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TEACHING CHILDREN TO SPELL: DECREASING CONSONANT CLUSTER ERRORS BY ELIMINATING SELECTIVE STIMULUS CONTROL

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Six elementary-aged children were taught to spell words containing initial consonant clusters (CCs). They were trained to select printed words in response to the corresponding spoken words using computerized matching-to-sample procedures. After each training session, they were tested for spelling with a constructed-response transfer test. Based on previous selective stimulus control research, we hypothesized that only the first letter of an initial CC might control spelling when CC spelling errors are made. Thus, a critical-difference matching-to-sample training condition that required the children to respond to both letters of the CC to be correct was compared to a multiple-difference training condition that required the children to respond to only one letter of the pair. Results showed that children made fewer errors during the multiple-difference training condition than during the critical-difference training condition. On the constructed-response transfer tests, however, more overall errors and CC errors were made in the multiple-difference condition than in the critical-difference condition, and the words trained in the multiple-difference condition required more training sessions to reach criterion. All children improved their spelling of novel CC words by the completion of training. If normal classroom or home reading was to be supplemented by computer tasks of the kind used here, some spelling problems could be circumvented without costly intervention by a teacher or a special trainer.

DESCRIPTORS: spelling, children, computers, education, stimulus overselectivity

Most research on spelling, and how to teach spelling, has been done by educational researchers based in cognitive psychology (Foorman, Francis, Novy, & Liberman, 1991; Griffith, 1991; Lewkowicz, 1980; Treiman & Zukowski, 1988, 1990). Within behavior analysis, Lee and colleagues (Lee & Pegler, 1982; Lee & Sanderson, 1987) have developed a conceptual basis for spelling that emerges from reading and suggested that researchers look more closely at the stimulus control involved in specific types of spelling errors. Dube, McDonald, McIlvane, and Mackay (1991), Stevens, Blackhurst, and Slaton (1991), and Moxley and Warash (1990–1991) have developed useful computer technologies for teaching spelling, whereas other applied behavior analysts have developed interventions that reinforce correct spelling (Gettinger, 1985; Greenwood et al., 1987; Neef, Iwata, & Page, 1980; Ollendick, Matson, Esveldt-Dawson, & Shapiro, 1980) and have looked at variables that control practice effects (Cuvo, Ashley, Marso, Zhang, & Fry, 1995; Gettinger, 1993).

Dube et al. (1991) taught 2 young men with intellectual disabilities to spell using a computer. Previously trained, arbitrarily matched words and pictures were used as visual stimuli. Participants were shown the stimuli and were required to select letters presented at the bottom of the screen with a touch screen to construct the matching word. The selection pool contained 10 letters, some of which, if selected in the right order, would spell the word corresponding to the picture. Dube et al. found that the

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use of this method decreased the number of spelling errors made by the 2 participants. Stromer and colleagues (Stromer & Mackay, 1992a, 1992b; Stromer, Mackay, & Stoddard, 1992), using the same computer technology with disabled and nondisabled participants, found that novel constructed-response spellings emerged after matching-to-sample techniques had established equivalence classes among pictures, printed words, and spoken words. This occurred when the student was able to perform a delayed matching-to-sample task in which the printed words were removed and the student constructed the word in the absence of the stimuli. Like Lee and Sanderson (1987), Stromer and Mackay (1992b) also noted in their discussion that more attention should be given to training discrimination of the individual letters in a word during reading and that such training might improve later spelling.

One of the more common types of spelling errors made by children is the misspelling of consonant clusters (CCs) (Bruck & Treiman, 1990; Treiman, 1993). Words with CCs have two or more consonants in sequence, such as *suCH* or *THat.* Read (1975) found that children often misspelled consonant clusters that occurred at the end of words, with the most common mistake being the omission of the first consonant in the cluster (e.g., HAD instead of HAND). CC errors have also been found to occur at the beginning of words, with the second consonant in such clusters being omitted (e.g., SAY instead of STAY) (Bruck & Treiman, 1990; Miller & Limber, 1985; Treiman, 1991). A review of the spelling skills of 67 first-grade children by Treiman (1991) found that 42% of initial CC errors were accounted for by the omission of the second consonant in the cluster.

In the study by Dube et al. (1991), the emphasis was on correct spelling using a constructed matching-to-sample task rather than on CC errors. However, Dube et al.'s (1991) raw data revealed some CC errors, although they were not all simple CC errors. For example, 1 participant constructed HN for HAND, FA for FLAG, and WH for WATCH, and a second participant constructed H for SHOE and FA for FLAG.

The present analysis follows up the suggestion of Dube et al. (1991) that procedures that are designed to overcome stimulus selectivity could be used to decrease CC errors (Allen & Fuqua, 1985; Reynolds, Newsom, & Lovaas, 1974; Schover & Newsom, 1976; Schreibman, Koegel, & Craig, 1977). In examining selective stimulus control, participants are taught to respond to multicomponent stimuli and then are tested for responding to the components separately. Selective stimulus control occurs when participants respond to only some components of the multicomponent stimuli. For CC errors, this means that the sound of the word SHOW controls only the printed letters S, O, and W. In particular, the SH sound controls only the printed letter S.

Allen and Fuqua (1985) used three different conditions in a discrimination training task to decrease selective stimulus control over a compound stimulus of geometric shapes. In the multiple-difference condition, the negative discriminative stimulus (S−) differed from the original positive discriminative stimulus (S+) in multiple ways (shape, orientation, number of elements, etc.). In the minimal-difference condition, the S− differed minimally from the S+ in no more than two ways. In the critical-difference condition, the S− differed from the S+ in only one way. Results from this study showed that more errors were made by the children in the multiple-difference condition than in both the minimal- or critical-difference conditions. Fewer trials were needed in the critical-difference conditions than in the other conditions to meet their 90% correct criterion. The results suggested that critical-difference training was an effective procedure for decreasing selective stimulus control. Applying this procedure to spelling the compound stimulus SH in the word SHOW, the use of PLAY as a comparison in matching-to-sample would be part of a multiple-difference condition, the use of SLOP would be part of a minimal-difference condition, whereas the use of SLOW would be part of a critical-difference condition. The present study applied only multiple- and critical-difference methods to CCs.

Interestingly, selective stimulus control has been found to be widespread in children with autism and intellectual handicaps but is not usually found in nondisabled children (Allen & Fuqua, 1985; Lovaas, Koegel, & Schreibman, 1979; Lovaas, Schreibman, Koegel, & Rehm, 1971). This might be a function of the types of stimuli examined, however. Nondisabled children might not have selectivity problems with the shapes and patterns commonly used to research selective stimulus control with people with intellectual disabilities or autism, but they might exhibit selective stimulus control with more complex stimuli. CC errors might be one example of selective stimulus control in nondisabled children (Lee & Sanderson, 1987; Treiman, 1993).

The aim of the current research was to reduce the number of initial CC errors made by nondisabled children by training word discriminations using multiple- and critical-difference methods and testing transfer to constructing the words from individual letters. The critical-difference condition trained the children to identify both letters of the CCs, whereas in the multiple-difference condition, the children needed to identify only the first letter of the word. The matching-to-sample task used to train the words was similar to Dube et al.'s (1991), except that the sample stimuli were spoken words rather than pictures. The question was whether the critical-difference and multiple-difference matching-to-sample discrimination training procedures would produce differences in performance on a constructed-response transfer test.

METHOD

Participants

Six parents volunteered their children as participants in this study after volunteers were recruited for a computer experiment. The children were of normal intelligence and were not selected because of special spelling problems. They were between the ages of 4 years 5 months (Fiona) and 7 years (Colin).

Materials and Setting

The experiment was carried out in a standard office, and the experimenter was present throughout each training session. Toys were available during breaks between sessions. The children could ask for a break from the experiment at any time during the session. An Apple Macintosh IIsi computer with a keyboard and mouse was used to present the visual and auditory stimuli. The visual experimental stimuli were displayed on a color screen (20 cm by 15 cm), and the auditory experimental stimuli were recorded in Hypercard® and attached as a resource file to the main program. Five different screen events, intended to give positive reinforcement and consisting of differing combinations of flashing colors, moving pictures, and sound, were constructed.

The child responded to the experimental stimuli by positioning an arrow on the screen with the mouse and then clicking the mouse on the key he or she had chosen. In the training sessions, the child selected one of three words presented on the screen. In the constructed-response tests, he or she chose letters to spell the stimulus word. The top portion of Figure 1 shows the training screen for preliminary training with three-letter words. In the experimental training

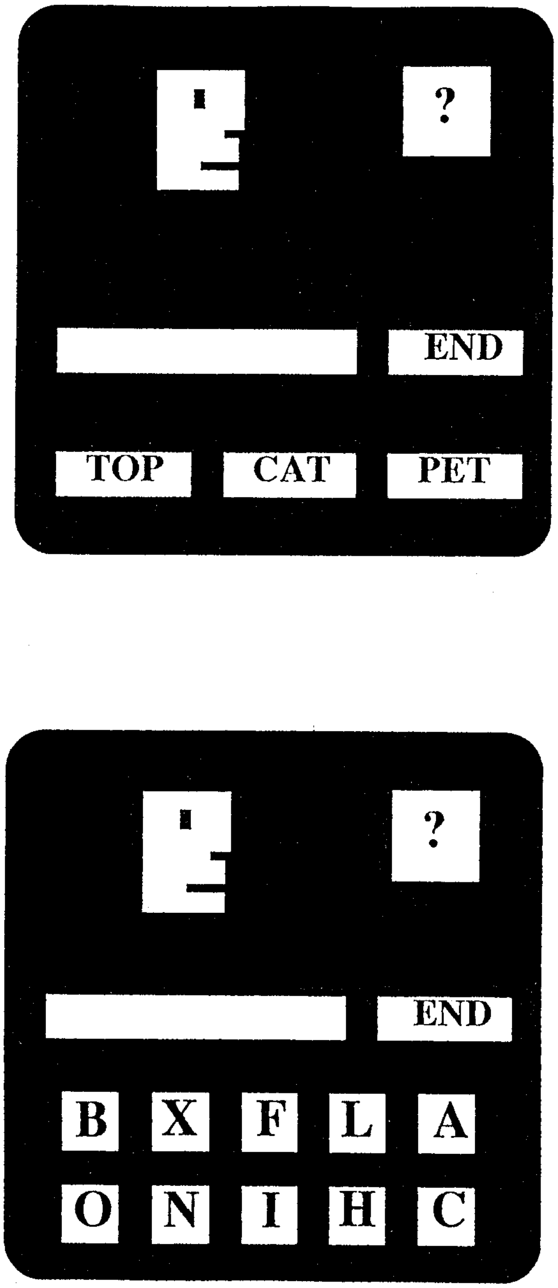

Figure 1. Computer screen layouts. The top portion depicts the screen layout for preliminary training. The critical-difference and multiple-difference training conditions were identical except that four-letter words were shown instead of three-letter words. The bottom portion shows the screen for the constructed-response tests.

Table 1
Word Lists for Multiple-Difference and Critical-Difference Training Sessions

Word number	Correct word	Critical-difference training comparison pool words		Multiple-difference training comparison pool words	
		1	2	1	2
1	SNOW	SLOW	SNAP	NICE	REST
2	SKIM	SWIM	SKED	MUCH	WALK
3	SLAT	SPAT	SLIP	GIRL	MINE
4	STAY	SPAY	STIR	FIND	TURN
5	SHOW	STOW	SHED	LIVE	HAND
6	SCAB	STAB	SCUM	SEED	HAIR
7	SMOG	SLOG	SMEW	PINT	LEFT
8	WHEN	WREN	WHAT	LONG	PART
9	WRIT	WHIT	WRAP	SUCH	FELT
10	PLAY	PRAY	PLOW	WENT	SOFT
11	BLEW	BREW	BLOT	SANG	GENT
12	BRED	BLED	BRAN	TOLD	SHIP
13	CHAP	CLAP	CHEF	BEST	WELL
14	CLIP	CHIP	CLUB	GONE	WORK
15	FROG	FLOG	FRET	READ	JUST
16	FLAY	FRAY	FLIP	BOOK	TOWN
17	GROW	GLOW	GRAB	BIKE	MIST
18	GLAD	GRAD	GLUM	FORK	JUMP
19	GNAT	GHAT	GNAW	HERE	FISH
20	GWEN	GLEN	GWAT	COST	ROAD
21	CROP	CHOP	CRAB	BABY	GAVE
22	THEY	TREY	THIS	COOK	KING
23	TWIN	THIN	TWAY	FROM	HOUR
24	TRIG	TWIG	TRAP	HOME	WASH

sessions, these were four-letter words. The bottom portion of Figure 1 shows the screen for the constructed-response tests.

Development of Word Lists

Two word lists were compiled, one each for the multiple-difference and critical-difference training conditions. All words are listed in Table 1, which shows the list of the correct words and the two comparison words that appeared in the selection pool. A total of 24 words were used; each word contained four letters, with two initial consonants, a vowel, and another consonant (CCVC). The same words were used in both critical- and multiple-difference training conditions, but the two comparison words in the selection pool differed between conditions.

As far as possible, the 24 words with initial CCs were common English words that have been found to result in spelling errors (Treiman, 1993), but this was heavily constrained by the availability of three critical-difference comparison words. The comparison words in the selection pool for the two training conditions were based on different criteria. In the critical-difference training sessions, the comparison words were minimally different from the correct word that was being trained. Only the second consonant in the first comparison word differed from the correct word, and the vowel and final consonant were different in the second comparison word. For example, when the correct word was SNOW, the first comparison word was SLOW and the second comparison word was SNAP. In order to adhere to these selection criteria, four of the selection pool words were nonsense words, although they were phonetically correct in English: SKED, SMEW, GWAT, and TWAY. In the multiple-difference training sessions, the first and second comparison words in the selection pool differed completely from the correct word. The comparison words all contained four letters and could include initial, final, or no CCs. For example, when the correct word was SNOW, the two comparison words were NICE and REST.

Procedure

Each child was given an initial oral spelling test consisting of the 24 training words. No reinforcement was given for correct or incorrect responses. Words that were spelled correctly in this initial oral test were not included in the experimental conditions for those children. Out of the 24 words, the children answered only 5, 6, 3, 2, 9, and 6 correctly (Anna to Fiona, respectively). They made 10, 13, 19, 26, 9, and 12 CC errors (Anna to Fiona, respectively). The Appendix shows the incorrect spellings of those words chosen for training (P).

Preliminary Screen Training

The object of the preliminary training was to teach the children to respond appropriately to the auditory stimuli by clicking the mouse on screen words or letters. This training used five three-letter words with no CCs, but was otherwise identical to the matching-to-sample discrimination training and constructed-response test conditions described below. The children were taught in three phases: first, to select the spoken letter from a selection of ten letters; second, to select a spoken three-letter word from a pool of three words; and last, to select the correct letters to spell those same three-letter words. On the first trial of each phase, only the correct words or letters were available for selection by making the other two gray and inoperative. Therefore, the children got all five correct. On the second trial, all words or letters were black and could be selected, but the correct one shook in an obvious manner as a prompt. After five correct words or letters in a row, the third trial began with all words or letters available and with no prompts. When a child made five consecutive incorrect responses, the second trial procedure reintroduced with its obvious prompts. All children completed this entire preliminary screen training in less than 50 min, at which point they had been trained to select the question mark for the presentation of the spoken stimulus words and then to select words or letters by using the mouse.

Experimental Conditions

At the beginning of the first session, constructed-response tests were given (0 in Appendix) of the three critical-difference condition words and the three multiple-difference condition words about to be trained—words that the children had spelled incorrectly on the initial oral test (P in Appendix).

Each session consisted of 30 training presentations, five for each of the six words being trained at any one time. At any time, there were usually three words being trained using the multiple-difference condition and three words using the critical-difference condition. Each session of 30 training presentations was immediately followed by six nonreinforced constructed-response tests, one for each of the six words being trained in that session. Occasional probes on words to be trained in future sessions were also given after the constructed-response tests (see Appendix, lower case words). Usually, two sessions were completed each day, with a break of an hour or more between sessions. The selection pool for training consisted of whole words, whereas in the constructed-response test condition, the selection pool consisted of 10 letters from which to construct (spell) the sample word.

Multiple-difference and critical-difference training presentations. The operating conditions, consequences for feedback, blackout, and the layout of the computer screens were the same for both the multiple-difference and the critical-difference conditions. The only differences between the two training methods were the incorrect comparison words that appeared for selection during training.

The children were presented with the screen shown at the top of Figure 1. They first clicked on the question mark (an observing response) to produce a "speech bubble" from the face on the screen and the auditory stimulus. The auditory stimulus consisted of an oral presentation of the word being trained and a sentence containing that word (e.g., "Snow. [pause] Snow is white."). The child could repeat the observing responses before responding. The child then selected the word from the selection pool that matched the auditory stimulus. Only one word from the selection pool could be chosen, because all the words in the selection pool became inoperable (gray) after the first response. The word that was selected appeared in the box just above the selection pool. The child then clicked on the END key to indicate that he or she had finished that presentation. Three seconds of blackout were presented after an incorrect response; a correct response received one of the five different feedback screens. The next trial followed immediately.

Six words were presented to each child five times each session. Three words were trained with each of the two different training conditions, and no word was trained in both conditions for any 1 child. The training condition used for a word was varied across the 6 children. Three children (Bella, David, and Fiona) received training on words selected from the first 12 words in Table 1 by the multiple-difference method and on words from the second 12 words by the critical-difference method. The words for the other 3 children (Anna, Colin, and Elena) were the reverse: critical-difference training on the first 12 words and multiple-difference training on the second 12 words. The actual words used depended upon each child's initial oral tests. The training conditions were also alternated within each session. For example, the first word might receive multiple-difference training, the second critical-difference training, the third multiple-difference training, and so on.

Constructed-response transfer test. After completing the 30 training presentations of each session, the six words being trained at that time were each tested once. No feedback or blackout conditions were presented during this test. The computer screen layout for the constructed-response test condition is shown at the bottom of Figure 1. The auditory stimuli were the same as in the critical- and multiple-difference training conditions. The child was required to click on the question mark to produce the auditory stimulus and then to construct a word by selecting up to six letters from the selection pool area. The letters appeared in the constructed-response box just above the selection pool after they were selected. The END key was again in operation, and no more than six letters could appear in the constructed-response box. The letters in the selection pool became inoperable (gray) when they had been selected; in this way a child could not select the same letter twice.

Data from the constructed-response test condition were analyzed at the end of each session. When a child had met criterion by constructing a word corrrectly for three consecutive sessions, that word was dropped and another word to be trained using the same type of condition was introduced. All new words were pretested again before training. If a word was spelled correctly, it did not undergo training, and pretesting continued until a new word was not correctly spelled. That word was then introduced in training.

Dependent Measures

The results that were of most interest were (a) the percentage of correctly selected words during training, (b) the number of sessions required to learn to construct the words correctly, (c) the percentage of words spelled correctly during the constructed-response tests, and (d) the percentage of CC errors during the constructed-response tests. CC errors were categorized as follows. A CC error was the incorrect spelling or omission of the first or second consonant in each word. A first omission CC error was the complete omission of the first consonant in any given word (e.g., NAP instead of SNAP). A second omission CC error was the complete omission of the second consonant in any given word (e.g., WEN instead of WHEN). A reverse CC error was the reversal of the second consonant and third vowel in any given word (e.g., SONW instead of SNOW). Finally, an insert error occurred when a letter was inserted between the two consonants of the cluster (excluding reverse CC errors) (e.g., SENOW instead of SNOW).

RESULTS

Matching-to-Sample Discrimination Training

Overall Percentage Correct in Training

The top panel of Figure 2 shows the percentage of correct responses made by each child during the training presentations, with the results separated for the critical-difference and multiple-difference conditions. Children selected whole words during this training, and did not construct words from individual letters. The data illustrate that a greater percentage of correct responses were recorded in the multiple-difference condition than in the critical-difference condition for all 6 children.

Constructed-Response Transfer Tests

Overall Percentage Correct

The middle panel of Figure 2 shows the percentage of correct responses made in constructed-response tests, separated by condition. The data illustrate that the percentage of correct responses was higher for all children in the critical-difference condition than in the multiple-difference condition.

Number of Training Sessions to Meet Constructed Word Criterion

The Appendix depicts the complete individual data for the constructed-response tests over all sessions separately for the two conditions. Words shown in capital letters were being trained when a constructed-response test was given. From this, the number of training sessions required for each word can be found. For example, with the critical-difference training, Anna required three training sessions for the word SNOW before meeting criterion and 11 training sessions

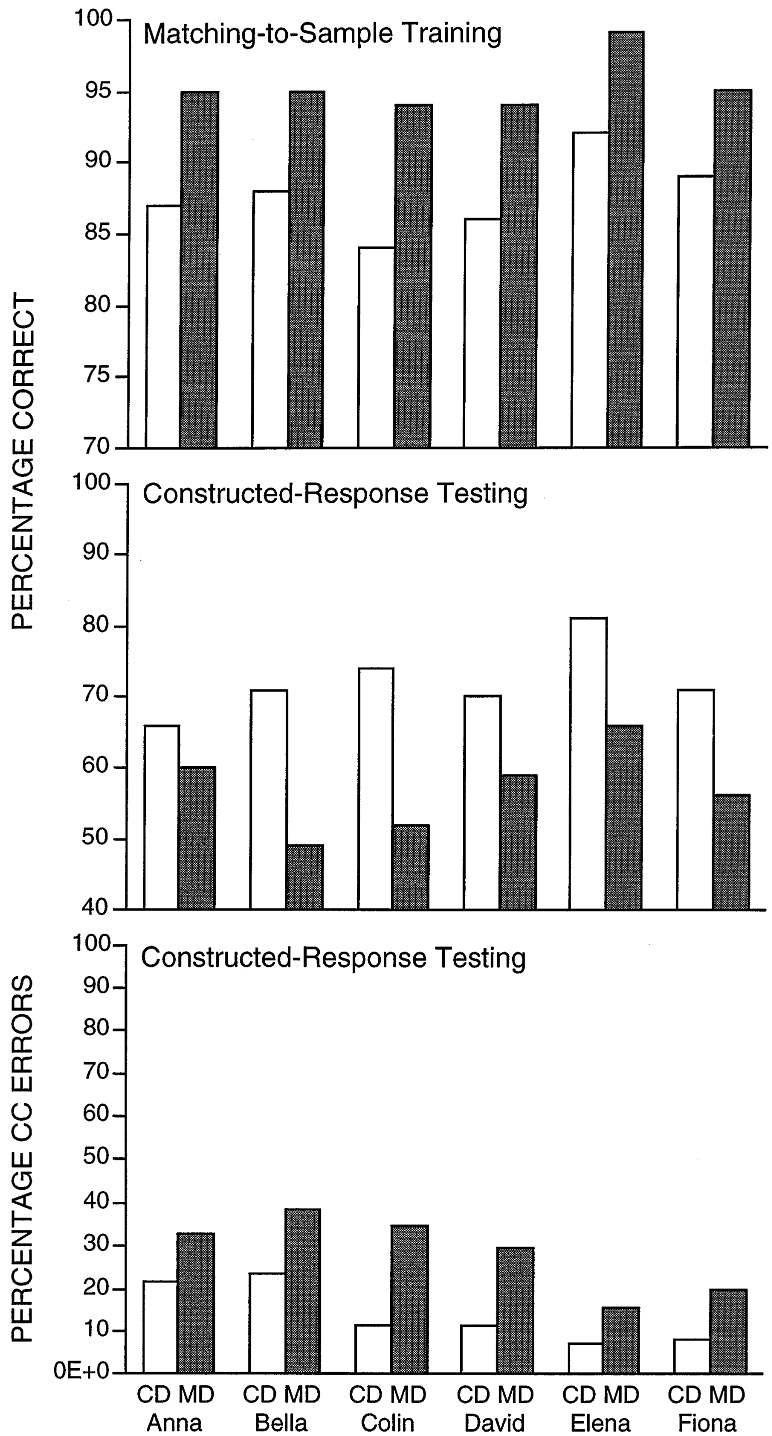

Figure 2. The top two panels show the percentage of words that were correctly selected during training and constructed-response tests for both the critical-difference (open bars) and multiple-difference (black bars) training conditions. The bottom panel shows the percentage of words spelled during constructed-response testing that contained CC errors for both the critical-difference and multiple-difference training conditions.

for the word WHEN. Over the six words trained with critical-difference training, she averaged 5.3 training sessions to meet criterion.

These results show that all children took fewer sessions to learn critical-difference words than multiple-difference words. The 6 children (Anna to Fiona, respectively) took an average of 5.3, 5.4, 4.8, 4.8, 3.7, and 4.7 sessions per word for the critical-difference training words and 6.0, 7.8, 11.7, 5.7, 5.3, and 6.4 sessions per word for the multiple-difference training words.

Fourteen of the 24 words were trained by both methods with at least 1 child per method, thus allowing a between-child comparison. For example, 5 children were trained on the word SKIM, 2 in the critical-difference condition and 3 in the multiple-difference condition. The Appendix indicates that for 9 of these 14 words, children took fewer sessions to complete training in the critical-difference condition than in the multiple-difference condition. Those words were SKIM (5, 4 vs. 5, 9, 9), STAY (3, 3, 7 vs. 11, 4, 8), SCAB (3, 4 vs. 6, 7), WRIT (5, 3, 3 vs. 9, 8, 5), BLEW (4, 10, 3 vs. 10, 4, 9), CHAP (4, 3 vs. 7, 6), FROG (6 vs. 10, 7), GNAT (3, 3, 3 vs. 5, 3, 5), and CROP (3, 6 vs. 12). Children took fewer sessions to complete training in the multiple-difference condition for only 2 of the 14 words: WHEN (11 vs. 6, 6) and TWIN (9, 9, 7 vs. 5, 5, 5). The remaining three words (SNOW, FLAY, and TRIG) did not show a clear difference in the number of sessions required to complete training.

Another result included in the Appendix is that for both training conditions, children improved their spelling of novel words by the end of the experiment. For all children, after six or seven words had been trained, the novel words presented as untrained probes were constructed correctly. For example, Anna was trained on six words with critical-difference training, and the next four probes were correctly spelled without training (SCAB, SHOW, PLAY, SKIM).

Consonant Cluster Errors

Of the 180 errors made in this experiment, 61% were CC errors. Of these 109 CC errors, 30 (27%) were made in the critical-difference condition and 79 (73%) were made in the multiple-difference condition.

Consonant cluster errors for each word. The bottom panel of Figure 2 shows the percentage of words that contained CC errors for both training conditions. The results show that all 6 children made more CC errors in the multiple-difference condition.

As can be seen in the Appendix, the children frequently made no CC errors for a word in the critical-difference condition, whereas they made numerous CC errors in the multiple-difference condition. Anna's data show that four of the six words trained in the critical-difference condition recorded no CC errors compared to only one of the five words in the multiple-difference condition. Bella's data show that in the critical-difference condition, four of the seven words recorded no CC errors, but all six words in the multiple-difference condition recorded CC errors. The results for Colin show that five of the nine words trained in the critical-difference condition recorded no CC errors compared to one out of nine in the multiple-difference condition. David's results show that seven of the nine words in the critical-difference condition recorded no CC errors compared to only three of the nine words in the multiple-difference condition. For Elena, in the critical-difference condition, five of the seven words recorded no CC errors, but in the multiple-difference condition two of the six words recorded no errors. Fiona's results show that six of the eight words in the critical-difference condition recorded no CC errors, whereas two of the seven words in the multiple-difference condition recorded no errors.

Table 2
The Number of Each Type of CC Errors for Both Training Conditions

Type of errors	Critical difference	Multiple difference	Total CC errors	Percentage of CC errors
First omission CC errors	1	7	8	7.3
Second omission CC errors	10	39	49	44.0
Reverse CC errors	11	19	30	27.5
Insert CC errors	8	7	15	13.8
Other CC errors	0	7	7	6.4
Total	30	79	109	100

Types of consonant cluster errors. Table 2 lists the total number of each type of CC error made by all the children in the constructed-response tests. The results show that for all CC error types (with the exception of insert CC errors), more were made for words that had been trained in the multiple-difference condition than in the critical-difference condition. A total of 109 errors were made, 30 in the critical-difference condition and 79 in the multiple-difference condition.

Only one first omission error was made in the critical-difference condition, but seven were made in the multiple-difference condition. As expected from past research on initial CC words, the most frequent CC error was the second omission error (a total of 49), which accounted for nearly half of all CC errors recorded. Most of these second omission CC errors (80%) occurred in the multiple-difference condition. Thirty reverse CC errors were recorded in total, the second most frequent type of error. Of these, 63% were made in the multiple-difference condition. The combined total of reverse and insert CC errors, both letters of the CC being present but not in the correct sequence, accounted for nearly half of the CC errors (45). The two training conditions did not differ in insert errors.

DISCUSSION

This study was based on the suggestion that CC errors occur because of selective stimulus control by one of the consonants. The present research compared the results of two matching-to-sample discrimination training conditions—critical-difference and multiple-difference training—in reducing these spelling errors made by children on a constructed-response transfer test. Overall, the constructed-response test results indicated that the critical-difference training condition was more effective than the multiple-difference training condition in reducing CC errors and overall errors. Thus finer discrimination training at the level of single letters led to improved spelling performance, as had been suggested by Dube et al. (1991), Lee and Sanderson (1987), and Stromer and Mackay (1992b).

The number of training sessions required before the constructed-response performance reached criterion decreased as training progressed under both conditions. This suggests that the critical-difference training condition focused the children's attention on critical aspects of the CC combination and that this generalized to performance under the multiple-difference condition. It is very likely that performance during the multiple-difference condition would have been worse in the absence of any critical-difference training. However, because training and time were confounded, it is possible that the overall improvement in performance was due to extraexperimental experiences. The fact that some words were constructed correctly in the absence of specific discrimination training strengthens the argument for the effect of such extraexperimental factors.

The results from the training conditions in which whole words were matched to sample showed that a greater number of errors were made in the critical-difference condition than in the multiple-difference condition. These results therefore show that training with the multiple-difference condition was easier than with the critical-difference condition, as would be expected. The data from the training condition alone do not establish the controlling factors that governed the children's behavior during the matching-to-sample training because selection was made from among whole words. However, the fact that more overall errors and CC errors occurred in the constructed-response tests with words trained in the multiple-difference condition indicates that the children were not identifying all four letters of the compound stimulus during training, which resulted in more mistakes being made in the constructed-response tests. These data are consistent with the results of Allen and Fuqua (1985), who used other types of stimuli.

With regard to the types and frequency of initial CC errors, Treiman (1991) found that second omission errors accounted for 42% of the CC errors. Other researchers have found that second omission errors accounted for 33% of the CC errors (Miller & Limber, 1985). Although the number of second omission errors that occurred in the critical-difference condition of the present study was very low compared to the number that occurred in the multiple-difference condition, second omission errors accounted for 44% of the total number of errors, close to that found by Treiman (1991). The second omission errors in both conditions therefore substantiate past findings that the most common error made by children trying to spell words that contain initial CCs is the omission of the second consonant in the cluster (Bruck & Treiman, 1991; Marcel, 1980; Miller & Limber, 1985; Treiman, 1991). The higher rate of second omission errors in the multiple-difference condition compared to the critical-difference condition provides further support that the spelling of CCs in words from the multiple-difference condition came under the control of only one of the components of the cluster—the initial consonant.

Another interesting finding was that reverse and insert CC errors combined accounted for nearly half of the CC errors. Both of these errors involve the sequencing rather than the occurrence of the two consonants; the consonants were there but were not in the correct sequence. This means that, as suggested by Stromer and Mackay (1992b), further discrimination training for sequencing may be required to overcome such CC errors. The training methods used here appeared to reduce only the reverse CC errors. The techniques used by Stromer and Mackay (1992b) and Stromer, Mackay, Cohen, and Stoddard (1993) seem to be promising for reducing sequencing errors.

The computer tasks were extremely useful in training the spelling of nondisabled children. However, these children exhibited some skills that might not have been present in the persons with intellectual disabilities who participated in previous research (Dube et al., 1991; Stromer & Mackay, 1992b), and supplementary training might be needed to replicate the present results with such populations. Further applications of basic stimulus control procedures to spelling should result in improved spelling. One example is the finer discriminative control of sequencing mentioned above (Green, Stromer, & Mackay, 1993).

Of most practical significance was that the computer-trained spelling, as in the work of Dube et al. (1991) and Stromer and Mackay (1992a, 1992b), did not require direct intervention by a teacher. If normal reading was to be supplemented by computer tasks of the kind used here and elsewhere (Stromer & Mackay, 1992b), some spelling problems, which might occur because natural contingencies are not sufficient to shape the finer discrimination of individual letters, could be circumvented without costly intervention by a teacher or a special trainer. The present research suggests that the application of selective stimulus control research to spelling merits further attention.

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STUDY QUESTIONS

1. What are words containing consonant clusters (CCs), and how are these words typically misspelled?

2. Describe the rules used for generating the experimental words and both the critical-difference and multiple-difference comparison words. Given *shot* as an experimental word, provide examples of its multiple-difference and critical-difference comparisons.

3. Describe the basic procedural difference between the training trials and the constructed-response trials.

4. How did the authors control for the different training approaches used?

5. What types of CC errors did the authors record?

6. Summarize the results in terms of (a) percentage correct during training and constructed response trials, (b) number of trials to criterion, and (c) CC errors.

7. What explanation was provided to account for the performance differences that were observed during training versus testing?

8. The authors suggested that performance during the multiple-difference condition might have been worse than that obtained had the children not been exposed to critical-difference training. How might the authors have controlled for the influence of critical-difference training?

Questions prepared by SungWoo Kahng and Michele Wallace, University of Florida

APPENDIX

Individual data for the initial oral test (P) and constructed-response test sessions, shown separately for the critical-difference and multiple-difference training conditions. At the beginning of the first session, the three words for training were retested (0). Words that were being trained at the time of any test are shown in capitals. Occasional probes for the next words to be trained are shown in lower case letters. Criterion was three correct consecutive spellings, at which point a new word was introduced to training.

Participant	Session					
Anna						
	Critical-difference training					
	P	sow	win	bid	sda	rat
	0	sow	wen	bed		
	1	SNOW	WN	BED		
	2	SNOW	WEN	BED	sea	
	3	SNOW	WHEN	BED		
	4		WEN	BRED	STAY	ret
	5		WHEN	BRED	STAY	
	6		WHEN	BRED	STAY	
	7		WHIN			WRIT
	8		WIEN			WRET
	9		WHEN			WRIT
	10		WHEN			WRIT
	11		WHEN			WRIT
	Multiple-difference training					
	P	sap	fog	nat	twn	gwin
	0	cip	fog	nat		
	1	CAP	FOG	NAT		
	2	CHAP	FOG	GAT		
	3	CAP	FOG	GNAT		
	4	CAP	FROG	GNAT	twn	
	5	CHAP	FROG	GNAT		gwen
	6	CHAP	RFOG		TIWN	
	7	CHAP	FRO		TWN	gwin
	8		FROG		TWIN	GWEN
	9		FROG		TWIN	GWEN
	10		FROG		TWIN	GWEN
	11					
Bella						
	Critical-difference training					
	P	cep	nat	towen	fog	trwr
	0	cip	nat	towin		
	1	CLIP	GNAT	TEWIN		
	2	CLIP	GNAT	TIWEN	fog	
	3	CLAP	GNAT	TIWN		thrig
	4	CLIP		TWIN	FROG	
	5	CLIP		TEWIN	FROG	
	6	CLIP		TIHWN	FOG	
	7			TWIN	FROG	TIRG
	8			TWIN	FROG	TRGE
	9			TWIN	FROG	TRIG
	10					THRG
	11					TIRG
	12					TRIG
	13					TRIG
	14					TRIG

APPENDIX

(Extended)

bli	sca	s	pla	scm
		show		
blewu			play	skim
BLW	scab			
BLEW		show	play	skim
BLEW		siow	play	
BLEW	scab	show		
	scab	show		skim
clp	fla	tha	gro	
		they		
clip	flay		grow	
clip	flay	thay	grw	
clip			grow	
	flay	they		
		they	grow	
flak	rrop	glrad	gren	thay
				they
		glad	gwen	
flye	crihp			
		glad	gwen	
				they
FLAY	CROP			
FLAY	CROP			
FLAY	CROP	glad	gwen	
				they

APPENDIX
(Continued)

Participant	Session					
	Multiple-difference training					
	P	sgem	wene	bole	rit	seteay
	0	sim	wen	blu		
	1	SEIM	WEN	BLOW		
	2	SIGM	WHEN	BEW	wrt	wsta
	3	SKIM	WEN	BLWE		
	4	SKIM	WHEN	BIEW		
	5	SKIM	WHEN	BELW		
	6		WHEN	BEW	WIT	
	7			BLWE	WEIT	SITY
	8			BLEW	WIRT	STYE
	9			BLEW	WRIT	STAY
	10			BLEW	WRIT	SITY
	11				WIRT	STIY
	12				WRIT	STAY
	13				WRIT	SATY
	14				WRIT	SATY
	15					STAY
	16					STAY
	17					STAY
Colin						
	Critical-difference training					
	P	s	low	soc	sme	reat
	0	so	bw	sok		
	1	SNOW	BOLW	SMOG		
	2	SNOW	BLOW	SMRG		
	3	SONW	BLEW	SMOG	skm	
	4	SNOW	BLAW	SMOG		bied
	5	SNOW	BLEW	SMOG		
	6	SNOW	BLIW		SIKM	
	7		BLOW		SIKM	BRED
	8		BLEW		SKIM	BDEM
	9		BLEW		SKIM	BRED
	10		BLEW		SKIM	BRED
	11					BRED
	12					
	13					
	14					
	15					
	16					
	17					
	Multiple-difference training					
	P	wooi	decf	copi	foc	mit
	0	roiw	rik	cop		
	1	GOW	TREG	CROP		
	2	GROW	TERG	GOP		
	3	GORW	GTR	CORP	forg	
	4	GROW	TREG	CROP		
	5	GROW	TROG	CROP		nat
	6	GROW	TREG	CORP		
	7		TROG	CORP	FORG	
	8		TRIG	CORP	FORG	

APPENDIX

(Extended - Continued)

sgarb	selet	brerde			
sacb	slat	bred			
SCBE	clat	bred			
SECB					
CGRB		bred			
SCAB	slat				
SCAB	slat				
SCAB					
	slat				
sti	whit	sab	sow	sat	
sta					
	rit			slat	
STAY	WRIT	caeb	seow		
STAY	WRIT	SCAB			
STAY	WRIT	SCAB		sait	
		SCAB	SHOW	slat	
			SHOW		
			SHOW	slat	
				slat	
tin	ilep	ceni	dladi	fae	thai
tein					

APPENDIX
(Continued)

Participant	Session					
	9		TRIG	CORP	FORG	
	10		TREG	CORP	FORG	
	11		TRIG	CROP	FROG	
	12		TRIG	CROP	FROG	
	13		TRIG	CROP	FROG	
	14					GNAT
	15					GNAT
	16					GNAT
	17					
	18					
	19					
David						
	Critical-difference training					
	P	croiw	corp	tewn	cilp	tha
	0	grw	cop	tiwen		
	1	GROW	CROUP	TEWIN		
	2	GROW	CROP	TIWN		
	3	GROW	CRUP	TAWIN	cihp	toey
	4		CROP	TWIN	CLIB	
	5		CROP	TWIN	CLP	
	6		CROP	TEWIN	CLIP	
	7			TWIN	CLIP	THAY
	8			TWIN	CLIP	THEY
	9			TWIN		THEY
	10					
	11					THEY
	12					
	13					
	14					
	15					
	Multiple-difference training					
	P	sgi	soiw	wen	pla	beed
	0	skm	soiw	wen		
	1	SKM	SOW	WEN		
	2	SIM	SHOW	WEN		
	3	SKM	SHOW	WIEN	pla	bied
	4	SKM	SOW	WHEN		
	5	SKIM	SHOW	WHEN		
	6	SCIM	SHOW	WHEN		
	7	SKIM	SHOW		PLAY	
	8	SKIM			PLAY	BED
	9	SKIM			PLAY	BED
	10					BED
	11					BRED
	12					BRED
	13					BRED
	14					
	15					
	16					
	17					

APPENDIX

(Extended - Continued)

	cilp				
			gaed	flay	
					thay
TIN	CIP	gwen	giad	flay	
TIN	CLIP	GEWN	GLAD		they
TWIN	CILP	GEN	GAD	flay	
TWIN	CLIP	GWEN	GLAD		they
TWIN	CLIP	GWEN	GLAD		
	CLIP	GWEN	GLAD	flay	they
cap	gen	nat	gilad	flaa	trik
cehap	win				
		nat	glad		
CAP			glad		
CHAP	GWN			flay	tig
CHAP	GWN	GNAT	glad		
CHAP	GWEN	GNAT		flay	TRG
	GWEN	GNAT			TRIG
	GWEN			flay	TRIG
					TRIG
rit	bliw	sta	so	siat	sab
rit	bw				
		stae		slat	
			sw		scab
RIT	BLUEW			slat	
RIT	BLEW				scab
WRAIT	BLEW			slat	
RIT	BLEW				
RIT		STA	SOW		scab
WRIT		STAY	SNOW		
WRIT		STAY	SNOW		
WRIT		STAY	SNOW		

APPENDIX
(Continued)

Participant	Session					
Elena						
	Critical-difference training					
	P	sa	blue	rite	scm	bed
	0	sae	ble	rit		
	1	STAE	BLEW	WRIT		
	2	SATY	BLEW	WRIT		
	3	STAY	BLEW	WRIT	sm	bed
	4	STA			SKM	BRED
	5	STAY			SKIM	BRED
	6	STAY			SKIM	BRED
	7	STAY			SKIM	
	8					
	9					
	10					
	11					
	Multiple-difference training					
	P	sap	nat	tri	flai	tin
	0	cab	nat	tik		
	1	CAP	GNAT	TIG		
	2	CHAP	GHAT	TRIC		
	3	CAP	GNAT	TRIG	flai	twn
	4	CHAP	GNAT	TRIG		
	5	CHAP	GNAT	TRIG		
	6	CHAP			FLAE	TWIN
	7				FLAI	TIWEN
	8				FLA	TWIN
	9				FLAY	TWIN
	10				FLAY	TWIN
	11				FLAY	
Fiona						
	Critical-difference training					
	P	fil	tik	gad	lip	gwn
	0	fai	tik	gad		
	1	FLAI	TIG	GLAD		
	2	FLAI	TRI	GLAD		
	3	FILAY	TRIG	GLAD	cilp	gwenm
	4	FLAY	TIRG		CLIP	
	5	FLAY	TRIG		CLP	
	6		TRIG		CLIP	
	7		TRIG		CLIP	GWEHN
	8				CLIP	GWEN
	9					GWEN
	10					GWEN
	11					
	12					
	13					
	14					

APPENDIX

(Extended - Continued)

plai	sab	smo	
plai			
	scrb	smog	
PLAY			
PLAY	SAB		
PLAY	SCAB	smog	
	SCAB	smog	
	SCAB		
wen	cip		
gwin			
	clip		
GWEM			
GWIN			
GWEN			
GWEN	clip		
GWEN	clip		
twn	fog	chab	nat
twnm	frog		
		cap	
			nat
TWN	frog		
TWUN		CHAP	
TWIN		CHAP	
TWEN		CHAP	GNAT
TWIN	frog		GNAT
TWIN			GNAT
TWIN			

APPENDIX

(Continued)

Participant	Session					
	Multiple-difference training					
	P	st	blu	sgb	sm	rit
	0	sate	blu	cab		
	1	STA	BLW	SAB		
	2	STAI	BILW	SCAB		
	3	STAY	BLUW	SAB	sm	
	4	STAE	BLIW	SGAB		rit
	5	STAE	BLEW	SCAB		
	6	STAY	BLIW	SCAB		
	7	STAY	BLEW	SCAB		
	8	STAY	BLEW		SGIM	
	9		BLEW		SKIM	RIT
	10				SKM	RIT
	11				SKM	WRIT
	12				SKIM	WRIT
	13				SIM	WRIT
	14				SKIM	
	15				SKIM	
	16				SKIM	

APPENDIX

(Extended - Continued)

sat	smoc	sow	bireed
sat		show	
	smok		
			bred
SLAT		show	bred
SLAT			
SLAT			
	SOG		
	SMOG	show	bred
	SMOG		
	SMOG		