A pilot investigation on electrical brain responses related to melodic uncertainty and expectation

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ABSTRACT

Background

Listening to music is often an active process of continuously forming expectations about how the music will unfold in time. Emotional and aesthetic responses to music are thought to depend partly on the fulfilment/violation of such expectations (Huron, 2006). However, not all melodic contexts allow for the generation of strong expectations about how those melodies will continue, i.e. melodic contexts differ in the uncertainty they create about the melodic continuation. Pearce and Wiggins (2006) developed a statistical learning model to quantify melodic uncertainty and expectation based on regularities in melodic sequences. This model takes sequential melodic context into account and estimates, for every note in a melody, a conditional probability distribution governing the probability of the pitch of the next note in a melody given the preceding notes. The entropy of this conditional probability reflects the uncertainty about the continuation of the melody, e.g a uniform distribution reflects maximum uncertainty since all pitches are equally likely to occur. The conditional probability of the note that is eventually played reflects the expectedness of that note, with low probability notes assumed to be unexpected at that position in a melody, and high conditional probability notes assumed to be expected.

Aims

Uncertainty and expectation are closely linked concepts but, importantly, relate to different points in time: Uncertainty is a property of the melodic context and relates to anticipation of the upcoming note, while expectation is a property of a single note played in a melodic context. The neural correlates of the fulfilment of expectation were studied earlier (Koelsch & Jentschke, 2010; Pearce et al, 2010), yet little is known about the brain responses related to uncertainty of expectation. The aim of the current study was to identify distinct brain responses reflecting uncertainty of melodic continuation, and unexpectedness of musical notes. Identifying such responses will be a first step towards continuously tracking the dynamic brain responses reflecting ongoing interactions of building up and fulfilling/violating expectations that occur while listening to real-life music.

Method

For a set of 97 monophonic hymn melodies consisting of 32 notes, our statistical learning model provided note-by-note estimates of the uncertainty of expectation and the unexpectednes. EEG data was recorded while participants (musicians, *n*=20) listened, with their eyes closed, to these melodies, which were played isochronously with an inter-note-interval of 900ms. Participants were asked to detect an occasional odd-ball timbre, which occurred in ~10% of the melodies. Melodies containing an odd-ball timbre were discarded from the analyses.

Linear regression-based models were used to analyze the relationships between single-trial EEG amplitude, relative to 100ms prestimulus baseline, and uncertainty or unexpectedness.

Results

A negative linear relationship between single-trial EEG amplitude and the unexpectedness of single notes was found around 120 ms after note onset over frontal areas. This initial relationship was followed by a positive relationship over more frontocentral areas between 200-300ms.

Uncertainty about melodic continuation showed an early negative relationship with frontal EEG amplitudes around 120ms after the onset of the note that sets up the uncertainty, followed by a recurrent occipital negativity ~470 and 580ms after note onset..

Conclusions

The early frontal negative relationship between unexpectedness and EEG amplitude seems to replicate results of previous studies in which ERPs to expected and unexpected notes were compared (Koelsche & Jentschke, 2010; Pearce et al, 2010), and probably reflects the detection of a syntactic violation in the melody. The later positive effect of unexpectedness over frontocentral areas seems to be a novel finding related to the processing of melodic expectation, possibly reflecting the processing of musical syntax at higher-order brain areas.

EEG amplitude over frontal areas showed an early negative relationship with the uncertainty about the melodic continuation, suggesting the possible involvement of these brain areas in predicting probabilistic events. During the second half of the ITI, uncertainty was negatively related with EEG amplitude over posterior areas, possibly reflecting the effort involved in anticipating the next note.

These findings provide first evidence of neural responses associated with the generation of melodic expectations, and altogether support our claim that statistical learning produces information-theoretic descriptions of music that are associated with distinct patterns of neural activity.

Keywords

Melodic Expectation, EEG, ERP, Time-Frequency Representation, Statistical Learning

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