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Original Article

Relationship between Mood States and Heart Rate Variability Coefficient & Event Related Potential P300 by Long-term Auditory Stimuli with Strong 1/f Fluctuation in Healthy Young Women

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Abstract

A study on relationship between mood states and heart rate variability coefficient & event related potential P300 by long-term auditory stimuli with strong 1/f fluctuation in healthy young women was done over 22 volunteered young healthy university female (12 subjects in the listening group, 10 subjects in the control group). Experiment was done on the long-term auditory stimuli. In the experiment, surveys about life style and life consciousness, measurement of ECG, ERP-P300 latency, and POMS test were done 3 times before and after 6- week auditory stimuli and at the end of 2- week non -listening period.

As a result, improvement of getting to sleep, increase of deeply sleeping and increase of enough time were found after long term auditory stimuli. Increase of 1/f fluctuation rhythm in heart rate variability property and shortening effect on ERP-P300 latency were indicated. Positive correlation between change of mood states (tension-anxiety, fatigue) and 1/f fluctuation rhythm increase in heart rate variability are recognized significantly. There was negative correlation between change of mood states (confusion) and ERP-P300 latency. Therefore, it is considered that emotion and mood states generated in the cerebral limbic system affect higher cerebral function (cognitive function).

Hence, we can safely assume that regularly listening to the music with strong 1/f fluctuation during mealtimes every day affects sending system of circadian rhythm. It is speculated that mood states generated in the cerebral limbic system control proportion of 1/f fluctuation rhythm of heart rate variability and affect the shortening of ERP-P300 latency which is known as an index reflecting the cognitive function. This study suggests that listening to the music with strong 1/f fluctuation for 1 hour every day during mealtimes possibly delays functional changes of cerebral cortex associated with aging, and reduces dementia. It probably is helpful for preventive care in aged society.

Key words： Mood States, Heart Rate Variability Coefficient, Event Related Potential P300

Ⅰ. Introduction

Two of three major causes of death are circulatory diseases, i.e., cerebrovascular disease and cardiac disease, which account for 30% of all causes of deaths. Cerebrovascular disease ranks first as the cause of care requirement (25.7%). It has close relevance to cerebrovascular dementia, in addition to elderly weakness (16.7%) and cognitive disease (10.3%) which stand second and fourth as a cause of care require-ment, respectively [1]. Therefore, it is considered that patients with cerebrovascular disease occupy consider-able part of people requiring care nursing. Cerebrovascular dementia and it associated with Alzheimer's disease are becoming major problem because these are hard to improve. Therefore preventive measures for care nursing related to cerebrovascular dementia are becoming a compulsory subject in the coming ultra-aged society.

Recently, music therapy has been attempted for the treatment of patients with cerebrovascular dementia, and its usefulness has been proved [2]. It has been reported that active music therapy twice a week for 4 weeks in patients with cerebrovascular dementia improves their cognitive function using an event-related potential (ERP)-P300 as an index [3]. ERP-P300, an evoked endogenous encephalogram, has been known as one of indices reflecting cognitive condition in higher cerebral functions [4]. It has been reported that mental fatigue prolongs P300 latency and decreases its amplitude [5], and that listening to music which gives relaxation effect increases P300 amplitude and improves fatigue caused by a calculation loading [6]. We also previously reported that acute listening to calm and comfort music sound for 30 min shortened ERP-P300 latency and that changes in P300 latency positively correlated with changes in the mood state of depressive condition [7]. The improvement of cognitive function by auditory stimuli can be explained from the aspect of cognitive psychology [8]. However, there has been no study on the physiological mechanism in which auditory stimuli activate cognitive function. Therefore, it is necessary to investigate the relationship between auditory stimuli with music sound and physiological functions of brain. We conducted the present study to examine the effects of long term auditory stimuli with calm and comfort music sound on ERP-P300, heart rate variability coefficient and mood states in young healthy female volunteers from aspects of the primary prevention of cerebrovascular disease and preventive care of cerebrovascular dementia. The purpose was to clarify the effects comprehensively from various aspects including a physical aspect in which the relevance of exogenous synchronization factors to endogenous synchronizing mechanism, physiological aspects in which cognitive condition in higher cerebral functions is examined using evoked encephalograms, and a psychological aspect in which mood state is tested. For this purpose, following tests and measurements were performed: analysis of 1/f fluctuation of sound in subject music, examination of ECG and analysis of 1/f fluctuation in heart rate variability, measurement of ERP-P300 latency, POMS test. Then, changes of these measurement and tests before and after the long term auditory and relationship among them were studied.

Ⅱ. Methods

1. Subjects

Subjects were 22 students in a women's university, who voluntarily accepted to participate in this study after receiving sufficient informed consent. They were done the experiment on the long term auditory stimuli. The subjects were randomly assigned to either of the listening group 12 subjects(average age 20.8 ± 1.1 years old) and the control group 10 subjects (average age 20.3 ± 1.2 years old) using a table of random numbers. This study was approved by the human study ethical committee in our university, and then conducted as a human study on the effect of music sound listening with voluntarily participating healthy female students in the same course and specialty in our university. The person who met the following criteria were included in this study: healthy person without auditory abnormality; person not having circulatory diseases, respiratory diseases, renal diseases, hepatocystic diseases or metabolic diseases; nonsmoker; subject not having medication; and person who had not taken alcoholic drinks within 3 days before the test or measurement.

2. Subject music

Four quiet music compositions chosen by a performance musician were edited to a calm and comfortable violin concerto. Then the concerto was recorded two times on a compact disc so that its playing time was to be 30 minutes, and used as the subject music. The subject music was the music sound used in our previous study [9], and fluctuation coefficients (Table 1) of power spectral density (PSD) of 1/f fluctuation of frequency and amplitude (effective sound pressure) of the music sound were − 0.7880 ± 0.0238 and − 0.7265 ± 0.0113, respectively (Mean ± SD). Both fluctuation coefficients of frequency and amplitude were calculated for 6 times of 5 minutes fractions. Moreover, fluctuation coefficient − 1 means that power of fluctuation is in proportion to recipropal of frequency fluctuation, so it is named 1/f fluctuation characteristics, which is known as a particular fluctuation well balanced with prediction and unexpected-ness [10]. The composer, name of composition, type of performance and playing time

Table 1 Fluctuation Coefficient Calculated from Power Spectral Density in Subject Music

Music	Fluctuation Coefficient	
	Frequency Fluctuation	Amplitude Fluctuation
S1	− 0.8957	− 0.7098
S2	− 0.7327	− 0.719
S3	− 0.8224	− 0.7145
S4	− 0.6478	− 0.6478
Mean ± SD#	− 0.7880 ± 0.0238	− 0.7265 ± 0.0113

#：These fluctuation coefficients were averaged for 6 times 5min fraction

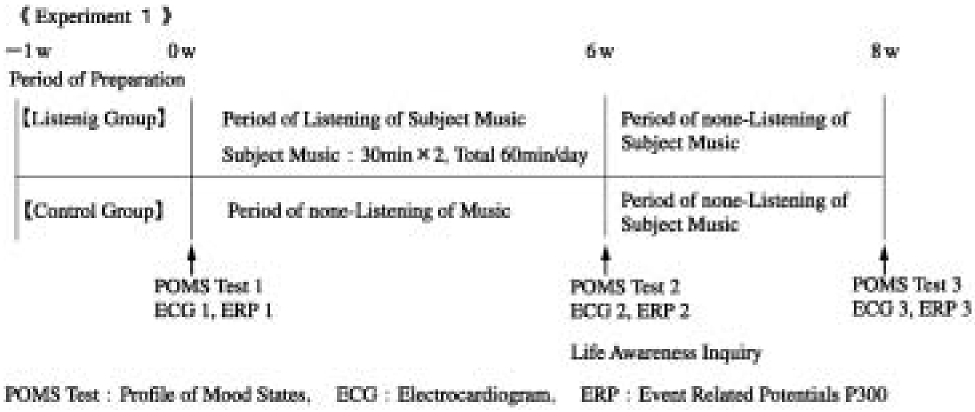

Figure 1 Experimental Design

of these music sound were as follows: The first piece (S1) − Charles Francois Gounod, Ave Maria, violin concerto, 3' 50" ; the second piece (S2) − Jules Masset, meditation from *Tais*, violin concerto, 4' 45"; the third piece (S3) − Nicolai Rimsky-Korsakov, song of India, violin concerto, 2' 45"; and the fourth piece (S4) − Niccolo Paganini, Cantabile, violin concerto, 3' 40". For these pieces, fluctuation coefficients of PSD of 1/f f fluctuation of frequency and amplitude were −0.6478 to −0.8957 and −0.6478 to −0.7196, respectively.

3. Experimental periods

The period of experiment was from May 18th, 2006 through July 13th, 2006. Measurements and tests were carried out from 4:00 pm to 6:00 pm on May 18th (the first day), June 29th (the day of the 6th week) and July 13th (the last day, the day of the 8th week).

4. Experimental design

The experimental design is shown in Figure 1. In experiment, measurement of ECG and ERP-P300, POMS test were done 3 time, i.e., at the beginning and the end of the 6-week period of listening to subject music, and the end of the 2-week non listening period. ECG was continuously recorded for 20 minutes in a room under the room temperature of 25 ± 1 ℃. To kept the listening condition of the subject music constant, the volume of a compact disc player was set to 48 ± 1 dB in advance by using a 93 W- loudness meter (VOS-11, Leader Electronics Co.). The subjects listened to the music sound in a sitting position with eyes open. To estimate listening rates, the subjects were requested to record the music sound they listened to by a data recorder which is capable to record for 8 hours, and the record was checked every week. The subjects in the listening group were requested not to listen to other piece of music than the subject music, and the subject in the non-listening group was requested not to listen to any piece of music.

5. Methods for measurements, tests and surveys

1) Analysis of 1/f fluctuation of the music sound

After the transformation to a WAV data format, PSD of frequencies and amplitudes (effective sound pressures) of four pieces of calm and comfortable music were analyzed by a frequency analysis based on a fast Fourier transformation using a 1/f fluctuation calculation program [11] which was made by the zero-cross method using a language for Fourier transformation, MATLAB. The fluctuation of PSD was analyzed by the least square method, and fluctuation coefficients of PSDs of frequencies and amplitudes (effective sound pressures) were calculated for the pieces of music (S1 − S4), and for 6 times of 5 fractions. Then, the mean and SD of fluctuation coefficients of all of 30-minute music performance contained in the compact disc were calculated.

2) Measurement of ECG and analysis of heart rate variability

The subjects had a holter ECG recorder (CR2100, Fukuda M.E. Kogyo Co., Ltd.) on the day of beginning and the day of the 6th week. ECG was measured for 20 minutes, and R-R intervals on the ECG were recorded. CSV files of recorded R-R interval were prepared by an ECG recording and analyzing system (HS1000, Fukuda M.E. Kogyo Co., Ltd.) using order-made software which output data of R-R intervals. With this file, PSD of 1/f fluctuation in heart rate variability was analyzed by a frequency analysis using a 1/f fluctuation calculation program [11] based on fast Fourier transformation using a language for Fourier transformation, MATLAB. Its fluctuation was analyzed by the least square method, and heart rate variability coefficients were calculated.

3) Measurement of ERP-P300 latency

ERP was measured using a basic medical science research

Table 2 Change of Life Style and Life Consciousness by Long-term Auditory Stimuli

(Mean ± S.D)

	Item	Listening Group (n=12)				Control Group (n=10)		
		Change Value#				Change Value#		
1	Get up time	-0.083	±	0.289		−0.100	±	0.568
2	Bedtime	0.083	±	0.515		0.000	±	0.667
3	Sleeping hours	0.167	±	0.389		0.000	±	0.471
4	Wake in mood	0.000	±	0.603		0.300	±	0.675
5	Get to sleep	0.417	±	0.514	*	0.300	±	0.483
6	Deeply sleep	0.333	±	0.492	*	0.100	±	0.875
7	Appetite	0.083	±	0.669		0.100	±	0.316
8	Willing	0.250	±	0.452		0.200	±	0.633
9	Concentration	0.083	±	0.668		0.300	±	0.483
10	Enough time	0.333	±	0.492	*	0.300	±	0.675
11	Relaxation	0.167	±	0.577		−0.100	±	0.568
12	Fatigue	0.083	±	0.289		−0.100	±	0.568
13	Condition	0.250	±	0.452		0.200	±	0.633
14	Mental health condition	0.167	±	0.389		0.300	±	0.675
15	Human relation	0.167	±	0.389		−0.100	±	0.568

＊：p<0.05 ＃：Minus mark is minus change、no mark is plus change

system, MP150 (BIOPAC Inc., USA), an evoked response amplifier, ERS100C (BIOPAC Inc.) and a stimulus response module, STM100C (BIOPAC Inc.) [12]. The subject performed an oddball paradigm in which the subject pushed a button when hearing pure sounds at 2000 Hz among the mixture of pure sounds at 1000 Hz (80%) and pure sounds at 2000 Hz (20%) randomly generated at 3 second-intervals. Averaged ERP of auditory evoked encephalograms (between the earlobe and Fz position) was recorded, and P300 latency was read out from the recording.

4) POMS test

POMS teat was carried out using the Japanese version POMS (Profile of Mood States [13]) which was a questionnaire surveying subject's mood states. The questionnaire consisted of 65 questions, and subject's answers were analyzed about following 6 items: 1) T-A (tension/anxiety); 2) D (depression); 3) A-H (anger/hostility); 4) V (vigor); 5) F (fatigue); and 6) C (confusion).

5) Surveys about actual situation of listening after long term auditory stimuli and about life style and life consciousness

The survey was conducted with a questionnaire. The questionnaire on actual situation of listening consisted of 2 items, i.e., the listening rate of the subject music and time for listening to other pieces of music (min/day). The questionnaire on life style and life consciousness consisted of following 15 items: Get up time and Bedtime(getting later/unchanged/getting earlier); Sleeping hours(getting less/unchanged/getting more); Wake in mood; Get to sleep and Deeply sleep (worsened/unchanged/getting better); Appetite; Willing and Concentration(decreased/unchanged/improved); Enough time; Relaxation; Fatigue (decreased/unchanged increased); Physical condition; Mental health condition and Human relation (worsened/unchanged/getting better). The subject's answer on each item was scored − 1 (worsened), 0 (unchanged) or + 1 (improved).

6. Statistical analysis

The fluctuation coefficient of PSD of 1/f fluctuation in R-R intervals on ECG, ERP-P300 latency and scores of POMS test were statistically analyzed using a statistical analysis program, SPSS for Windows ver.11.5. Differences in the mean values of paired data were analyzed by the paired t test, and differences in the means between groups were analyzed by the t test. Nonparametric analysis of paired data was carried out by the Wilcoxon test. Correlation was analyzed by the Pearson's correlation analysis or Spearman's rank correlation analysis, and significance was judged by r or ρ values. The difference with P value less than 0.05 was considered to be statistically significant.

Ⅲ. Results

1. Changes in life style and life consciousness before and after long term auditory stimuli

Table 2 shows changes in life style and life consciousness between before and after the 6-week long term auditory stimuli in the listening and the control groups. In the 6-week listening group, score for "Get to sleep" (p<0.05), "Deeply sleep"

Table 3 Change of Heart Rate Variability Coefficient Calculated from Power Spectral Density in R-R Intervals in Before and After of Long-term Auditory Stimuli

(Mean ± S.D.)

	Before	After
Heart Rate Variability Coefficient	−0.5225 ± 0.1114	−0.5705 ± 0.0915 *

＊：p <0.05

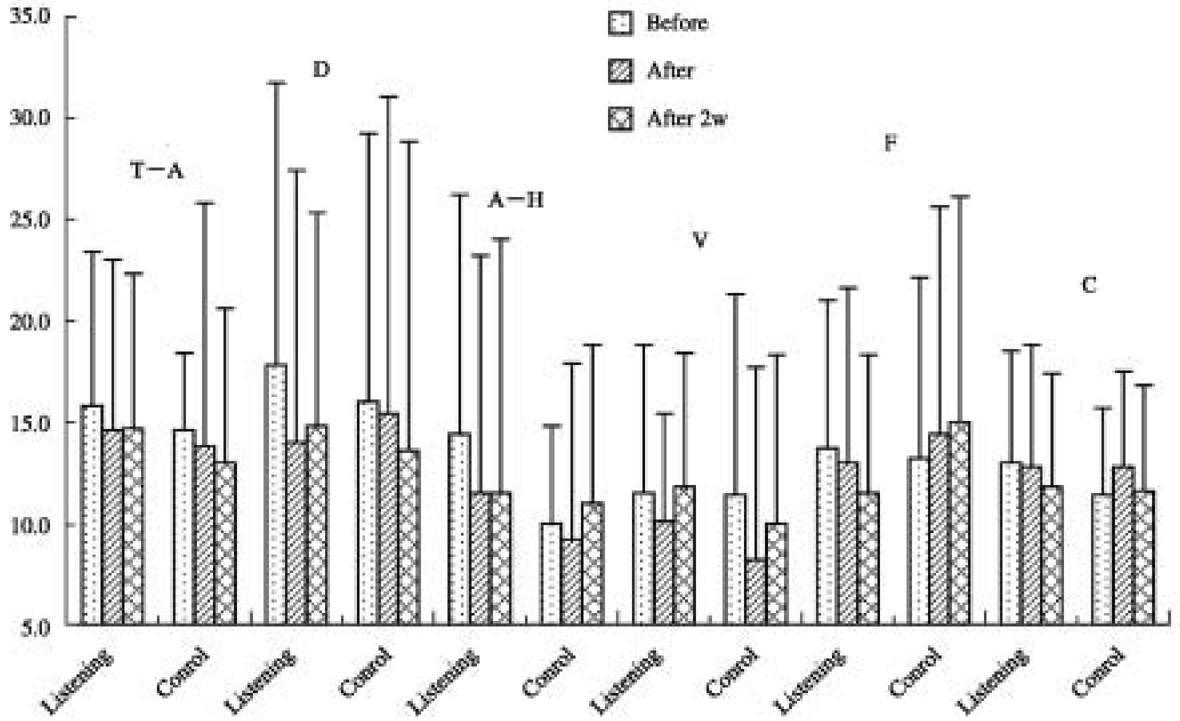

Figure 2 Change of Scores of Mood States in Before and After of Long-term Auditory Stimuli and After 2w Without Auditory Stimuli

T-A：Tension/Anxiety, D：Depress, A-H：Anger/Hostility, V：Vigor, F：Fatigue, C：Confusion

(p<0.05) or "Enough time" (p<0.05) was significantly higher after the 6-week auditory stimuli compared with that before the stimuli. No significant differences were found between before and after the stimuli in the control group. These results suggest that 6-week auditory stimuli with the subject music improve easiness to get to sleep, increase or lengthen deep sleep, and increases leisureliness. The listening rate of the subject music checked with data recorders was 91.6%, and average daily time for listening to other pieces of music was 6.3 minutes according to their-own reports in the listening group.

2. Changes in 1/f fluctuation rhythm in heart rate variability after long term auditory stimuli

Table 3 shows the fluctuation coefficients of PSD of 1/f fluctuation in heart rate variability before and after the 6-week long term auditory period. PSD was obtained by frequency analysis of R-R intervals on ECG. As a result, the fluctuation coefficient was significantly higher (p<0,05) after the 6-week auditory stimuli than that before the stimuli, suggesting increase of 1/f fluctuation rhythm in heart rate variability by the stimuli.

3. Psychological changes after long term auditory stimuli

1) Changes in mood states

Figure 2 shows changes in scores related to mood states before and after 6-week long term auditory stimuli, and at the end of the 2-week non-listening period in the listening group and the control group. In the listening group, any significant changes were found in scores representing tension/anxiety (T-A), depression (D), anger/hostility (A-H), Vigor(V), fatigue (F)

Table 4 Correlation between Change of Mood States and Change of Heart Rate Variability Coefficient in Before and After of Long-term Auditory Stimuli

Spearman Rank Correlation Coefficient on Table

	Change of Mood States					
	Tension/Anxiety	Depress	Anger/Hostility	Vigor	Fatigue	Confusion
Change of Heart Rate Variability Coefficient	0.671*	0.164	0.424	−0.248	0.817***	0.316

* : $p<0.05$, *** : $p<0.001$

and confusion (C) among before and after the long term auditory stimuli, and at the end of the non-listening period. There were no significant differences in scores representing mood states, either, in the control group.

2) Relationship between changes in mood states and fluctuation coefficient of PSD of 1/f fluctuation in heart rate variability

Table 4 shows the relationship between changes in mood states and changes in fluctuation coefficients of PSD of 1/f fluctuation in heart rate variability. The relationship was expressed with the correlation coefficient calculated by Spearman's rank correlation analysis. Among 6 items representing mood states, changes in the scores representing fatigue ($p<0.001$) and tension/anxiety ($p<0.05$) positively correlated with changes in the fluctuation coefficients of PSD of 1/f fluctuation in heart rate variability. These results indicate that 1/f fluctuation rhythm in heart rate variability increases with increase of changes in the mood of tension/anxiety and fatigue, suggesting the relationship between the change in the mood state by 6-week auditory stimuli with music sound and increase in 1/f fluctuation rhythm in heart rate variability.

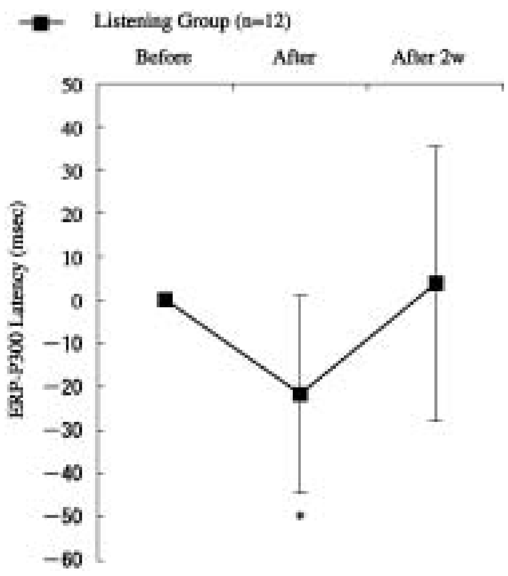

Figure 3 Shortening of ERP-P300 Latency in Before and After of Long-term Auditory Stimuli and Aftetr 2w Without Auditory Stimuli

* : $p<0.05$, Vertical line is difference between listening group and control group

4 Changes in ERP-P300 latency after long term auditory stimuli

Figure 3 shows changes in ERP-P300 latency with difference made by deducting the amount of the control group from that of the listening group before and after the 6-week long term auditory stimuli with music sound and at the end of the 2-week non-listening period. In the listening group, ERP-P300 latency was significantly shorter after the 6-week auditory stimuli than that before the stimuli ($p<0.05$), but there was no difference between that before the stimuli and that at the end of the non-listening period probably due to rebound. The results indicated the shortening effect of the 6-week long term auditory stimuli on ERP-P300 latency.

5 Relationship between changes in mood states and ERP-P300 latency

Table 5 shows the correlation between changes in scores

Table 5 Correlation between Change of Mood States and Change of ERP P300 Latency in Before and After of Long-term Auditory Stimuli

Spearman Rank Correlation Coefficient on Table

	Change of Mood States					
	Tension/Anxiety	Depress	Anger/Hostility	Vigour	Fatigue	Confusion
Change of P300 Latency	−0.423	0.158	−0.128	−0.025	−0.458	−0.692*

* : $p<0.05$

of 6 items representing mood states and shortening of ERP-P300 latency before and after the 6-week long term auditory stimuli. The results are expressed with correlation coefficient ρ calculated by the Spearman's rank correlation analysis. There was significant negative correlation between changes in ERP-P300 latency and changes in the score representing the state of confusion ($p<0.05$). No significant correlations were found between changes in ERP-P300 latency and changes in five other items relating to mood states. The results suggest that changes in the confusion state was smaller as the change in ERP-P300 latency, an index of cognitive function, was larger after the 6-week long term auditory stimuli with music sound.

Ⅳ. Discussion

ERP-P300, one of evoked endogenous encephalograms has been known as an index reflecting the cognitive condition in higher cerebral functions4). Enoki et al. studied the age-dependent changes in P300 latency with subjects from child to elderly, and demonstrated that it sharply shortened in children ranging in age from 7 years to 15 years, was constant in subjects ranging in age from 15 years to 40 years, and significantly longer in subjects over the age of 40 years [14]. Brown et al. reported the positive correlation between age and P300 latency in healthy subjects ranging in age from 15 year to 80 years demonstrating prolongation of P300 latency with age[15]. Gordon divided healthy subjects into adult and elderly subjects, and analyzed correlation between age and P300 latency; the result demonstrated the greater prolongation of P300 latency with age in population over the age of 63 years[16]. Therefore, it is considered that aging/senescence induces various structural and functional changes in the brain which is reflected to P300 latency, an index of cognitive function in higher cerebral functions[17]. In addition, correlation of severity of impaired cognitive function with prolongation of P300 latency was reported in patients with dementia, indicating that decreased intellectual function in dementia, a pathological aging, results in decreased cognitive function represented by P300[18]. Furthermore, negative correlation has been reported between the blood flow and carbohydrate metabolic rate in the cerebral cortex and P300 latency in patients with multiple cerebral infarcts including patients with dementia[19), 20]. These studies suggest the relationship between functional changes in the cerebral cortex and impairment of cognitive function, which is reflected to P300. On the other hand, it has been reported that mental fatigue due to calculation loading prolongs P300 latency and decreases its amplitude, and listening to calm and comfortable music which gives relaxation effect increases P300 amplitude and improved fatigue [6]. We also previously reported that 30-minute acute listening of calm and comfortable music with strong 1/f fluctuation shortened P300 latency [7]. The improvement of cognitive function by auditory stimuli can be explained from the aspect of cognitive psychology [8]. However, there has been no study on the physiological mechanism in which auditory stimuli activate cognitive function. It also has been reported that relatively long-term music therapy in patients with senile dementia shortens their P300 latency [3]. However, it is considered that, in addition to music listening, physical exercise by instrumental performance or other action and psychological therapy by therapists also contribute to the shortening effect in the study. Therefore, it is necessary to clarify the effect of long term auditory stimuli with music sound on physiological functions of brain.

In the study, the study subjects were requested to listen to the subject music for 60 minutes a day in total (30 min × 2 times/day) in mealtimes, and not to listen to other pieces of music. Results showed that listening rate of the subject music was 91.6% and time for listening to other pieces of music was 6.3 minutes/day. The listening rates during breakfast time, lunch time and dinner time were 28.1%, 23.9% and 48.0%, respectively. Since the subject music has relatively strong 1/f fluctuation in its frequency and amplitude and rich in 1/f fluctuation rhythm, it is expected to act as an exogenous synchronizing factor of circadian rhythm. As the subjects were requested to listen to the subject music during mealtimes, the mealtime itself is also expected to act as an exogenous synchronizing factor. Three dispatch mechanisms of circadian rhythm has been recently considered [21), 22]. The first dispatch mechanism is located in the suprachiasmatic nucleus in the hypothalamus. It strongly couples with phenomenon in the circadian rhythm and controls rhythms of melatonin secretion, cortisole secretion, deep body temperature and REM sleep appearance. Illuminance higher than 2500 lx and exercise have been known as synchronizing factors (time cues [23]). Subject music rich in 1/f fluctuation rhythm may give strong influence on the circadian rhythm through the synchronizing mechanism as a time cue. The location of the second dispatch mechanism has not been known, but it is a clock mechanism relatively weakly coupled with the first circadian rhythm phenomenon (internal synchronization), and controls sleep/awake rhythm through the rhythm of non-REM sleep appearance. Time cues known include social regulation. In the questionnaire on life style and life consciousness, scores relating to "Get to sleep" and "Deeply sleep" after the 6-week long-term auditory stimuli was improved in the listening group. This result suggests that habitual listening to music possibly becomes a time cue. The third mechanism is located in peripheral organs including the liver. The mechanism is considered to control the rhythm of metabolism in each organ utilizing the timing of meal as a time cue. In the present study, the 6-week long term auditory stimuli of music sound with strong fluctuation increased the fluctuation coefficient of PSD of 1/f fluctuation in heart rate variability controlled by the autonomic nervous system. Therefore, it is considered that music sound with strong 1/f fluctuation, i.e., rich in 1/f fluctuation, activates heart rate variability poor in 1/f fluctuation rhythm to increase its 1/f fluctuation component. It has been known that the heart rate rhythm was influenced by the respiratory rhythm generated in pre-Bottzinger complex of the pneumotaxic center in the pons of the brain stem, and controlled by the parasympathetic vagal nervous system [24]. The autonomic nervous system consists of the sympathetic and parasympathetic nervous systems and controlled by the circadian rhythm. Therefore, daily listening to music sound with strong 1/f fluctuation during mealtimes may give influence on the dispatch mechanism through its action on synchronization mechanism of the circadian rhythm.

Then, the influence of emotion and mood states which is considered to be generated in the cerebral limbic system was studied. For this purpose, we compared the POMS scores before and after the 6-week long term auditory stimuli and at the end of the non-listening period, but we did not find any significant changes in the score. Previously we reported 2 times that the 6-week long term auditory stimuli with the music sound used in the present study improved the POMS scores [7),25)], and that the improving effect lasted after the subsequent 2-week non-listening period [25)]. Although the reason for the failure to show the improving effect in this study has not been clarified, variations of the life environmental factors around the subjects for 8 weeks possibly hindered the stress-relief effect of the music sound. On the other hand, positive correlations were found between the POMS score representing fatigue or tension/anxiety and the fluctuation coefficient of PSD of 1/f fluctuation in heart rate variability. These results indicate that the fluctuation coefficient of PSD of 1/f fluctuation in heart rate variability increases with increase of change in the mood of tension/anxiety and fatigue, suggesting the relationship between the change in the mood state and activation of 1/f fluctuation in heart rate variability by long term auditory stimuli with music sound.

The 6-week long term auditory stimuli with music sound with strong 1/f fluctuation shortened P300 latency indicating its improving effect on cognitive function in the present study. It was previously demonstrated that the acute auditory stimuli by music listening shortened P300 latency [7)]. In the present study, however, the measurement was done in the condition where the subjects were not listening to the music sound before and after the 6-week long term auditory stimuli. Therefore, it is considered that shortening effect of acute auditory stimuli on P300 latency gradually accumulated during 6-week long term stimuli. On the other hand, a negative correlation was found between the change in P300 latency, an index of cognitive function, and the change in the score representing confusion of the POMS test. The result suggests that the change in ERP-P300 latency is larger as changes in the confusion state is smaller, suggesting the dependency of cognitive function on mood state of the confusion. Therefore, it is speculated that emotion and mood states generated in the cerebral limbic system affect the cognitive function.

In summary, it is considered that regular listening to music sound with strong 1/f fluctuation (i.e., rich in component of rhythm) twice a day during mealtimes as an environmental synchronizing factor affects synchronization mechanisms of multiple circadian rhythm systems to give influence on dispatch mechanisms. Then, it not only exerts the effect on sleep mechanism but also regulates the autonomic nervous system. And finally it activates 1/f fluctuation in heart rate variability and increased its 1/f fluctuation rhythm. On the other hand, it is considered that changes in mood states, such as tension/anxiety and fatigue, generated in the cerebral limbic system induced by 6-week long term auditory stimuli regulates fluctuation coefficient of PSD of 1/f fluctuation in heart rate variability, i.e., ratio of component of rhythm. In addition, it is speculated that changes in emotion of confusion generated in the limbic system affect the shortening of ERP-P300 latency, an index of cognitive function. It is undeniable that synchronization mechanism which regulates emotion of tension/anxiety or emotion of fatigue and 1/f fluctuation rhythm of heart rate variability is coupling with circadian rhythms (internal synchronization). Present study suggests that, in the modern society facing to ultra-aged society, it is helpful for preventive care in aged society to listen to calm and comfortable music with strong 1/f fluctuation for 1 hour every day during mealtimes as BGM, because it possibly delays functional changes of cerebral cortex associated with aging and reduces subsequent impairment of cognitive function leading to dementia.

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