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RECOMBINATIVE GENERALIZATION OF SUBWORD UNITS USING MATCHING TO SAMPLE

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The purpose of the current study was to develop and test a computerized matching-to-sample (MTS) protocol to facilitate recombinative generalization of subword units (onsets and rimes) and recognition of novel onset–rime and onset–rime–rime words. In addition, we sought to isolate the key training components necessary for recombinative generalization. Twenty-five literate adults participated. Conditional discrimination training emerged as a crucial training component. These findings support the effectiveness of MTS in facilitating recombinative generalization, particularly when conditional discrimination training with subword units is used.

Key words: matching to sample, reading, recombinative generalization

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The process of rearranging previously learned linguistic units into novel patterns is referred to as *recombinative generalization* (Goldstein, 1993). Matching-to-sample (MTS) procedures have proven to be effective for producing within-word recombinative generalization (e.g., de Rose, de Souza, & Hanna, 1996). For example, Mueller, Olmi, and Saunders (2000) presented 3 prereading children with consonant-vowel-consonant (CVC) words formed from onsets (i.e., an initial consonant sound) and rimes (i.e., the vowel and any remaining consonants). After hearing a sample spoken word (e.g., "mat"), the children selected the corresponding printed word from among two to four printed-word comparison stimuli. Following training, the children correctly matched some novel generalization words (e.g., "mop"), although accuracy varied (see also Saunders, O'Donnell, Vaidya, & Williams, 2003).

In the Mueller et al. (2000) study, there was no explicit training for the individual onset and rime subword units found in the presented words, and the children matched printed words to spoken word samples initially. Symmetrical relations (i.e., matching spoken words to printed-word samples) were not taught. However, learning how printed letters relate to sounds in a symmetrical relation is important for reading (Goswami, 2005; Rayner, Foorman, Perfetti, Pesetsky, & Seidenberg, 2002; Sidman, 1971), and direct instruction in these relations may facilitate recombinative generalization (see de Rose et al., 1996).

The present study aimed to develop a computerized training protocol to promote recombinative generalization of subword units (onsets and rimes), using an adaptation of the Mueller et al. (2000) procedure. The adaptations included adding onset and rime conditional discrimination training (e.g., training the spoken /h/ to written *h*), symmetry training (e.g., training *h* to /h/), and recombinative generalization training whereby the computer program presented noncombined onset–rime CVC words (e.g., /h/-/at/) prior to recombined onset–rime CVC words (e.g., /hat/). To assess the contribution of each of these three components in facilitating recombinative generalization, each was removed separately from the training procedures and recombinative general-

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ization was examined. Literate adults participated to test the effectiveness of the protocol prior to its intended use with children learning to read; thus, we used a novel (invented) script comprised of abstract symbols and nonwords. We also tested generalization of established subword units to novel disyllabic CVCVC words. If participants could read these CVCVC combinations following training, this would support a key role for recombinative generalization in productive reading skills and would further support the potential benefits of using similar procedures with children learning to read.

METHOD

Participants

Twenty-five literate adults aged between 18 to 46 years (median, 21 years) participated.

General Procedure

Tasks were presented using SuperLab Pro software. Four consonants (/t/, /s/, /n/, /y/) and four vowel–consonant pairs (/af/, /ek/, /ol/, /im/) were selected as onset and rime sounds, respectively. Each onset and each rime sound corresponded to one abstract symbol.

We used an MTS procedure with two trial types. In sound-to-symbol trials, a sample sound played, and participants selected one of four comparison symbols in response. In symbol-to-sound trials, a symbol appeared on the screen, and participants selected one of four comparison sounds. As each comparison sound was played, a blue star appeared to mark the location of that sound on the screen. The computer provided corrective feedback (e.g., "well done, correct" or "incorrect") for all training trials, but not during testing.

Overview of Training and Recombinative Generalization Testing

During onset sound-to-symbol conditional discrimination training, a block of trials included the presentation of 16 onset sound-to-symbol training trials. Participants were required to identify 14 of 16 correct responses to proceed to onset symbol-to-sound symmetry training trials. During onset symbol-to-sound symmetry training, participants were required to identify 14 of 16 correct responses within five blocks (or return to onset sound-to-symbol training). Mixed onset test trials presented eight onset sound-to-symbol and eight onset symbol-to-sound test trials. Participants were required to identify 15 of 16 correct responses after one block of 16 trials (or return to onset sound-to-symbol training).

Rime sound-to-symbol conditional discrimination training, rime symbol-to-sound symmetry training, and mixed rime test trials were identical to their respective onset training or test trials, except that four rime sound–symbol pairs were trained and tested.

In mixed onset and rime sound-to-symbol training, the four onset and four rime sound–symbol relations trained in onset sound-to-symbol conditional discrimination training and rime sound-to-symbol conditional discrimination training were presented in blocks of 32 training trials (16 onset sound-to-symbol and 16 rime sound-to-symbol trials). Participants were required to produce 30 of 32 correct responses within four blocks of training trials or return to onset sound-to-symbol conditional discrimination training. Mixed onset and rime symbol-to-sound training was identical to mixed onset and rime sound-to-symbol training except that symbol-to-sound training trials were employed.

For the recombinative generalization training, each of the four onset sounds was combined with each of the four rime sounds to produce 16 onset–rime CVC sounds presented with a slight pause between the onset and rime (e.g., /t/-/af/). Participants completed a block of 32 noncombined onset–rime CVC sound-to-symbol trials, followed by a block of 32 noncombined onset–rime CVC symbol-to-sound trials. No feedback was presented. On each trial, the correct onset–rime comparison (e.g., /t/-/af/) was presented with three incorrect onset–rime comparisons (e.g., /t/-/ek/, /s/-/af/, /s/-/ek/) that were constructed to preclude responses based on onset or rime alone.

The first recombinative generalization test was similar to the recombinative generalization training, except that the recombined CVC words were articulated without a pause. Participants completed 32 onset–rime CVC sound-to-symbol recombinative test trials followed by 32 onset–rime CVC symbol-to-sound recombinative test trials.

The final recombinative generalization test assessed recognition of the more difficult recombined onset–rime–rime CVCVC items. For this test, 16 sound-to-symbol and 16 symbol-to-sound trials were presented. Each of the four onsets was joined once to each of the rimes (e.g., /taf/, /tek/, /tol/, /tim/) to form the initial onset–rime sequence of the CVCVC word. An end rime (/af/, /ek/, /ol/, /im/) was joined to this sequence to form the CVCVC word (e.g., /tafek/). Thirty-two different CVCVC words were presented.

To identify the training components conducive to producing the recombinative generalization effect, modifications were made to the training procedure. Five participants were exposed to the complete protocol. Ten additional participants received no symmetry training. To control for the effects of type of training trial presented, 5 of these participants completed sound-to-symbol training and sound-to-symbol testing for the onsets and rimes, and 5 participants completed symbol-to-sound training and symbol-to-sound testing for the onsets and rimes. The recombinative generalization training with the noncombined CVC words was omitted for an additional 5 participants. Five participants had no conditional discrimination training with the onset or rime symbol–sound relations and only attempted the mixed tests before the recombinative generalization tests were introduced.

RESULTS AND DISCUSSION

Figure 1 shows the mean accuracy on the recombinative generalization tests for all participants. Participants who completed the entire protocol, or who received no symmetry training (completing sound-to-symbol or symbol-to-sound trials instead) or no recombinative generalization training, passed all of the training. When the entire protocol was completed or when symmetry training or recombinative generalization training only was omitted, participants demonstrated at least 94%, 88% (sound-to-symbol trained), 94% (symbol-to-sound trained), and 88% accuracy, respectively, in recognizing the novel recombined onset–rime CVC words, and a mean of 92%, 88%, 95%, and 93% accuracy, respectively, in recognizing the recombined onset–rime–rime CVCVC words. Thus, at least 88% accuracy was shown when responding to the CVCVC words, with the exception of 1 participant who received no symmetry training but completed sound-to-symbol training and testing and demonstrated 66% accuracy. The greatest number of errors in matching the recombined sound–symbol CVC and CVCVC words occurred when conditional discrimination training for the onset and rime sound-to-symbol relations was removed. When the conditional discrimination training was omitted, participants responded correctly to less than 16% of the CVC words, and the mean accuracy was 10% for the CVCVC words.

The results show that participants who did not receive symmetry training or recombinative generalization training were still able to identify a large proportion of the recombined onset–rime CVC and onset–rime–rime CVCVC words successfully. By contrast, recognition of the recombined words was not evident when participants had not participated in conditional discrimination training. These findings support the critical importance of conditional discrimination training (Johnson & Dixon, 2009) in facilitating the emergence of recombinative

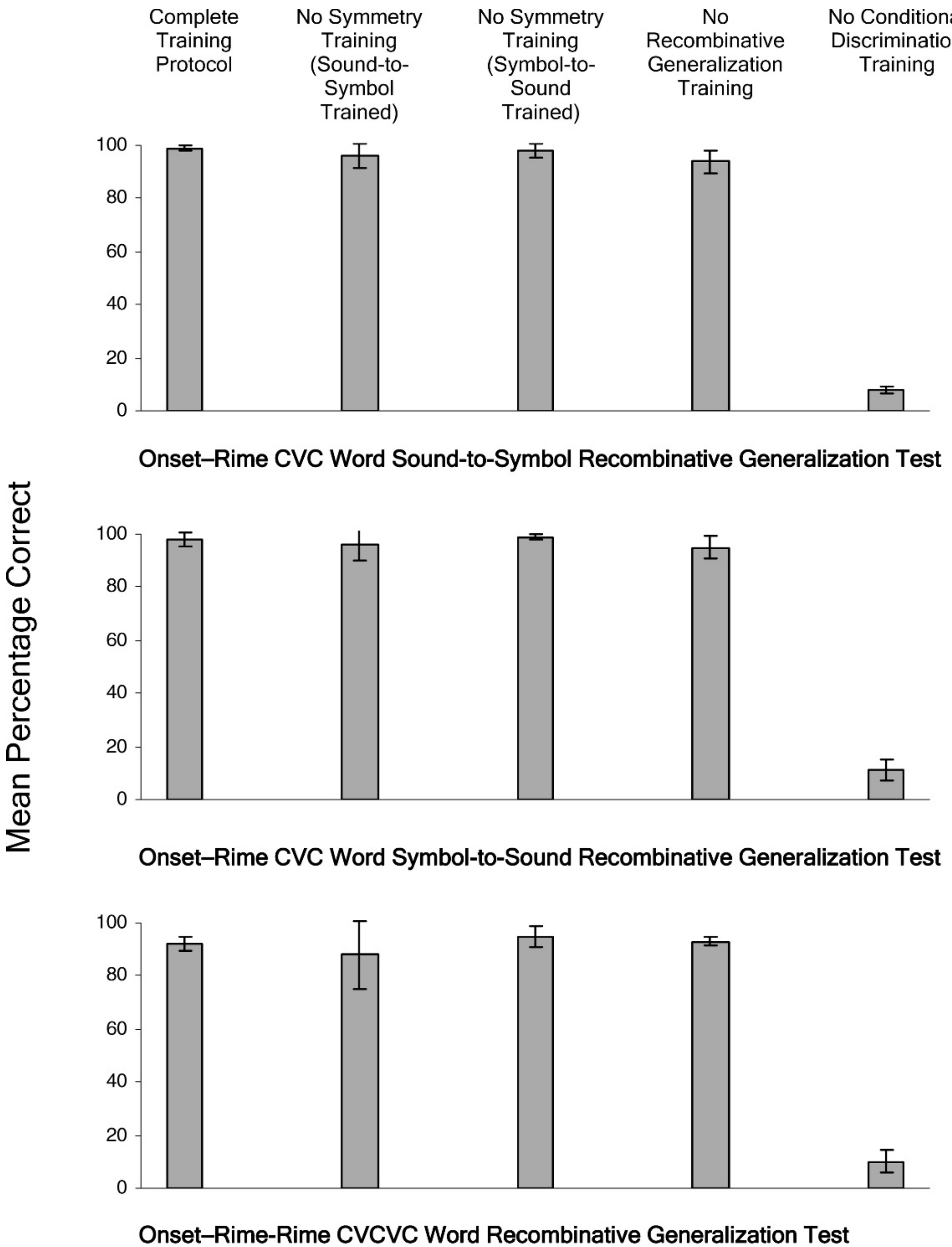

Figure 1. Mean percentage correct on the recombinative generalization tests (onset–rime CVC words and onset–rime–rime CVCVC words) for participants who completed the entire protocol; received no symmetry training (sound-to-symbol trained or symbol-to-sound trained); had no recombinative generalization training with noncombined onset–rime CVC words; or received no conditional discrimination training. Standard error lines are shown for each bar.

generalization. In other words, it appears that training established the sound–symbol relations for the onsets and rimes, from which the recombined words could be recognized. These findings are consistent with the view that learning how printed letters relate to sounds is essential for reading (Goswami, 2005; Rayner et al., 2002).

Despite having no previous exposure to the onset–rime–rime stimuli, participants could recognize the more complex CVCVC words. These findings are important because they suggest that the MTS protocol is not limited to facilitating recognition of one type of word (e.g., CVC words) but appears to be effective in promoting recognition of untrained words composed from the symbol–sound relations. We are currently extending the use of the protocol by examining recognition of derived recombined words (e.g., words formed from new onsets and rimes derived from explicitly taught onsets and rimes). Overall, the current research is very much in accordance with earlier studies (e.g., Mueller et al., 2000; Saunders et al., 2003) in demonstrating the effectiveness of MTS training in this domain.

Literate adults participated in the current study. Although a novel script was employed, the adults had relational histories built through reading experience and were all able to match letters to particular sounds. We have, however, begun to use a similar protocol with extensive conditional discrimination training for actual letter–sound relations with children who experience difficulties learning to read, and the preliminary findings are encouraging.

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