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Research article

Expertise-dependent motor somatotopy of music perception

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HIGHLIGHTS

- Auditory-motor integration subserves performance of skillful behaviors.
- Transcranial stimulation over the motor cortex was applied while listening to sound.
- Listening to piano tones but not noise elevated motor excitability in pianists.
- The elevation occurred in a muscle-specific manner.
- No modulation of corticospinal excitability was evident in non-musicians.

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ABSTRACT

Precise mapping between sound and motion underlies successful communication and information transmission in speech and musical performance. Formation of the map typically undergoes plastic changes in the neuronal network between auditory and motor regions through training. However, to what extent the map is somatotopically-tuned so that auditory information can specifically modulate the corticospinal system responsible for the relevant motor action has not been elucidated. Here we addressed this issue by assessing the excitability of corticospinal system including the primary motor cortex (M1) innervating the hand intrinsic muscles by means of transcranial magnetic stimulation while trained pianists and musically-untrained individuals (non-musicians) were listening to either piano tones or noise. M1 excitability was evaluated at two anatomically-independent muscles of the hand. The results demonstrated elevation of M1 excitability at not all but one specific muscle while listening to piano tones in the pianists, but no excitability change in both of the muscles in the non-musicians. However, listening to noise did not elicit any changes of M1 excitability at both muscles in both the pianists and the non-musicians. These findings indicate that auditory information representing the trained motor action tunes M1 excitability in a non-uniform, somatotopically-specific manner, which is likely associated with multimodal experiences in musical training.

1. Introduction

Integration of sensory information into planning and execution of motor actions plays an important role in both feedforward and feedback control of skillful behaviors. A putative neurophysiological mechanism mediating sensorimotor integration is a neuronal network connecting regions responsible for sensory and motor processes [1,2]. Musicians have gained attention as a model for studying neuroplasticity of the sensorimotor network in humans [3–8]. A particular focus of the literature has been on formation of an auditory-motor network through musical training [3,9–11]. Neuroimaging studies have provided converging evidence of co-activation of the motor and auditory cortices during either listening to sound without moving the body or vice versa in musicians [11–14]. The co-activation occurs through musical training, suggesting neuroplastic development of the auditory-motor connection [3,10]. However, to what extent neural representation of motor action and auditory perception has fine-tuned somatotopy in the cortical motor area and its plasticity through training has not been elucidated [15]. Of particular interest, therefore, is whether listening to tones modulates motor cortical excitability of a specific group of muscles or rather in a muscle-nonspecific fashion only in trained individuals. To address this issue is important

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to better understand functional significance of the auditory-motor neuronal network.

Transcranial magnetic stimulation (TMS) allows the assessment of excitability of the corticospinal system including the primary motor cortex (M1). A seminal TMS study demonstrated facilitation of the corticospinal system in the wrist extensor muscle while pianists were listening to well-rehearsed music [9]. Another TMS study also reported that in musicians, listening to groovy music elevated M1 excitability of both the wrist extensor and the hand intrinsic muscles to a similar extent [16]. These and other findings [14] let us postulate that musical training brings about global functional modulation of M1 in a muscle-nonspecific manner through listening to tones. By contrast, some other studies provided evidence of an alternative possibility that auditory information functionally modulates the corticospinal system controlling a specific group of muscles associated with production of listened tones. For example, in speech, perception of speech sounds generated by the lip and tongue is mediated by motor representation of the lip and tongue, respectively [17]. In pianists, but not musically-untrained individuals (i.e. non-musicians), visual observation of a fingering error in piano performance specifically modulated M1 excitability of a muscle involved in the erroneous action [18].

Using single-pulse TMS, the present study compared M1 excitability of two hand intrinsic muscles without any movements (i.e. at rest) during listening to either piano tones or noise between trained pianists and non-musicians. We postulated first that listening to piano tones but not noise facilitates M1 excitability of musically trained but not untrained individuals, and second that this modulation is somatotopically specific.

2. Material and methods

2.1. Participants

Ten trained pianists (age 23.8 ± 4.1 years; 1 males, all right-handed) and ten age-matched musically-untrained individuals (=non-musicians) (age 21.4 ± 1.5 years; 2 males, all right-handed) were recruited as participants in the study. Results of the Edinburgh handedness test were 96.9 ± 6.5 and 96.8 ± 9.5 for the pianists and non-musicians, respectively. They had no histories of neurosurgery, movement and neuropsychiatric disorders, or metal or electronic implants. The pianists commenced to play the piano at age 4.3 ± 0.6 yrs old, and have underwent piano training for 19.5 ± 3.9 yrs. All of the pianists have majored piano performance at some musical conservatory. During the last three months, the average duration of daily piano practice was 2.9 ± 1.6 h. In accordance with the Declaration of Helsinki, the experimental procedures were explained to all participants. From all participants, written informed consent was obtained prior to participation in the study. The experimental protocol was approved by the ethics committee of Sophia University.

2.2. Experimental design

2.2.1. EMG recording

To record the motor evoked potentials (MEPs) and background muscular activities, surface electromyography (EMG) data were recorded from the first dorsal interosseous (FDI) and abductor pollicis brevis (APB) muscles of the right hand using Ag/AgCl disposable electrodes with diameters of 23 mm (Biorode SDC112 GE Healthcare, USA) (Fig. 1). Standard skin preparation was performed prior to attachment of the electrodes. The electrodes were placed in a belly-tendon montage. The EMG signals were amplified, band-pass filtered (10–1000 Hz), sampled at 2 kHz (PowerLab, ADInstruments, UK), and stored on a personal computer for offline analysis using LabChart software (ADInstruments, UK).

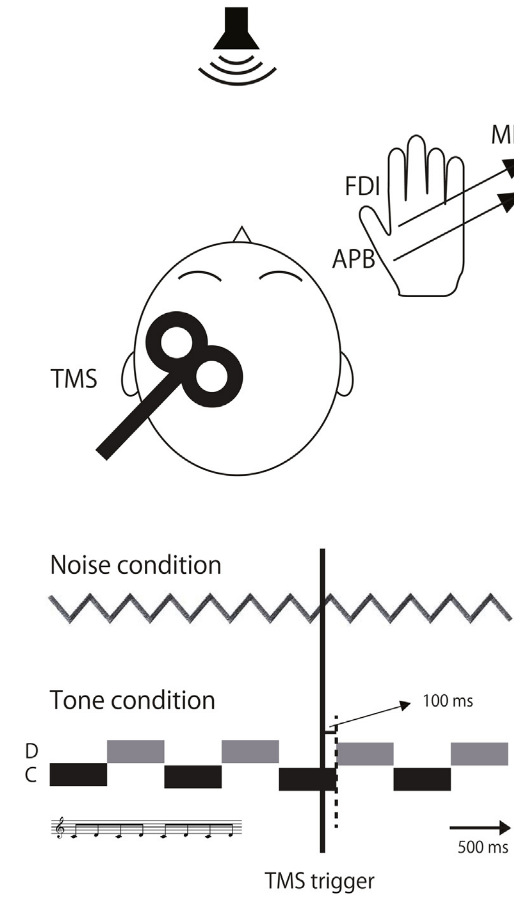

Fig. 1. Experimental setup and task. A participant was listening to either a succession of two adjacent piano tones (C3: lower and D3: higher) or white noise at rest. In the tone condition, an interval between the two tones was 500 ms, and TMS was applied 100 ms prior to production of the higher tone (D3). TMS was applied over the left M1.

2.2.2. TMS recording

The participants were seated in a comfortable chair with both arms resting on a cushion while supinated. Single-pulse TMS was delivered with a figure-of-eight shaped coil (wing diameter of 70 mm) connected to a high-power Magstim 200^2 machine (Magstim Company, Dyfed, UK). An experimenter held a coil tangentially to the scalp with keeping the handle oriented backwards at a 45° angle from the sagittal plane, which yielded a posterior-to-anterior current direction [19,20], to activate the corticospinal system. The coil was placed over the location for evoking the largest MEP in the FDI and APB, which is the target muscle of the present experiment. To ensure proper coil placement throughout the experiment, the experimenter marked this position on the scalp with a red felt-tip pen. All of the participants underwent stimulation over the left M1 to elicit MEPs in the right hand. The intensity of a test stimulus was adjusted to elicit not only MEPs of 1 mV in peak-to-peak amplitude at FDI, but also MEPs of no less than 1 mV at the APB, at rest prior to initiating the experimental session. In the end, we found the stimulation location and intensity that can elicit 1 mV peak-to-peak MEP at both APB and FDI in all participants. The entire TMS assessment procedure followed standard guidelines [21].

The TMS recording session consisted of a single-pulse TMS experiment with two different conditions. Each participant was stimulated while listening to either piano tones elicited by a digital piano (DGP-5, YAMAHA co.) ("tone condition") or white noise