Effects of comparison interval and order on subjective evaluation test of loudness

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Abstract: In this paper we investigated effects of the presentation time interval on a subjective evaluation test of loudness. We carried out paired comparison experiments of pure tones loudness with changing the time interval of the comparison. As the results, two characteristic effects were obtained. The difference limen of the loudness was almost proportional to the time interval in below 10 s and was almost the same value of 1.5 dB in above 10 s. On the other hand, the effect of the presentation order was smallest at the time interval of about 5 s.

1. Introduction

A subjective evaluation test of loudness is frequently performed not only in a psychoacoustics study but also in a product development. If the accuracy of a subjective evaluation test is low, it is useless to perform a high-grade process to the data obtained from the evaluation test, and we cannot get a correct result. Therefore it is very important to carry out a subjective evaluation test of loudness accurately.

In order to accurately evaluate loudness, we must choose a suitable method and its environments. It is known that the constant method [1], which is possible to reduce context influence by presenting stimuli in random order and has few loads to a subject, is one of the most accurate methods.

About the evaluation environments, the constant method as paired comparisons has some important factors. One of them does not change any parameters except for an evaluation target. Another one does not spend too much time for a comparison interval. However, it takes much time for changing the target parameter if the evaluation object is too large or complex. In such situations it is desired to clarify the relationship between the evaluation accuracy and the comparison interval.

There are some researches on the subjective evaluation test of loudness in the past [2-5]. However, most of them use the relative discrimination ability [6] as an index of evaluation accuracy, not difference limen. Also they have not reported about the order effect.

In this paper we investigate effects of the comparison time interval on a subjective evaluation test of loudness. We carry out a subjective evaluation test of loudness using paired comparison experiments with changing the time interval of the comparison and show the dependency of the time interval on the difference limen and on the effect of the presentation order of stimuli.

2. Experiment

In this section we carry out a subjective loudness evaluation of two pure tones using paired comparison experiments.

2.1 Apparatus and Stimulus

The test signal is pure tone at a frequency of 1 kHz and at a duration of 3 s with a logarithmic fade-in and fade-out for 0.1 s in order to reduce the transient response. The sound pressure level of the base sound is 60 dB, which was adjusted using a dummy-head microphone. The sound pressure levels of the comparison sounds are 50, 54, 57, 58, 59, 60, 61, 62, 63, 66, and 70 dB. Eleven sounds are compared with the base sound in total. All pairs of the base and comparison sounds were recorded to a digital audio tape as the test stimuli. The stimuli are reproduced via a headphone to the subject.

2.2 Subject

Twelve males, aged 21 to 23 years, served as the subjects. All subjects had normal hearing acuity.

2.3 Procedure

The pairs of the base sound (60 dB) and the comparison sounds are reproduced to each subject using a headphone. First, the former stimulus is presented. Next, the later stimulus is presented after some time interval. Four kinds of the time interval, 1, 5, 10, and 30 s, are tested. This experiment is separated into four sessions for every time interval. Each pair of the stimuli is presented for three times in random order. 132 trials (11 pairs × 4 sessions × 3 times) are performed in each subject in total. The subject is asked to select the following after each presentation on an answer sheet (Fig. 1):

a) the former sound is louder,

b) the later sound is louder,

c) the same or undecided.

Evaluation of Loudness Answer Sheet

Year/Month/Date: / / /

Start Time: Test System:

Name: Interval Time:

Sex: Age:

	The former sound is louder	The later sound is louder	The same or undecided
Practice 1			
Practice 2			
	The former sound is louder	The later sound is louder	The same or undecided
No1			
No2			
No3			
No4			
No5			
No6			
No7			
No8			

Fig.1: Answer sheet

Each subject performed two practice trials before every session. We also divided the pairs of the stimuli into two groups of (A), in which the former stimulus is the base sound, and (B), in which the later stimulus is the base sound. We adjust the number of the group (A) and (B) to the same number.

3. Analysis

In this paper we perform an analysis of the constant method [7] to obtain the difference limen and the order effect. They are calculated from the selection probability of the three kinds of answers. Figure 2. shows a graph of an analysis of the constant method. First, we calculate the selection probability of the three answers on each comparison sound. Next, the most-fitted normal distribution curve is calculated on each of three selection groups ,e.g., the former sound is felt louder. Then the difference of the sound pressure level between the stimulus that the largest number of subjects felt the both sounds have the same

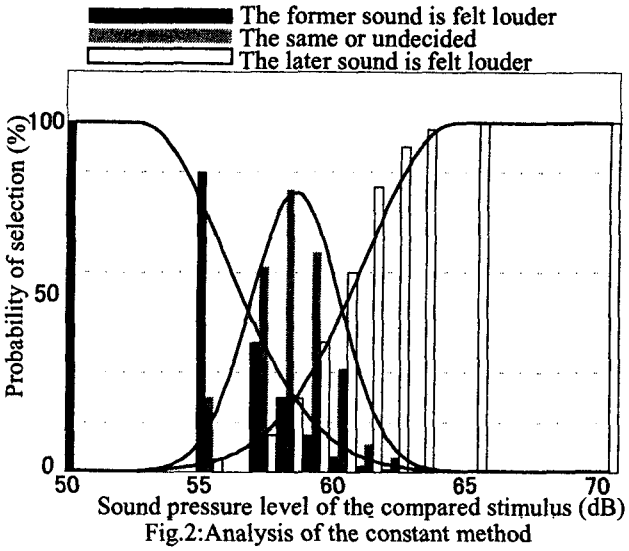

Fig.2:Analysis of the constant method

loudness and the stimulus that 75% of the subjects felt louder is the difference limen.

To obtain the order effect, an analysis is performed separately according to presentation order. Therefore we can obtain the amount of the deviation between the stimulus which the largest number of subjects felt the both sounds have the same loudness and the base stimulus (60dB). That is the order effect.

4. Result

We obtained the effect of the presentation time interval on the difference limen and the effect of the presentation order using the constant method .

Figure 3. shows the time interval dependency on the difference limen. In this figure we obtain the difference limen of 1.05 dB at the time interval of 1 s.

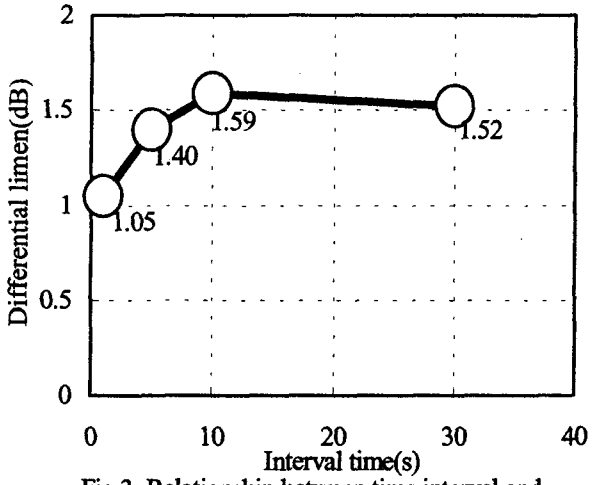

Fig.3: Relationship between time intervel and differential limen

This result almost agrees with the result of Jesteadt et al [8]. When the time interval is below 10 s, the difference limen is almost proportional to the time interval. In the case of the time interval from 10 to 30 s, there is almost the same difference limen of about 1.5 dB.

Figure 4. shows the relationship between the order effect and the time interval.

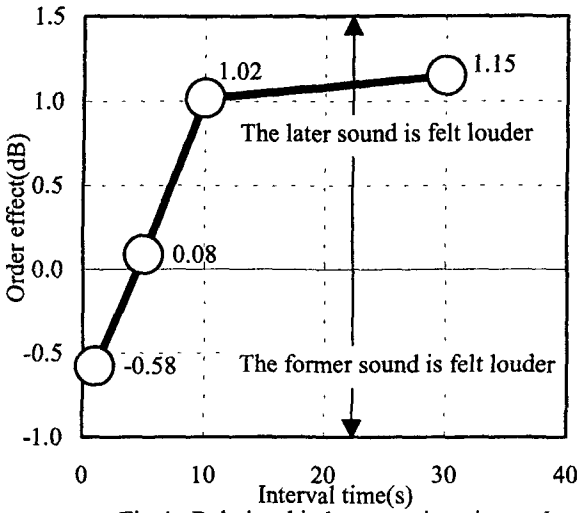

Fig.4: Relationship between time interval and order effect

This figure shows that the subjects perceived the later stimulus 0.58 dB smaller than the former stimulus, although hearing the same sound pressure level of 60 dB. On the contrary, the subjects perceived the later stimulus about 1 dB louder than the former stimulus at the time interval of above 10 s. When the time interval of 5 s, the subjects perceived the former stimulus as loud as the later stimulus.

5. Discussion

5.1 Differential limen

It is considered that the dependency of the time interval on the difference limen is related with a memory system that controls a human's memory length of auditory information. A typical research on the human memory system is "The multi-store model of memory" (Atkinson and Shiffrin, 1968) [9]. In the paper it is reported that there were three types of memories. The first one is a sensory memory where the information is not analyzed yet, just kept there. The sensory memory for auditory stimuli is defined as "echoic memory". Human can keep the auditory information in the echoic memory for about 5 s.

The second one is a short-term memory where the information is paid attention and moves here from the sensory memory. Human can keep the information in the short-term memory for about 15 to 30 s. The last one is a long-term memory where the information is repeated many times and moves here from the short-term memory. Human can keep the information permanently in the long-term memory. In the recent research [10] it is reported that the echoic memory is forgotten generally in 10 s. Therefore it is considered that the difference limen is almost proportional to the time interval up to 10 s, is related with the echoic memory.

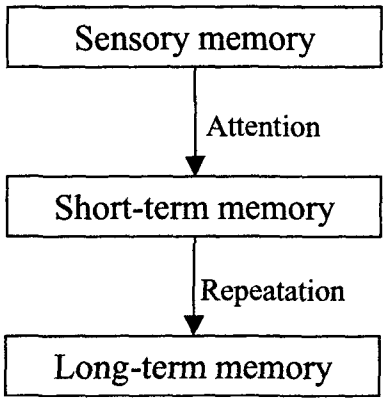

Fig.5: "The multi-store model of memory" (Atkinson and Shiffrin, 1968)

5.2 Order effect

It is considered that the dependency of the time interval on the order effect is related with an auditory adaptation and an auditory fatigue. An auditory adaptation is a balance process. If a human hears a continuous sound for a long time, the human feels smaller than the real loudness. An auditory fatigue is a temporary threshold shift immediate after hearing a loud sound [11]. The auditory fatigue is often investigated by hearing a very loud sound (about 120dB) [12]. However, it is reported that the auditory fatigue occurs even at 60dB[13].

It is, therefore, considered that the order effect, when time interval is 1 s, is effected by the auditory adaptation and fatigue, additionally, human's hearing acuity recovers when time interval is 5 s because there is no order effect.

On the other side, we consider when time interval is 10 to 30 s, human feels the auditory information in the echoic memory (the later stimulus) is louder than the information in the short-term memory (the former stimulus).

6. Conclusion

In this paper we investigated effects of the presentation time interval on a subjective evaluation test of loudness. We carried out paired comparison experiments of pure tones loudness with changing the time interval of the comparison.

As the results, two characteristic effects were observed. The difference limen of the loudness was almost proportional to the time interval in below 10 s and is almost the same value of 1.5 dB in above 10 s. On the other hand, the effect of the presentation order was smallest at the time interval of about 5 s. It is considered that these results are useful for a subjective evaluation test of loudness. In future work we will investigate the effects of the longer time interval of above 30 s on the subjective evaluation.

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