The Power of Listening

Auditory-Motor Interactions in Musical Training

AMIR LAHAV,[a,b] ADAM BOULANGER,[c] GOTTFRIED SCHLAUG,[b]
AND ELLIOT SALTZMAN [a,d]

[a]*The Music, Mind and Motion Lab, Sargent College of Health and Rehabilitation Sciences, Boston University, Boston, Massachusetts 02215, USA*

[b]*Department of Neurology, Beth Israel Deaconess Medical Center and Harvard Medical School, Boston, Massachusetts 02115, USA*

[c]*The Media Lab, Massachusetts Institute of Technology, Boston, Massachusetts 02139, USA*

[d]*Haskins Laboratories, New Haven, Connecticut 06511, USA*

ABSTRACT: We trained musically naive subjects to play a short piano melody by ear in a fully monitored computerized environment and tested their potential to acquire a functional linkage between actions and sounds. Individual notes that were simply acoustic pretraining signals became "physically meaningful" posttraining. In addition, we found preliminary evidence that passive listening to a newly learned musical piece can enhance motor performance in the absence of physical practice.

KEYWORDS: musical training; performance; auditory-motor; implicit learning

INTRODUCTION

When playing a musical instrument, movements are naturally paired with direct auditory feedback. Musical training, therefore, can establish a multimodal functional mapping that links what we hear and what we play. Professional musicians often report feeling a physical sensation when listening to music they know how to play. Similarly, recent studies in the visual-motor domain have shown that when dancers watched familiar and performable dancing movements, their brains automatically simulated those movements.[1] While one may speculate on the underlying neural perception-action mechanisms in the musician's brain,[2] it is unclear whether such an audiomotor linking capability is an innate predisposition and even a prerequisite for becoming a musician, or is simply experience dependent.[3] To address this, we trained nonmusicians to play a novel piece of music and closely monitored their learning process. We expected that subsequent listening to the acquired musical

Address for correspondence: Amir Lahav, The Music, Mind and Motion Lab, Boston University, 635 Commonwealth Ave., Boston, MA 02215. Voice: 617-353-7497.
lahav@bu.edu

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piece might unconsciously prime the listener's corresponding motor repertoire, which in turn might lead to motor improvement.

METHODS

Experiment 1

Fifty-eight right-handed nonmusician college-level subjects (32 women, 26 men; mean age = 22.3 ± 2.8) attended a single piano session, in which they learned to play a novel musical piece (FIG. 1) on a piano keyboard, using their right hands and a set of five adjacent keys (F-G-A-B$^\flat$-C), in a fixed fingering position (i.e., the same finger always hit the same key). Motivated by previous training tools,[4] we designed innovative MIDI-based software for learning by ear with no sight-reading required. Subjects learned to play the piano role (solo) along with a prerecorded accompaniment (guitar, bass, and drums), while a computer didactically notified them when note (wrong key press) or timing (± >1/16th) errors occurred. To complete a piano

FIGURE 1. The musical piece: Subjects learned the piano part gradually, section by section, in the following measure order: 1–2; 3–4; 1–4; 5–6; 1–6; 7–8; 1–8.

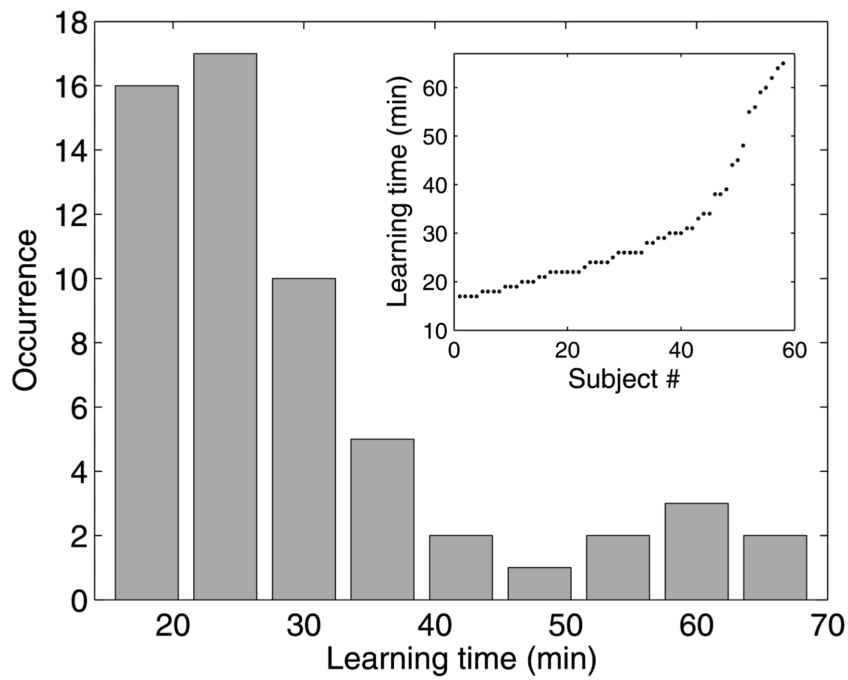

FIGURE 2. Learning times of the musical piece are shown for group distribution and for individual subjects (*inset*).

session, subjects went through a series of trials until reaching error-free performance. The minimum possible learning time was 12 minutes.

Pitch-Recognition-Production Test

Before and after their piano-training session subjects were presented with single notes (taken from the piano piece) in random order, and were asked after hearing each note, to press the corresponding piano key. Percent correct responses was measured.

Experiment 2

Following the initial piano session (Exp. 1), subjects (n = 36) were randomly assigned into three groups and underwent three additional 20-minute listening/practicing sessions over a period of one week. The *piano-listening group* passively listened to the same musical piece they had previously learned. During listening sessions, subjects lay supine with their palms facing up. Finger positions were monitored digitally using a motion-tracking system and a passive-marker glove to ensure that subjects followed instructions to stay as still as possible. The *nature-listening group*

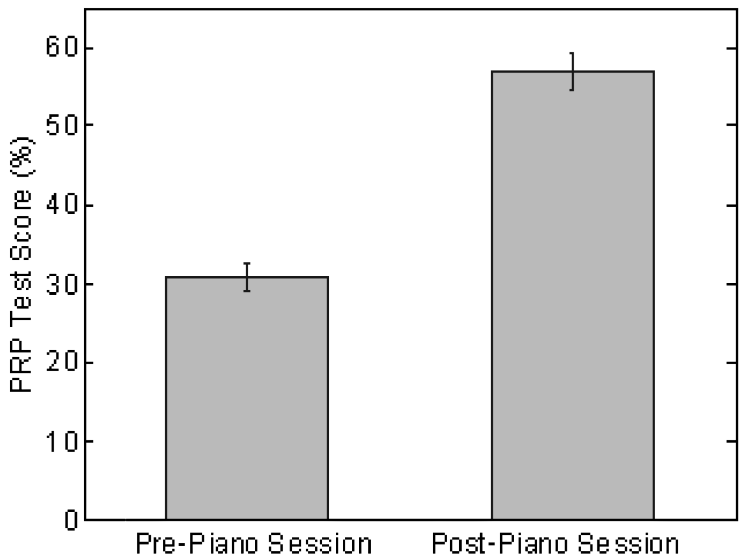

FIGURE 3. Mean PRP test score before and after piano training session. *Error bars* represent standard error of the mean.

listened to nature sounds, to control for treatment effects due merely to auditory exposure. The *practicing group* received additional practice sessions with the initial musical piece.

Performance Test

Subjects were asked to play the whole musical piece as accurately as possible, while their keyboarding was not accompanied by the original rhythmic-harmonic background instrumentation. Subjects' note/timing errors were measured.

RESULTS AND DISCUSSION

Nonmusicians Learn to Play by Ear

We first examined how nonmusicians learn to play a musical piece for the first time (Exp. 1). The average learning time to error-free performance was 28.5 minutes (STD = 12.9). Interestingly, learning times followed a bimodal distribution (FIG. 2), with most subjects learning relatively quickly and a small group taking considerably longer. A similar distribution pattern was found also for learning a different musical piece (data not shown). Classifying subjects by their learning times may open an experimental window for future brain imaging studies comparing neural activity of super learners versus poor learners.

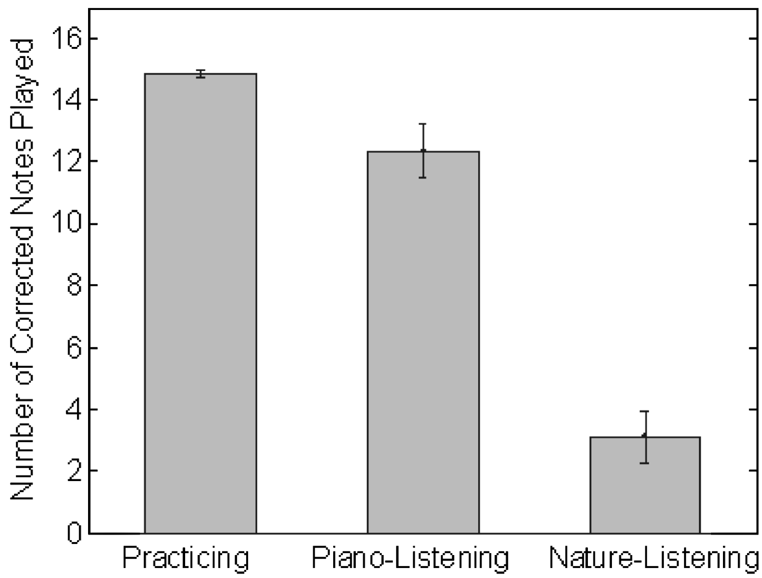

FIGURE 4. Mean correct notes for the musical piece played at the right time during performance test. *Error bars* represent standard error of the mean.

A Single Piano Session Facilitates Pitch Recognition

Here we ask whether learning to play a musical piece by ear could act to induce a pitch-to-key mapping, in which perceived notes can be identified independently of their original musical context. To this end, a pitch-recognition-production (PRP) test was performed before and after the initial piano session. To rule out learning effects during the PRP test, subjects did not receive knowledge of results (auditory feedback) when pressing the piano keys. Results showed that subjects improved their scores from approximately 30% pretraining to about 60% posttraining (FIG. 3, $P = 1 \times 10^{-15}$). These findings hint at a newly learned pitch recognition skill, consistent with the view that the ability to encode pitch develops with experience.[5]

Passive Listening to Music Improves Motor Performance

We tested the three listening/practicing groups (see METHODS, Exp. 2) on subjects' ability to play the previously learned musical piece. On average, the piano-listening group performed significantly better in the performance test than the nature-listening group ($P = .01$), but not as well as (though not far behind) the practicing group (FIG. 4, $P = 1 \times 10^{-7}$). Analysis of our digital motion-tracking system verified that subjects' fingers indeed did not move during listening sessions. These findings suggest that during passive listening, neural mechanisms linking sounds and actions may implicitly facilitate musical motor performance. We are now in the process of investigating further behavioral and functional imaging measures to determine in greater detail the processes underlying this motor improvement (manuscript in preparation).

[Competing interests: The authors declare that they have no competing financial interests.]

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