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Pre-attentive auditory processing of non-scale pitch in absolute pitch possessors

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HIGHLIGHTS

- We investigated MMN elicited by non-scale note in absolute pitch (AP) possessors.
- MMN elicited by non-scale note was distinct compared to scale note in AP group.
- AP group could discriminate non-scale note from scale note pre-attentively.
- Non-AP group processed scale note and non-scale note in the same way.
- AP may be characterized as preattentive discriminability of non-scale note.

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ABSTRACT

Absolute pitch (AP) refers to the ability to identify the pitch of sound without reference. To clarify the neurophysiological characteristics of AP, we compared mismatch negativity (MMN) elicited by scale and non-scale notes between AP possessors and non-AP individuals. Eight individuals who were able to identify pitch with perfect accuracy were defined as AP possessors. Eighteen participants who failed to achieve perfect accuracy were included in the non-AP group. We presented participants with two tone pairs, in a scale condition and a non-scale condition. The frequency ratios of the two pairs were the same. MMN over the frontal region in the non-scale condition was larger in the AP group than the non-AP group. In contrast, no such difference was observed between the two groups in the scale condition. The results suggest that pre-attentive processing of non-scale note sounds in the auditory cortex is a salient neurophysiological characteristic of AP.

1. Introduction

The Western tonal system is based on 12 tones (scale notes), fixed according to the equal-tempered tuning system. In this system, a semitone corresponds to exactly one twelfth of an octave, corresponding approximately to a 6% frequency difference between two tones. Absolute pitch (AP) or perfect pitch is relatively rare and refers to a long-term internal representation of the pitch of tones in the musical scale [12]. AP is typically manifested behaviorally as the ability to identify, by the name of the musical note, the pitch of any sound without reference to another sound, or by producing a given musical tone on demand [16], as well as the ability to precisely distinguish a non-scale note from a scale note. Although a number of previous studies have examined the neural basis of AP, its precise mechanisms remain unclear.

The effects of AP on the time course of neural processing of musical tone characteristics are not well understood. Event-related potentials (ERPs) provide precise information about the temporal dynamics of processing and may be a useful tool to resolve this issue. Auditory predictions are even generated automatically (i.e. non-intentionally on a pre-conscious processing level) on the

Abbreviations: MMN, mismatch negativity; ERP, event-related potential; AP, absolute pitch; SOA, stimulus onset asynchrony.

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basis of detected regularities of the acoustic world [10]. The mismatch negativity (MMN) is an auditory ERP that reflects auditory pre-attentive processing. An MMN is elicited when infrequent ("deviant") sounds violate the pattern of a previously detected sequence of repetitive ("standard") sounds [6]. The MMN appears with a typical latency the MMN peaks between 100 and 300 ms as a negative deflection over fronto-central scalp sites [4] and a positive deflection over mastoid sites when recorded with a nose reference [2]. Its generators are located in the auditory and in the frontal cortex [11]. Assuming that each incoming sound is compared against a prediction derived from the present regularities [10,15], the MMN can be interpreted as an error signal in the auditory system that is triggered whenever a sound violates a prediction. Previous auditory studies have demonstrated that the MMN amplitude increases with the magnitude of the deviance between the standard and deviant stimuli (physical deviance) [8]. The MMN can also be used to index training-related improvements in discrimination ability (i.e. discriminability) [14]. Non-musicians discriminate dissonant–consonant chords more easily than major–minor chords, and this discrimination effect is associated with a larger MMN amplitude for dissonant chord processing [14]. Recent research by Matsuda et al. [5] compared the MMN elicited by a change from scale note to non-scale note with a change from scale note to scale note. Despite a smaller physical deviance, the MMN elicited by a change from a scale note (F0 = 440 Hz; A4) to a non-scale note deviant (F0 = 506; B4 + 42¢) was larger than the MMN elicited by a change from the same scale note (F0 = 440 Hz; A4) to another scale note deviant (F0 = 523 Hz; C5).

To elucidate the differences in pre-attentive auditory processing between AP possessors and individuals without AP (non-AP), the current study investigated MMN elicited by a non-scale note. Since non-AP individuals cannot distinguish a non-scale note from a scale note, we hypothesized that a non-scale note pair and a scale note pair would be processed in the same way by people who do not possess AP. Furthermore, we examined whether AP possessors would process a non-scale sound pair differently from a scale sound pair. To this end, we used two pairs of violin sounds to create two conditions: (1) a scale note condition, in which both the standard and deviant stimuli were scale note sounds, and (2) a non-scale note condition, in which both stimuli were non-scale note sounds. The frequency ratios of the two pairs were fixed (Figs. 1 and 2).

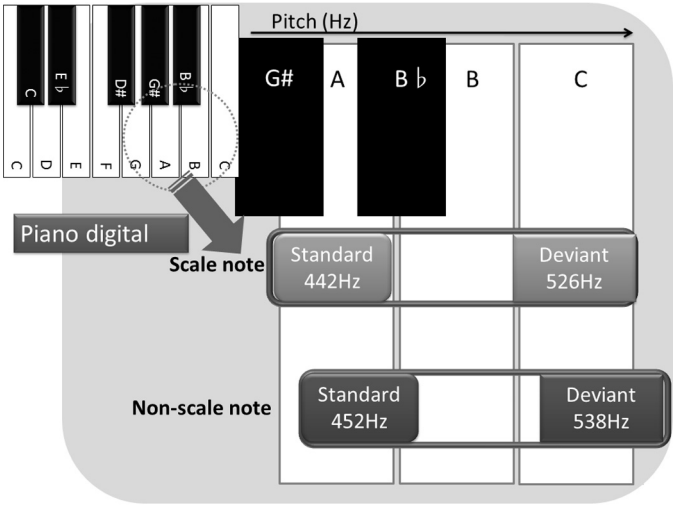

Fig. 1. Details of the four stimuli (Scale-A, Scale-C, Non-scale note X and Non-scale note Y).

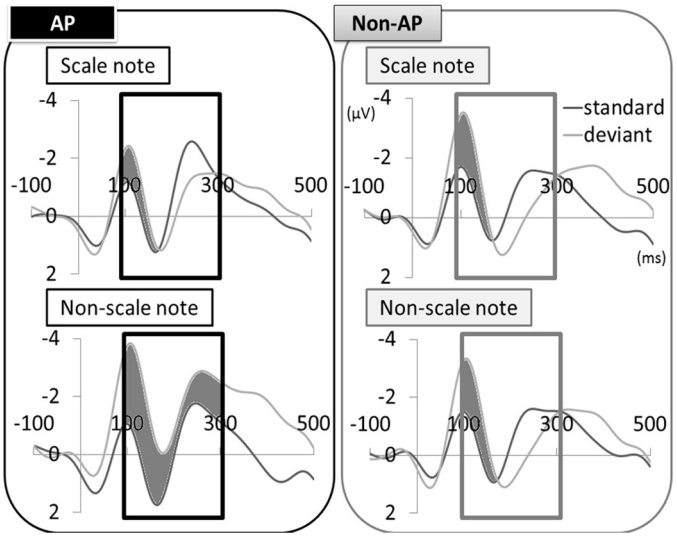

Fig. 2. Grand average waveforms for the standard stimuli (black line) and for the deviant stimuli (gray line) in the AP group (left) and in the non-AP group (right) at Fz. The gray areas between the two grand average waveforms at 100–300 ms represent MMN responses. Note that the MMN response in the non-scale condition was substantially larger in the AP group than in the non-AP group.

2. Methods

2.1. Subjects

Twenty-six healthy subjects participated in the experiment (22 females, four left-handed and one ambidextrous, mean age: 21.9 ± 1.7 years). The exclusion criteria were psychiatric disease, substance abuse or dependence, and impairments of hearing or vision. The study was approved by the Ethics Committee at Tokyo Medical and Dental University, and written informed consent was obtained from each participant.

2.2. Behavioral experiment (AP test)

Prior to the EEG experiment, each participant completed an AP test in which 32 pure tones, including 25 scale notes and seven non-scale notes (three octave tones), were presented pseudo-randomly through a speaker to the participants, who were seated. Each pure tone was presented for 500 ms at intervals of 3000 ms. The note names: Do, Do#, Re♭, Re, Re#, Mi♭, Mi, Fa, Fa#, Sol♭, Sol, Sol#, La♭, La, La#, Si♭, and Si (fixed do solmization) were printed on piano digital picture sheets. The sheets were given to the participants, who were instructed to circle the corresponding piano key on the sheet after hearing each scale note. In the case of the non-scale notes, the participants were asked to write down the two adjacent scale notes that surrounded the non-scale note. Participants did not receive any feedback while completing this task.

The AP test took approximately ten minutes in total, including instruction. To elucidate the characteristics of AP in the current experiment, we decided that a narrow and strict definition of AP would be appropriate. Therefore, we classified the eight individuals who scored 100% on the AP test into an AP group and the other individuals into a non-AP group. This classification was used for later analysis of the electroencephalography (EEG) data. After the EEG experiment, we interviewed both groups concerning their subjective impressions of the occurrence of non-scale notes.