# Recombinative Generalization: An Exploratory Study in Musical Reading

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The present study aimed to extend the findings of recombinative generalization research in alphabetical reading and spelling to the context of musical reading. One participant was taught to respond discriminatively to six two-note sequences, choosing the corresponding notation on the staff in the presence of each sequence. When novel three- and four-note sequences were presented, she selected the corresponding notation. These results suggest the generality of previous research to the context of musical teaching.

*Key words*: recombinative generalization, music teaching, codic behavior, verbal behavior

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In Skinner's (1957) analysis of verbal behavior, units may be recombined, generating novel responses. Studies about procedures to teach reading and spelling exemplify this possibility. For instance, Mueller, Olmi, and Saunders (2000) taught nonreading kindergartners to select printed words such as *mat*, *sat*, *sop*, and *sug* and showed generalization to words such as *mop* and *mug* that recombined within-syllable units of the trained words. The recombined units in this study were onsets (initial consonant sounds in a syllable) and rimes (the vowel and subsequent consonants in the syllable). Similar results have been obtained with Portuguese-speaking children, in studies that extended generalization to words that recombined syllables of the training words (e.g., de Rose, de Souza, & Hanna, 1996; Hübner, Gomes, & McIlvane, 2009; Matos, Avanzi, & McIlvane, 2006).

Some of these studies have suggested that recombination of units can be obtained by exposing participants to multiple-exemplar training with words that have common components (e.g., Hübner et al., 2009). Thus, as Skinner (1957) pointed out, teaching individuals to read whole words can also produce control by smaller units (e.g., syllables, phonemes, or onsets and rimes). On the other hand, many studies indicate that recombinative generalization is easier to obtain when the smaller units are directly taught (Adams, 1994; de Souza et al., 2009).

In Skinner's (1957) taxonomy of verbal behavior, the basis of reading is a verbal operant called *textual* behavior, in which visual stimuli (or tactile stimuli as in braille) are discriminative for vocal responses, with a point-to-point correspondence between stimuli and responses. In musical reading, the main stimuli are dots on a staff (five horizontal lines). The position of the symbol on the staff corresponds to the pitch. The symbols are small circles, which may be filled or open, and may have stems, with these features corresponding to the relative duration of the corresponding notes. Musical reading is not

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This research was supported by the State of São Paulo Foundation for Research Support (FAPESP), Grant 03/09928-4. The second author was supported by a Research Productivity Grant from the National Council for Scientific and Technological Development (CNPq). Both authors are affiliated with the Instituto Nacional de Ciência e Tecnologia sobre Comportamento, Cognição e Ensino, supported by FAPESP (Grant 08/57705-8) and CNPq (Grant 08/57705-8).

We thank Bill Dube, Deisy de Souza, and Elenice Hanna for valuable comments on this research and manuscript.

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strictly textual behavior, because the response is not necessarily vocal: Musicians may say that someone ''reads'' a musical score when he or she plays the score on a musical instrument. Michael (1982) coined the term *codic*, which encompasses both musical reading and textual behavior. In codic behavior, the response form is controlled by a verbal stimulus with which it has point-to-point correspondence, and there is no formal similarity between stimulus and response product. Moreover, an individual who has learned a small set of units (e.g., control by graphemes on the production of the respective phonemes) can recombine these units in ''texting'' a virtually infinite number of words (as well as sentences, paragraphs, etc.). Likewise, in musical reading, it is possible to read novel melodies by recombination of a small number of units (individual notes represented on the staff and the response to them).

Musical stimuli were first used to investigate the emergence of novel behavior by Hayes, Thompson, and Hayes (1989), with the stimulus equivalence paradigm. According to Sidman and colleagues (e.g., Sidman, 1971, 1994; Sidman & Tailby, 1982), a textual stimulus, such as a printed word, bears an equivalence relation to the corresponding spoken word and its *referent*, such as a picture of the object designated by the word. The equivalence relation is documented by the emergence of untrained relations among these stimuli. Hayes et al. extended the equivalence paradigm to musical stimuli. They taught college students to match a position on the staff to the name of the corresponding note, to the corresponding key on a keyboard, and to the finger used to hit this key. Subsequent tests documented the emergence of untrained relations among note names, keys, and fingers, showing that each position on the staff comprised a class of equivalent stimuli together with the respective note name, key, and finger. Participants also formed classes that consisted of note durations, duration names, and the corresponding symbols. In a subsequent test, participants showed fast improvement in a keyboard-playing task in which they were asked to play scores of 12 notes, suggesting that they learned individual units that could be recombined in new sequences. However, interpretation of these data is not entirely clear because students could learn to play each score across several trials, and the actual number of errors is not reported, only the number of trials to achieve a criterion of less than four errors in a particular score.

Batitucci (2007) studied recombinative generalization after training with sequences of notes rather than with individual notes, as in Hayes et al. (1989). Also, Batitucci taught auditory–visual relations and verified recombination of units to generate new auditory–visual relations. In this study, college students learned a matching-to-sample task in which samples were three-note melodies and the comparison stimuli were notations on the staff (in either G or F clef). Participants showed equivalence between melodies and notations in different clefs. Once participants learned to respond to two different melodies (C-E-G and E-G-C), the notes were recombined in three- and four-note sequences (e.g., G-C-E and C-E-G-E). Although performance of 2 participants in these tests was more accurate than in a pretest, recombinative generalization was generally poor.

In Batitucci's (2007) study, participants were taught to respond only to units formed by three-note sequences (C-E-G and E-G-C). Studies on recombinative generalization in alphabetic reading (e.g., de Souza et al., 2009) suggest that recombinative generalization in musical reading could be enhanced if participants were taught to respond to smaller textual units. We report here a preliminary study in which a young woman learned to select six two-note sequences written on a staff when the corresponding notes were sounded, and recombination was then tested with three- and four-note sequences.

## METHOD

### *Participant*

A 25-year-old woman with an undergraduate degree in psychology participated. She was musically illiterate and never had formal musical training. She volunteered because, according to her report, she was interested in improving her musical abilities.

### *Apparatus, Setting, and Stimuli*

The experimental sessions were conducted in a quiet room (2 m by 3 m) in the laboratory.

| Training phase: auditory-visual (AB) relations with two-note sequences | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Stimuli | Auditory (A) | C – E | C – G | E – G | G – E | G – C | E – C | Number of presentations per block | Number of comparisons | Number of sessions until reach criterion |
| | Visual (B) | | | | | | | | | |
| Training steps | 1st | • | | | | | • | 8 | 2 | 1 |
| | 2nd | | • | | | • | | 8 | 2 | 1 |
| | 3rd | | | • | • | | | 8 | 2 | 1 |
| | 4th | • | | • | | | | 8 | 2 | 1 |
| | 5th | | | | • | | • | 8 | 2 | 2 |
| | 6th | • | • | | | • | • | 4 | 4 | 6* |
| | | | | | | | | | 2 / 4 | 4 |
| | 7th | • | | • | • | | • | 4 | 4 | 4* |
| | | | | | | | | | 2 / 4 | 1 |
| | 8th | • | • | • | • | • | • | 2 | 4 | 2 |

* Criterion was not reached with four-comparisons training trials. Then, sessions composed of two blocks with two-comparisons trials followed by two blocks of four-comparison trials were carried out.

*Figure 1.* Summary of procedure and results of training phase.

There was a chair and a table on which a computer and its keyboard and mouse were placed. The MTS 11.6.7 (Dube & Hiris, 1999) software was used to control stimuli presentation and to record the participant's responses.

Auditory stimuli consisted of 18 recorded sequences of musical notes played successively on the piano. The notes that formed the sequences were middle C, E, and G, and the visual stimuli were the corresponding sequences of notes written out on a staff, in G clef. The stimuli used in different phases are shown in Figure 1 (training) and Figure 2 (recombinative generalization testing).

### *Procedure*

Experimental sessions were comprised of auditory–visual matching-to-sample trials. At the beginning of each training trial, the sample, a sequence of two notes, was played together with the presentation of two or four staves as comparison stimuli. Each staff had a sequence of two notes; only one of the staves had the notation that corresponded to the sample. Choosing the correct staff was followed by the presentation of a short ascending sequence of musical notes and visual display of stars in random positions. Choosing the incorrect comparison was followed by 1 s of a black screen. The intertrial interval was 1 s.

Before starting the procedure, experimenters provided minimal instructions for the participant to perform the task.

*Pretest*. The participant was pretested for all the relations that were trained. Each relation was presented once in a four-comparison trial.

*Training*. During training, the participant learned six relations between two-note sequences and the corresponding notes written on the staves. The training phase was divided in eight steps. In Steps 1 to 5, trial blocks consisted of only two relations between sequences of sounds and their notations (e.g., CE and EC in the first block, CG and GC in the second block, etc.). In Steps 6 and 7, four relations comprised each trial block. In Step 8, all relations were presented together within the same block. Figure 1 presents the sequence of training steps.

Two blocks of trials comprised each experimental session. During each session, performing 97% of responses correctly was the learning criterion. The number of presentations of each relation across training steps and the number of comparison stimuli that were used are shown in the right portion of Figure 1.

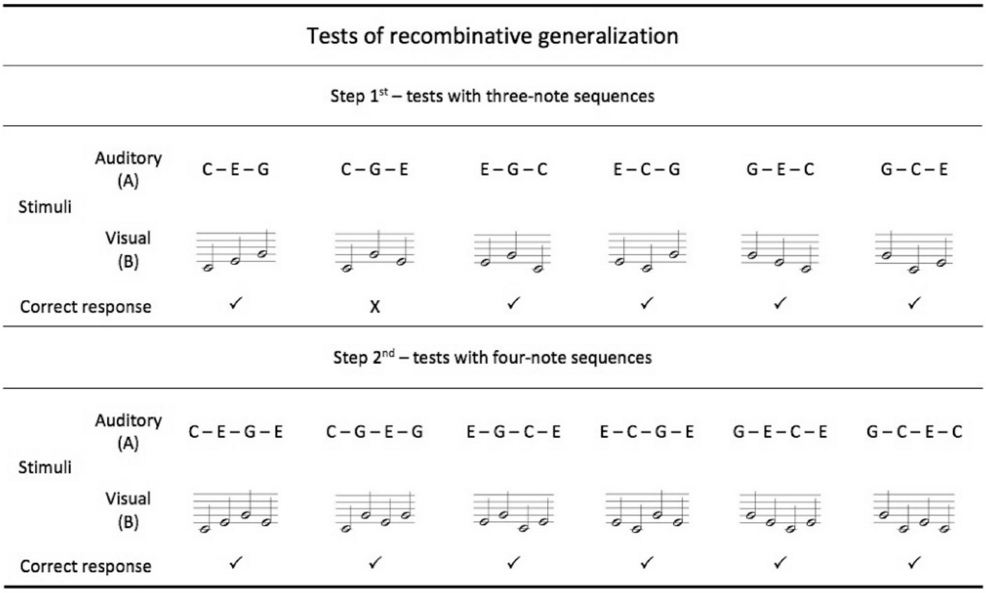


*Figure 2.* Summary of procedure and results of tests.

*Testing*. After performing the training relations correctly, the participant was tested for recombinative generalization, with novel sequences that recombined the trained unit. Steps 1 and 2 presented, respectively, sequences with three and four notes. Test trials for each recombination were presented only once, and four comparisons were used. No differential consequences followed responses. During test sessions, two test trials were interspersed within a baseline training block.

## RESULTS

The participant's responses on the pretest remained at chance level (two correct responses in six trials). The results of the training phase are shown in the rightmost column of Figure 1. In Steps 1 through 4, the participant needed only one session to attain criterion. In Step 5, she needed two sessions. In Step 6, however, she did not reach criterion in six sessions. We then reduced the number of comparisons to two, and after the participant reached criterion increased it again to four. She needed four sessions to achieve criterion after this procedural adjustment (second line for the sixth step in Figure 1). A similar procedural adjustment was made in Step 7, after she did not achieve criterion in four sessions. She then attained criterion in one session. After only two sessions in Step 8, the participant correctly performed all baseline relations, thus showing discriminative control by all six units.

Results of tests with three- and four-note sequences are shown in the middle and bottom of Figure 2, respectively. The participant made a correct response for 11 of the 12 recombinations that were tested.

## DISCUSSION

The participant learned to choose the notation in the staff corresponding to two-note samples. During the test, when these sequences of notes were recombined in novel sequences, the participant chose the correct staff in 92% of the cases. Despite the fact that each recombination was presented only once, correct responding in 11 of the 12 trials is an indication of recombinative generalization.

The main contribution of the present study is that it presents a method to study recombinative generalization in musical reading. The study raises several questions to be addressed in future research. First, it is necessary to replicate the study with more participants to evaluate intersubject generality. Generality also needs to be assessed with a larger number of trained units, including at least all seven notes of the diatonic scale and different intervals between the notes. The training of only three notes combined in two-note sequences restricted the scope of recombinations that could be generated. This increases the probability of control by specific features or parts of the stimuli, such as the initial notes of a sequence. To strengthen evidence of recombinative generalization, future studies should also repeat test trials and vary the comparisons used, to rule out control by part of the sequence. Second, it would be interesting to perform ‘‘naming’’ tests, in which participants produce the stimuli, for instance pressing keys on a piano keyboard, as in the studies of Hayes et al. (1989) and Batitucci (2007). This would also be important to insure control by all the notes in the sequence. A third area for future investigation would be the possibility of generalization to intermediate notes that are not presented in training, such as D and F. No such generalization could occur in alphabetic reading, because the correspondence between phonemes and graphic characters is arbitrary. However, the correspondence between musical pitches and their notation is mostly nonarbitrary, with higher pitches represented by dots in a higher position on the staff. This analogical component of the system could allow generalization to untrained notes.

This study investigated only one aspect of musical notation, namely the representation of pitch by the position of dots on the staff. Musical notation represents other features of music, such as rhythm, dynamics, and articulation. Not all of these aspects may be generative in the same way as pitch notation is. The same is true in the alphabetical system, which contains, for instance, punctuation signals that cannot be recombined.

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