditory discrimination, CRC, CRS with feedback, and CRS without feedback). These sessions were designed to ensure that failure on the comprehensive spelling pretests could not be attributed to a lack of familiarity with the tasks, the specific stimuli, and the discrimination requirements involved. The four words used in the Pretraining CRS sessions („sit, tap, pin, nap") were taken from the participants' reading curriculum and did not include vowel sounds used later in the study.

Letter and word-naming. The letters used in the study were: f, e, d, l, o, g, h, b, m, r, and c. To determine whether the participants knew the names of the letters, we presented them with a letter-naming task. Each participant was shown an individual letter on a computer screen and was instructed: „Say the letter if you know it, but you can say: 'I don't know' if you do not know the letter. It is okay if you don't know the letter." Ten seconds were allotted for each response. If the participant did not respond within 10 seconds after the presentation of the letter, or did not name the letter correctly, the experimenter scored an incorrect response. If she made an unclear response, the experimenter prompted the child to repeat it. Each session consisted of 11 trials (1 trial per letter). If accuracy on the letter-naming task was 100% during the first session, this task ended. If accuracy was below 100%, training was administered.

The training was conducted in a table-top manner using index cards with individual lower case letters printed on them. The experimenter modeled the name of each letter to the child („This is 'h'") and then asked the child to name the letter independently („What letter is it?"). When the child named the letters off the index cards at 100% accuracy three sessions in a row, they were given the computer letter naming session again. If the accuracy was 100%, the letter naming training ended. If accuracy was below 100%, the table-top letter naming training continued and progressed according to the described criteria.

To ensure that participants read the four words used in the Pretraining Phase („sit, tap, pin, nap"), we presented them with a reading task. This task and its scoring were very similar to the letter naming task. The reading sessions consisted of 12 trials (3 trials per word). If the participants did not score 100% on this computerized reading session, training followed. The training was conducted in a table-top manner using index cards with individual printed words on them. Teaching followed the same format as teaching letter names. When the child read all four words off the index cards at 100% accuracy three sessions in a row, she was given the computer reading session again. If the accuracy was 100%, the reading pretraining ended. If accuracy was below 100%, the table-top reading training continued and progressed according to the described criteria.

Auditory discrimination. This two-choice MTS task ensured that the participants could discriminate the spoken consonant-vowel-consonant (CVC) words that differed by either onset or rime. We used eight words that were later used in the study and that could be represented by pictures. Three word pairs differed in onset only (bed-red, log-hog, fed-led), and three word pairs differed in rime only (hed-hog, fed-fog, led-log). The words were presented in quasirandom order as samples, and the comparisons were two photos. The correct choice was the photo that corresponded to the spoken word, and the incorrect choice was always the photo corresponding to the other member of the word pair. There were two trials per each pair of words (each word was presented as a sample once). If accuracy was 100% on one session or at least 92% on two consecutive sessions, this training ended.

Constructed-response copying (CRC). This training ensured that participants were familiar with the task of constructing a word using a written model. Later, the training in constructed-response spelling used CRC as a prompt. A session began when one of the three three-letter words (fed, led, fog) was displayed in the sample area. A touch to the sample produced an array of 11 letters in the choice pool area. First, the experimenter ran a 3-trial (one trial of each word) demonstration session in which she modeled for the participant what to do. She pointed to each letter in the sample word and said: „Find this letter and touch it just as I am doing it now." Next, a new session started for the participants to learn CRC. The three words were shown in a random order. When the participant constructed three consecutive words correctly, this training ended.

Constructed-response spelling (CRS). This task ensured that the participants were familiar with the spoken-to-printed word constructed-response training format and that they had mastered spelling of several words. We used four words („sit, tap, pin, nap") that were not in the group of the 26 study words. We will refer to those four words from this point on as baseline words.

As part of the training sequence, each word was taught individually using a prompt-fading procedure. A trial began when the word was displayed in the sample area and the computer presented a spoken word corresponding to the written word. The participants copied the written word (as in CRC). Across subsequent trials, the prompt of the written word was gradually faded, beginning with the absence of the third letter, then the second, and the first until finally the spoken word was not accompanied by a written one. The fading procedure advanced one step (one letter disappeared) following two correct responses and backed up one step (one letter was added) following an error. The training continued until the word was spelled correctly twice in a row in response to only the spoken word.

The sequence of teaching was as follows: teach the first word to mastery using prompt fading, teach the second word to mastery using prompt fading, teach a mixture of the two words to a criterion of four consecutive correct responses (two for each word), teach the third word to mastery using prompt fading, teach spelling words 1, 2, and 3 when they are presented randomly to a criterion of six consecutive correct responses, teach the fourth word to mastery using prompt fading, and teach a mixture of all four words presented randomly to a criterion of eight consecutive correct responses. The program automatically branched to the next teaching step when the mastery criterion was met. The criterion for ending this training was one full session at 100% or two consecutive sessions at 11/12 (92%) with all four words intermixed.

Constructed-response spelling without feedback (CRS without feedback). During this session, the participants were asked to spell the four baseline words (three trials per each word, presented randomly). They did not receive any feedback for correct or incorrect responding. This session was to prepare the participants for tests (without feedback) to be presented in Phase 2. If the accuracy was at least 92% on two consecutive sessions, Phase 1 ended. If accuracy was below 92%, retraining that was based on the child's error pattern was presented. Once the child completed retraining, she was given the CRS without feedback session again. If the accuracy was at least 92% on two consecutive sessions, Phase 1 ended. If accuracy was below 92%, retraining continued.

3.1.2. Results

All of the participants named at least 8 out of the 11 letters. Connie did not require any training on letter naming; Ella was trained on „b" and „d," and Molly was trained on „b," „d," and „h." Following the training, both Ella and Molly scored 100% on the computerized letter naming session. All three participants required training to name the four words. The initial accuracy on reading those words ranged from 0% to 25%. The participants required between four and eight table-top sessions to master naming those words. Following the training, their accuracy on the computerized word naming session was 100%. On auditory discrimination, both Ella and Molly scored 100% on the first session, and Connie scored 92% and 100% on two consecutive sessions. All three participants demonstrated mastery of the constructed-response copying in one session.

Regarding the constructed-response spelling of the four baseline words, Ella required 120 trials to demonstrate spelling mastery of those words. Connie required 96 trials, and Molly 240. Ella's and Connie's responding did not deteriorate when they were presented with the constructed-response spelling session with no feedback. Both of them scored 100% correct. Molly, however, scored 83% on the no feedback session and required retraining. Following this retraining, she scored 92% and 100% on the no feedback sessions.

3.2. Phase 2: Comprehensive Pretests on Spelling and Word-Naming

3.2.1. Method

Two kinds of pretests (i.e., spelling and word-naming) were administered during eight sessions. All pretest sessions were administered without feedback. The sessions consisted of 12 trials, within which eight or nine presented study words and the rest were baseline trials (four words taught in CRS pretraining). The baseline word trials were included to ensure that the participants experienced some success during the pretest sessions. Regarding the study word trials in each of the pretest sessions, there were two or three trials of exemplar words, two trials of onset/rime recombination words, and four trials of within-rime recombination words. Additionally, within each session the trials were distributed in a way to represent all of the onsets and rimes.

For both the comprehensive spelling pretest and comprehensive word-naming pretest, we presented four sessions, one per day. They had the same content and differed only in what the child was supposed to do – spell or name words. Three pretest sessions (sessions A, B, C) encompassed all of the study words with intermixed baseline words. The fourth session was a repetition of one of the pretest sessions to control for practice effects. Sessions A and B each had nine experimental trials (i.e, 9 of 26 study words were presented once each) and three baseline trials, which were randomly presented. Session C had eight experimental trials (i.e., the eight study words were also presented once each) and four baseline trials.

Comprehensive Pretest on Spelling. During the spelling pretest sessions, the participants were asked to spell words using CRS when they heard the words dictated by the computer. We measured the percentage of words spelled correctly. For example, if the participant was to spell „mop," but spelled „mep" instead, the score for the whole word was 0% correct. We also measured the percentage of correct letters in each word that were placed in appropriate positions. For example, if the participant was to spell „mop," but spelled „mep" instead, we scored 67% of letters in correct position because 2 of 3 letters were where they were supposed to be.

Comprehensive Pretest on Word-Naming. During the word-naming pretest sessions, the participants were asked to read the words presented on a computer screen. We measured the percentage of words read correctly. The experimented scored accuracy manually and taped most of the sessions so that interobserver agreement could be assessed.

3.2.2. Results

The first panel of Figures 7, 8, and 9 shows accuracy on the comprehensive spelling pretest for the three participants. The bars show accuracy of whole words and the dots show accuracy of individual letter placement. The fourth column of Figures 10, 11, and 12 provides the participants' actual responses to each test trial. Figure 7 shows that Ella did not spell any of the 26 study words correctly on the comprehensive pretest. Her accuracy on the baseline words, however, was perfect (not shown in Figure 7). For the study words, she did type some letters and placed them in correct positions. She placed 29%, 56%, and 33% of letters in correct positions for the exemplar, onset/rime recombination, and within-rime recombination words, respectively. Figure 10 shows that Ella typed each of the seven onsets on at least one occasion. Additionally, for 9 of the 13 words (69%) that had the vowel „o" in the middle, she placed „o" in the correct position. In contrast, she never typed „e."

Figure 8 shows that Connie did not spell any of the 26 study words correctly. She spelled 3 of 4 baseline words correctly (not shown in Figure 8). Similar to Ella, she also placed some of the letters in correct positions. She typed 33% of letters for the exemplar words, 39% for the onset/rime generalization words, and 36% for the within-rime recombination words. Figure 11 shows that Connie typed in the correct onset for 25 of the 26 words. For „mog," she typed in „log" although she correctly repeated the word to be spelled. With the exception of „mog" she never spelled any of the rimes.

Figure 9 shows that Molly did not spell any of the study words correctly on the comprehensive spelling pretest. Her accuracy on the baseline words was perfect (not shown in Figure 9). Molly placed 25% of letters in correct positions for the exemplar words, 17% for the onset/rime recombination words, and 22% for the within-rime recombination words. Figure 12 shows that Molly typed correctly the onsets „f, l, b, m, r" for most of the appropriate words. She never typed the onsets „h" or „c" for the appropriate words. Additionally, she did not spell any rimes.

Finally, Figure 13 (the first bar in each panel) shows accuracy on the comprehensive word-naming pretest for the three participants. Ella named correctly 8% of the study words; Connie read 38%; and Molly 15 %. The participants' accuracy on the baseline words varied. Molly named correctly 93 % of the four words, Connie 100%, and Molly 60%. The reliability of the word-naming results was calculated using at least 40% of the trials for each participant. The reliability for Ella was 94%, for Connie 88%, and for Molly 97%.

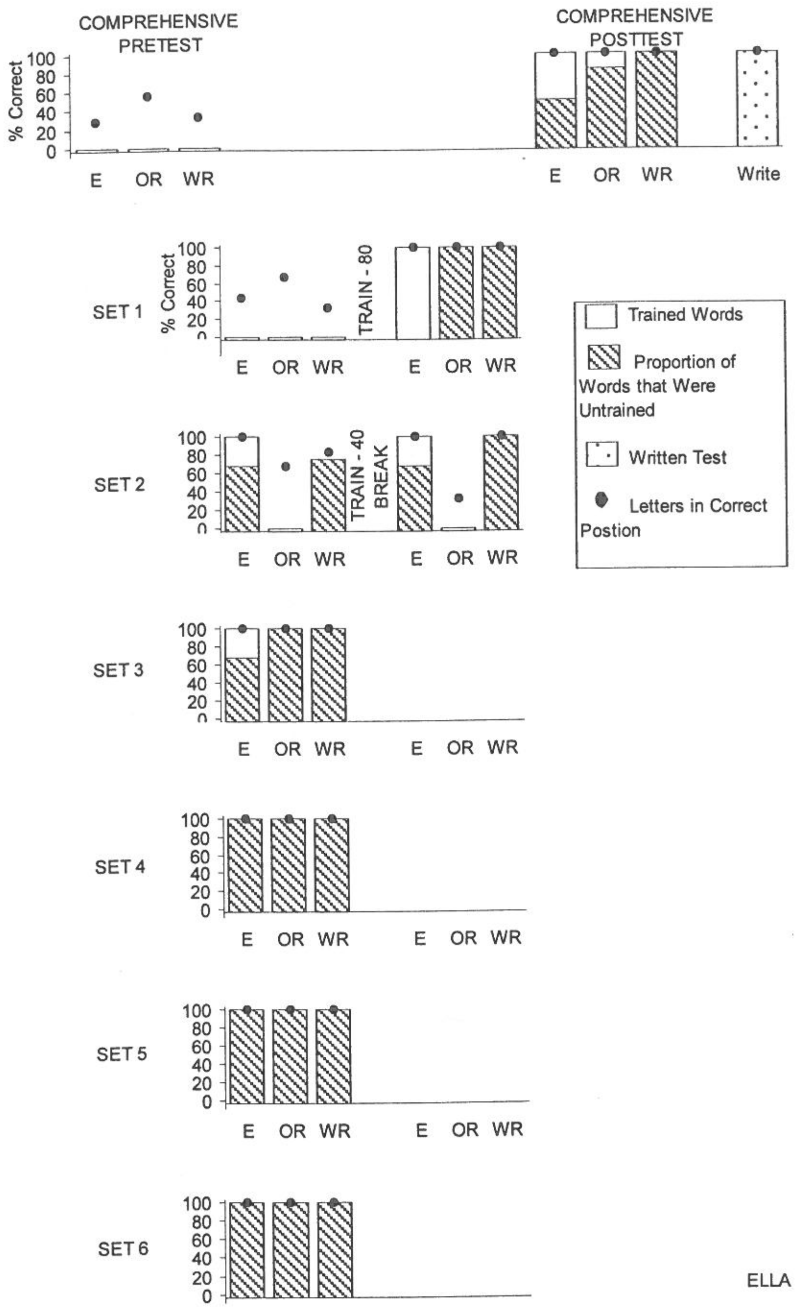

Figure 7. Ella's accuracy of words spelled correctly (bars) and letters in correct position (dots) in each of the three word groups (E = exemplar words, OR = onset/rime recombination words, WR = within-rime recombination words) during the comprehensive spelling pretest, the individual word set tests, the comprehensive spelling posttest, and the written spelling test. Training is indicated by the word "TRAIN" followed by the number of trials required for criterion accuracy.

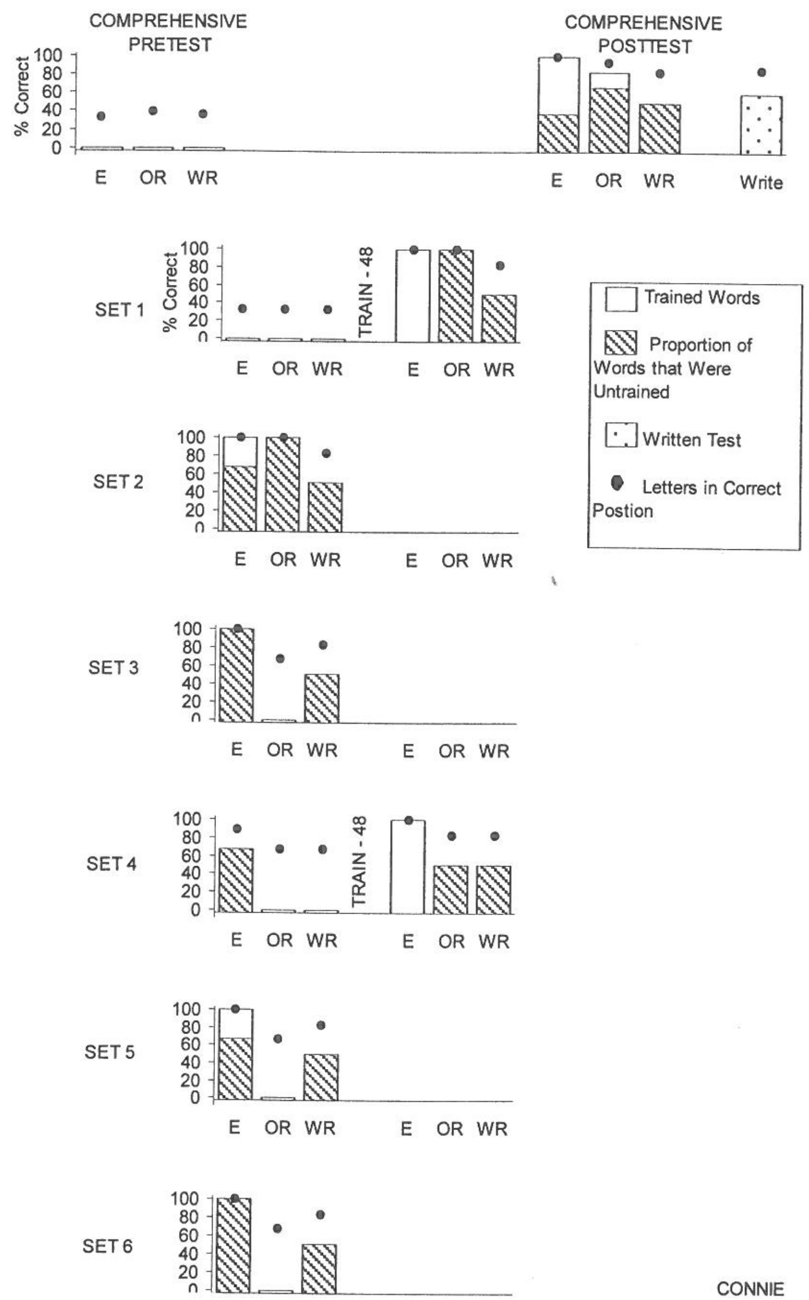

Figure 8. Connie's accuracy of words spelled correctly (bars) and letters in correct position (dots) in each of the three word groups (E = exemplar words, OR = onset/rime recombination words, WR = within-rime recombination words) during the comprehensive spelling pretest, the individual word set tests, the comprehensive spelling posttest, and the written spelling test. Training is indicated by the word "TRAIN" followed by the number of trials required for criterion accuracy.

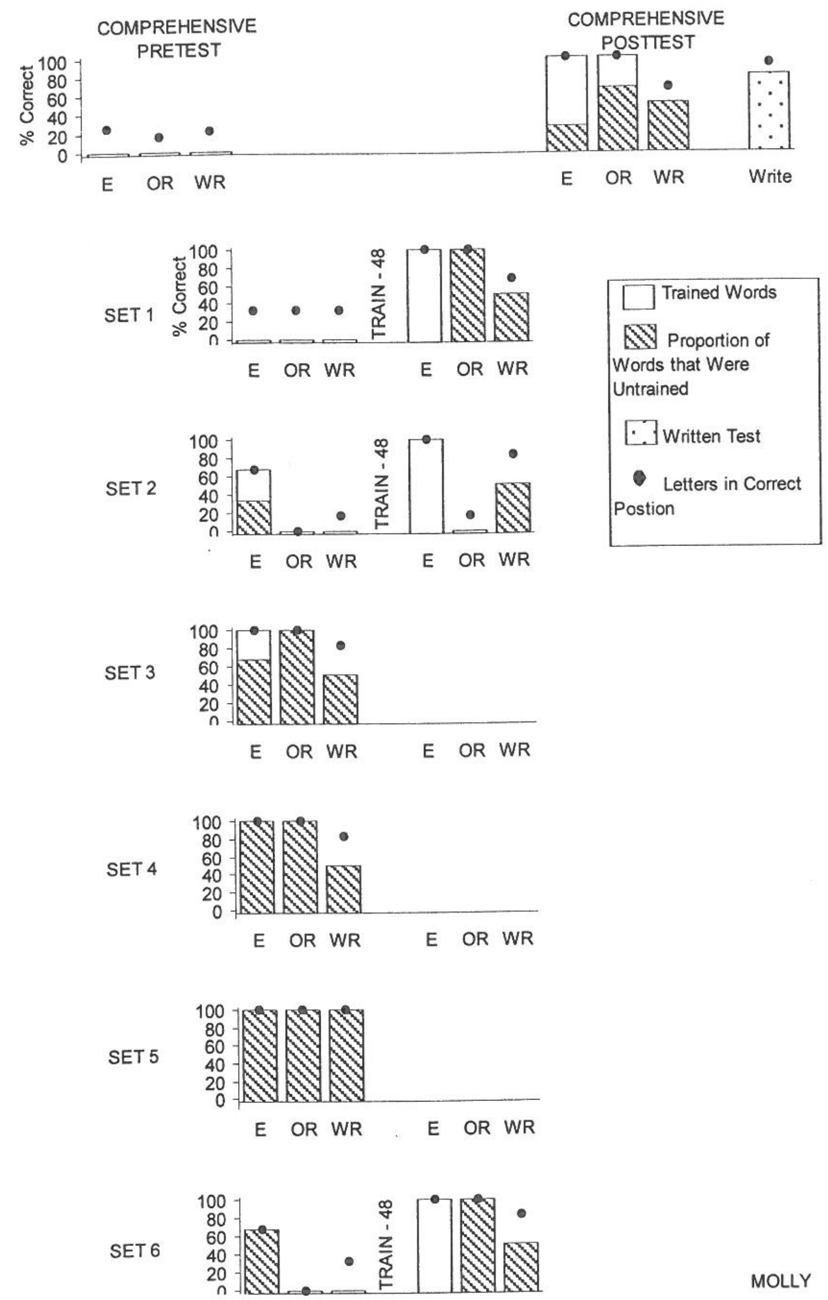

Figure 9. Molly's accuracy of words spelled correctly (bars) and letters in correct position (dots) in each of the three word groups (E = exemplar words, OR = onset/rime recombination words, WR = within-rime recombination words) during the comprehensive spelling pretest, the individual word set tests, the comprehensive spelling posttest, and the written spelling test. Training is indicated by the word "TRAIN" followed by the number of trials required for criterion accuracy.

Pretest				Set 1		Set 2						Set 3			Set 4			Set 5			Set 6			Posttest			
Set	Word	Score	Incorrect response	Train	Post	Pre	Train		Pre	Train	Post	Pre	Train	Post	Pre	Train	Post	Pre	Train	Post	Pre	Train	Post	Score	Incorrect response	Write	Incorrect Response
6	rod	67-0	rob																		100-100			100-100		100-100	
	ceg	33-0	c																		100-100			100-100			
	cog	67-0	coc																		100-100			100-100		100-100	
	ced	0-0	***																		100-100			100-100		100-100	
5	mod	67-0	mob															100-100						100-100			
	reg	33-0	r															100-100						100-100			
	rog	67-0	ro															100-100			100-100			100-100			
	red	33-0	r															100-100			100-100			100-100			
4	bod	33-0	dob												100-100									100-100			
	meg	33-0	m												100-100									100-100			
	mog	67-0	mo												100-100			100-100						100-100		100-100	
	med	33-0	m												100-100			100-100						100-100			
3	hod	0-0	ob									100-100												100-100			
	beg	33-0	b									100-100												100-100		100-100	
	bog	67-0	bo									100-100			100-100									100-100			
	bed	0-0	d									100-100			100-100									100-100		100-100	
2	lod	33-0	l			100-100			100-100															100-100			
	heg	0-0	o			67-50			100-100															100-100			
	hog	0-0	o			67-0			33-0			100-100												100-100			
	hed	33-0	h			100-100	T		100-100			100-100												100-100		100-100	
1	fod	33-0	fd		100-100																			100-100			
	leg	33-0	l		100-100																			100-100			
	log	67-0	lo		100-100	100-100	T		100-100															100-100		100-100	
	fog	67-0	fo	T	100-100																			100-100		100-100	
	led	33-0	l	T	100-100	100-100	T		100-100															100-100			
	fed	33-0	f	T	100-100																			100-100		100-100	

Figure 10. Ella's accuracy on the comprehensive spelling pretest, the individual word set tests, the comprehensive spelling posttest, and the written spelling test. The two numbers in each cell represent percent of letters in correct position (first number) and percent of words spelled correctly (second number). Letter "T" represents training and shaded cells represent words not directly taught. Beginning with Set 1, columns labeled "Pre" or "Post" indicate one test session, whereas columns labeled "Train" indicate the occurrence of one or more training sessions - until criterion

Pretest				Set 1		Set 2			Set 3			Set 4			Set 5			Set 6			Posttest			
Set	Word	Score	Incorrect response	Train	Post	Pre	Train	Post	Pre	Train	Post	Pre	Train	Post	Pre	Train	Post	Pre	Train	Post	Score	Incorrect response	Write	Incorrect Response
6	rod	33-0	r															67-0			67-0	red	67-0	red
	ceg	33-0	c															100-100			100-100			
	cog	33-0	c															67-0			100-100		67-0	ceg
	ced	33-0	c															100-100			100-100			
5	mod	33-0	m												67-0						67-0	med		
	reg	67-0	rcg												100-100						100-100			
	rog	33-0	r												67-0			100-100			67-0	reg		
	red	33-0	r												100-100			100-100			100-100			
4	bod	33-0	b									67-0		67-0							67-0	bed		
	meg	33-0	m									67-0		100-100							100-100			
	mog	67-0	log									67-0		83-50	100-100						100-100		67-0	meg
	med	33-0	m									100-100	T	100-100	100-100						100-100			
3	hod	33-0	h						67-0												67-0	hed		
	beg	33-0	b						100-100												100-100		100-100	
	bog	33-0	b						67-0			67-0	T	100-100							100-100			
	bed	33-0	b						100-100			100-100	T	100-100							100-100		67-0	bad
2	lod	33-0	l			67-0															67-0	led		
	heg	33-0	h			100-100															100-100			
	hog	33-0	h			100-100			100-100												100-100			
	hed	33-0	h			100-100			100-100												100-100		100-100	
1	fod	33-0	f		67-0																67-0	fed		
	leg	33-0	l		100-100																100-100			
	log	33-0	l		100-100	100-100															100-100		100-100	
	fog	33-0	f	T	100-100																100-100		100-100	
	led	33-0	l	T	100-100	100-100															100-100			
	fed	33-0	f	T	100-100																100-100		100-100	

Figure 11. Connie's accuracy on the comprehensive spelling pretest, the individual word set tests, the comprehensive spelling posttest, and the written spelling test. The two numbers in each cell represent percent of letters in correct position (first number) and percent of words spelled correctly (second number). Letter "T" represents training and shaded cells represent words not directly taught. Beginning with Set 1, columns labeled "Pre" or "Post" indicate one test session, whereas columns labeled "Train" indicate the occurrence of one or more training sessions - until criterion met.

Pretest				Set 1		Set 2			Set 3			Set 4			Set 5			Set 6			Posttest			
Set	Word	Score	Incorrect response	Train	Post	Pre	Train	Post	Pre	Train	Post	Pre	Train	Post	Pre	Train	Post	Pre	Train	Post	Score	Incorrect response	Write	Incorrect Response
6	rod	0-0	***															67-0		67-0	67-0	red	67-0	rid
	ceg	0-0	***															0-0		100-100	100-100			
	cog	0-0	***															0-0		100-100	100-100		67-0	gog
	ced	0-0	***															0-0	T	100-100	100-100		100-100	
5	mod	33-0	m												100-100						67-0	med		
	reg	33-0	r												100-100						100-100			
	rog	33-0	r												100-100			100-100	T	100-100	100-100			
	red	33-0	r												100-100			100-100	T	100-100	100-100			
4	bod	33-0	b									67-0									67-0	bed		
	meg	33-0	m									100-100									100-100			
	mog	0-0	l									100-100			100-100						100-100		100-100	
	med	33-0	m									100-100			100-100						100-100			
3	hod	0-0	***						67-0												67-0	hed		
	beg	33-0	b						100-100												100-100		100-100	
	bog	33-0	b						100-100			100-100									100-100			
	bed	33-0	b						100-100			100-100									100-100		100-100	
2	lod	33-0	l			33-0		67-0													33-0	l		
	heg	0-0	***			0-0		100-100													100-100			
	hog	0-0	f			0-0		17-0	100-100												100-100			
	hed	0-0	***			0-0	T	100-100	100-100												100-100		100-100	
1	fod	33-0	f		33-0																33-0	f		
	leg	33-0	l		100-100																100-100			
	log	33-0	l		100-100	100-100	T	100-100													100-100		100-100	
	fog	33-0	f	T	100-100																100-100		100-100	
	led	33-0	l	T	100-100	100-100	T	100-100													100-100			
	fed	33-0	f	T	100-100																100-100		100-100	

Figure 12. Molly's accuracy on the comprehensive spelling pretest, the individual word set tests, the comprehensive spelling posttest, and the written spelling test. The two numbers in each cell represent percent of letters in correct position (first number) and percent of words spelled correctly (second number). Letter "T" represents training and shaded cells represent words not directly taught. Beginning with Set 1, columns labeled "Pre" or "Post" indicate one test session, whereas columns labeled "Train" indicate the occurrence of one or more training sessions - until criterion met.

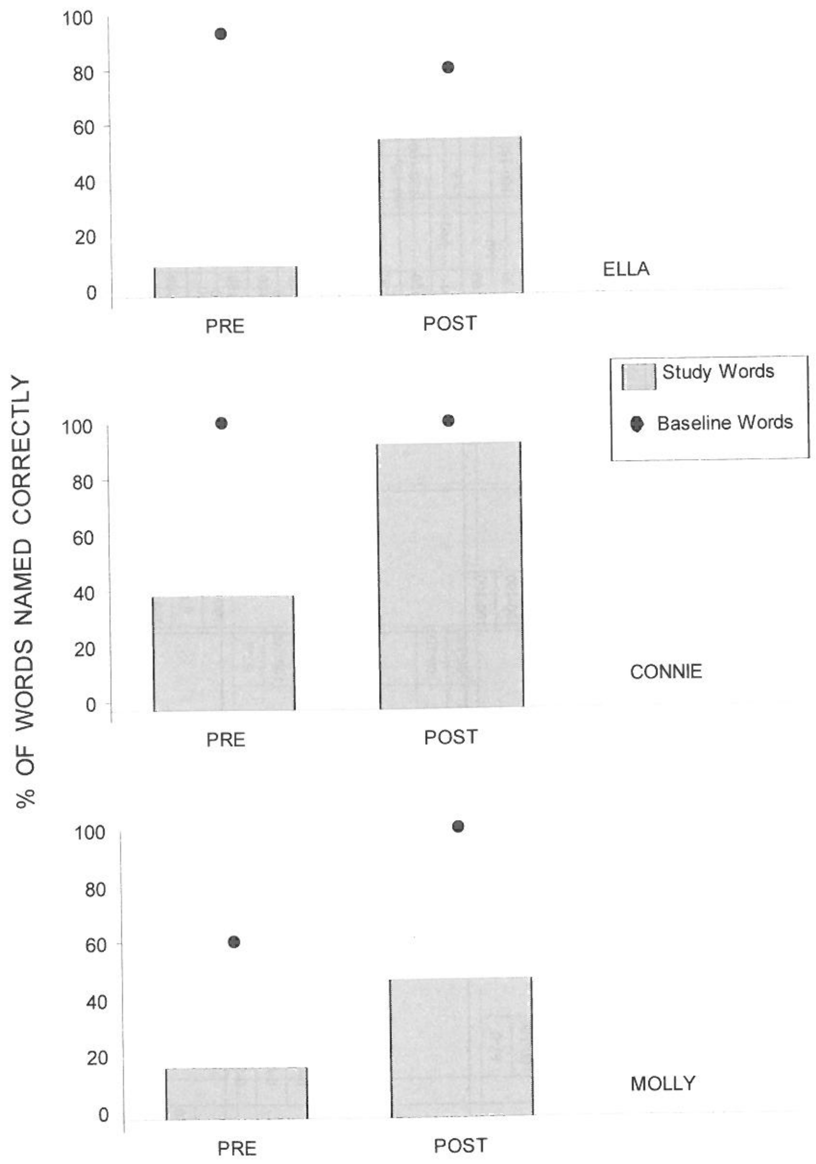

Figure 13. Ella's, Connie's, and Molly's accuracy on the comprehensive word-naming pretest and posttest. Bars represent the study words and black dots represent the baseline words

3.3. Phase 3: Individual Word Sets: Pretest, CRS Training, and Posttest

3.3.1. Method

Tab. 1. Selection and arrangement of the 26 study words into six sets

Set	Exemplar Words			Generalization Words		
				Onset/Rime	Within Rime	
1	fed	led	fog	log	leg	fod
2	led	hed	log	hog	heg	lod
3	hed	bed	hog	bog	beg	hod
4	bed	med	bog	mog	meg	bod
5	med	red	mog	rog	reg	mod
6	red	ced	rog	cog	ceg	rod

Word sets were presented in the order shown in Table 1.Training and testing followed the same sequence of steps for each word set, as shown in Figure 1. All sessions consisted of 12 trials and used the CRS teaching procedure.

Pretest. Each pretest was given „without feedback." The first three trials were presentations of the three exemplar words from the previous set. These words were mastered by the time they were used in these pretests. If the three words were not spelled correctly, the program continued with the exemplar words. If the first three words were spelled correctly, the program automatically branched to the other nine trials. The other nine trials were intermixed presentations of the six words from the set that was being pretested (one trial per word) and the three exemplar words from the previous set. The pretest was omitted for Set 1; Set 1 pretest data were taken from the comprehensive spelling pretest.

Beginning with Set 2, if the child scored 100% correct on the exemplar words in the set that was pretested [e.g., words „led", „hed", and „log" for Set 2], she moved directly to the pretest for the next word set. That is, a child could miss some or all of the onset/ rime and within-rime recombination words during the pretest, and still move to the pretest for the next set. The reason for this rule was that training and posttesting was not necessary if the participant spelled correctly at the pretest all words that were to be trained. If a participant did not score 100% correct on the exemplar words in the set that was being pretested, she moved to the training phase.

CRS Training. These sessions involved the three exemplar words in each set. The training sequence and mastery criteria (described in the CRS section) were the same for all of the sets.

Posttest. Each posttest was given „without feedback." The first three trials were presentations of the three exemplar words learned in the current set. If the child was correct on those three trials, the program automatically branched to the other nine trials. These trials were intermixed presentations of the exemplar words (three trials) and the generalization words (six trials – two trials per word).

3.3.2. Results

Figures 7, 8, and 9 (six panels representing the six word sets) and Figures 10, 11, and 12 (columns representing testing and teaching of the six word sets) present accuracy on the pretests and posttests for the individual word sets.

Figure 7 shows that on Set 1 Ella did not spell any of the six words correctly. She was trained on the exemplar words in Set 1 („fed, led, fog"). Ella required 80 trials of training to reach mastery criterion on the three words. She made two mistakes on those 80 trials. Following training, she spelled all of the Set 1 generalization words correctly („log, leg, fod"). When we administered the pretest for Set 2, Ella spelled correctly the exemplar words („led, hed, log"), two of which had not been yet taught. Thus, the proportion of words spelled correctly without direct training was 67%. She did not spell the onset/rime recombination word („hog") and she spelled correctly 75% of the within-rime recombination words („heg, lod"). For the within-rime recombination words, she missed „heg" once by spelling it „hg." For the onset/rime recombination word, she spelled it „oog" twice. We began training Ella on Set 2. She received 40 trials of training before the summer break began. She made one mistake during training. Due to the break, she had not had sessions for approximately three months. When she returned to school, we administered the pretest for Set 2 again. She showed nearly perfect recombination (missed „hog" only by typing „oeg"). From this point on, she had not made any mistakes on the subsequent Pretests. We did not administer any further training or posttests on individual sets, because we followed the rule specifying that if a participant spelled all of the exemplar words correctly on a pretest for a given set, they should move on to the pretest for the next set. To summarize, Ella was taught to spell five words („fed, led, fog, log, hed") and she constructed the rest of the study words (21) correctly without additional training (see also Figure 10).

Figure 8 shows that on Set 1 Connie did not spell any of the six words correctly. We trained her on the exemplar words. Connie required 48 trials to reach mastery criterion on the three words. She made one mistake during training. Following training, she spelled the exemplar words and the onset/rime recombination word 100% correctly. She scored 50% correct on the within-rime recombination words by spelling „leg" correctly on two trials, and missing „fod" on two trials. However, the percentage of letters in correct position for „fod" was scored as 83% because she put 4 out of 6 letters in correct positions. That is, she spelled „fed" instead of „fod" twice. When we administered the pretest on Set 2, Connie spelled correctly the three exemplar words and the onset/rime recombination word. She missed 50% of the within-rime recombination words. She spelled correctly „heg" but misspelled „lod." Since she put „led" instead of „lod," the percent of letters placed in correct positions for the within-rime recombination words was 83%. Following the study's procedures, we did not train Set 2. On the pretest for Set 3, Connie spelled correctly all of the exemplar words, did not spell the onset/rime recombination word, and spelled 50% of the within-rime recombination words. Again, the percentage of letters in correct position was higher than the percentage of words spelled correctly because for almost every misspelled word, she placed two letters (the first and the last one) in correct positions. Because Connie did not score 100% on the exemplar words on the pretest for Set 4, she was trained on this set. She required 48 trials to reach the mastery criterion and did not make any mistakes on those trials. Following this training, she spelled correctly the exemplar words, and 50% of the onset/rime and within-rime recombination words. For both groups of words, she put the incorrect vowel when she was spelling the words with „o" in the middle. Thus, the percentage of letters in correct position amounted to 83%. The results for the pretests for Sets 5 and 6 are very similar. Connie spelled 100% of the exemplar words, neither of the onset/rime recombination words, and 50% of the within-rime recombination words. The mistakes were associated with the vowel „o." In summary, Connie was trained on six words („fed, led, fog, bed, bog, med"). For the sets that did not require training (Sets 2, 3, 5, 6), this participant spelled correctly on the pretests 8 of 8 words that contained „e" in the rime („hed, heg, bed, beg, red, reg, ced, ceg") and only 1 of 8 words that contained „o" in the rime („hog") (see also Figure 11).

Figure 9 shows that on Set 1 Molly did not spell any words correctly. She required 48 trials to reach mastery criterion on the three exemplar words in Set 1. She did not make any mistakes during the training. Following training, she spelled correctly 100% exemplar and onset/rime recombination words, and 50% of within-rime recombination words. She misspelled „fod" twice by typing only „f." Thus, the percentage of letters in correct positions for the within-rime recombination words was 67%. On the pretest for Set 2, Molly spelled correctly 2 of the 3 exemplar words. Out of the two correctly spelled words, one had not been trained. Molly scored 0% correct on the onset rime recombination and the within-rime recombination words. Additionally, the percentage of letters in correct positions for these words was very low (17% at the most). She required 48 trials to reach mastery criterion during training for Set 2. She did not make any mistakes. Following training, Molly spelled correctly all of the exemplar words, none of the onset/rime recombination words, and 50% of the within-rime recombination words. She missed „hog" and „lod" on both trials for each word. The percentage of letters in correct positions increased from 0% to 17% for the onset rime recombination words and from 17% to 83% for the within-rime recombination words. On the pretest for Sets 3 and 4, Molly scored 100% correct on the exemplar and onset/rime recombination words and 50% on the within-rime recombination words. For the within-rime recombination words, she missed „hod" in Set 3 and „bod" in Set 4. Since she only misspelled the vowel in each of those words, the percentage of letters in correct positions for within-rime recombination words for both sets was 83%. The pretest on Set 5 showed perfect spelling of all six words within this set. However, on the pretest for Set 6, she spelled correctly 2 of the 3 exemplar words and none of the onset/rime or within-rime recombination words. She missed „rod" and all of the words that had „c" as the onset. She required 48 training trials to achieve mastery criterion on the three exemplar words in Set 6. She made one mistake during training. Following training, she spelled correctly all of the exemplar and onset/rime recombination words and 50% of the within-rime recombination words. For those words, she missed „rod" twice by constructing „red." Thus, the percentage of letters in correct positions was 83%. In summary, Molly was trained on eight words („fed, led, fog, log, hed, red, rog, ced"). For the sets that did not require training (Sets 3, 4, 5), this participant spelled correctly on the pretests 6 of 6 untrained words that contained „e" in the rime („bed, beg, med, meg, red, reg") and 4 of 6 untrained words that contained „o" in the rime („bog, mog, rog, mod") (see also Figure 12).

3.4. Phase 4: Comprehensive Posttest on Spelling and Word-Naming

3.4.1. Method

These final tests were given after a participant completed all six word sets. All sessions were administered without feedback. During this phase, only one session took place each day. First, we administered the comprehensive spelling posttests followed by the written spelling test on selected words. The comprehensive spelling posttest consisted of three sessions (A, B, C) that were identical to the comprehensive spelling pretest sessions. The written test consisted of one 10-trial session. The computer dictated the 10 words to be spelled one at the time. The letter pool was not visible. The child wrote the words on a piece of paper. The written test was given to investigate generalization of spelling across topographies (writing vs. constructing). Following the spelling posttests, we administered three sessions of the word-naming posttests, which were the same as the word-naming pretest sessions.

4.4.2. Results

Figures 7, 8, and 9 (first panel, the three bars entitled „Posttest") and Figures 10, 11, and 12 (the last four columns) present accuracy on the comprehensive spelling posttest and the written spelling test for the three participants. Figure 7 shows that Ella spelled correctly 100% of the three types of words. She spelled correctly eight exemplar words, four of which had not been trained (50%); six onset/rime recombination words, five of which had not been trained (83%); and 12 within-rime recombination words, none of which had been trained. Thus, Ella had been trained on five words and spelled correctly all 21 untaught words on the comprehensive posttest (see Figure 10). On the written test, she spelled correctly 10 out of 10 words.

Figure 8 shows that Connie spelled correctly 100% of the exemplar words, 83% of the onset/rime recombination words, and 50% of the within-rime recombination words. Regarding the exemplar words, 3 of the 8 words (38%) had not been trained yet spelled correctly. Out of the 5 onset/rime recombination words that Connie spelled correctly, 4 had not been trained (66%). The percentage of letters in correct positions for those words was 94%. Connie spelled half of the within-rime recombination words – all of the words with „eg" as the rime and none of the words with „od" as the rime. None of those words had been trained. The percentage of letters in correct positions was 83%. In summary, Connie spelled correctly all of the words that had been taught directly, plus 13 of 20 untaught words on the comprehensive posttest (see Figure 11). On the written test, she spelled correctly 6 of 10 words. The mistakes were associated with the vowels. The other letters in each misspelled word were correct. Thus, the percentage of letters in correct positions was 87%.

Figure 9 shows that Molly spelled correctly 100% of the exemplar and onset/rime recombination words, and 50% of the within-rime recombination words. Out of the eight exemplar words that were spelled correctly, only two had not been taught (25%). Four of the six onset/rime recombination words (67%) had not been taught and none of the six within-rime words that were spelled correctly had been trained. Regarding the within-rime recombination words that Molly misspelled, like Connie, she made errors on all of the „od" words. She missed the vowel in four words and she only spelled the first letter in two other words. Thus, the percentage of letters in correct positions was 67%. In summary, Molly spelled correctly all of the words that had been taught directly, plus 12 of 18 untaught words on the comprehensive posttest (see Figure 12). On the written test, she spelled correctly 8 of 10. She wrote „rid" instead of „rod" and „gog" instead of „cog." Thus, the percentage of letters in correct positions was 93%.

Finally, Figure 13 (the second bar in each panel) shows accuracy on the comprehensive word naming posttest for the three participants. Ella named correctly 54% of the study words; Connie read 92%; and Molly 46%. The participants' accuracy on the baseline words was 80% for Ella and 100% for both Connie and Molly. The reliability of the word naming results was calculated using 100% of trials. The reliability was 94% for Ella and 97% for both Connie and Molly.

4. DISCUSSION

The present study investigated whether children at a very early stage of reading instruction spelled correctly untrained CVC words once they had been trained to spell other words containing the same letters as the untrained words. The results showed that one child demonstrated nearly perfect recombination after she had been taught to spell five words; this child spelled correctly the remaining 21 study words without additional training. The other two children showed partial recombination. They were trained on six and eight words, respectively and spelled correctly two thirds of the remaining study words. These results provide a convincing demonstration of recombinative generalization of within-syllable units in spelling of three-letter words.

These positive results could have been facilitated by the use of matrix training. In some previous studies of within-word recombination, relatively small recombination effects were shown [e.g., Goswami 1986]. However, those researchers trained the participants on some, but not all, components that overlapped with the untrained words. Matrix training, in contrast, ensures that the trained words incorporate all of the elements needed to construct the untrained words. Matrix training results in mastery of the larger, trained units (CVC words) that are composed of common, smaller elements (onsets, rimes, or individual phonemes). Perfect accuracy on the untrained items would demonstrate recombinative generalization and show that an individual's responding is under the control of those smaller units. Matrix training, then, is an excellent means for programming recombinative generalization.

In this study, some generalization words required recombination of onsets and rimes (e.g., „log" in Set 1), and some required recombination within the rime (e.g., „leg," „fod" in Set 1). We expected that the participants would demonstrate recombinative generalization more readily for the onset/rime recombination words because these words included intact trained rimes. Thus, the construction of the within-rime recombination words might be expected to be more difficult. We also thought that if the participants did not demonstrate the onset/rime recombination, they would not demonstrate the within-rime recombination. However, the data from the present study did not support this prediction.

Regarding the first hypothesis, Ella's and Molly's responses on the tests for the individual word sets and on the comprehensive spelling posttest showed that those children spelled almost equally well all of the onset/rime recombination words („og" rimes) and all of the within-rime recombination words that included „eg" as the rime. The data for those two participants imply that the within-rime recombination words may not be more challenging to spell than the onset/rime recombination words, but this conclusion is merely suggestive because there was only one onset/rime recombination word per set. It is noteworthy that the errors were made mostly on the within-rime recombination words, especially those with „od" as the rime. This mistake pattern will be discussed later. Regarding the second hypothesis, on several occasions the participants misspelled the onset/rime recombination word, yet spelled correctly the within-rime recombination words (e.g., Ella on the second pretest for Set 2; Connie on the pretest for set 3; Molly on the posttest for Set 2). Thus, demonstrating recombination on the onset/rime recombination words was not a prerequisite for recombination on the within-rime recombination words.

Connie's and Molly's errors warrant further discussion. Generalization words in each set contained two words with „o" rimes: „og" and „od." Connie was given seven tests during Phase 3 of the experiment. She misspelled the words with the rime „og" on five of the seven tests and the words with the rime „od" on all of the tests. Furthermore, on the comprehensive spelling posttest she misspelled one of the six „og" words and all six „od" words. Molly was given eight tests during Phase 3. She misspelled the words with the rime „og" on three of the tests and the words with the rime „od" on seven of those tests. On the comprehensive spelling posttest, she did not spell correctly any of the „od" words. She did spell correctly all of the „og" words. Thus, the performances of Connie and Molly suggest that there is a difference in recombination involving „e" and recombination involving „o," especially the „od" rime. The present study's procedures and design did not allow firm conclusions as to what might have resulted in such a difference. However, this seemingly vowel-associated disparity could be due to the different amounts of practice the participants received on both vowels. In each set, the exemplar words included two words with „e" in the middle and only one with „o." Thus, when a participant was trained on the exemplar words, she received more training on the words with „e" in the middle.

de Rose et al. [1996] and Mueller et al. [2000] suggested that demonstration of within-word and within-syllable recombination provides an example of the notion that minimal units that have not been presented independently can develop from larger units. Control by the minimal units would require that the participants recognize that words consist of smaller units (i.e., letters) and that there is a relation between individual sounds and letters. The present study provides additional data to support this notion. However, one needs to take into consideration that the nature of the teaching procedure (i.e., visual prompt fading one letter at a time) could have cued the participants to the fact that each word consisted of three smaller units.

The second purpose of the present study was to investigate the relation between the participants' spelling and printed word naming accuracy. Although spelling and reading repertoires might be functionally independent when an individual is just learning basic literacy skills, once the individual becomes a more sophisticated reader and speller, those repertoires become interrelated [Ehri, 1987, 1997; Lee Pegler, 1982; Skinner 1957]. The present study suggests that such independence might not be necessary. All three participants named correctly very few study words at the beginning of the experiment. Following the CRS training, each participant read correctly more words. Three points should be mentioned. First, we did not provide any word naming instruction with regard to the study words and the baseline words were taught as sight words. Thus, the improvements in printed word naming were most likely related to the spelling training, and not our explicit teaching of word naming or implicit teaching of sounding-out words. It is remotely possible that other, uncontrolled variables, for example classroom reading activities, resulted in better word naming at the end of the study. However, the classroom records indicate that the children did not make much progress in their reading curriculum during the span of the study. Moreover, the vowels used in the present study had not even been introduced in the reading series by the end of the study. It is unlikely that the improved accuracy of word naming was due to teaching reading in the classroom.

A limitation of the present study is that we are not sure what processes were involved in correct printed word naming. In the case of directly trained words, the correct word naming could have been a result of the development of the alphabetic principle in the course of CRS training. However, correct word naming of trained words could also have been due to „memorization" of the spoken counterpart of the written word prompt that the participants copied numerous times during training. In the case of untrained words, the correct word naming was most likely related to auditory abstraction and learning of letter-sound relations.

The third purpose of our study was to examine the effectiveness of the visual prompt fading procedure for teaching spelling of three-letter words. The very small number of errors made by the participants and the rapid acquisition of spelling of the trained words suggest that the visual prompt fading was an effective technique for teaching rudimentary spelling. However, we do not know whether or not the mastery criteria for fading the prompts were excessive. That is, the children might have learned to spell the trained words equally well if the program removed one letter from the written prompt contingent on one correct response, and not two as in the present study. Additionally, because we did not compare the visual prompt fading procedure with any other procedure, we do not know how effective this technique is in comparison to other teaching methods.

These limitations notwithstanding, the present study offers convincing evidence of recombinative generalization of within-syllable units in spelling three letter words. Future research might investigate whether children with fewer phonological skills (i.e., children who do not accurately spell even the initial consonants) demonstrate recombinative generalization and under what conditions. Additionally, the present study should be replicated with individuals with mental retardation to complement research on recombination in reading with this population. From an applied point of view, future studies might focus on the integration of the spelling and reading curricula when designing a spelling instruction program. Lastly, because the present study provides a promising step in the development of a computerized technology for teaching rudimentary spelling, future research should continue exploring variables that lead to even more effective technology of teaching.

To conclude, the present study provides evidence in favor of matrix training as effective means of facilitating generative spelling. This study also constitutes

a much-needed example of recombinative generalization of within-syllable units. As such, our work can be conceptualized as „bridge" research that connects basic and applied behavioral sciences. The present study offers an insight into our understanding of the processes underlying human verbal behavior, including spelling and reading, and into designing effective technologies for producing functional spelling skills. Further research on recombinative generalization in spelling will broaden the applicability of this process for spelling instruction.

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