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Acoustical Analysis and Evaluation of Psychological Effect of Cricket Songs

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This study investigated the characteristics of the songs of crickets and considered how the songs affect the human mind from the points of acoustics, physiology and psychology. The songs of five cricket species, *Homoeogryllus japonicus* (HoJ), *Teleogryllus emma* (TE), *Oecanthus indicus* (OI), *Tettigonia yama* (TY) and *Hexacentrus japonicus* (HeJ), were used for this study, and the acoustical characteristics, mode of 1/f fluctuation, electroencephalogram and the psychological questionnaire on the songs were carried out. In the song of HoJ, the fundamental pitch was seen at 5 kHz; TE and OI were at 3 kHz; TY was 9 kHz; and HeJ was at 12 kHz. When the fluctuation patterns of the songs were analyzed with Fast Fourier Transformation, a 1/f mode was often seen at a low frequency regions of power-spectrum. The alpha wave was often observed with electroencephalograph when the subjects listened the sounds. From the results of questionnaire with SD method, it was revealed that HoJ and TE seemed to be preferred by subjects, rather than OI, TY and HeJ. The factor analysis showed the feature of each song as follows; HoJ and TE, comfortable sound; OI, non-rhysimical sound; TY and HeJ, loud sound. These results suggest that the songs are pleasant for human mind.
Key words: Songs of Crickets, 1/f Fluctuation, Electroencephalogram , Factor Analysis, Nature Technology

1. INTRODUCTION

The natural environments differ among different countries, and the influences of nature on the lives of inhabitants are also different. Japanese people have been attracted with the changes of natural environment, and such a nationality is seen in many works of art and music [1]. For example, in "Haiku", the word "cricket" which chirps during the nighttime in autumn has been used as a season-word of Japanese autumn. We say that the human feels a comfort with the chirps of crickets, however, a few studies have been carried out about the characteristics of the sound of insect and its psychological effects to human mind. In this study, we focused on the characteristics of the sound of crickets, and the pleasantness of the songs was investigated from the points of acoustics, physiology and psychology. Our final goal is to construct a healing environment using biological activities, and in this study, the outline is discussed.

2. MATERIALS AND METHOD

In this research, five cricket species, *Homoeogryllus japonicus* (HoJ), *Teleogryllus emma* (TE), *Oecanthus indicus* (OI), *Tettigonia yama* (TY) and *Hexacentrus japonicus* (HeJ), were used. Among these five species, HoJ, TE and OI belong to family Gryllidae, and TY and HeJ belong to familly Tettigoniidae. The recording of songs was made under a dark condition in the shield room of the VBL building in Ibaraki University. One male of each species was put in an insect cage, and the song was recorded with a microphone (SONY, ECM-G5M, 40 to 20000 Hz) set at 20 mm above the cage and the data was stored in a computer. The recordings were performed using a single monaural channel at a sampling frequency of 44.1 kHz. Sonogram analysis was used to determine the frequency range of the sound. The total measurement duration of each cricket was as following; HoJ (Number of samples, N = 8), 75 min; TE (N = 10), 88 min; OI (N = 2), 42 min; TY (N = 3), 50 min; HeJ (N = 2), 18 min).

In this study, we employed three indexes of comfortness of the songs; 1) $1/f^n$ fluctuation in loudness and pitch, 2) occurrence of alpha wave and 3) the impression of subjects to the songs

To guess whether the song is comfort sound or not, the modes of $1/f^n$ fluctuations in pitch and amplitude were analyzed with fast Fourier transform (FFT: Window function, humming; Window length, 30 ms; Frame length, 10 ms), since it has been considered that there is a deep relation between the $1/f^n$ fluctuation and the comfort of human mind [2-3]. All the sound data were divided into 1 min, and the fluctuations of loudness and pitch were analyzed with a software, SP4WIN (NTT Advanced Technology). After the analysis, the values of power spectrum were averaged.

The electroencephalogram at the forehead was measured with electroencephalograph (Nihon Koden, EEG-9100). During the measurement, one subject was sat in shield room under dark condition. Firstly, the subject listened no sound for 2 min, and then, each cricket song was played for 2 min, i.e., 12 min for one subject. Each data for 2 min was averaged. The occurrence rate of alpha wave by the songs was evaluated by the equation below.

$$\alpha = \frac{\text{alpha wave with listening a cricket song}}{\text{alpha wave with no sound}}$$

here, it was considered if the value was below 1 (< 0.95), alpha wave was decreased by the song; if the value was

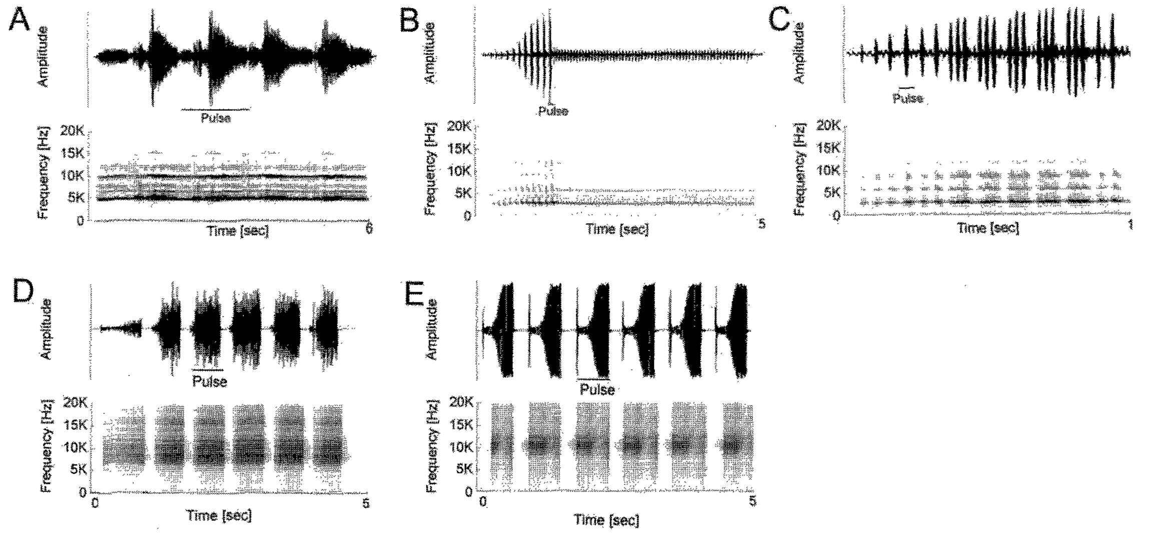

FIGURE 1. A sound of the song of *Homoeogryllus japonicus* (A), *Teleogryllus emma* (B), *Oecanthus indicus* (C), *Tettigonia yama* (D), *Hexacentrus japonicus* (E): (upper) temporal changes of the phrase; (lower) sonogram of the waveform.

approximately equal to 1 (0.95 < value < 1.05), the subject did not affected by the song; and if the vale was higher than 1 (> 1.05), alpha wave was induced by the song. χ^2 test was used to determine the difference among the three groups. In this measurement, the number of subject was 13 people, most all of whom were male of 20's.

The questionnaire survey based on the Semantic Differentials (SD) method [4] was done to evaluate the psychological effect of the sounds on human mind. The subjects seated in front of the two speakers (Yamaha, YTS M20DSP, 70-20,000 Hz) and were required to listen to the sounds of five crickets. Sounds were played in random order for 30 sec. The volume of each sound was set in the range from 48 to 58 dB with a sound level meter (CENTER Co., type 329, 40 to 130 dB). The questionnaire items were shown in Fig. 3. The number of subjects for questionnaire survey was 30 people, and the age of subjects ranged from 20's to 50's, most all of whom were male.

Factor analysis (principle factor analysis with varimax method) was performed to determine the common factors for the five calling song with the results of questionnaire. The factor analysis was continued until the contribution ratio exceeds 80 %. A post-hoc test (Tukey-Kramer test, P < 0.05 level) were employed to detect the significant differences in the results of factor scores. All the statistical tests were done with StatView 5.0 (SAS Institute) with Machintosh computer.

3. RESULTS

3.1 ANALYSIS OF CALLING SONGS OF CRICKETS

Figure 1 shows the temporal changes of the amplitude of cricket sounds and the sonogram. The songs were consisted of many pulses. A phrase (specific changes of pulses) was found in the song of HoJ, TE and HeJ, while the songs were consisted of continuous pulse in the song of OI and TY. Table I shows the frequency ranges of fundamental tone and the harmonic overtone. The sound of HeJ was the highest fundamental tone among the five species. In TE and OI, the frequency ranges of the fundamental tones and the harmonic overtones were similar. The band of fundamental tone was distinct in HoJ, TE and OI, while was indistinct and wide in TY and HeJ. In all the songs, the loudness was approximately 70 dB.

3.2 MODE OF 1/f FLUCTUATION

Figure 2 shows the $1/f^n$ fluctuation of the averaged power spectra in the pitch and the amplitude. In all the sounds, 1/f component of the spectrum was seen in both

Table I The range of fundamental tone (FT) and harmonic overtones (HT) of the five cricket songs

Species name	FT (kHz)	HT (kHz)
Homoeogryllus japonicus	5	10 and 15
Teleogryllus emma	3	6 and 9
Oecanthus indicus	3	6 and 9
Tettigonia yama	9	9 and 18
Hexacentrus japonicus	12	no

Table II The number of subjects categorized into tree grades of alpha wave. *Homoeogryllus japonicus* (HoJ), *Teleogryllus emma* (TE), *Oecanthus indicus* (OI), *Tettigonia yama* (TY) and *Hexacentrus japonicus* (HeJ)

	Species name					
Value of alpha wave	HoJ	TE	OI	TY	HeJ	Total
α<1	3	4	1	3	2	13
α=1	8	3	5	3	3	21
α>1	2	6	7	7	8	31*

* P<0.0001, χ^2 test

the amplitude (from 1 to 12 sec) and the pitch (from 3 to 12 sec) of the sounds. The range of 1/f fluctuation in the fluctuation of amplitude was rather wider than that of pitch.

3.3 OCCURENCE OF ALPHA WAVE

Table II shows the number of subjects divided into three categories on the occurrence rate of alpha wave. Approximately half subjects belonged to the category of high-rate of alpha wave ($\alpha > 1$), in spite of calling songs. Whereas in the case of HoJ, the subjects belong to the category of high-rate of alpha wave was small, and most people were not influenced by the song ($\alpha = 1$). When data for all songs were pooled to increase the statistic power, the number of subjects were significantly large in the category of high-rate of alpha wave (N=65, χ^2 test, $\chi^2 = 22.2168$, $P < 0.05$), showing that alpha wave was often induced when the subjects listened any kinds of the songs.

3.4 RESUTS OF QUESTIONNAIRE SURVEY

Figure 3 shows the mean (N = 30 for each species) value of the results of questionnaire on the songs of five crickets. In this figure, horizontal axis represents the degree of the answer for each item. For example, in the item of "Beautiful - Ugly", if a symbol locates left side from zero, the sound is felt to be ugly. The gryllidine species, i.e., HoJ, TE and OI located more beautiful, and tasteful, rich side than those of Tettigoniidine species. Compared among the species, the values were similar between HoJ and TE, and between TY and HeJ, respectively; the value of OI located mid of them.

3.5 FACTOR ANALYSIS

Four common factors were obtained from the result of factor analysis, and each factor was named as "Nature & seasons", "Biotic rhythm", "Richness of sound" and "Heart warming." Figure 4 shows the mean (N = 30) factor score for each cricket. In Fig. 4, horizontal axis represents the score of four factors. For example, in the Factor-1, it is considered that people feel nature and seasonality to the sound if the score is at positive side of the score. In Factor-1 and 2, statistical differences were found among the songs (Tukey-Kramer test, $P < 0.05$). In the Factor-1, the score of TE and HoJ located positive side and the values were higher than the other species. In the Factor-2, the values of HoJ and TE were also higher than the other species. On the other hand, the values of OI, TY and HeJ often located at negative side of score.

4. CONCLUSION

This study revealed the characteristics of the calling songs of the insects and analyzed their associated impressions with SD method and factor analysis. (1) There were differences in amplitude and pitch among five insects from a series of sound analysis, (2) The 1/f

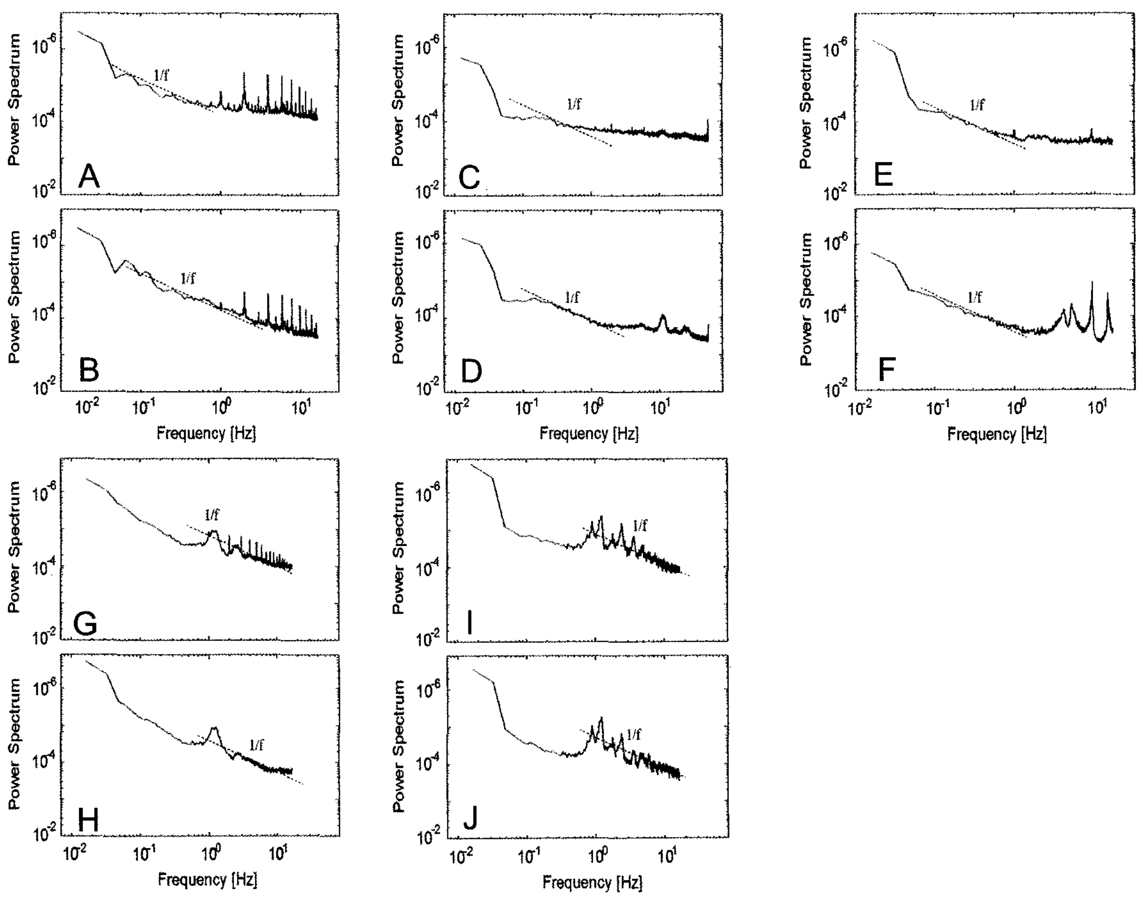

FIGURE 2. Averaged power spectrum of the song of *Homoeogryllus japonicus* (N = 88, A, B), *Teleogryllus emma* (N = 75, C, D), *Oecanthus indicus* (N = 42, E, F), *Tettigonia yama* (N = 50, G, H), *Hexacentrus japonicus* (N = 18, I, J): fluctuation of pitch, A, C, E, G and I; fluctuation of amplitude, B, D. F. H and J.

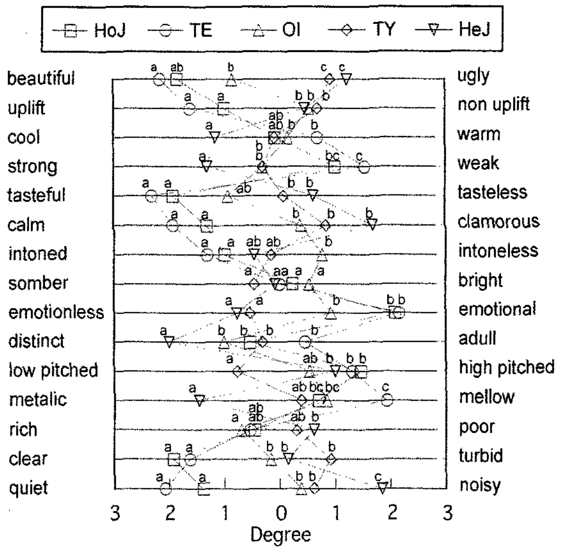

FIGURE 3. Results of questionnaire on the songs of five crickets, *Homoeogryllus japonicus* (HoJ), *Teleogryllus emma* (TE), *Oecanthus indicus* (OI), *Tettigonia yama* (TY) and *Hexacentrus japonicus* (HeJ). In each questionnaire item, symbols with different letters were statistically different (Tukey-Kramer test, P < 0.05).

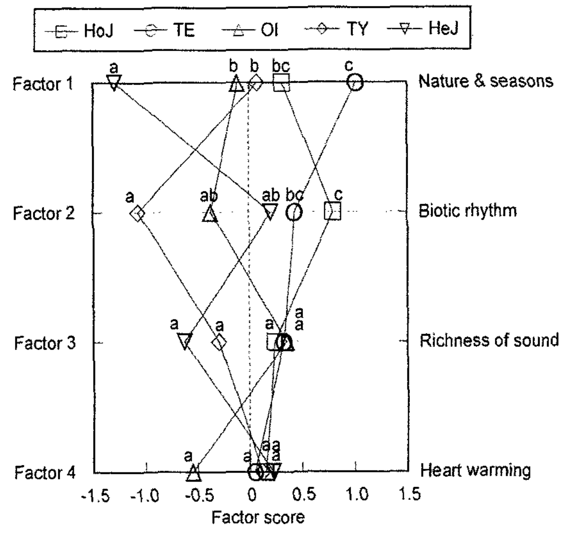

FIGURE 4. Scores of factor analysis on the songs of five crickets, *Homoeogryllus japonicus* (HoJ), *Teleogryllus emma* (TE), *Oecanthus indicus* (OI), *Tettigonia yama* (TY) and *Hexacentrus japonicus* (HeJ)In each factor, symbols with different letters were statistically different (Tukey-Kramer test, P < 0.05).

fluctuation was seen in the sounds of all insect songs analyzed, (3) The songs induced the alpha wave to the subjects, and (4) Calling songs of insects had an effect that people feel comfortable and characteristic of the sound.

Recently, the relationship between nature and the human sense (image and feeling which human hold) has become more distinct [5], and it has been suggested that some natural scenes invoke a relaxing effect up on the human mind [6-9]. For example, a relaxing effect is associated with seeing the flashing of fireflies and the mood associated with the environments they inhabited, such as soft murmuring of a stream and/or the resulting of plants in these environments [6]. The relaxing effect induced by nature is currently being given serious attention in the field of human engineering [10]. Given that Japanese people have a close affinity toward natural sounds, such as the songs of insects, the healing effect of these songs is expected to have potential for application as a type of music therapy. For the application, based on the results of present study, it can be proposed that the following songs are preferred: a frequency of fundamental tone ranges from 3kHz to 5kHz; some harmonic overtones; pulses construct a phrase, i.e., not monotone. So, such as song of TE is suitable for Japanese people with the unique acoustical characteristics. We consider that a healing environment can be realized by applying the biological activities of those insects which make Japanese people relaxing.

5. Acknowledgement

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