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Electrophysiological correlates of subjective equality and inequality between neighboring time intervals

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ABSTRACT

Background

Rhythm perception and production are important aspects of music, and equality or inequality of neighboring time intervals often characterizes rhythm. However, perception of equal or unequal time intervals does not simply result from physically equal or unequal time intervals. When two neighboring time intervals *t1* and *t2* are marked by three successive tone bursts, human listeners are able to judge whether these intervals are equal or unequal. When the intervals are around 200 ms or below, the equality appears as a category in a range $-80 \leq t1 - t2 \leq 50$ ms. However, the perception displays some ambiguity around a categorical boundary. In our previous study (Mitsudo et al., 2009), a temporal pattern in which the neighboring time intervals were *t1* = 280 and *t2* = 200 ms caused both "equal" and "unequal" judgments to substantial amounts, although "unequal" judgment was clearly dominant.

Aims

We aimed at examining whether different judgments to the same temporal pattern could be related to any particular brain activities observed in the event-related potentials (ERPs) of the scalp. If this was the case, it was also important to clarify when and how the difference in electrophysiological indices between "equal" and "unequal" judgment was accumulated.

Method

We reanalyzed a part of a new set of ERP data (Mitsudo et al., 2012). The ERPs were recorded from 19 scalp electrodes while participants listened to the temporal patterns and made judgments about the subjective equality. The time interval *t1* was varied from 80 to 320 ms in 7 steps while *t2* was held constant at 200 ms in Experiment 1. Similarly, the time interval *t1* was held constant at 200 ms and *t2* was varied from 80 to 320 ms in 7 steps in Experiment 2. We took the data for (*t1, t2*) = (120, 200), (280, 200), (200, 120), and (200, 280), as they led to both "equal" and "unequal" responses to substantial amounts. Selective average waveforms were calculated for the "equal" and the "unequal" responses for each temporal pattern for each participant. They were converted to z-scores for each recording site. A histogram of the normalized ERP voltages across the individual participants was formed as a probabilistic distribution at each temporal sampling point. The obtained distributions then yielded a series of Bhattacharyya distances defined as the negative logarithm of the integrated square root of the product of the probability densities between the "equal" and the "unequal" distributions. Finally, correlation was calculated between the rate of "equal" judgment and the integral of the Bhattacharyya distance over each of the 400-ms interval before and the 100-ms interval after the onset of the third tone burst.

Results

The obtained Bhattacharyya distances showed increase if they were small at the beginning, and reached a certain level after the presentation of the third tone burst. A significant correlation was found between the inequality response rate and the integrated Bhattacharyya distance over the 100-ms interval after the onset of the third tone burst, suggesting that the ERP waveforms shortly after the presentation of the third tone burst were substantially different depending on the perceptual judgment for the temporal pattern. No such correlation was found in the 400-ms interval before the third tone burst.

Conclusions

The results showed that the different judgments to the same temporal pattern could be related to different overall brain activities as appeared in the ERP waveforms immediately after the presentation of the neighboring time intervals. The most important brain activities for the temporal judgment seem to take place after the last temporal marker for a period that can be as short as 100 ms. Probably, an elementary process within such a short period enables the brain to capture rhythm in real time.

Keywords

time perception, event-related potential, multivariate analysis,

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