Evoked Potentials to Test Rhythm Perception Theories

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ABSTRACT: The general aim of this study was to investigate how rhythmic information is processed by the brain and how a mental representation of a rhythm leads to expectancies about events in the near future. We investigate this by means of EEG recordings from which evoked potentials (EPs), resulting from sensory and cognitive neural activity, are extracted.

KEYWORDS: rhythm; evoked potentials; expectancy; P_3; omissions; temporal information processing

INTRODUCTION

Evoked potential (EP) measurements have been proved to be well suited for studying aspects of music cognition.[1] It has long been known that expectancy modulates EPs. When expectancy is violated, auditory EPs (AEPs) typically show a large positive wave, the P_3.[2] A similar wave can be measured if a stimulus is expected yet omitted from a regular temporal pattern, the omission evoked potentials (OEPs).[3,4]

There are several theories concerned with rhythm perception.[5–9] These theories lead to different predictions about when a following event is maximally expected given a rhythmic sequence, thus predicting different AEP and OEP results.

METHODS

Musicians ($n = 14$) and nonmusicians ($n = 14$) participated in the experiment. All participants signed a written informed consent.

In experiment 1, we presented probe-beats on either the 1/3, 1/2, or 2/3 position within a test bar. Probe beats were preceded by two bars of either a duple- or triple-meter context (FIG. 1A). We hypothesized that sequential processing of rhythmic patterns[5] would lead to a maximal context effect on probe beats presented at the 1/3

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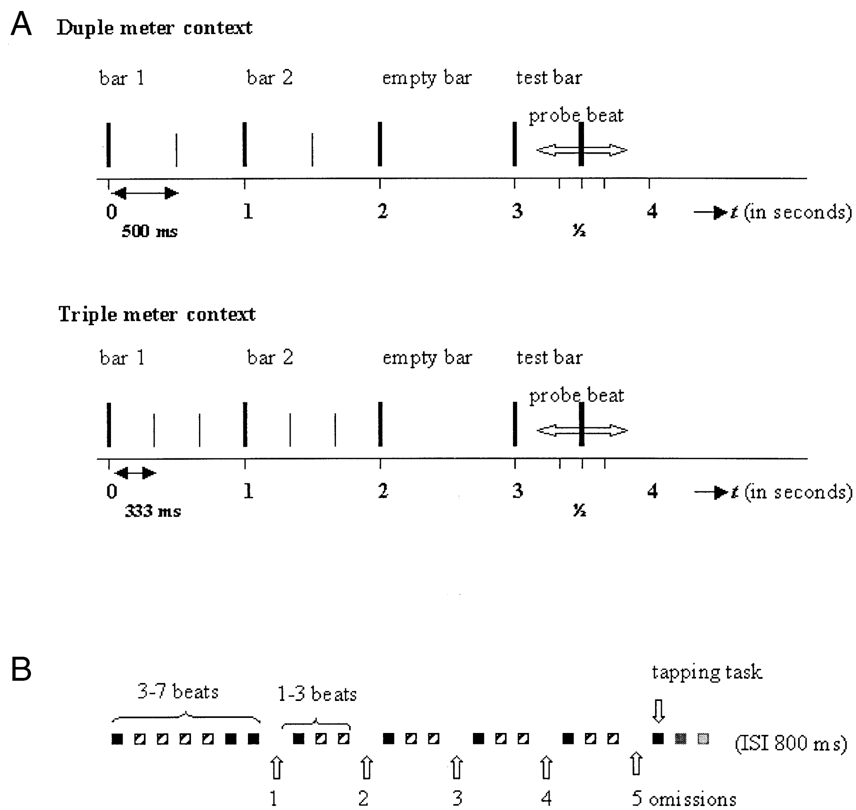

FIGURE 1. **(A)** Paradigm experiment 1; **(B)** paradigm experiment 2.

position, whereas hierarchical processing[5–9] would lead to a maximal context effect on probe beats presented at the ¼ position. Besides the AEP P_3 component, behavioral ratings, reflecting how well probe beats fit the preceding metric context (scale 1–7) were obtained.

In experiment 2, trials ($n = 90$) contained five stimulus omissions (ISI 800 ms). Three types of trials were presented, with one, two, or three beats interspersed among a total of 5 omissions (FIG. 1B). The task of the participant was to silently count the five omissions and to tap along with the first beat after the fifth omission.

RESULTS

In experiment 1, we found in nonmusicians a maximal difference between metric contexts on the 1/3 position probe beat. However, in musicians a maximal difference between metric contexts on the ½ position probe beat occurred, this for both the AEP P_3 amplitude (FIG. 2A and B) and the ratings (FIG. 3A and B).

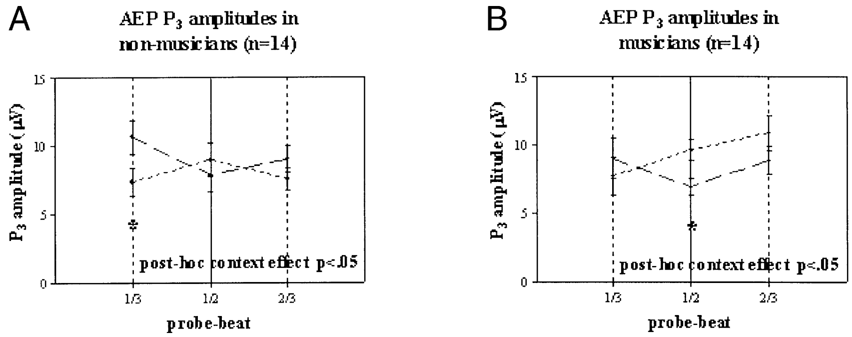

FIGURE 2. (**A**) AEP P_3 amplitudes in nonmusicians (n = 14); (**B**) AEP P_3 amplitudes in musicians (n = 14).

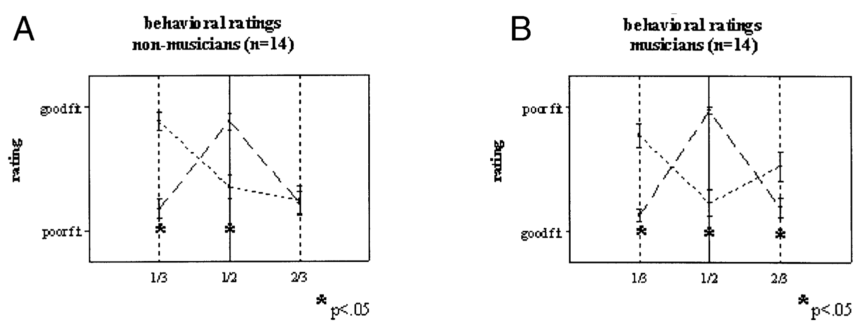

FIGURE 3. (**A**) Behavioral ratings in nonmusicians (n = 14); (**B**) behavioral ratings in musicians (n = 14).

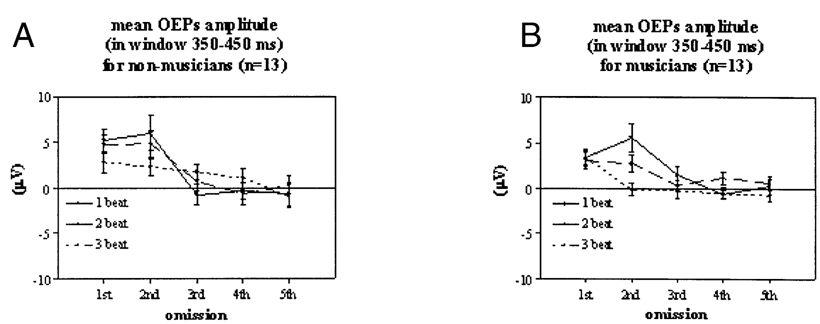

FIGURE 4. (A) Mean OEPs amplitude (in window 350–450 ms) for nonmusicians (n = 13); (**B**) mean OEPs amplitude (in window 350–450 ms) for musicians (n = 13).

In experiment 2, we found that OEPs did occur in response to unpredictable stimulus omissions, that is, the first two omissions in each trial type. OEPs were maximal in the window 350–450 ms after omission onset over Pz (FIG. 3A and B). However, musicians showed no OEPs in response to the second stimulus omissions in the three-beat interspersed trials. This result showed that musicians could predict this second omission (i.e., if after the first stimulus omission three beats have occurred, then the following event must be another omission). Thus, musicians used higher-order stimulus characteristics for making predictions.

DISCUSSION

Our results support the view that temporal patterns are processed sequentially in nonmusicians and hierarchically in musicians. Metric expectations thus influence both behaviors, the AEP $P_{3,}$ and the OEPs. Therefore, we argue that the AEP P_3 and OEPs can be used to test theoretical predictions regarding rhythmically induced expectancies.

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REFERENCES

1. BESSON, M. & A.D. FRIEDERICI. 1998. Language and music: a comparative view. Music Percept. **16:** 1-10.
2. CASTRO, A. & F. DIAZ. 2001. Effect of the relevance and position of the target stimuli on P300 and reaction time. Int. J. Psychophysiol. **41:** 43-52.
3. RUCHKIN, D.S., S. SUTTON, R. MUNSON, *et al.* 1981. P300 and feedback provided by absence of the stimulus. Psychophysiology **18:** 271–282.
4. JONGSMA, M.L.A., A.M.L. COENEN & C.M. VAN RIJN. 2002. Omission evoked potentials (OEPs) in rats and the effects of diazepam. Psychophysiology **39:** 229–235.
5. MARTIN, J.G. 1972. Rhythmic (hierarchic) versus serial structure in speech and other behaviour. Psychol. Rev. **79:** 487–509.
6. POVEL, D. 1981. Internal representation of simple temporal patterns. J. Exp. Psychol.: Human. Percept. Perform. **7:** 3–8.
7. PALMER, C. & C.L. KRUMHANSL. 1990. Mental representations for musical meter. J. Exp. Psychol. **16:** 728–741.
8. LARGE, E.W. & C. PALMER. 2002. Perceiving temporal regularity in music. Cognit. Sci. **26:** 1–37.
9. DESAIN, P. & H. HONING. 1994. Advanced issues in beat induction modelling: syncopation, tempo and timing. *In* Proceedings of the 1994 International Computer Music Conference. :92–94. International Computer Music Association. San Francisco.