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Fijihira, Haruna
Department of Acoustic Design, Schoolof Design, Kyushu University

Shiraishi, Kimio
Department of Human Science, Facuity of Design, Kyushu Universiy

Saito, Mutsumi
Department of Human Science, Facuity of Design, KyushuUniversiy

Takagi, Hideyuki
Department of Human Science, Facuity of Design, KyushuUniversiy

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MEASUREMENT OF TINNITUS USING INTERACTIVE EVOLUTIONARY COMPUTATION IN SUBJECTS WITH TINNITUS

Haruna FUJIHIRA*, Kimio SHIRAISHI **, Mutsumi SAITO**, Hideyuki TAKAGI**

*Department of Acoustic Design, School of Design, Kyushu University
**Department of Human Science, Faculty of Design, Kyushu University

4-9-1 Shiobaru, Minami-ku, Fukuoka, 815-8540 Japan
Tel: +81-92-553-4554
Fax: +81-92-553-4554
E-mail: ** kimio@design.kyushu-u.ac.jp

ABSTRACT

This study describes a tinnitus test using interactive evolutionary computation (IEC) based on acoustic characteristics of onomatopoeia of subjects with tinnitus. Using acoustic characteristic of onomatopoeias helped to select test tones for subjects with tinnitus. Two methods of tinnitus pitch-match testing, i.e., a tinnitus test using IEC based on acoustic characteristics of onomatopoeia and a conventional clinical pitch-match test, were used for three subjects with tinnitus for two days. Their subjective tinnitus sound did not change for two days. For each subject, the difference between two days for tinnitus testing using IEC was smaller than that for conventional testing. These results of tinnitus testing using IEC were consistent with the subjective reports of unchanged tinnitus pitch. This study suggests that tinnitus testing using IEC based on acoustic characteristics of onomatopoeia of subjects with tinnitus made it possible to measure the fine pitch of tinnitus.

KEYWORDS: Tinnitus, Pitch match testing, Interactive evolutionary computation, Onomatopoeia

INTRODUCTION

Tinnitus is defined as "the sensation of sound without external stimulation [1]." As tinnitus is a subjective experience, it is hard for other people to know the exact characteristics of tinnitus sounds. For clinical assessment of tinnitus, pitch-match testing with an audiometer is generally

used. However, it has been very difficult to investigate the fine characteristics of tinnitus sounds, because an audiometer has limitations in the number of pure tone frequencies and the bandwidths of noise. For that reason, we developed a tinnitus test using interactive evolutionary computation (IEC) based on the patient's evaluation [2]. This method optimizes the process of automatic test-tone generation for probing the acoustic characteristics of the patient's tinnitus. The utility of the tinnitus test using IEC with a monaural, pseudo-tinnitus tone has been investigated for normal hearing subjects. However, whether this method is suitable for patients with tinnitus is still unclear. Because tinnitus sounds vary among patients (e.g., a pure tone or a noise, with a high pitch or a low pitch), it may be hard to determine a test-tone for each patient using IEC.

According to a clinical study, most patients with tinnitus use "onomatopoeia" when they express how their tinnitus sounds like. Fukuyo [3] reported relationships between the onomatopoeia and acoustic characteristics from the results of a factor analysis. Therefore, in this study we investigated a tinnitus test with IEC, based on the acoustic characteristics of onomatopoeia of subjects with tinnitus.

METHODS

Three subjects (2 males and 1 female, with a mean age of 73.3 years) participated for two days in this study. Their subjective tinnitus sound did not change for two days. In order to test each subject's tinnitus pitch, we used two methods. One was a tinnitus test using IEC, based on acoustic characteristics of onomatopoeia. The other was a conventional clinical pitch-match test.

Tinnitus test using IEC based on acoustic characteristics of onomatopoeia

IEC is an optimization method that adopts evolutionary computation (EC). It is used in system optimization that is based on subjective human evaluation [4]. In this study, the IEC-method employed genetic algorithms (GAs). The GAs were used to measure tinnitus pitch as follows.

1) Twenty test tones (pure tones or band noises), randomized with regard to frequency range, were generated as the initial group of test tones. The center-frequency step for each pure tone was 1/24 octave. The cut-off frequency bandwidth was set in steps of 1/12 octave. Test tones (pure tones or band noises) and frequency range were determined by acoustic characteristics of onomatopoeias in Table 1. For example, when a subject expressed his/her own tinnitus as "kiin" in onomatopoeia, test tones were selected from among pure tones within a frequency range from 1,943 Hz to 11,986 Hz, according to acoustic characteristics of No.12 in Table 1.
2) The similarity between each tone of the initial group and the subject's tinnitus tonality was scored from one (not similar) to five (very similar) by the subject.
3) The higher scored tones were selected as dominant genes in the IEC and were crossed-over with each other to produce a new group of twenty test tones. A few test tones were generated with a low probability, regardless of their similarity, as mutant.

The process (steps 1-3) was repeated five times. The test tone was either a pure tone with an intensity of 15 dB SL or a band noise with an intensity from 5 to 15 dB SPL above the pure tone's threshold in the frequency range of test tone. The test tone was presented monaurally for 2 s.

Conventional clinical pitch-match testing

Conventional clinical pitch-match testing was carried out with an audiometer (RION AA-79). The test tones consisted of 11 pure tones (frequency range from 125 Hz to 8,000 Hz), 11 band noises, and white noise. The pitch-match testing employed the bracketing method [5]. The pure tones had an intensity of 15 dB SL, whereas the band noises had an intensity of 15 dB SPL above the threshold of the band noise's center-frequency. The test tones were presented monaurally, consecutively for 225 ms each, with an inter-tone interval of 225 ms.

For subjects 1 and 2, test tones were presented contralaterally to the ear with tinnitus because their ear had severe hearing loss. For subject 3, test tones were presented ipsilaterally to the ear with tinnitus.

Table 1. Relationships between the onomatopoeia and acoustic characteristics from the results of a factor analysis.

	onomatopoeia	125	250	500	1000	2000	4000	8000 (Hz)
1	guun	○	○					
2	waan	○	○					
3	uun	○	○					
4	waan	○	○					
5	buun	○	○	○				
6	puu	○	○	○	○			
7	wiin		○					
8	poo		○	○	○			
9	kuun		○	○	○	○	○	
10	tsuun			○	○	○	○	○
11	pii				○	○	○	○
12	kiin					○	○	○
13	gougou	●	●					
14	gaa	●	●	●				
15	zaa	●	●	●	●	●	●	●
16	jyaa	●	●	●	●	●	●	●
17	hyuu			●	●	●		
18	shurushuru				●	●	●	
19	pyurupyuru					●	●	
20	jii						●	●
21	doo	○●	○●					
22	gwoo	○●	●	●				
23	goo	○●	○●	●				
24	koo	○	○	○●	○●			
25	byuu	○	○●	●	●	●		
26	miin					○●	○●	○●
27	tii					○●	○●	○●
28	siin							○●
29	rii					○	○●	
30	bii	○●					○●	○●

Printed from Fukuyo [3] (1984).

○ pure tone

● band noise

RESULTS

Figure 1 shows the results from three subjects with the two methods for two days. The results of tinnitus test using IEC show the frequencies of the high-scored tones in the 5th generation. The frequencies of the high-scored tones were close to the matching frequencies for conventional clinical pitch-match testing, as illustrated in Figure 1.

To present the differences between the pitch match tones on Day 1 and Day 2, differences of the matching frequencies were calculated for each subject and each method. The matching frequencies for the tinnitus test using IEC were determined by averaging the frequencies of score 5 in the 5th generation. These results are summarized in Table 2. For the tinnitus test using IEC, the maximum of the difference of the matching frequencies was 0.1 octave in Table 2. For conventional clinical pitch-match testing, the difference was 0.4 octave.

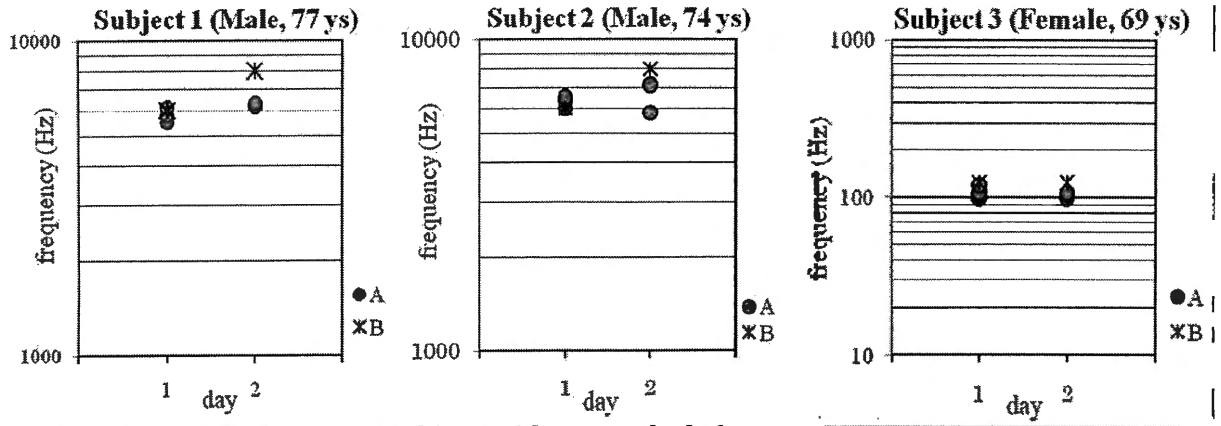

Figure 1. Results from three subjects with two methods for two days.

A: Tinnitus test using IEC
B: Conventional clinical pitch-match testing

CONCLUSION

By applying acoustic characteristics of onomatopoeia to tinnitus testing using IEC, the tinnitus pitch of subjects with tinnitus could be obtained. It was found that the frequencies of the high-scored tones for tinnitus testing using IEC were close to the matching frequencies for conventional clinical pitch-match testing. For each subject, the difference between two days for tinnitus testing using IEC was smaller than that for conventional clinical pitch-match testing. These results of tinnitus testing using IEC were consistent with subjective reports of unchanged tinnitus pitch. We suggest that tinnitus testing using IEC made it possible to measure fine pitch of tinnitus. To improve the reliability of the IEC-based test, further studies with more subjects with tinnitus are needed.

Table 2. The differences of the matching frequencies on Day 1 and Day 2.

	Tinnitus test using IEC	Conventional clinical pitch-matching testing
Subject 1	0.1	0.4
Subject 2	0.04	0.4
Subject 3	-0.04	0

(oct.)

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