Neuroscience Letters 355 (2004) 189–192

Neuroscience Letters

www.elsevier.com/locate/neulet

Rhythmic training decreases latency-jitter of omission evoked potentials (OEPs) in humans

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Received 21 August 2003; received in revised form 31 October 2003; accepted 31 October 2003

Abstract

In this study omission evoked potentials (OEPs) were studied in rhythmic experts ($n = 12$) and non-musicians ($n = 12$). Trains of auditory stimuli were presented. Trials ($n = 90$) contained five omissions and started with a random number of beats, thus making every first omission unpredictable. Participants had to tap along with the first beat after the fifth omission ($n = 90$), thus determining timing-accuracy. Single-trial OEPs elicited by every first omission were obtained by means of wavelet denoising allowing determination of latency-jitter. Clear OEPs, consisting of a slow positive wave, maximal over Pz, were observed in response to unpredictable omissions. No group differences in OEPs amplitudes or latencies were observed. However, rhythmic experts showed less latency-jitter of both the OEPs positive wave and of behavioral responses compared with non-musicians.

Keywords: Event-related potentials; Omitted stimuli; P300; Rhythm; Music; Timing accuracy; Latency-jitter

Evoked potentials (EPs) are small voltage fluctuations in the EEG resulting from sensory, cognitive, or motor evoked neural activity. Omission evoked potentials, or OEPs, are EPs elicited by stimulus omissions occurring within a regular train of stimuli. These OEPs have been reported to consist of a late positive wave similar to the P300 [4,7,9,10,16,18,20]. Evoked Potentials to omitted stimuli are supposed to reflect expectancy and are strongly influenced by attention [4,5].

Though OEPs have been known to exist in human participants for years [16,18] OEPs appear difficult to measure. Alain et al. [1] observed in only half of his participants OEPs. Others have excluded subjects who failed to show an OEPs from their experiments [4,19]. In addition, Näätänen et al. [13] observed considerable variability of OEPs between individual subjects, such that no consistent OEPs over subjects could be detected. Finally, several investigators have reported that training of subjects was required before an OEPs could be measured [4,5,16]. Why OEPs are hard to measure might be explained by the fact that OEPs are conventionally obtained by averaging over a large number of trials. While a component of interest may occur in individual trials, these components could become smeared in the average OEPs due to latency-jitter. Latency-jitter is the phenomenon of varying component latencies over trials in reference to the timing of the (omitted-) stimulus presentation. OEPs might be especially sensitive to latency-jitter since no external stimulus marks their exact onset times. Training, however, may influence the accuracy with which a participant is able to judge the moment in time when a stimulus should occur, leading to less internally induced latency-jitter. Therefore, in this study we measured OEPs in both rhythmically trained and musically untrained participants. We hypothesize that rhythmically trained participants will respond with less latency-jitter.

Rhythmically trained participants ($n = 12$) consisted of professional drummers and bass guitarists. They had on average 15.6 ± 11.16 (mean ± SD) years of musical experience and a mean age of 32.7 ± 12.65 (mean ± SD) years. Musically untrained participants ($n = 12$) never received any formal music or dance education, and had a mean age of 23.1 ± 4.08 (mean ± SD) years. All partici-

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0304-3940/03/$ - see front matter © 2003 Elsevier Ireland Ltd. All rights reserved.
doi:10.1016/j.neulet.2003.10.070

pants signed an informed consent. A tap pad was used to register the motor response.

The stimuli were presented via a loudspeaker at a distance of one meter in front of the participant. The sound consisted of a short ‘high woodblock’ percussion sound of 81 dB at the participants’ position.

Three types of trials were presented, with either one-, two or three beats presented between omissions (with a fixed 800 ms inter-stimulus interval (ISI) between beats, and beats and omissions). A variable Inter-trial Interval of 2.5–3.5 s was used. Trials were presented in a random order. The first omission of each trial of every trial type was preceded randomly by three to seven beats. Thus, the occurrence of the first omission per trial was unpredictable. The task of the participants was to silently count the five omissions and to tap along with the first beat after the fifth omission, thus making it possible to measure timing consistency. Since clear OEPs only appeared in response to unpredictable stimulus omissions [11], data of all first omissions ($n = 90$) were further analyzed. As a control condition, EEG epochs preceding each trial ($n = 90$) of 2048 ms were also analyzed.

EEG was derived from 19 electrodes (Fz, Cz, Pz, Fp1, Fp2, F3, F4, F7, F8, C3, C4, T7, T8, P3, P4, P7, P8, O1, O2) according to the international 10–20 electrode system [8]. The left mastoid served as reference and a ground electrode was placed on the forehead. Electrode impedance of all cortical electrodes was less than 3 kOhms. EEG was filtered between 0.016 and 100 Hz, sampled at 500 Hz. Trials containing EOG artifacts were manually excluded.

All single-trial first omissions were denoised by means of a recently proposed algorithm based on the wavelet transform. The accuracy of this method to obtain single-trial EPs has been demonstrated with both simulated data as well as visual and auditory EP data [14]. Denoising parameters were the same for all participants and the same for both OEPs and control OEPs. After denoising, positive maxima of all single-trials were determined, thus resulting in single-trial OEPs amplitudes and latencies. Latency-jitter of OEPs was defined as the SD of the peak-latencies of the single-trial OEPs. In addition, for both groups, SDs of behavioral response times were calculated.

Two ANOVA tests, one between (group) and one within (OEPs versus control OEPs) were performed using the measured peak amplitudes and latencies. Since no OEPs could be detected in the control epochs, no latency-jitters were calculated in this condition. In addition, separate t-tests with respect to OEPs latency-jitter and behavioral SDs were calculated.

Figs. 1a–d shows both scalp distributions and averaged denoised OEPs at Pz of both groups and for both OEPs and control OEPs conditions. Figs. 1e,f shows OEPs amplitudes and latencies. Fig. 2a shows latency-jitter of OEPs amplitudes and Fig. 2d shows latency-jitter of behavioral responses.

Control OEPs amplitudes were lower then OEPs amplitudes ($F(1, 22) = 30.72$, $P < 0.001$). No effects of rhythmic training were observed with respect to mean OEPs amplitudes or latencies. Rhythmically trained participants showed less latency-jitter of OEPs amplitudes ($t = 3.09$; $\mathrm{df} = 22$; $P = 0.006$) and lower SD in the behavioural response ($t = 2.47$; $\mathrm{df} = 22$; $P = 0.022$) in comparison with musically untrained participants.

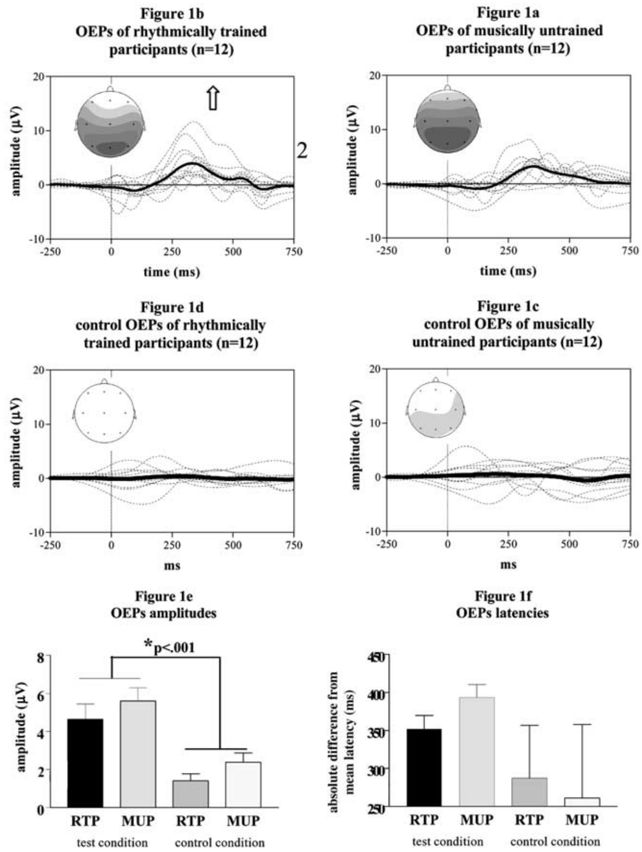

Fig. 1. Averaged denoised OEPs and their scalp distributions for rhythmically trained participants (a); and for musically untrained participants (b). (c, d) Are the same as a, b, but for the control OEPs. Solid lines depict group averages, dotted lines depict individual averages, as derived from Pz. (e, f) Shows OEPs amplitudes (e); and latencies (f) for both OEPs and control OEPs of rhythmically trained and untrained participants.

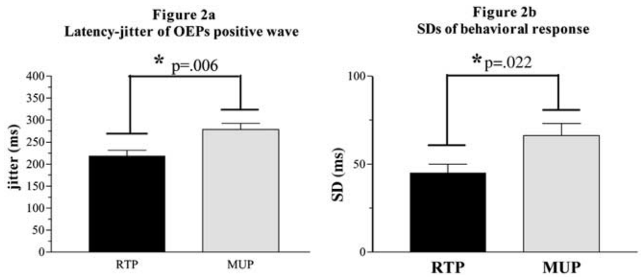

Fig. 2. (a) Shows the latency-jitter of the OEPs (mean + SEM) for both groups. (d) Shows SDs of behavioral responses (mean + SEM) for both groups.

In this study we were able to measure OEPs in response to unexpectedly omitted stimuli. No such OEPs could be found in the control EEG epochs. Thus, the wavelet denoising procedure seems to be a useful tool to filter out components of interest without introducing unwanted artifacts.

In a previous study [11] we assumed that the accuracy and consistency with which a participant is able to judge the moment in time when a beat or omission should occur (based on the pattern of previously heard beats) may be influenced by musical training. Rhythmically trained participants are generally found to be both more accurate and consistent in their responses compared to musically untrained participants [2,11]. The assumption was made that consistency in the tapping task highly correlates with the phenomenon of latency-jitter.

We found indeed that our group of rhythmically trained participants showed less latency-jitter of the OEPs positive wave (see Fig. 2a) and performed more accurate and consistent in the tapping task (see Fig. 2b).

Note that the SD of the behavioral response was much lower (factor 4) then the latency-jitter of the OEPs positive wave. This might be due to the fact that the behavioral response is executed at the end of the trial, after the rhythmic pattern has been learned. In agreement with our results, we therefore expect the behavioral response to be more time-locked then the OEPs amplitude, thus resulting in a lower SD.

In this study, there was a significant age difference between our two groups. Age differences have been reported on the EP P300 [6]. To control for age differences, we compared younger participants (taking from both groups the six youngest participants) with older participants (the six oldest of each group). This way the age difference remained similar (older participants 33.4 ± 12.3; younger participants 22.3 ± 2.9) whereas rhythmical training was evenly divided between groups. No differences with respect to latency jitter or to behavioral SD were found. Therefore, the observed differences between rhythmically trained and musically untrained participants in our study cannot be ascribed to aging.

Since OEPs emerge in the absence of a stimulus, they have been proposed to be very sensitive to the effects of latency-jitter. Gathering data from specifically rhythmically trained participants seems to be worthwhile when measuring such responses, because the onset times of such events appears to be more consistent over trials then would be without rhythmical training.

Others have reported differences in EPs between musicians and non-musicians with regard to, e.g. superior detection of temporal deviations in musicians [17], detection of pitch and harmony [12], temporal and harmonic incongruities [3], though others failed to find group differences in detection of harmonic incongruities [15]. In this study we also observed that rhythmically trained participants showed less latency-jitter of the OEPs positive wave then musically untrained participants.

Acknowledgements

This project was supported by the Netherlands Organization for Scientific Research, NWO VENI project nr. 451-02-026 ‘It is all in the rhythm’. We hereby greatly acknowledge Peter Desain and Henkjan Honing for their valuable input, Kathleen Jenks for gathering part of the data, Gerard van Oijen and Paul Trilsbeek for technical support and Elsbeth Jongsma for language corrections.

References

[1] C. Alain, F. Richer, A. Achim, J.-M. Saint Hilaire, Human intracerebral potentials associated with target, novel and omitted stimuli, Brain Topogr. 1 (1989) 237–245.

[2] G. Aschersleben, Temporal control of movements in sensorimotor synchronization, Brain Cogn. 48 (2002) 66–79.

[3] M. Besson, F. Faïta, An event-related potential (ERP) study of musical expectancy: comparisons of musicians with non-musicians, J. Exp. Psychol. [Hum. Percept. Perform.] 21 (1995) 1278–1296.

[4] M. Besson, F. Faïta, C. Czternasty, M. Kutas, What’s in a pause: event-related potential analysis of temporal disruptions in written and spoken sentences, Biol. Psychol. 46 (1997) 3–23.

[5] T.H. Bullock, S. Karamürsel, J.Z. Achimowicz, M.C. McClune, C. Basar-Eroglu, Dynamic properties of human visual evoked and omitted stimulus potentials, Electroenceph. clin. Neurophysiol. 91 (1994) 42–53.

[6] A.M. Fjell, K.B. Walhovd, Effects of auditory stimulus intensity and hearing threshold on the relationship among P300, age, and cognitive function, Clin. Neurophysiol. 114 (2003) 799–807.

[7] P. Janata, Brain electrical activity evoked by mental formation of auditory expectations and images, Brain Topogr. 13 (2001) 169–193.

[8] H.H. Jasper, The 10–20 electrode system of the International Federation, Electroenceph. clin. Neurophysiol 10 (1958) 371–375.

[9] E.L. Jocoy, J.E. Arruda, K.M. Estes, Y. Yagi, K.L. Coburn, Concurrent visual task effects on evoked and emitted auditory p300 in adolescents, Int. J. Psychophysiol. 30 (1998) 319–328.

[10] M.L.A. Jongsma, A.M.L. Coenen, C.M. Van Rijn, Omission evoked potentials (OEPs) in rats and the effects of diazepam, Psychophysiology 39 (2002) 229–235.

[11] M.L.A. Jongsma, P. Desain, H. Honing, C.M. Van Rijn, Evoked potentials to test rhythm perception theories, Ann. N. Y. Acad. Sci. (2004) (in press).

[12] S. Koelsch, E. Schroger, M. Tervaniemi, Superior pre-attentive auditory processing in musicians, NeuroReport 26 (1999) 1309–1312.

[13] R. Näätänen, P. Paavilainen, K. Alho, K. Reinikainen, M. Sams, The mismatch negativity to intensity changes in an auditory stimulus sequence, in: R. Johnson Jr, J.W. Rohrbaugh, R. Prarsuraman (Eds.), Current Trends in Event-Related Potential Research. EEG Supplement 40, Elsevier, Amsterdam, 1987, pp. 125–131.

[14] R. Quian Quiroga, H. Garcia, Single-trial event-related potentials with wavelet denoising, Clin. Neurophysiol. 114 (2003) 376–390.

[15] P. Regnault, E. Bigand, M. Besson, Different brain mechanisms mediate sensitivity to sensory consonance and harmonic context: evidence from auditory event-related brain potentials, J. Cogn. Neurosci. 13 (2001) 241–255.

[16] D.S. Ruchkin, S. Sutton, R. Munson, K. Silver, F. Macar, P300 and

feedback provided by absence of the stimulus, Psychophysiology 18 (1981) 271–282.
[17] J. Rüsseler, E. Altenmuller, W. Nager, C. Kohlmetz, T.F. Munte, Event-related brain potentials to sound omissions differ in musicians and non-musicians, Neurosci. Lett. 308 (2001) 33–36.
[18] R. Simson, H.G. Vaughan Jr, W. Ritter, The scalp topography of potentials associated with missing visual or auditory stimuli, Electroenceph. clin. Neurophysiol. 40 (1976) 33–42.
[19] I.M. Tarkka, D.S. Stokic, Source localization of P300 from oddball, single stimulus and omitted stimulus paradigms, Brain Topogr. 2 (1998) 141–151.
[20] H. Yabe, M. Tervaniemi, K. Reinikainen, R. Näätänen, Temporal window of integration revealed by MMN to sound omission, NeuroReport 8 (1997) 1971–1974.