Effect of Musical Training on Auditory Event Related Potentials N200 (Mismatch Negativity) and P300

Müzik Eğitiminin İşitsel Olaya İlişkin Potansiyellerden N200 (Uyumsuzluk Negativitesi) ve P300 Üzerine Etkisi

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ABSTRACT Objective: Studies with endogenous event related potentials, demonstrated that musical training influenced auditory brain functions. The aim of the present study was to investigate whether auditory event related potentials (ERPs)-mismatch negativity (MMN) and P300-differ between musically trained and musically lay subjects. **Material and Methods:** MMN and P300 were recorded in 19 musically trained (mean age 20.2 ± 2.38 years) and in 17 musically lay subjects (20.76 ± 1.75 years) using an "oddball paradigm". 20% of stimuli were rare (target) tones of 2000 Hz, whereas the remainder was frequent (non-target) tones of 1000 Hz. Subjects were instructed to press a button when they encountered the rare stimuli. Latencies and amplitudes of auditory MMN and P300 responses obtained from musically trained subjects were compared to those obtained from musically lay subjects. **Results:** In musically trained subjects, MMN latencies were significantly decreased while MMN amplitudes did not differ between the 2 groups. P300 latencies and amplitudes did not differ between musically trained and musically lay subjects. **Conclusion:** Decreased latencies of MMN in musically trained subjects suggest that musical training might influence pre-attentive auditory processing and auditory sensory memory mechanisms can be modulated by musical experience. It is possible that electrophysiological responses obtained from musicians reflect structural adaptations in response to long term music training.

Key Words: Event-related potentials, P300; music

ÖZET Amaç: Endojen olaya ilişkin potansiyellerle yapılan çalışmalarda, müzik eğitiminin işitme ile ilgili beyin fonksiyonlarını etkilediği gösterilmiştir. Bu çalışmanın amacı, olaya ilişkin potansiyellerin -uyumsuzluk negativitesi (MMN) ve P300-müzik eğitimi almış ve müzik eğitimi bulunmayan deneklerde farklılık gösterip göstermediğini araştırmaktır. **Gereç ve Yöntemler:** Müzik eğitimi almış 19 denek (yaş ort. 20.2 ± 2.38 yıl) ile müzik eğitimi bulunmayan 17 denekte (yaş ort. 20.76 ± 1.75 yıl) "şaşırtmacalı uyaran dizisi" kullanılarak MMN ve P300 kayıtlandı. Uyarımların %20'si 2000 Hz'lik seyrek (hedef) tonlar iken geri kalanı 1000 Hz'lik (hedef olmayan) tonlardı. Deneklerden seyrek uyaranla karşılaştıklarında bir düğmeye basmaları istendi. Müzik eğitimi almış deneklerden elde edilen işitsel MMN ve P300 yanıtlarının latans ve amplitütleri müzik eğitimi bulunmayan deneklerinkiyle karşılaştırıldı. **Bulgular:** MMN amplitütleri 2 grup arasında fark göstermezken, MMN latansları müzik eğitimi almış deneklerde anlamlı derecede düşük bulundu. P300 latans ve amplitütleri müzik eğitimi almış deneklerle müzik eğitimi bulunmayan denekler arasında fark göstermedi. **Sonuç:** Müzik eğitimi almış deneklerde MMN latanslarının kısalmış olması müzik eğitiminin işitsel bilginin dikkat öncesi işlemlenme evresini etkileyebileceğini ve müzik tecrübesinin işitsel bellek mekanizmalarını değişime uğratabileceğini düşündürmektedir. Müzisyenlerden elde edilen elektrofizyolojik yanıtların uzun süren müzik eğitimine yanıt olarak oluşan yapısal adaptasyonları yansıtıyor olması mümkündür.

Anahtar Kelimeler: Olaya ilişkin potansiyeller, P300; müzik

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Long latency-evoked potentials related to aspects of cognitive processing are referred to as cognitive evoked potentials or endogenous ERPs.[1] ERPs are usually elicited by auditory stimuli, although some reports suggest that they can be studied also in visual and tactile modalities.[2]

Processing of an auditory material involves 3 stages; 1) the external stage, in which the auditory material is expressed in physical magnitudes 2) the psychoacoustic stage, which determines the components of pitch, loudness etc. and the features of their perception, and 3) the cognitive stage in which reference is made to familiar systems such as scales, intervals, chords or any information in the memory.[3] While auditory evoked potentials reflect the processing of the physical stimulus (the 2nd stage), ERPs are caused by "higher" processes (the 3rd stage) that might involve memory, expectation, attention, or changes in the mental state among others.[4]

The P300 and the MMN or auditory N200 are often elicited with a simple discrimination task, termed the "oddball paradigm" in which subjects are exposed to a continuous succession of two types of auditory stimuli; one presented regularly (termed standards) and the other displayed sporadically (termed deviants).[5] Any change in regular sequences of an auditory stimulus (deviant) gives rise to ERP components MMN and P300. In addition to simple physical deviants (such as duration, pitch and intensity), MMN is also elicited by more complex irregularities such as changes in sequences of several tones.[6]

Studies examining the processing of auditory stimuli by professional musicians compared with non-musicians suggested qualitative differences of the neural correlates of auditory processing between musicians and non-musicians.[6-13] Professional musicians, unlike non-musicians, showed an MMN for slightly impure chords that were presented among perfect major chords and for small changes in the contour of transposed melodies.[8,12] There is also evidence that sensitivity of the P300 in response to disparities in melodic contour and pitch interval is increased in musicians.[3,14] However, in most of these studies, subjects were presented with musical tones (e.g. piano, violin) or musical sequences, but not with pure tones. In the present study, we aimed to test if musically trained subjects might also discriminate the incongruities in non-musical or pure tones more easily than musically lay subjects. For this purpose, we encountered both groups with pure tones only instead of more complex musical sequences. Thus, we aimed to decrease the advantage of musical training to the minimum.

MATERIAL AND METHODS

We investigated 19 musically trained students from the Department of Fine Arts-Music in Selçuk University Faculty of Education (4 males, 15 females, 20.2 ± 2.38 years old). Controls were 17 students from the same university (6 males, 11 females, 20.76 ± 1.75 years old) who did not play a musical instrument and had no formal musical training throughout their lives. Students from the Music Department had played both violin and piano for 4 years at the university. They had graduated from the Fine Arts High School where they were trained intensively in music for 4 years. The study protocol was approved by the Local Ethics Committee and subjects gave informed consent.

The ERPs were studied using a Nihon Kohden Neuropack 4200 K device. All subjects were examined in the same laboratory conditions between the hours of 16:00-18:00. The ERPs were obtained during an auditory oddball paradigm. This paradigm was based on distinguishing a target stimulus repeated randomly and less frequently from the non-target stimulus of frequent repetition. The subject was asked to press a button only when she/he encountered the rare stimuli. Binaural auditory stimuli were presented by earphones. The oddball paradigm consisted of frequent (1000 Hz) and rare (2000 Hz) tones with respective probabilities of 0.8 and 0.2. All tones were 80 dB and 50 ms in duration. The stimulus sequence was random. The recordings were made by Ag/AgCl electrodes. The reference electrodes were placed over the mastoid regions and the active electrodes over Fz and Cz. All the electrodes had a resistance of 5 kOhm or less and the frequency limits were set at 0.1-50 Hz. 32 responses recorded by the target stimuli were averaged.

N100 and P200 were seen in response to both rare and frequent tones, but N200 (MMN) and P300 were recorded only for the rare tones. Both latencies and peak to peak amplitudes of the maximal negative and positive deflections within a specified latency range were measured based on visual inspection. The P300 component was defined as the most positive occurring peak 250 to 600 ms from the stimulus. The MMN was measured on the difference ERP waveforms within a latency range of 100-250 ms (Figure 1 A, B). Difference waves were obtained for two reasons. First, ERP components other than P300 are of relatively small amplitude and thus are difficult to separate from the background. Second, most of these components occur at relatively short latencies and overlap considerably with the simultaneously occurring "stimulus related" (exogenous) potentials. Thus, specific procedures are required to demonstrate them. Hence, ERPs to the frequent tones were subtracted from the ERPs to the rare tones and difference waves were obtained. The amplitudes were measured as peak to peak voltage for MMN (P200 to N200), and P300 (N200 to P300) in response to the rare stimuli.

The latencies and amplitudes of the MMN and P300 responses to the rare stimulation were compared with those of the control group using independent Student's-t test.

RESULTS

Table 1 and 2 summarizes the ERP data obtained from musically trained subjects and controls. A statistically significant decrease in MMN latencies was observed in musically trained subjects ($p < 0.05$). MMN amplitudes did not differ significantly between the two groups. There were no significant differences in the P300 amplitude and latencies of musically trained subjects and the control group.

DISCUSSION

Electrophysiological investigations demonstrated that brains of musicians and non musicians re-

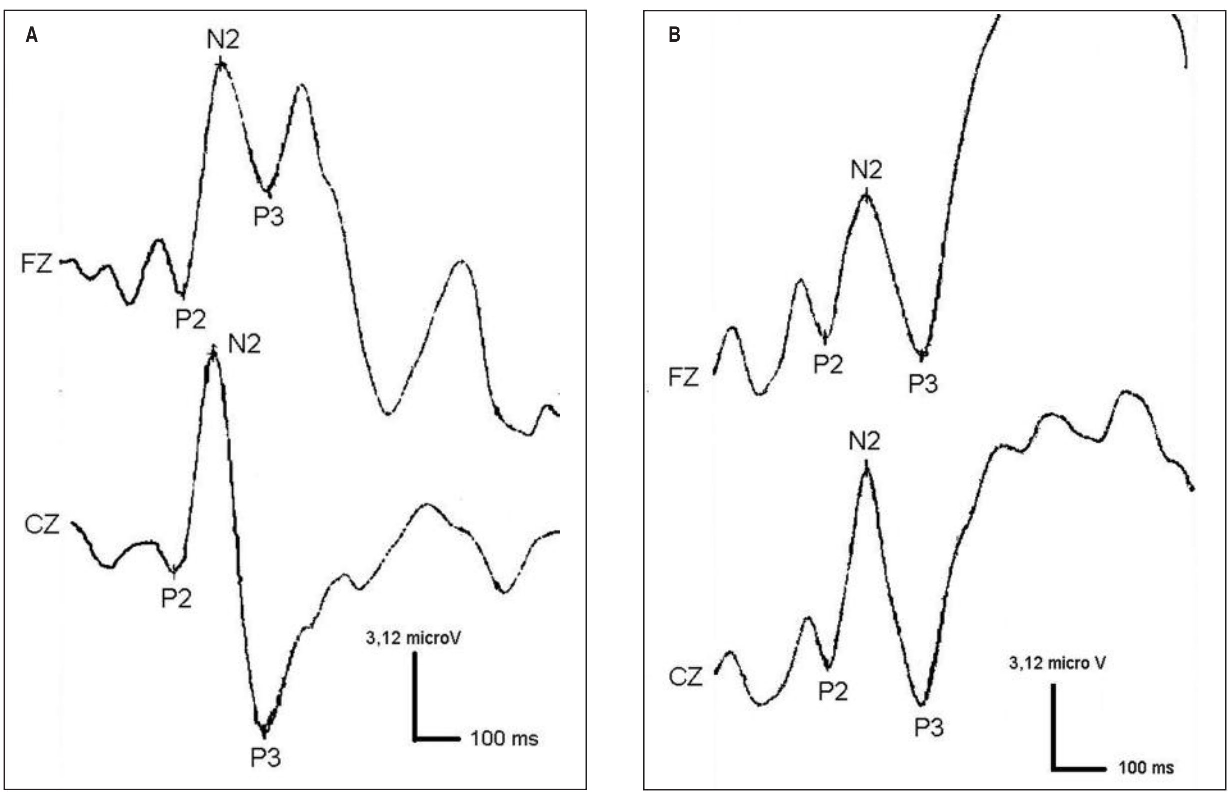

FIGURE 1: Typical computer print-outs of subtracted waveforms: **A**, in musically trained subjects; **B**, in musically lay controls.

TABLE 1: Mean latencies and amplitudes of event related potential components recorded from Fz.

	Musically Trained	Control	p
MMN latency (ms)	207.32 ± 11.31	220.47 ± 13.52	0.003
P300 latency (ms)	305.11 ± 32.69	319.59 ± 22.95	0.138
MMN amplitude (μV)	3.45 ± 2.15	3.95 ± 2.48	0.524
N2P3 amplitude (μV)	4.14 ± 3.31	5.94 ± 3.52	0.125

TABLE 2: Mean latencies and amplitudes of event related potential components recorded from Cz.

	Musically Trained	Control	p
MMN latency (ms)	201.00 ± 18.24	219.71 ± 20.21	0.006
P300 latency (ms)	307.74 ± 37.61	322.94 ± 25.66	0.171
MMN amplitude (μV)	4.99 ± 2.72	5.64 ± 3.10	0.504
N2P3 amplitude (μV)	10.04 ± 3.83	9.29 ± 4.29	0.582

sponded differently to auditory stimuli associated with musical performance. As may be expected, musicians can discriminate incongruities in musical sounds or occasional and unexpected endings of a melodic pattern more easily than non-musicians can. This hypothesis was supported by carefully designed auditory ERP studies comparing musicians with non-musicians.[6-13,15]

Two components of the ERPs, MMN and P300 appear to be closely associated with the cognitive processes of perception and selective attention.[5] For this reason, these components have been widely used to examine various memory mechanisms with their processing strategies and neural correlates related to language and sound processing.[15] ERPs have also been used to examine the processing of auditory stimuli by professional musicians compared with non-musicians. This comparison is an ideal model for examining whether, and if so, where a functional and structural brain plasticity occurs. This is because musicians acquire and continuously practice a variety of complex motor, auditory and multimodal skills throughout their careers.[16]

MMN is considered to be a neurophysiologic index for the echoic memory or pre-attentive auditory processing.[8] The brain encodes physical features of an acoustic input as a neuronal model and compares each input with this norm.[5] In order to compare arrival times of 2 sounds, the 1st sound needs to be retained until the 2nd one arrives and echoic memory fills up this gap.[17] Thus, echoic memory is considered to be the earliest cognitive memory system.[8] According to the "Atkinson-Shiffrin Multistore Model of Memory", information in the echoic memory store is passed to short term or working memory only by attention.[17] The latency of P300 is considered to reflect this passage process or updating of the working memory.[14] This means that P300 reflects match/mismatch with a consciously maintained working memory trace.[5] MMN differs from P300 in its insensitivity to attentional factors.[12,18,19]

Our study was designed to investigate whether auditory ERP components MMN and P300 in response to pure tones were also influenced by musical training. The results demonstrated that MMN latencies evoked by pure tones were shortened in musically trained subjects compared with control subjects who were not trained musically. MMN amplitudes did not differ significantly between the 2 groups. There were no significant differences in the P300 amplitudes and latencies of musically trained subjects and the control group. Thus, decreased MMN latencies in musically trained subjects in our study may support the previous research findings suggesting that pre-attentive auditory information processing was enhanced in musically trained subjects.

Koelsch et al provided the 1st evidence for preattentively superior auditory processing in musicians, demonstrating that when slightly impure chords were presented among perfect major chords, a distinct MMN response was elicited in professional musicians but not in non-musicians. This result demonstrates that musicians are superior in pre-attentively extracting more information out of musically relevant stimuli.[8]

In our literature review, we found that ERP responses of musicians to pure tones were investigated in a small number of studies.[7, 13,10] Although these studies are methodologically different from and more complex than our study, some of their results appear to be in line with ours. In the study of

Lopez et al, 5 oddball paradigms with increasing levels of complexity were used. The authors recorded the ongoing electrical and magnetic activity during oddball paradigms of “note”, “chord”, “arpeggio” and music sequences of Mozart and Bach. In the “note” condition, 300 standard tones of 1310 Hz and 100 deviant tones of 1390 Hz were presented every 1 second. The musicians had significantly shorter peak latencies and larger amplitudes for the MMN and the P300 than those of the non-musicians.[7] In this study, the advantage of musical training was more evident in the complex test sequences, whereas responses to simpler ones did not discriminate between musicians and non-musicians. This means that musicians are more advantageous in discriminating the incongruities in musically relevant stimuli. Luo et al studied the MMN and P300 on children who had been trained with musical meditation for 6 months. They also used pure tones as the auditory stimuli with the standard and deviant tones of 900 Hz and 1000 Hz respectively. They demonstrated significantly increased MMN amplitudes in musically trained children while MMN latencies did not differ between the experiment and control groups.[10]

In another study, Shahin et al demonstrated that P2 and N1c components of the auditory event related potentials evoked by both musical and pure tones were enhanced in skilled musicians compared with control subjects who were not trained musically. These two components were previously shown to be sensitive to remodeling of the auditory cortex by training in non-musician subjects. Thus, their enhancement was suggested to reflect neuroplastic changes in the musicians' brain.[13]

Musically trained subjects in our study did not differ from musically lay subjects in terms of short-term memory functioning, as P300 amplitude and latencies demonstrated no significant difference between the 2 groups. Luo et al consistently demonstrated discordance between MMN and P300 in normal children with and without musical meditation training. In their study, MMN amplitudes were larger than those in the control group were while there were no significant differences in the P300 latencies and amplitudes between the musically trained and non-trained children. The authors suggested that musical meditation training influenced auditory brain function but MMN and P300 might reflect different aspects of the brain function. Indeed, MMN does not account for all factors affecting sensory memory and it is possible to have a good MMN and good echoic memory with poor short-term memory and vice-versa.[10]

The finding that MMN amplitudes are not affected in our experiment group suggests that effects of musical training are reflected on the MMN latencies rather than on MMN amplitudes. This result is not consistent with previous reports which demonstrated that MMN amplitudes were significantly increased in musically trained subjects.[7, 10, 12] However, the difference between our results and theirs might be caused by the methodological differences that do not enable a direct comparison between studies. Moreover, it is assumed that MMN latency reflects the onset of auditory stimulus change in structure, while its amplitude reflects the magnitude of the change and saturates with the increment of perceived discrimination.[20] It might be that the magnitude of the frequency change between standard and deviant sounds in our study, which was high enough to be distinguished even by non-trained individuals, has led to the absence of a significant MMN amplitude difference between the 2 groups. On the other hand, onset of auditory stimulus change in structure appears to be more readily distinguished by the musically trained subjects.

Results of the present study suggest that musical experience might influence pre-attentive auditory processing and auditory sensory memory mechanisms can be modulated by musical training. After years of musical training, neuronal populations in the auditory cortex might be shaped such that they automatically detect changes in auditory stimulus sequences with simple or higher order regularities. It seems plausible to assume that electrophysiological responses obtained from musicians might represent structural adaptations in response to training.

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