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Analysis of Environment to Relieve Stress Experienced by Children with Developmental Disorders—Research for Development of Biofeedback Support System Using Music

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In recent years, the number of children with developmental disorders has significantly increased in Japan, accounting for 6% of children attending regular classes. Although schools have been required to support children with special needs since 2016, sufficient support is yet to be made available. Children with developmental disorders are sensitive to various types of stress and experience coping difficulties. Therefore, a favorable environment should be created to relieve the stress experienced by children with developmental disorders. We believe that inducing eustress via subsets of the five senses is an effective way to relieve distress. To investigate this, we made the subjects listen to music, which was safe and easy to implement. We observed the impact of various types of music as positive stressors on the subjects and discerned the effectiveness of music in inducing a state of relaxation based on measurements obtained on an electroencephalogram (EEG). Cognitive tasks and EEG results showed that concentration and flexibility of thoughts were influenced by music. We confirm that music relieves stress and the types of music that lower stress are different for every individual. We confirm that music as a good stressor relieves bad stress, and the types of music that cause good stress are different for every individual.

1. Introduction

In recent years, the number of students who feel embarrassed at school has increased in Japan, and many such students have been diagnosed with one or more developmental disorders, such as autism spectrum disorder, attention deficit disorder, attention deficit hyperactivity disorder, and learning disorders.(1) Children with these disorders receive inadequate support, and the impact of the disorders on them is serious. Therefore, it is important to support children with developmental disorders individually because each of them has specific needs and disorder characteristics. Developmental disorders have

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recently been estimated to afflict as many as 6% of students attending regular classes.[2–9] Children with developmental disorders require special support in many aspects of their life, and individual educational support is particularly important. For support, it is important to know the characteristics of the person with developmental disorders.

Therefore, we developed a web database system that acquires and stores biological data such as behavior data and brain wave data of the person with developmental disorders.[1] In this system, biological information of various states is acquired from the sensors and accumulated, and in this research, we accumulate and analyze brain wave information related to stress and music.

Children with developmental disorders are sensitive to various types of stress and experience coping difficulties. Stress is not always bad for the health. Accordingly, it has been differentiated into eustress (positive stress) and distress (negative stress). Excessive distress causes disorders such as migraine and hyperventilation syndrome. Therefore, effectively relieving distress is essential for the mental and physical well-being of a child. With these assertions in mind, in this research, we aimed to develop an environment to relieve stress among children with developmental disorders.

We consider that inducing eustress via subsets of the five senses is an effective way of relieving distress. Listening to music, which is safe for the human body and easy to implement, was employed to relieve distress.[10,11] We observed the impact of various types of music as the stressor on the subjects and then discerned the effectiveness of the stressor to induce a state of relaxation. Electroencephalogram (EEG) analysis was carried out during the course of the experiment to analyze the state of relaxation. We compared relaxation effects induced by the stressor for three states (normal state, anxious state, and state while being subjected to a stressor) of the experimental participants. The following three methods were used to measure the states: (1) EEG analysis, (2) measurement of stress value by salivary amylase activity, and (3) questionnaire for experimental participants. Previous studies have shown that we can identify the various states of experimental participants, such as relaxation and anxiety, by analyzing the measurements obtained on an EEG.

Alpha and beta waves, with frequency ranges of 8–13 and 14–40 Hz, respectively, are types of brain waves detected on an EEG. Alpha waves are observed during a calm state that is associated with feelings of deep relaxation. Beta waves are associated with conscious thought and logical thinking and manifest in a state of consciousness that is required to easily focus and complete school- or work-based tasks. An abundant manifestation of beta waves may also be the result of excessive stress and anxiety. In this research, we identified the state of the experimental participants by measuring their alpha and beta waves. Considering these points, we propose a system that encourages the stimulation of alpha waves using music for stressed experimental participants.

2. Methods and Procedures

2.1 Procedure of experiment

The following procedure was adopted (Fig. 1):

(1) The task was explained to the participant.
(2) The participant moved to the experimental setup and wore the EEG measurement device.
(3) The participant's stress value was measured on the basis of salivary amylase activity.
(4) The participant answered a multiple-choice evaluation questionnaire.
(5) The participant performed simple calculations.
(6) The participant's stress value was measured on the basis of salivary amylase activity.
(7) The participant listened to music.
(8) The participant's stress value was measured on the basis of salivary amylase activity.
(9) Experimental steps (5) to (8) were repeated for four different types of music.
(10) The participant answered a multiple-choice evaluation questionnaire.

We performed subjective evaluation before and after listening to music. Participants performed simple calculations that stressed them (mental load work) for 1 min and then listened to music for 2 min. We obtained EEG measurements of the participants while they performed calculations and listened to music. The participants were tested for their salivary amylase activity after performing calculation and after listening to music.

We hypothesized that classical music in A minor would give the most relaxing effect. The reason for this hypothesis is that because minor music is slow, the tune induces tranquility.

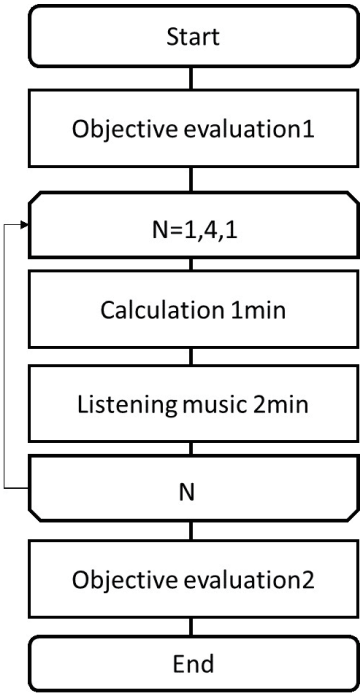

Fig. 1. Experimental procedure.

It is confirmed that listening to minor music produces an effect of relaxation. Listening to classical music to relieve stress is common. Therefore, we hypothesized that classical music in A minor containing the two elements would have the most relaxing effect.

2.2 Experimental participants

Six individuals (four males and two females) aged 19–20 years were included in this study. All of them had normal hearing and normal, or corrected to normal, vision.

2.3 Stimuli and materials

2.3.1 Music

We used four types of music: (1) nursery rhyme in C major, (2) nursery rhyme in A minor, (3) classical music in A minor, and (4) classical music in C major.

2.3.2 EEG measurement device

The impedances on all electrodes were measured and were confirmed to be less than 10 kΩ both before and after testing. The following specifications of electrodes were used in the experiment:

—Electrode material: Ag/AgCl (Nihon Kohden Corp., Japan, NE-113A)
—Electrode geometry: discs
—Size: 7 mm in diameter
—Gel, paste, or alcohol applied to cleanse skin and skin abrasion
—Interelectrode distance: 13 mm

The following combination of analog/digital converter and amplifier was used to obtain EEG measurements. The model, resolving power, and sampling rate were as follows:

—Converter/amplifier: Bio-top mini (East Medic Corporations)
—Sampling rate: 2000 Hz
—AD card: 32 ch, 16 bits
—EEG band pass filter: 0.1–30 Hz

2.3.3 Salivary amylase activity monitor

—Main unit: Nipro Corporation 59-011
—Chip: Nipro Corporation 59-010
—Instructions for usage
[1] Saliva was collected into a mouth tip sheet.
[2] The tip sheet was secured in a holder.
[3] A chip set was inserted in the body and certain operations were performed.
[4] On the screen, numerical results were displayed.

2.4 EEG procedure

EEG data were collected in an electromagnetically and acoustically shielded chamber, where the participant sat in a comfortable chair. Disk electrodes were applied to the face above and below the eyes and behind each ear (mastoids). The computationally linked mastoids were used as reference electrodes. Data were collected from five electrodes attached to scalp positions, Fz, C3, Cz, C4, and Pz, using the international 10–20 method of electrode placement (Fig. 2). The alpha wave appears in the superior occipital position, but we measure the alpha waves at the C3 and C4 positions because the participants lean their heads toward the comfortable chair in a relaxed state and the electrodes easily come off. We collected data sets every 4 s. The impedances on all electrodes were measured and confirmed to be less than 10 kΩ both before and after testing.

Data were analyzed using the software Octave. For each segment, the integrated power in the 8–13 Hz range was computed using a fast Fourier transform. Data were segmented into epochs of 2 s beginning at the start of the segment, and fast Fourier transforms were performed on the epoched data (2000 points).

3. Results

Figure 3 shows the average difference in the amount of alpha waves. The order of music in the figure from left to right is the nursery rhyme in C major, the nursery rhyme in A minor, the classical music in A minor, and the classical music in C major.

We extracted data at intervals of 4 s for each music and performed *t*-test for each individual. Figure 3 shows the results of the *t*-test performed within individuals and the significant differences obtained. There was no significant difference for each type of music. However, a significant difference was observed for some participants. For an 18-year-old male participant, in the case of A minor, the amount of alpha waves was significantly higher when listening to

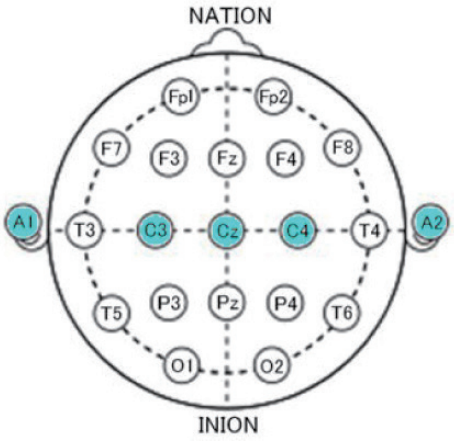

Fig. 2. (Color online) 10–20 method of electrode placement.

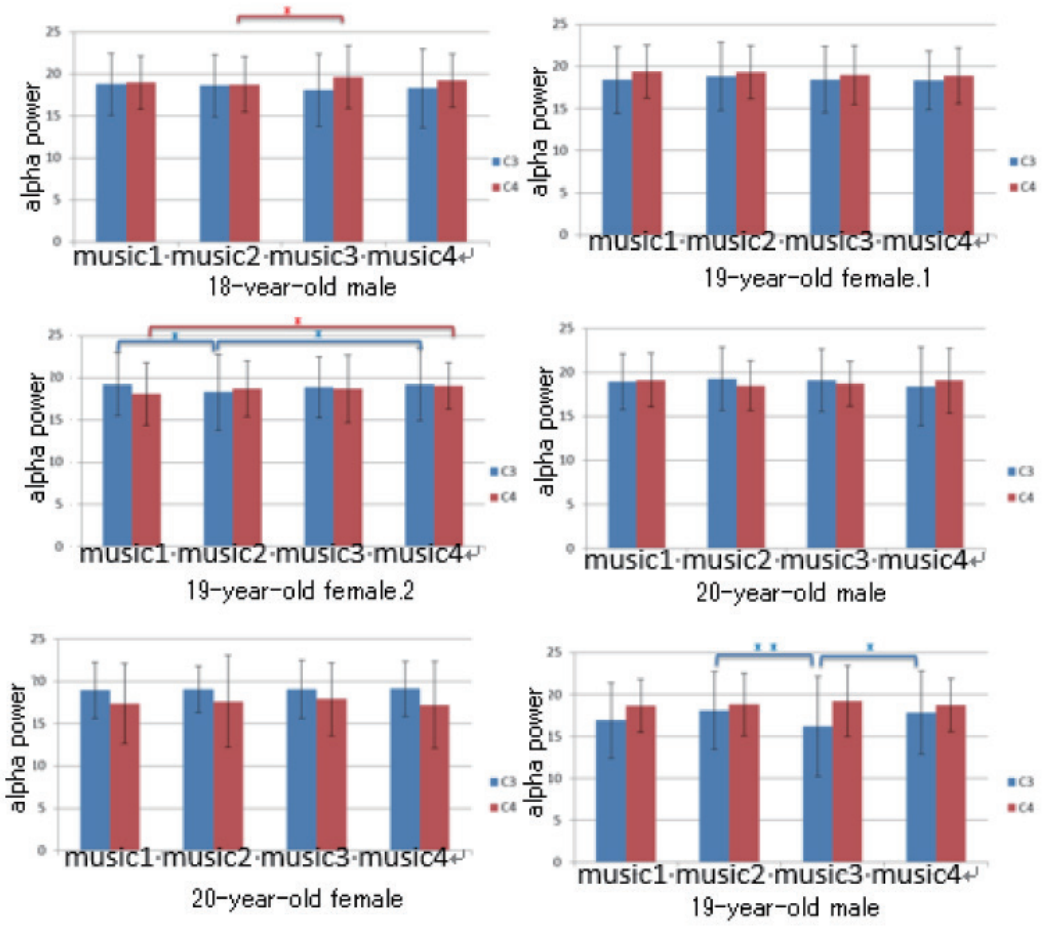

Fig. 3. (Color online) Individual *t*-test results.

classical music than to nursery rhymes. For a 19-year-old female participant, in the case of C major, the amount of alpha waves was greater when listening to classical music than to nursery rhyme. Although there were individual differences in the amounts of alpha waves, it can be concluded that the content ratio of alpha waves was higher for classical music than for children's music.

Figure 4 shows the salivary amylase activities of the participants. The stress values of participants increased after performing the calculation, confirming that they were stressed by this task. However, it cannot be said that the values always decreased after listening to music. The values for a 20-year-old male (4) were much lower after calculation and listening to music. However, for a 20-year-old female (5), the values were higher after listening to music. Therefore, relaxation induced by listening to music differed between individuals.

We plotted the average results for six people based on EEG (C3, C4) and salivary amylase measurements. Figure 5 shows the values for individual salivary amylase activity tests. In the EEG experiment, no significant main effect of music style was found. However, the salivary amylase activity test showed that classical music in A minor was the least stressful.

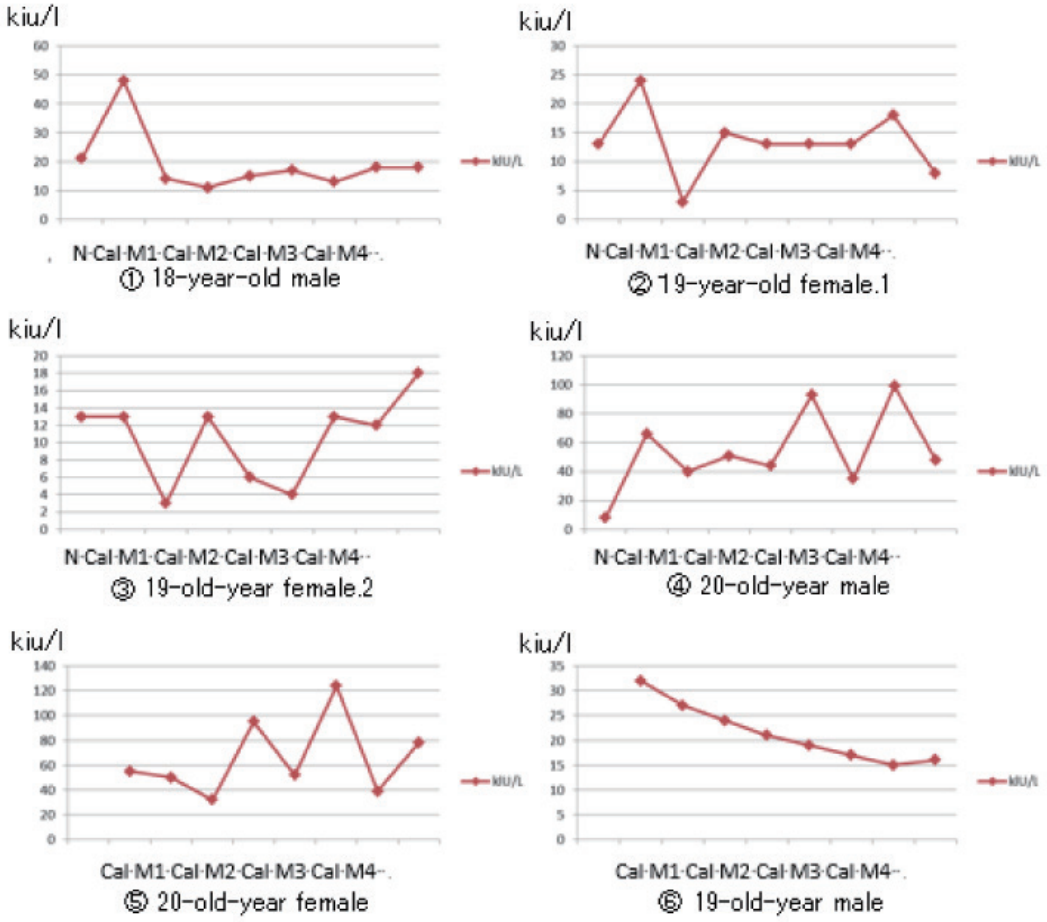

Fig. 4. (Color online) Salivary amylase activities of individual participants (N: Normal condition; Cal: After calculation condition; M1: After listening to music 1 condition; M2: After listening to music 2 condition; M3: After listening to music 3 condition).

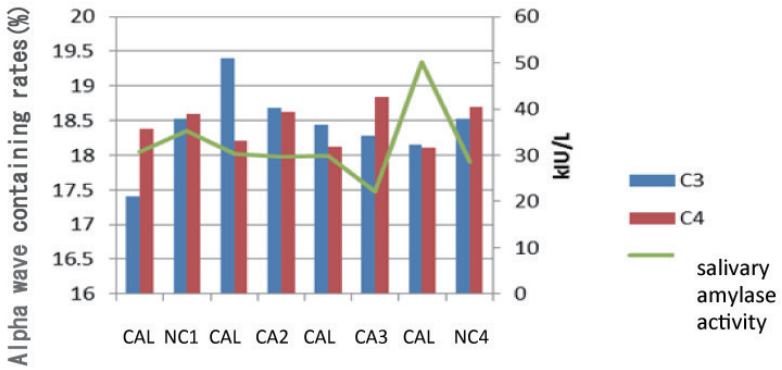

Fig. 5. (Color online) Average results for salivary amylase activity of six people (CAL: Calculation condition; NC1: Nursery rhyme in C major; CA2: Nursery rhyme in A minor; CA3: Classical music in A minor; NC4: Classical music in C major).

Table 1
Subjective evaluation results.

	Before experiment		After experiment	
	Average	Standard deviation	Average	Standard deviation
Hostility	0.79	0.81	0.67	0.77
Depression/anxiety	1.29	0.93	1.10	0.62
Fatigue	1.19	0.81	1.15	0.99
Inactive comfort	1.17	0.69	1.67	0.52
Concentration	1.5	0.77	1.45	0.54
Active comfort	1.69	1.12	1.96	0.90

Table 1 shows the average subjective evaluation for the participants. The values of inactive pleasure and depression/anxiety increased. In the questionnaire, a pleasant question was, for example, "I feel relaxed" or "I feel calm". It was an emotional question reflecting the relaxed state of an individual. Depression and anxiety had questions like "I am anxious" or "I am not confident".

4. Discussion

There was no significant difference in the music type. We deduce that the reason was individual preference. Classical music in A minor was presumed as having the most relaxing effect, but no significant difference was observed in the relaxing effect between the types of music used. In some participants, the alpha wave content was higher after listening to classical music than after listening to children's music. The classical music in A minor had the lowest stress value in the salivary amylase activity test. For individual results, most participants had high stress values after the calculation, but some had a contrary result. This may be because the calculation was based on simple and easy tasks. Some participants are good at such simple tasks, whereas others are not good at repeating the same activity. The feeling of stress varies with individuals.

We urged all participants to solve the calculation as fast as possible before beginning the calculation, but whether they were stressed following the urging differed for each of them. The subjective evaluation showed that four of six people said the classical music in A minor was their favorite music.

"For Elise" was the most familiar among the four types of music, and it was music that most of the participants had listened to because of its fame. This may be why the song was the most popular in the subjective evaluation. The EEG experiments showed differences within individuals, making it difficult to determine which music was most relaxing. However, on the basis of subjective evaluation using the salivary amylase, the classical music in A minor was considered the most relaxing.

5. Future Work

Our experiment confirmed that music relieves stress and that the types of music that reduce

stress differ for individuals. For future study, we plan to examine intervention methods other than music, such as natural sounds, aromas, and taste stimuli. We also plan to investigate if acclimatization will occur by letting each subject listen to music many times.

We are developing a support system for persons with developmental disorders. In this support system, we collect daily behavior data of persons with developmental disorders and biometric data such as EEGs using sensors and store them in a database while providing support according to individual characteristics. By analyzing the database, we can provide better support. We acquired subjective data and EEG data from the sensors to analyze the relationship between stress and music. In future works, we will accumulate data and analyze the support system database to provide individual support.

Acknowledgments

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