Effects of Auditory and Motor Mental Practice in Memorized Piano Performance

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Abstract

The study examined the effects of two types of mental practice in learning to perform an unfamiliar piece: auditory and motor practice. Sixteen pianists performed unfamiliar music from notation during ten practice trials, with the presence or absence of auditory feedback and motor feedback (finger movements). Pianists were instructed to mentally practice the missing feedback. After the practice trials the pianists performed from memory under normal performance conditions. Errors during performance from memory showed significant effects of both motor and auditory feedback during practice. Comparisons with aural skills posttests indicated that pianists with strong aural skills were least affected in memory tests by removal of auditory feedback during practice. Pianists with high self-ratings of playing by ear scored higher on the aural skills test and performed better from memory in the absence of auditory feedback. These findings suggest that an accurate auditory image is important for successful performance from memory.

Introduction

Many studies have examined the factors that influence performers as they learn unfamiliar music. One of the most crucial factors is practice. Two major components of practice are the auditory information that performers receive in feedback about their productions, and the motor information they receive from kinesthetic movements associated with the execution of the performance (Finney & Palmer, 2003; Palmer & Meyer, 2000; Ross, 1985). Finney and Palmer (2003) showed that the absence of auditory feedback during practice of an unfamiliar piece did not affect pianists' accuracy while the music notation was in front of them, but the absence of auditory feedback during practice did impair their later performance from memory. Comparison of performance errors made by novice and skilled pianists suggested that novice pianists are more dependent on motor information (hand and finger positions) during learning than are skilled pianists (Palmer & Meyer, 2000). Ross' (1985) study of trombonists indicated that information received during normal practice conditions (rehearsal with both auditory and kinesthetic feedback present) allowed musicians to make corrections and adjustments to their performance. McPherson (1995, 1997) demonstrated positive correlations between musicians' ability to perform rehearsed music and their sight-reading, playing by ear, and improvising abilities.

In addition to physical practice, mental practice can also influence performers as they learn unfamiliar music. Coffman (1990) described mental practice as "the covert or imaginary rehearsal of a skill without muscular movement or sound" and showed that pianists' mental practice improved their performance compared with no practice. Although several meta-analyses have compared effects of different types of mental practice (Driskell, Copper & Moran, 1994; Feltz & Landers, 1983), few studies have compared types of mental practice in the context of music performance. Pianists' mental practice with an auditory model showed advantages over mental practice alone

(Lim & Lippman, 1991; Theiler & Lippman, 1995). Rubin-Rabson (1937) showed that analytical pre-study of the score often aided performers' memorization of unfamiliar music; this analytical study may lead to auditory imagery or motor imagery (Lim & Lippman,1991).

Mental practice may help musicians learning to perform unfamiliar music by facilitating the creation of an auditory and/or motoric image. Comparison of different practice conditions showed that listening to a performance is an effective aid to learning unfamiliar music (Rosenthal, 1984; Rosenthal, Wilson, Evans, & Greenwalt, 1988), and musicians given supplemental aural training instruction were more accurate in error detection than a control group without such training (Sheldon, 1998). Not all studies show a facilitation of mental practice, however; Rosenthal et al (1988) found that silent analysis (mental practice, without explicit instructions) followed by sight-reading was not more effective than just sightreading.

The purpose of this study is to contrast mental and physical practice, in terms of auditory and motor feedback, to determine their role in how pianists learn to perform unfamiliar music. Effects of mental practice were tested by replacing auditory or motor feedback with instructions to imagine the missing feedback: how the piece sounds, or how the finger movements feel, during practice. After performers practiced from a musical score, the score was removed, and pianists performed from memory under normal feedback conditions. Because meta-analyses of mental practice indicated individual differences in imagery abilities that may influence the efficacy of mental practice, we use a within-subjects design to compare physical and mental practice effects on each performers' memory. We also collected two independent measures of mental imagery ability, one for motor imagery and one for auditory imagery, for comparison with the effects of mental practice. Finally, pianists gave self-report measures of memorization, playing by ear, and sight-reading abilities.

Method

Participants.

Sixteen adult pianists were recruited from the Columbus, OH community; all pianists were currently performing, and half were music majors at a large midwestern university. Pianists were informed they would be sight-reading and memorizing short musical excerpts at the time of recruitment. Participants had at least 6 years of individual piano instruction (mean = 10 years, range = 6 to 15).

Stimulus Materials.

Four musical pieces were composed for the experiment, based on the compositional style of early Baroque era organ works. Each piece was two measures long, in a different key signature (two were major and two were minor) and each consisted of 20 individual tones in the left and right hand parts. Figure 1 displays the four musical pieces, with initial fingering positions. For the Auditory Only practice condition, an auditory recording of each stimulus was created. The recordings had a tempo of 90 beats per minute with a concert piano timbre and metronomic timing (each quarter-note duration = 625 ms).

Two posttests were used to provide independent measures of auditory and motor imagery abilities. The auditory posttest was adapted from Wing's (1968) tests of aural skills. Participants were shown a single-line melody (7-10 pitches) and heard a similar melody, which was the same as the notated melody or had a difference of one pitch. The stimuli in the Wing tests did not control for the size of interval changes, however, which made some melodies easier than others. The stimuli were adjusted by making the one-note difference a change of 1-2 semitones; the total number of changes that moved up or down in pitch were balanced. Eight of the 12 melodies presented had a one-note difference. The 12 melodies were sounded over headphones, and subjects

Figure 1. Musical pieces composed for the experiment.

compared the notation and the aural stimuli in a same-different task. Each stimulus was sounded twice, and each had a quarter-note duration of 625 ms (total duration of each stimulus was between 2500 – 5000 ms). Participants were told to indicate if any of the printed notes were different from the ones sounded.

The motor imagery posttest, motivated by work on infant imitation of motor movements (Gleissner, Meltzoff & Bekkering, 2000), contained a sequence of 7 pictures of the right hand with one highlighted finger in each picture, to correspond to a sequence of finger movements. Pianists were instructed to imagine and memorize the movement sequence while holding their hands in loose fists. Then the sequence was removed and a sequence of 7 letters was presented that corresponded to pitches on the keyboard (such as G C F E D E C). Pianists were told to memorize and perform this pitch sequence with the right hand on an electronic piano with no auditory feedback, and to indicate whether the sequence they performed was the same or different from the imagined sequence. There were 12 stimuli, 8 of which had a single movement (digit) difference between the imagined sequence and the performed sequence. The differences were always one digit away from the correct finger in the imagined sequence.

Equipment.

Pianists' performances were recorded in MIDI on a PC-monitored Roland RD-600 digital keyboard using the "Standard Concert Piano 1" timbre. The presentation of auditory stimuli and the recording of pitch and timing information in the performances was controlled by computer. The pianists heard their performances through AKG-K270 Studio headphones.

Design.

Each experimental session consisted of practice conditions, during which the independent variables of auditory and motor feedback were manipulated, followed by test conditions, during which pianists performed from memory under normal performance conditions (auditory and motor feedback present). In the Normal practice condition, pianists moved their fingers on the keys and heard themselves play over headphones during practice. In the Motor Only practice condition, the pianists moved their fingers on the keys but auditory feedback was removed. In the Auditory Only practice condition, motor feedback was removed (the pianists held their fingers in loose fists) but auditory feedback was present (pianists heard a computer-generated recording of the piece). In the Covert practice condition, both motor feedback and auditory feedback were removed during practice (pianists held their fingers in loose fists and heard silence). Each subject participated in each practice condition with a different stimulus piece (practice condition was a within-subject variable). The ordering of the 4 practice conditions and order of stimuli were counterbalanced across subjects with a Latin-square design.

Procedure.

Pianists were first given a consent form and a questionnaire that examined their musical training and background. In a practice trial, pianists practiced a 1-measure musical excerpt (similar to the actual stimuli) 5 times under normal conditions (with normal motor and auditory feedback). Then the notation was removed and the pianists performed the piece 3 times from memory. The pianists then performed the four conditions of the experiment; in each condition, pianists received specific instructions and practiced each piece 10 times with the musical notation present. In the Normal practice condition, pianists were simply instructed to perform the piece. In conditions in which one or both types of feedback were removed, pianists were instructed to imagine the missing feedback. In the Motor Only practice condition, they were told that they would not be able to hear the performance as they moved their fingers on the keys, and to imagine what the piece would sound like; in this condition, the first chord of the piece was sounded at the beginning to serve as an auditory reference. In the Auditory Only practice condition, they were told to hold their hands and fingers in loose fists (to reduce any undesired motor movements) as they heard the piece and to imagine what the finger movements would feel like. In the Covert practice condition, both of these instructions were given; in addition, pianists were told to depress the foot pedal each time they began to imagine the piece's sound and movements (to supply a measure of amount of time spent imagining). After each practice stage ended, the notation was removed and pianists played the piece 4 times from memory. During these 4 test trials, the feedback conditions were always normal.

Following the completion of the memory task, the two imagery posttests were administered. The motor imagery test was conducted first; pianists memorized the pictorial sequence of finger movements and used the electronic keyboard to "perform" (without auditory feedback) the subsequent letter sequences, and recorded their same-different answers on an answer sheet. Then the auditory imagery test was administered. On each trial, pianists listened to short sequences presented over headphones while reading music from notation, and indicated same-different on an answer sheet. The subjects were also asked to circle which pitch had changed in each example, if they were able. Finally, self-report measures were administered; pianists were asked to rate their sight-reading, memorizing, and playing by ear skills on a 10-point Likert scale (1=poor, 10 = excellent).

Results

The number of pitch errors was detected in the MIDI-recorded performances with a computer error-detection algorithm (see Large, 1993; Palmer & van de Sande, 1993), and error scores were converted to percentage of total notes in the music that were correctly recalled. (Duration errors were rare, due perhaps to the rhythmic simplicity of the music.) Performance at the end of practice was examined first, to ensure that the pianists correctly learned the music; participants were included only if the last 4 trials in the Normal practice condition showed percent correct notes of more than 95% .

An analysis of variance on the percent correctly recalled notes at test (from memory) by practice condition (Normal, Auditory Only, Motor Only, Covert) indicated a significant effect of practice condition, F (3, 45) = 8.2, $p < .01$. As shown in Figure 2, performance following Normal practice was best and Covert practice was worst. Tukey post-hoc tests indicated that performance in the Covert condition was significantly worse than in each of the other conditions ($p < .05$), and performance in the Normal condition was significantly better than in the Motor Only condition ($p < .05$). There was no significant difference between Motor Only and Auditory Only conditions, or between Normal and Auditory Only conditions. Presence of auditory or motor feedback at practice aided pianists' recall at test.

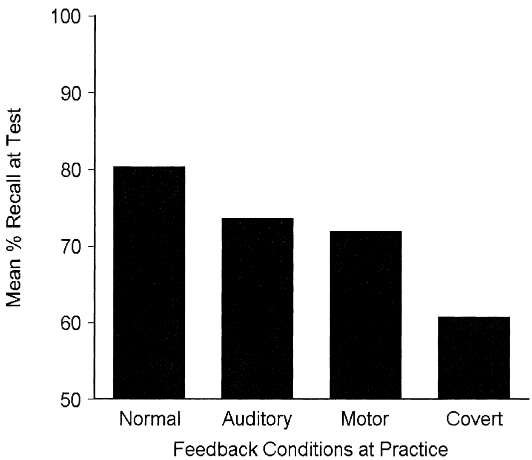

Figure 2. Pianists' mean percentage of pitches correctly recalled from memory at test for each feedback practice condition.

Pianists' scores on the auditory imagery posttest (perceiving melodic differences) and the motor imagery posttest (perceiving fingering differences), computed as percent correct responses, were examined next. A paired-sample t-test indicated that pianists' scores on the auditory imagery posttest (mean = 62.8 %) were significantly lower (t (15) = -2.86, $p < .05$) than their scores on the motor imagery posttest (mean = 81.8 %). There were no significant correlations between scores on the motor posttest and performance in any of the memory task conditions. The correlations between the auditory posttest scores and the memory task were significant; the auditory posttest scores correlated with pianists' recall scores in the memory task following the Covert condition ($r = .76, p < .01$) and the Motor Only condition ($r = .51, p < .05$), the two conditions in which auditory feedback was removed and pianists were instructed to imagine the sound. Pianists with higher auditory posttest scores were less affected by the removal of auditory feedback at practice than those with lower auditory posttest scores.

To further examine the effects of aural skills on the memory task, the pianists were divided into 2 groups based on a median split of the auditory posttest scores: those with the 8 highest scores (mean = 80%) and 8 lowest scores (mean = 46%). Results in the memory task for the high and low scorers are shown in Figure 3. There was a significant interaction between aural skills level and the practice condition, F (3, 42) = 2.72, p = .05. As shown in Figure 3, pianists with lower aural skills scores performed worse from memory than pianists with higher scores, in the Motor Only and Covert practice conditions — the two conditions in which auditory feedback was removed. Aural skills aided pianists' ability to memorize music that was learned in the absence of sound.

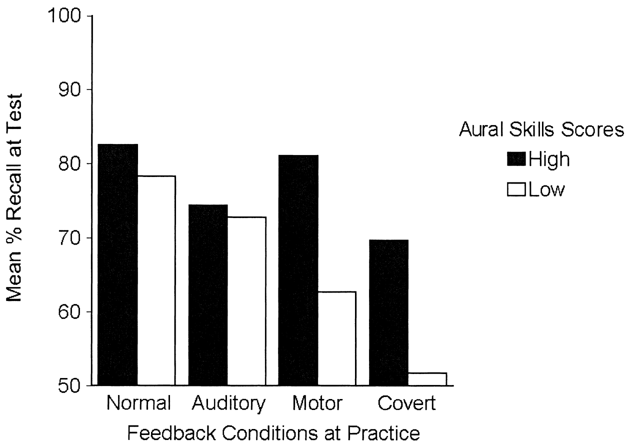

Figure 3. Mean percentage of pitches correctly recalled from memory at test for each feedback practice condition, for pianists with higher (n=8) and lower (n=8) aural skills scores.

Finally, the pianists' self-ratings of sight-reading ability, ability to memorize, and playing by ear were compared with other performance measures. Only self-ratings of playing by ear (mean = 4.7 out of 10) correlated with other variables; pianists' ratings of playing by ear correlated significantly with their auditory posttest scores ($r = .71, p < .01$) and with performance from memory at test across all practice conditions ($r = .54, p < .01$). Self-ratings of memorizing skills (mean = 7.2) or sight-reading skills (mean = 6.8) did not correlate with any variables.

Discussion

Both auditory and motor forms of practice facilitated pianists' subsequent performance from memory of unfamiliar music. Removal of auditory or motor feedback at practice caused significant memory deficits in later performance, despite the presence of both types of feedback at test. Physical practice conditions (in which auditory and/ or motor feedback were present) led to better performance recall than conditions with mental practice. Recall was best following normal practice conditions, and worst when both auditory and motor feedback were removed during practice. Furthermore, performers who had strong aural skills were least affected by the absence of auditory feedback during learning. Whereas previous studies demonstrated the overall efficacy of mental practice in music performance (Coffman, 1990; Ross, 1985), these findings suggest specifically that auditory forms of mental practice aid performers' learning of unfamiliar music.

Good performance in the absence of feedback could be due to little or no reliance on that type of feedback, or alternatively, to good imagery skills that allow performers to use mental practice to "fill in" for the missing feedback. Several aspects of this study are consistent with the latter explanation. First, there was a strong correlation between individual performers' aural skills measures and their performance from memory following the absence of auditory feedback at practice (Motor Only and Covert conditions). This finding suggests that musicians with strong aural skills can successfully create an auditory image of that information during practice. Second, the correlations between pianists' subjective measures of their ability to play by ear, the objective aural skills measures, and performance from memory in all memory conditions support the notion that mental practice can help substitute for missing auditory information. The advantage of an accurate auditory image during mental practice is consistent with previous studies that document the increased efficacy of mental practice with an auditory model (Lim & Lippman, 1990; Rosenthal et al, 1988; Theiler & Lippman, 1995).

Although the measures of performance from memory, aural skills, and self-ratings of playing by ear consistently point to the role of auditory mental practice, some aspects of the findings may be attributed to the design of the study. For example, all pianists were required to be capable of performing the music correctly by the end of practice, to ensure that the results reflected memory problems instead of learning problems. This criterion could account for the lack of effects of the motor imagery posttest, on which all of the pianists scored high. The test may have been too easy for the calibre of pianists who participated in the study. Novice performers may have weaker motor imagery abilities than the pianists included in this study (Palmer & Meyer, 2000). In addition, the method of practicing a piece ten times without stopping or correcting mistakes, although allowing consistent amounts of practice across individuals, was somewhat artificial. Despite these limitations, the study provides some insight into the relationship between practice and performance from memory. The significance of auditory feedback during practice for improving performance from memory suggests that performers should concentrate on the sound of the piece during practice rather than on the movements that create that sound. In other words, the goals of practice should match the goals of performance.

Music performance is often depicted as both a cognitive and motoric task (Palmer & Meyer, 2000; Theiler & Lippman, 1995); from this perspective, it is not surprising to find effects of both auditory and motor mental practice in performance from memory. What is more surprising is the association documented here between individual performers' memory and imagery skills. The individual differences suggest that performers differ in their motor imagery and learning versus their auditory imagery and learning. Although most comparisons of mental practice methods rely on cross-group comparisons (see Driskell, Copper & Moran, 1994; Feltz & Landers, 1983), the presence of individual differences suggests that within-subject designs — those that allow comparisons across all conditions within individual performers — may be necessary for evaluating the relative efficacy of mental practice methods. Future studies may trace the development of auditory imagery and motor imagery abilities in performance.

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