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EFFECTS OF MUSICAL MEDITATION TRAINING ON AUDITORY MISMATCH NEGATIVITY AND P300 IN NORMAL CHILDREN△

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The auditory mismatch negativity(MMN) and P300 of event-related potentials were compared in normal children either with or without musical meditation training. The experimental group consisted of 11 subjects who had been trained with musical meditation for six months and the control group consisted of 12 subjects(matched for age, sex and grade) who had not received musical meditation. MMN amplitudes in the trained children were larger than those in the control group. In addition, the MMN amplitudes were identical in attend and ignore conditions for both groups. This evidence suggests that auditory brain function has been affected by musical meditation training. It thus suggests that the MMN is capable of assessing changes to the brain function in normal subjects. There were no significant differences in the P300 latencies and amplitudes between the two groups. This result suggests that MMN and P300 may reflect different aspects of the brain function.

INTRODUCTION

Musical meditation is increasingly being used as a form of relaxation therapy by psychologists, counselors, physicians, and dentists in Western countries. It is widely known that listing to music can reduce anxiety and facilitate a relaxed mood. Behavioral measures are often used to assess the efficacy of musical therapy. However, behavior may be an unreliable index because it is sometimes influenced by social factors that are not easily controlled. More objective measures of the effects of musical training are physiological markers such as event-related potentials (ERPs). In the field of the ERP, the clinical application of P300 is widely used. Some researchers report that P300 amplitude and latency are related to the training of absolute pitch ability(1). Katayama, et al. (2) reported that the N2 amplitude and latency were affected by different pitches and suggested that the N2 reflects the subjective distance between standard

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and deviant tones. More recently, the clinical application of another ERP component called mismatch negativity (MMN) has begun to yield the important data. The MMN, first reported by Naatanen(3), is elicited during active/passive oddball paradigm. The MMN is a difference wave, which is obtained by subtracting the ERP for standard stimuli from that for deviant stimuli. The MMN has been used in the diagnosis and assessment of cognitive impairmen(4). Recently, Tervaniemi, et al. (5) reported that the MMN is sensitive to the discrimination of absolute pitch (AP) changes. Differences have not been investigated so far in auditory information processing reflected by the MMN in groups which were matched with regard to musical therapy. Little is known about whether or not the MMN can be used as an index to observe the effects of musical therapy in normal subjects, especially in children. Musical meditation training is a type of music therapy that is used in China, even in some schools. However, quite a few studies used the MMN to evaluate cognitive function of normal subjects. It thus is necessary to further investigate whether the MMN can provide a sensitive index of the effects of musical therapy on auditory brain function. The present study intends to provide an objective evidence for the change of brain mechanism after musical meditation, and to provide further experimental certification for application of the MMN by investigating the relationship between the effect of musical meditation and the MMN in normal children.

METHODS

Subjects. 23 students 13 years old of age (11 male, 12 female) from the first grade of Beijing No. 2 Middle School, voluntarily served as subjects in the present experiment. The experimental subjects came from a class in which the teacher had adopted a musical meditation training program that was not an ordinary part of the students' curriculum. The students in this class had been trained with musical meditation for six months before the experiment. These students trained together for 10 minutes before class every morning. In the training course, they were instructed to sit quietly, close their eyes, relax their bodies and minds, and listen respectfully to the music "Aria on G string" by Bach. Out of 50 children who attended this class, eleven children were randomly selected to form the experimental group. Twelve control subjects were randomly selected from another class in the same grade of the same school. Children in the two groups were matched for age (all subjects of 13 years), sex (5 males and 6 females for experimental; 6 and 6 for control group), and grade (86.3 ± 13.8 and 86.7 ± 12.5). All children were right handed with normal hearing, and did not have any history of neurological and mental illness.

Stimuli. The auditory oddball paradigm was used. 400 tone pips delivered through two earphones were used as the auditory stimuli. These were produced by Stim system (Neuro Scan Inc. USA). The tone pip duration was 40 ms (including rise and fall time of 5 ms each). The intensity was 70 dB. SPL and the interstimulus intervals (ISIs) were constant 850 ms in duration. The standard stimuli were 900 Hz with a presentation probability of 85% and the deviant stimuli were 1000 Hz with 15%.

ERP recording. The EEG recording electrodes were placed at scalp sites Fz, Cz, Pz, C3 and C4 (International 10–20 system), with a reference Ag/AgCl electrode to the right mastoid. The EOG was recorded with electrodes placed 5 mm above the brow and 10 mm laterally from the canthus of the right eye. The electrode impedance was maintained below 5 kΩ. The EEG and EOG were both amplified with filter 0.3–40 Hz and recorded continuously at a sampling rate of 500 Hz (each channel) for off-line analysis by Scan system (Neuro Scan Inc., USA). The epoch was 800 ms including a 100 ms baseline.

Procedure. Subjects were tested in a sound-attenuated electrically isolated chamber. The passive and active ERPs were measured for both experimental and control subjects. In the passive condition, subjects were instructed to read a text, remember the main plot and answer two questions regarding the story after their EEGs were recorded. In the active condition, subjects were instructed to discriminate two different tones and count silently the deviant stimuli as targets. Some practice trials were run until the performance was correct and skilled.

Data analysis and statistics. EOG artifact was automatically corrected and other artifacts were rejected in the process of averaging. The difference wave was obtained by subtracting ERPs of the standard stimuli from those of the deviant stimuli. The range of the peak of ERPs components was identified according to previous reports (3) and the results of grand-average ERPs. The MMN was identified as a negative-going potential, the largest peak at the Fz site 80–250 ms after the onset of stimuli while the P300 component was identified as the largest positive-going potential at the Pz site 240–500 ms. The latencies were measured from per subject at the peak in the above stated ranges. Peak amplitudes were measured relative to the pre-stimulus baseline for MMN and peak to peak for P300. In addition, the mean amplitudes of the MMN was measured according to the window mentioned above. Results were expressed as mean±SD.

The t-test for the independent samples was used to determine if the mean amplitudes during the measurement windows significantly differed in between-groups. In addition, a mixed model analysis of variance (ANOVA) with two within-subject factors and one betweensubjects factor was conducted and the Greenhouse-Geisser correction was employed. The within-subject factors were attention (attend and ignore conditions) and electrode position (5 sites); the between-subject factor was group (experimental and control). All statistical analyses were performed using SPSS software.

RESULTS

Behavioral data. The error percentages were obtained for each block per group by calculating the percentage of the difference between the reported and actual number of targets. The error percentages were 2.7±5.9% and 2.8±4.0% in the experimental and control group respectively. The t-test did not show significant difference between groups.

Active ERPs. The grand-average ERPs to standard (dashed line) and deviant (solid line) stimuli in the discrimination task for experimental and control subjects are presented at the top of Fig 1. The bottom in Fig 1 shows the grand-average ERPs obtained by subtracting the standard ERPs from target ERPs in the experimental (solid line) and control (dashed line) group.

MMN. The latencies of MMN at Fz were 137.0±20.5 and 146.3±26.4 ms for the experimental and control group respectively. There was no significant difference in the MMN latency between the two groups. The amplitudes of the experimental group were significantly larger than those of the control group at Pz, C4 (Table 1). The MMN mean amplitudes for the experimental group were also significantly larger than those for the control group over all 5 electrode sites (Table 2).

Table 1. The amplitude of active and passive difference ERPs (μv) between-group

Electrode position	Attend condition		Ignore condition	
	Experimental	Control	Experimental	Control
MMN				
Fz	−4.9±2.7	−3.1±1.5	−4.6±1.5	−3.1±1.7*
Cz	−3.5±2.9	−2.0±2.7	−4.2±2.5	−3.2±1.8
Pz	−3.1±2.3	−1.2±1.5*	−3.5±2.4	−2.4±1.5
C3	−3.7±2.3	−2.7±3.0	−4.7±2.7	−3.9±1.9
C4	−4.2±2.5	−2.2±2.1*	−3.9±2.0	−2.9±1.3
P3				
Fz	9.5±3.8	8.5±3.4	3.2±1.9	2.0±2.2
Cz	10.3±3.9	11.0±3.6	2.7±1.9	2.3±1.5
Pz	12.4±2.9	10.7±3.3	2.3±1.5	2.5±1.5
C3	11.1±5.1	10.8±5.3	2.1±1.8	2.3±1.5
C4	10.3±3.4	9.0±2.0	2.1±2.1	2.4±1.6

* $P < 0.05$

Table 2. The mean amplitude of the MMN comparison between-group in attention condition (μv)

Electrode	Experimental	Control
Fz	−3.4±3.1	−1.2±1.7*
Cz	−1.9±2.8	0.9±2.2*
Pz	−0.5±2.5	1.6±2.1*
C3	−1.8±2.8	0.3±2.4*
C4	−2.3±2.4	0.1±2.3*

* $P < 0.05$

P300. The P300 latencies at Pz were 348.9±33.9 and 340.7±29.7 ms for the experimental and control groups respectively. The amplitudes at each scalp electrode are shown in Table 1. There was no significant difference in the P300 latencies and amplitudes between the two groups.

Passive ERPs. The grand-average ERPs to standard (dashed line) and deviant (solid line) stimuli in the ignore condition for experimental and control subjects are shown at the middle of Fig 1. The MMN latencies at Fz were 155.7±34.9 ms, 173.3±23.3 ms; the P300 at Pz were 286.2±32.5 and 280.8±29.9 ms for the experimental and control group respectively. There was no significant difference between the two groups. Table 1 also shows the amplitudes of the passive MMN and P300. The MMN amplitude for the experimental group at Fz was significantly larger than that for the control group (Table 1 and Fig 1).

There was a significant main effect of factor group on the MMN, attention on P300, and electrode

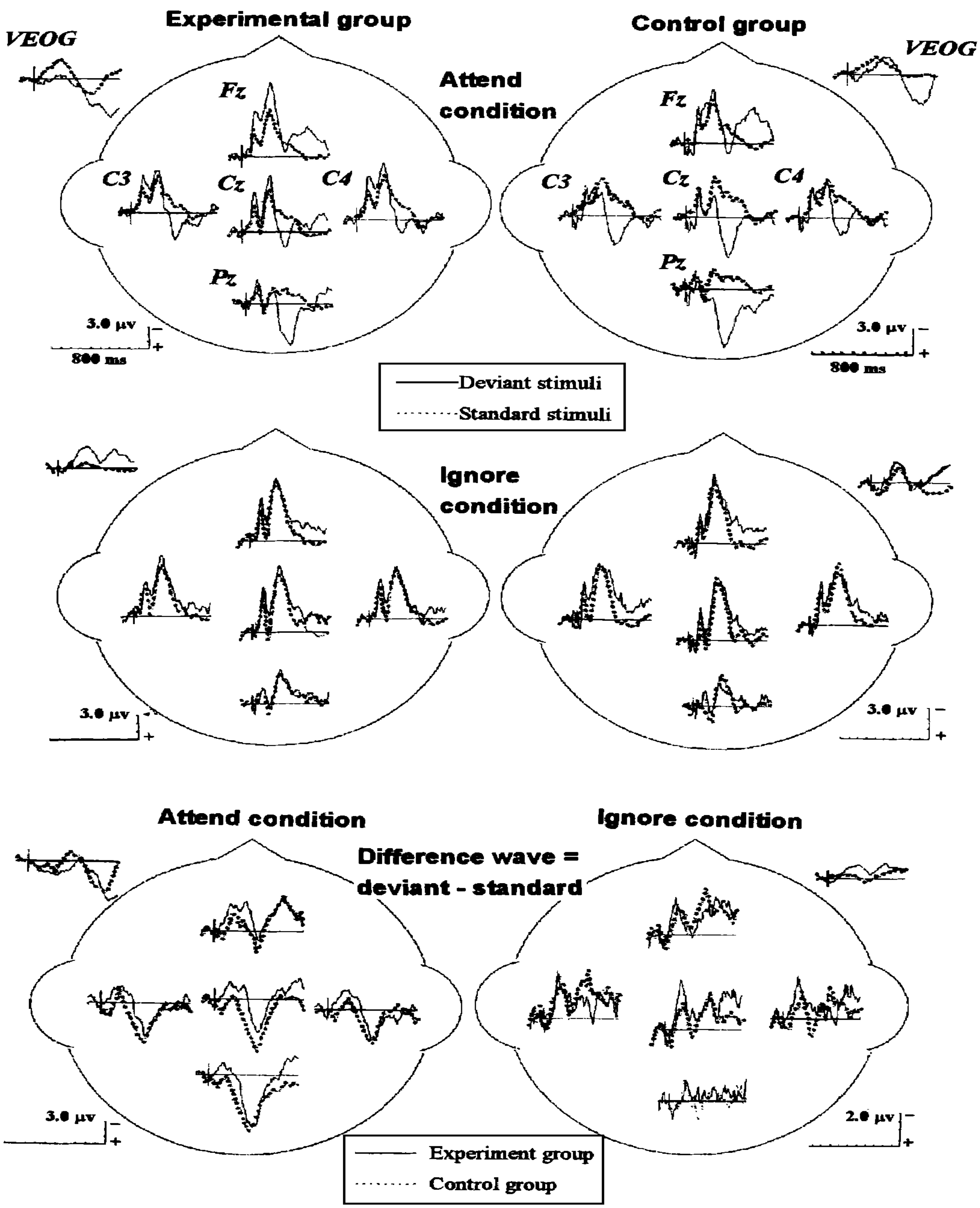

Fig 1. Top: Grand-average ERPs to deviant stimuli(solid line) and standard stimuli(dashed line) in attend condition. Left: Experimental group; Right: Control group.

Middle: Grand-average ERPs to deviant stimuli(solid line) and standard stimuli(dashed line) in ignore condition. Left: Experimental group; Right: Control group.

Bottom: Grand-average of the difference waves obtained by subtracting ERPs to the standard stimuli from that to the deviant stimuli for experimental(solid line) and control(dashed line) groups. Left: In attend condition; Right: In ignore condition.

position on the MMN and P300 (Table 3). This can be interpreted to show that the MMN in the experimental group is larger than that in the control group; P300 amplitudes are larger in attend than in ignore condition; and the MMN amplitude gradually decreased but P300 amplitude increased from anterior to posterior. The interaction between attend and sites reaches significant levels for P300 only.

Table 3. ANOVA results for difference ERPs amplitude

Source of variance	df	MMN	P300
G	1, 21	8.36*	0.91
A	1, 21	1.97	32.10**
E	4, 84	9.07**	15.67**
G×A	1, 21	0.12	1.47
G×E	4, 84	0.45	0.62
A×E	4, 84	1.56	14.96**
G×A×E	4, 84	0.26	1.63

* $P < 0.01$, ** $P < 0.001$, G: Group, A: Attend, E: Electrode

DISCUSSION

The data from this study show that amplitudes of the MMN in normal children were significantly larger in subjects meditated by music when comparing with controls. This evidence suggests that auditory brain function has been affected by musical meditation training. It thus suggests that the MMN is capable of assessing changes to brain functions in normal subjects. It is still a controversial issue as to whether the MMN is affected by attention. Naatanen (3) found that the MMN amplitudes were similar under attend and unattended conditions, suggesting that attention does not affect the MMN. However, Woldorff and Hillyard (6) showed that the MMN is greater in an attend compared to an unattended condition. The present results show that the passive MMN was not smaller than the active MMN for children, providing the evidence to support Naatanen's position. The finding that the MMN is not affected by attention, suggests that it is a product of automatic processing. The result that the MMN was larger in the experimental group than in the control group also suggests that changes to brain function in the trained group were manifested in the automatic processing. These changes may reflect the improvement of auditory automatic discrimination capabilities.

P300 has already been widely applied for diagnostic purposes and for the assessment of dementia and other cognitive function impairment (7, 8). In dementia, P300 usually shows a delay in latency, a decrease in amplitude and irregular wave form. Recently, Frank, et al. (9) reported that the P300 amplitude was decreased in children with learning disabilities compared with normal controls. The MMN and P300 may also reflect different cognitive processing processes. It is often assumed that P300 reflects the updating of context in working memory, but the MMN could in fact reflect the individual discrimination ability of simple and complex sound features as well as automatic processing processes. The musical meditation training used in the present study showed effects on the MMN rather than on P300. The MMN and P300 may therefore play a different role in the assessment of auditory brain function. The results also suggest that the effects of musical meditation training probably reached sensory discrimination level in the present experiment. However, the data do not provide the conclusive evidence to prove that the musical meditation training actually improves the higher cognitive function. This issue awaits further investigation.

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