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Effects of Short-Term Experience on Music-Related ERAN

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ABSTRACT

Background

This study uses MEG to investigate how short-term musical experience modulates the strength of the early-right anterior negativity (ERAN) response to implied harmonic-syntax violations. Our hypothesis is that the ERAN response should sustain during the short-term experience, challenging the view that it depreciates significantly over time. This hypothesis is supported by preliminary analysis of four subjects. The ERAN is a recently discovered event-related potential (ERP) that is proposed to be implicated in syntactic processing in both music and language. It is a type of mismatched negativity that has anterior scalp distribution, right-hemispheric weighting, and relies on schematic representations of musical regularities. Previous studies have shown that the ERAN can be modified by short-term musical experience. However, these studies rely on complex (literal) harmonic stimuli and implicit listening strategies. Moreover, the earlier analyses examine only changes of ERAN in syntax-violated conditions, and do not compare these to responses to the control stimuli, hence it remains questionable whether the perceived modulation is due to reduced level of attention alone. In an effort to better understand how habituation may affect the ERAN in musical contexts, this study asked musicians and non-musicians to directly attend to simple melodies that are either syntactically well-formed, conforming to common-practice tonality (M1), or end with an out-of-key pitch (M2).

Aims

This study uses MEG to investigate how repeated hearings change the brain's response to musical-rule violations. This poses two issues. First, how can we reliably represent musical repetition in a neuroimaging context? Second, how can we analyze data to show changes over time? This study investigates how short-term experience modulates the strength of the ERAN response to implied harmonic-syntax violations. Previous studies have shown that the ERAN can be modified by short-term musical experience (Koelsch 2008). However, these studies rely on complex (literal) harmonic stimuli and experimental paradigms where stimuli are presented simultaneously with visual images and written text. In an effort to better understand how habituation may affect the ERAN in musical contexts, this study will ask subjects to directly attend to simple melodies (implied harmonies) that are either syntactically well-formed, conforming to common-practice tonality (M1), or end with an out-of-key pitch (M2). This study attempts to model the phenomena of "musical rehearings" in neuroimaging studies by capitalizing on diachronic listening and describing how the neural response to a stimulus changes over time. In addition, this study will work toward establishing reliable working paradigms for music neuroimaging studies using MEG. fMRI and EEG are the dominant neuroimaging methods for music-cognition studies. MEG has the advantage of millisecond temporal resolution and good spatial resolution, making it a very promising modality for investigating temporally-related human-brain responses to music.

Method

Stimuli
Each participant is exposed to two trial conditions. Condition 1 (M1) is comprised of a five-note well-formed tonal diatonic melody (pitches: G-B-A-F#-G) and condition 2 (M2) is comprised the same melody but ending with an out-of- key note (pitches: G-B-A-F#-G#). Each melody comprised 5 pure tones of 750ms duration for a total stimulus time of 3750ms. Each subject was exposed to 80 trials of M1 and 80 trials of M2. The trials were played sequentially within condition, with an inter-trial interval varying between 2.5 and 3.5 seconds and a refocusing task every 20 trials. The re-focusing task consisted of a simple button press (left or right, using the MEG-compatible pads) based on the positions of a red square on the screen.

Acquisition
All subjects gave their written informed consent approved by the University of Pittsburgh (protocol PR010060166) Institutional Review Boards. MEG data were recorded using an Elekta Neuromag device (Elekta Oy), which has a total of 306 channels. These channels are distributed in 102 sensor triplets, each containing one magnetometer and two gradiometers that measure the differential magnetic field in orthogonal directions. The data were acquired at 1 kHz, high-pass filtered at 0.1 Hz and low-pass filtered at 330 Hz. Eye movements (EOG) were also monitored by recording differential activity of muscles above, below, and lateral to the eyes. Additionally, four head position indicator (HPI) coils were placed on the subject's scalp to record the position of the head with relation to the MEG helmet at the beginning of each session. These coils, along with three cardinal points (nasian, left and right pre-auricular), were digitized into the system and were later used for source localization.

Pre-Processing
The data were preprocessed using the Signal Space Separation method (SSS). SSS divides the measured MEG data into components originating inside the sensor array vs. outside or

very close to it, using the properties of electromagnetic fields and harmonic function expansions. The temporal extension of SSS (tSSS) further enables suppressing components that are highly correlated between the inner and close-by space, such as mouth movement artefacts. Finally, tSSS realigned the head position measured at the beginning of each block to a common location. The MEG signal was then low-pass filtered to 50 Hz to remove the contributions of line noise and down-sampled to 200 Hz. The Signal Space Projection method (SSP) was then used to remove signal contamination by eye blinks or movements, as well as MEG sensor malfunctions or other artifacts.

Analysis

Once data have been collected and corrected for artifacts using the temporal extension of SSS and SSP, it moves through two analytical stages. The first stage is to identify the largest evoked brain response to the final pitch of M2 both spatially (channel location) and temporally (time after stimulus onset) over all trials. Pilot subjects all show a spatiotemporal response that is consistent with the ERAN literature. Once the largest evoked brain response's spatiotemporal locations are identified, the two coordinates (time and space) are entered into a program that averages the response to both M1 and M2 using a scheme involving a step (r) and a window (w). For example, r =6 and w =10 means that the values for repetitions 1:10 will be averaged, then the values for repetitions 6:15, then 11:20, etc. This creates a "time" series for each channel and condition. Such time series would be suited for statistical curve fitting and hypothesis testing, with the aim to examine whether evoked brain responses to musical syntax violation persist through the experiment. In addition, in contrast to an earlier study (Koelsch, et al., 2008a), the proposed study examines the difference between M1 and M2 rather than just a subject's response to the deviant condition (M2), allowing confounds such as attentional drift to be removed by comparison to baseline conditions.

Results

Our work has reliably replicated ERAN-type results found in EEG/ERP studies. Using the step/window analysis model we were able to create a time series for subjects' responses to M1 and M2. Our results clearly show that while significant change can appear in a subject's response to the errant (M2) condition, that change is mirrored in the subject's response to the control condition. By examining the relationship between responses to M1 and M2 conditions, we find that there is no significant habituation to M2 that is independent of M1. This suggests that changes in a subject's response to M2 could be due to attentional drift rather than an adaptation. We conclude that listeners do not habituate to errors in tonal syntax in melodies in the short term.

Keywords

MEG, ERAN, Music, Syntax, Expectation, Habitutaion

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