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Brain and Cognition 61 (2006) 249–254

Brain and Cognition

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Reduced P50 auditory sensory gating response in professional musicians

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Accepted 22 January 2006
Available online 9 March 2006

Abstract

Evoked potential studies have demonstrated that musicians have the ability to distinguish musical sounds preattentively and automatically at the temporal, spectral, and spatial levels in more detail. It is however not known whether there is a difference in the early processes of auditory data processing of musicians. The most emphasized and studied early process, especially for neuropsychiatric purposes, is sensory gating. The suppression percentage of the midlatency auditory evoked potential P50, and rarely the N100, wave is used for sensory gating studies. Our aim in this study was to investigate whether there was a difference in the auditory P50 and N100 suppression of control subjects who were professional musicians with no psychiatric problems. 34 professional musicians and 19 non-musicians (the control group) were included in this study. P50 and N100 measurements were taken, the suppression percentage of P50 and N100 was calculated and the results compared. Musicians showed significantly less P50 suppression when compared to non-musicians. There was no significant difference for N100 suppression. What the decreased P50 suppression in musicians when compared to non-musician subjects means, when we also take into account that N100 suppression is not decreased, and how it may contribute to the music perception and production processes of these persons is discussed.

Keywords: Musician; P50; Sensory gating

1. Introduction

Functional imaging and neurophysiological studies on musical ability and associated brain structure and functionality in the last decade have shown that musicians have different brain structure and music-related data processing compared to non-musicians (Gaser & Schlaug, 2003; Pantev et al., 1998, Pantev, Roberts, Schulz, Engelien, & Ross, 2001, 2003; Schlaug, Jancke, Huang, Staiger, & Steinmetz, 1995). There are many studies emphasizing the structural differences in the auditory cortex, anterior corpus callosum, and Heschl gyrus in musicians (Gaser & Schlaug, 2003; Schlaug et al., 1995; Schneider et al., 2002).

In addition to these structural differences, the neurophysiological foundation of musical ability is also the subject of research. These studies have demonstrated many differences in music perception and production, which are the various aspects of musicality, in musicians. Some authors emphasize the ability of musicians to notice the holistic characteristics of music while recent studies have focused mostly on the cognitive aspect of musical ability (Tervaniemi, Ilvonen, Karma, Alho, & Naatanen, 1997). Musicians have been shown to have many cognitive differences compared to non-musicians in areas such as discriminating musical phrases, identifying melodic contour and pitch interval discordance and detecting change of musical sound patterns (Besson & Faita, 1995; Koelsch, Schroger, & Tervaniemi, 1999; Naatanen, 1992; Ritter et al., 1992; Tervaniemi et al., 1997; Trainor, 1999).

However, we do not have detailed information on whether there is a difference in the auditory data processing processes of musicians at an early stage. This early stage may be related to the 'increased auditory stimulus perception' that many musicians state as a personal and

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doi:10.1016/j.bandc.2006.01.006

disturbing experience. There are no reported studies on the neurophysiological potentials reflecting the processes encoding auditory stimuli in musicians. These potentials also include the midlatency auditory EPs that appear in the first 100 ms of the auditory stimulus. The midlatency auditory EPs are known to decrease in amplitude with repetition at short intervals and are thus suitable for examining habituation or sensory gating (Fruhstorfer, 1970). The most commonly used midlatency auditory EPs for sensory gating studies are P50 and less frequently N100 (Boutros, Korzyukov, Jansen, Feingold, & Bell, 2004; Freedman, 1996). The P50 EP is a small amplitude positive component that appears 40–90 ms after an auditory stimulation (Ghisolfi et al., 2004) and N100 is a negative component seen ≈80–150 ms following an auditory stimulation (Boutros et al., 2004). Both midlatency auditory EP waves, P50 and N100 are thought to contain preattentive components.

A broad definition of sensory gating refers to the ability of the brain to modulate its sensitivity to incoming sensory information. Sensory gating capabilities impact stimulus identification and subsequent evaluation (Crawford, McClain-Furmanski, Castagnoli, & Castagnoli, 2002). The decrease in sensory gating has mostly been studied in schizophrenics and interpreted as a pathological finding but differences in gating has also been shown among healthy groups (Hetrick et al., 1996).

In the paired click paradigm, the first (conditioning) of a pair of stimuli (S1) is followed by an identical (test) stimulus (S2) a short time later (e.g., 500 ms). The magnitude of the brain's response to these acoustic stimuli is quantified by measuring the deflections in the EP, the P50 is a positive-going component that appears ≈50 ms after presentation of the stimulus (Ringel, Heidrich, Jacob, & Fallgatter, 2004). The inhibitory capability of the brain is then measured as the ratio of the amplitude of the P50 and N100 EP components to S2 stimuli to the amplitude of the S1 response (S2/S1), or as the mathematical difference between the two responses (S1–S2) (Smith, 1994). Higher ratios or smaller differences are presumed to reflect worse "gating out" of irrelevant input.

As mentioned above, musicians have been shown to have differences in various stages of the auditory data processing compared to non-musicians. We are however not aware of any studies on the state of the sensory gating function in musicians. We performed sensory gating evaluation using the double-click paradigm of P50 and N100 evoked potentials in professional musicians with no psychiatric problems, and compared them with non-musician subjects.

2. Materials and methods

We investigated 34 professional musicians (24.6 ± 5.0 years of age; 15 females, 19 males) who were instructors (8) and students (25) at the Music Department of Inonu University, Faculty of Fine Arts. "Professional musicians" were defined as performing artists, full-time music teachers, or full-time Faculty of Fine Arts or conservatory students having an average daily practice time of at least 1 h (Gaser & Schlaug, 2003). Professional musicians with <1 h of daily practice time were not included in this study. Non-musician controls ($n = 19$) were Inonu University staff members and students (25.3 ± 3.3 years of age; 9 females, 10 males) who did not play a musical instrument and had no formal musical training (the control group was questioned formally). Before the experiment, all subjects were interviewed to collect information about their onset of musical training (age), duration of musical training (years), daily playing time (hours), musical skills, listening habits, and the musical interests of their parents and siblings.

Only healthy participants, not using any medication and without a neurological history, participated in the experiment. The subjects were informed about the research project and signed a consent form. They were not allowed to drink coffee or to smoke cigarettes prior to the tests on the day of the investigation.

An experienced psychiatrist carried out the clinical psychiatric evaluation of the subjects and the SCID II (The Structured Clinical Interview for DSM-IV) was applied (First, Gibbon, Spitzer, Williams, & Benjamin, 1997). Subjects with no psychiatric or personality disorders were included in the study. Musicians or non-musicians who had a relative with history of psychosis were excluded from the study.

The P50 measurements were performed at the electrophysiology laboratory of our hospital.

3. P50 measurements

The electrophysiological examination was performed at the Laboratory of Clinical Neurophysiology at the Department of Neurology, University of Inonu, only during the morning hours (at the same time of the day for all subjects) (Ghisolfi et al., 2004).

The subjects were seated in a comfortable chair in a sound- and light-attenuated, electrically shielded room. The subjects were instructed to relax with the eyes open and to fixate on a point straight ahead to avoid eye motion artifacts.

The electroencephalogram (EEG) was recorded with a MEM-4200K evoked potential recorder (Nihon Kohden, Japan) system in four channels for recording of evoked responses, integrated with an auditory stimulator. The test stimulus, a click sound of 0.1 s duration set 60 dB above the auditory threshold with a rarefaction output phase, was presented binaurally through earphones. The auditory threshold of each subject was measured 15 min before the recordings through earphones. The interval between the first and second clicks (interstimulus interval = ISI) was 500 ms, and the interval between two pairs of clicks was 10 s.

Electroencephalographic activity was recorded from a disk electrode affixed to the vertex (Cz) and referenced to left mastoid (except one musician where the right mastoid was used as the reference as he had a local lesion). The mean signal was registered in two channels, and amplified 20,000 times with a bandpass filter between 1 and 100 Hz. EEG data were collected for 1000 ms for each paired stimulus presented. Additional channels were used to record the electro-oculogram (EOG) between the superior orbita and lateral canthus.

Trials were rejected automatically by the device if they contained artifacts indicated by a response of ±100 μV over the area of P50 for evoked potentials or the EOG recordings. Thirty non-rejected waves were added together to give an average signal, which was used for analysis. EEG was collected for 1000 ms for each paired stimulus presented. The averages of S1 waves and of S2 waves were collected in sequence. The S1 and S2 wave averages were then considered separately for analysis.

The wave peaks were determined visually and the latencies and amplitudes were marked manually. The most positive peak between 40 and 90 ms after the conditioning stimulus was selected as the P50 final latency and the wave amplitude (S1) was measured from baseline to peak. The second wave (S2 = test) was determined using the corresponding peak between S1 ± 10 ms away from latency of the first wave form (conditioning) and its amplitude was also measured from baseline to peak. The most negative peak 80–150 ms after the conditioning stimulus was selected as the N100 final latency. Amplitude of the N100 was measured from baseline to peak. The second wave (test) was determined using the corresponding peak between S1 ± 20 ms away from latency of the first wave form (conditioning) and its amplitude (S2) was also measured from baseline to peak.

The data were collected by one investigator and analyzed by an independent trained evaluator blind to the state of the subjects. Averages with no discernible conditioning P50 and N100 waves were excluded from the analysis and the analysis was repeated in the four subjects in this position. The percentage of P50 and N100 suppression was calculated by using the following formula: (1 − [second click amplitude/first click amplitude]) × 100 (Light, Geyer, Clementz, Cadenhead, & Braff, 2000).

Results were expressed as median values ± standard deviation.

4. Statistical methods

P50 and N100 variables of the musician and control groups were compared. The Kolmogorov–Smirnov test showed that there was not normal distribution of the variables. Therefore comparisons between the groups were performed using the χ^2 test (for gender) and the Mann–Whitney *U* test for means. The suppression percentage of amplitudes were separately correlated with age, the onset of musical training, the duration of musical training, and daily playing time in the musician group (Pearson's correlation coefficient). The criterion for significance was $p < .05$ for all tests. Statistical analysis was carried out with SPSS 10.0 for Windows.

5. Results

The gender, age, P50 amplitude, and latency, percentage of P50 suppression, N100 amplitude and latency, and the suppression percentage of N100 of the musician and control groups and the onset of musical training, duration of musical training and daily playing time for the musicians are presented in Table 1, together with the *p* values.

Table 1
Demographic data and P50 and N100 values

	Control (*n*:19) mean ± *SD*	Musician (*n*:34) mean ± *SD*	*p*
Gender (male/female)	10/9	19/15	NS[b]
Age	25.32 ± 3.32	24.65 ± 5.03	NS[a]
Onset of musical training (age)		13.36 ± 4.24	
Duration of musical training (years)		11.12 ± 7.08	
Daily playing time (hours)		4.27 ± 2.79	
P50 response to click 1			
Amplitude (μV) (baseline to peak)	5.40 ± 4.12	5.80 ± 4.42	NS[a]
Latency (ms)	57.50 ± 10.79	58.30 ± 8.10	NS[a]
P50 response to click 2			
Amplitude (μV) (baseline to peak)	2.26 ± 1.78	4.54 ± 3.05	0.008
Latency (ms)	56.83 ± 11.16	59.27 ± 9.17	NS[a]
The suppression percentage of P50	50.78 ± 39.65	15.38 ± 49.94	0.003
N100 response to click 1			
Amplitude (μV) (baseline to peak)	6.05 ± 4.51	6.80 ± 5.42	NS[a]
Latency (ms)	102.76 ± 7.92	98.29 ± 9.95	NS[a]
N100 response to click 2			
Amplitude (μV) (baseline to peak)	4.38 ± 4.76	3.96 ± 3.30	NS[a]
Latency (ms)	98.29 ± 8.11	95.81 ± 9.68	NS[a]
The suppression percentage of N100	41.77 ± 40.60	41.03 ± 37.58	NS[a]

SD, standard deviation; NS, non-significant.
[a] Mann–Whitney *U*.
[b] Chi-square.

Professional musicians showed lower P50 suppression (Fig. 1), when compared to non-musician subjects (Fig. 2). The conditioning amplitudes (S1) did not differ, whereas test (S2) amplitudes were significantly greater for professional musicians than for controls. Latencies of the conditioning (S1) and test waves of the P50 component of auditory evoked potentials were not different in the two groups.

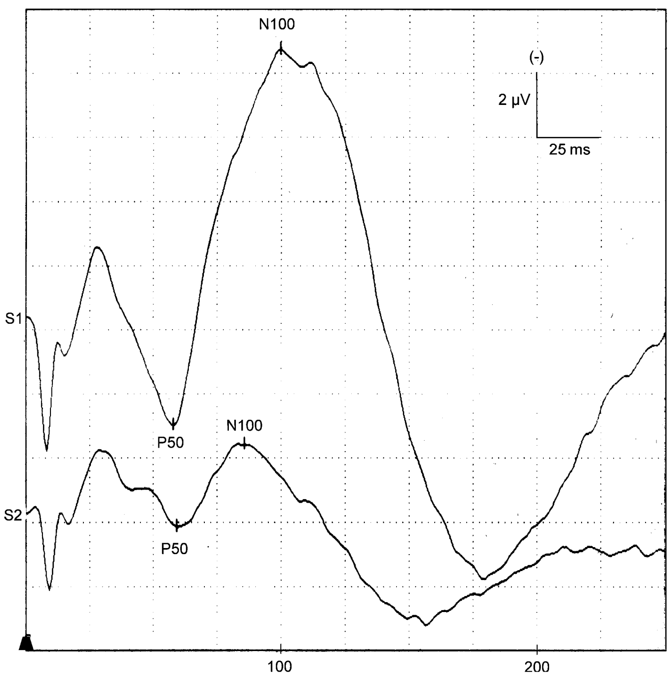

Fig. 1. The grand averages of the P50 EPs in professional musicians. Calibration bars indicate 2 µV and 25 ms. S1, conditioning stimulus; S2, test stimulus. ▲, the onset of stimulus. Amplitüde measurements were from baseline to peak. One hundred milliseconds increments were marked on the *X* axis.

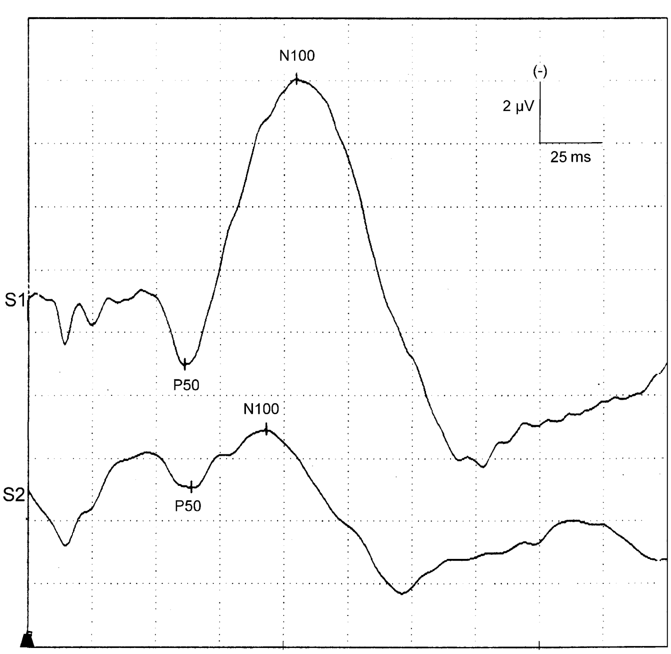

Fig. 2. The grand averages of the P50 EPs in non-musician subjects. Calibration bars indicate 2 µV and 25 ms. S1, conditioning stimulus; S2, test stimulus. ▲, the onset of stimulus. Amplitüde measurements were from baseline to peak. One hundred milliseconds increments were marked on the *X* axis.

There was no correlation within the musician group between the onset of musical training, duration of musical training and daily playing time and the P50 1st and 2nd wave amplitudes, latencies, and suppression percentage of P50.

There was no difference between musicians and non-musicians as to N100 amplitudes and latencies and suppression percentage of N100. There was no correlation between the N100 amplitude, latency, and suppression percentage and the P50 first and second wave amplitude, latency, and percentage values in the musician group.

6. Discussion

We found that P50 wave, but not the N100 wave, is suppressed less in musicians than non-musicians. This decrease in P50 suppression in professional musicians was observed only in the test (S2) stimulus wave amplitude, in contrast to schizophrenic patients, where the decrease is most associated with the conditioning (S1) stimulus. The unchanged N100 amplitude suppression in the musician group compared to non-musicians indicates that the sensorial gating difference is limited to the early stage.

Sensory gating studies have mostly been on neuropsychiatric disorders and usually schizophrenia (Adler et al., 1982, 2004; Boutros et al., 2004; Freedman et al., 1987). Sensorial gating is usually studied with the P50 and was defined as the ability of neuronal networks within the human brain to transmit only a small part of incoming information and to filter out irrelevant stimuli (Adler et al., 1982). However, it is now defined more widely as the ability of the brain to modulate its sensitivity to incoming sensory information and tests such as N100 are also used in addition to P50 for its study (Boutros et al., 2004). This partial expansion of the definition of sensory gating is perhaps related to associated research in fields other than psychiatry in recent years. Abnormal P50 suppression has been found to be related with various neurological conditions and non-pathological states and not only with psychiatric diseases (Adler et al., 1998; Ambrosini, De Pasqua, Afra, Sandor, & Schoenen, 2001; Ghisolfi et al., 2004; Grunwald et al., 2003). For example male subjects have shown lower "P50 suppression" than females (Hetrick et al., 1996) and nicotine application has changed the "P50 suppression" in a study (Crawford et al., 2002), while migraine patients have lower P50 suppression between attacks (Ambrosini et al., 2001).

It is also interesting that in schizophrenic patients the N100, appearing right after P50, is suppressed less just like P50. The situation is different in relatives of schizophrenic patients with decreased P50 suppression but no N100 suppression and sometimes even more N100 suppression than control subjects (Waldo, Adler, & Freedman, 1988). The sensory gating abnormality in schizophrenic patients, usually demonstrated with the P50 test, has also been found to be associated with amplitude variability of the conditioning (S1) stimulus and not only the potential change related to the second (S2 = test) stimulus (Patterson et al., 2000). These results indicate that sensory gating is a multistage data processing that has augmentation characteristics in addition to inhibition (Boutros, Belger, Campbell, D'Souza, & Krystal, 1999).

Increased N100 suppression accompanying decreased P50 suppression, also found in healthy subjects who have a risk of developing Alzheimer's disease (Boutros, Burns, Wu, & Nasrallah, 1995a) and in relatives of schizophrenics, has been interpreted as the correction during the later stages of the sensory gating abnormality seen in the early stages (Boutros et al., 1995b). We found decreased P50 suppression in musicians but no increase in the N100 suppression as shown in the relatives of schizophrenic patients. Whether there is a gating correction for the decreased P50 sensory suppression in musicians that could lead to sensory flooding can be determined by studying other stages of sensory gating. Musicians have been shown to have differences in many stages of music-associated cognitive processes compared to non-musicians. It has also been demonstrated that professional musicians are superior in preattentive processing of sounds. However, it is reported that the superiority is more marked for the sensory part of melodic information and not the cognitive part (Fujioka, Trainor, Ross, Kakigi, & Pantev, 2004; Koelsch et al., 1999; Tervaniemi et al., 1997). Musicians have a longer temporal window of sound integration (Russeler, Altenmuller, Nager, Kohlmetz, & Munte, 2001) and appear to be able to use musical context to speed up preattentive detection of pitch anomalies (Brattico, Winkler, Naatanen, Paavilainen, & Tervaniemi, 2002). Moreover, a specificity of neurophysiological responses with regard to the instrument played by the musician (string/wind instruments) has been reported (Pantev et al., 2001) and musicians have been shown to be better than non-musician subjects at preattentively discriminating sounds on the basis of their timbre. Auditory selective attention capabilities are also improved in musicians (Nager, Kohlmetz, Altenmuller, Rodriguez-Fornells, & Munte, 2003).

The contribution of these and similar differences in cognitive processes to the perception and production of music is still a matter of speculation. Some of these differences are due to natural talent while others are the result of long-term training (Weinberger, 2004). The decreased P50 suppression we found in professional musicians did not correlate with their age and/or duration of musical training. This provides no evidence that the difference is the result of musical training. P50 suppression may also have a genetic foundation (Adler et al., 1998), and it may be beneficial to study the P50 abnormality we found in musicians from the genetic viewpoint as well.

What the decreased P50 suppression in musicians means and how it may contribute to the music perception and production processes of these persons needs to be determined. We studied P50 and N100 suppression in musicians using only the 500 ms ISI. Sensory gating studies in these groups using various ISI's will help us understand the difference we found in musicians for P50 suppression, which is only one of the early auditory data processing.

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