EFFECTS OF SOUND MARKER DURATIONS ON THE PERCEPTION OF INTER-ONSET TIME INTERVALS

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Abstract

We examined whether the duration of two successive short sounds can affect the perception of the time interval marked by the onsets of these sounds. An experiment was conducted using marker durations of 20 to 100 ms and inter-onset time intervals of 120, 240, and 360 ms. The effects of marker duration were summarized as follows: 1) Lengthening both the first and the second marker clearly causes the interval to be judged longer, 2) Lengthening the first marker tends to cause the interval to be judged longer, and 3) Lengthening the second marker also tends to cause the interval to be judged longer.

When two short sounds are presented successively, they can act as markers of an *empty time interval*. Many studies have been made on the perception of empty time intervals, and it has been assumed that rhythm is based on the *onset-to-onset* timing of the elements (e.g., Handel, 1993). Thus, we define empty time intervals as temporal distances between onsets of successive sounds.

The purpose of this study was to investigate how the perception of inter-onset time intervals is influenced by the marker durations. We conducted an experiment using sounds of different durations as markers.

Method

Participants

Nine listeners (6 females and 3 males) with normal hearing participated. Their ages ranged from 22 to 30.

Stimulus patterns

Each presentation consisted of two pairs of markers, the first pair marking the standard time interval, and the second pair the comparison interval (Figure 1).

All markers were pure tones of 1000 Hz. All possible combinations of six marker durations, 20, 30, 40, 60, 80, and 100 ms, were used for the standard. The markers of the comparison were always 20 ms. A rise time and a fall time of 10 ms were included in the durations of the markers. To keep the markers of different durations from being too different in loudness, the total energy (not the amplitude) of all markers were made constant. The presentation level of the 20 ms marker was 82.8 dBA, measured as the level of a continuous tone of the same amplitude.

The inter-onset interval, IOI, of the standard was 120, 240, or 360 ms. The IOI of the comparison was adjusted by the participant.

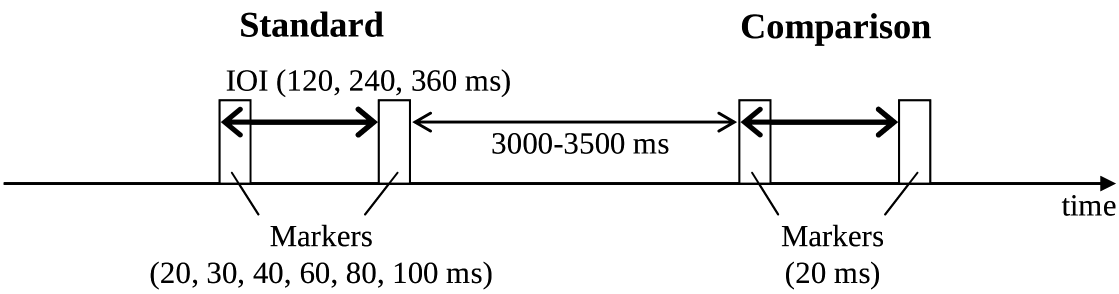


Fig. 1. Stimulus patterns.

Thus, the total number of the standard time intervals were 108 [6 (first marker duration) × 6 (second marker duration) ×3 (IOI)].

Procedure

A method of adjustment was used to measure the point of subjective equality, PSE, of the participants for each standard. The participants were instructed to adjust the comparison time interval until it was perceived as equal to the standard time interval. The final comparison interval in each trial was recorded as the PSE. The stimulus patterns were presented to both ears of the participants via headphones.

For each of the 108 standard time interval, there were an ascending series and a descending series, and the PSE for each participant was calculated by averaging the adjusted values obtained from both series.

Thus, the total number of trials were 216 [108 (standards) × 2 (ascending/descending)]. These trials were divided into 12 blocks. Each block consisted of 20 trials (2 warm-up trials + 18 experimental trials in random order). Before beginning the experiment, 27 practice trials were carried out.

Results and Discussion

For each of the 108 standard time intervals, 9 PSEs were obtained from 9 participants.

Figure 2 shows the mean PSEs for the time intervals marked by two successive sounds of the same duration. The PSEs clearly increased when the markers lengthened in all IOI conditions.

To determine which of the two markers was responsible for this increase in PSE, we examined the effect of each marker separately. PSEs were plotted as functions of the duration of the first marker and the duration of the second marker (Figure 3 and Figure 4). The horizontal axis shows the duration of the first marker in Figure 3 and the duration of the second marker in Figure 4. For the effect of the first marker, PSEs tended to increase as the first marker lengthened (Figure 3). This tendency was clear when the IOI was 240 or 360 ms but was not very clear when the IOI was 120 ms. When the IOI was 120 ms and the second marker was 20 ms, the PSE even decreased as a function of the first marker duration (Figure 3 (a)). For the effect of the second marker, PSEs tended to increase as the second marker lengthened (Figure 4). This tendency was seen in all IOI conditions.

A three-way (IOI × first marker duration × second marker duration) ANOVA was performed. The main effect of IOI, which is trivial in the present paradigm, appeared [F (2, 16) = 285.101, p < .000]. The results showed significant main effects by both

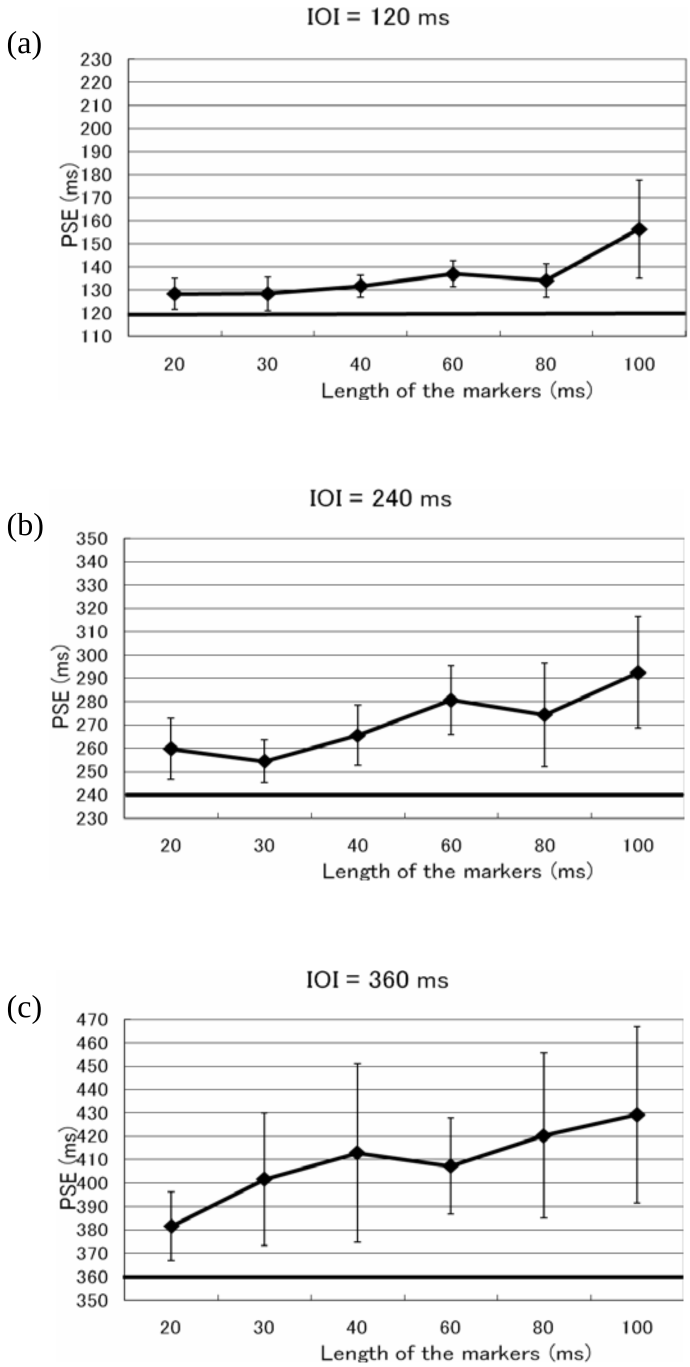


Fig. 2. Mean PSEs for time intervals of which the first and the second marker have equal duration. The error bars show the standard deviation obtained from the PSEs for each participant.

the first marker duration and the second marker duration [F (5, 40) = 4.511, $p < .002$; F (5, 40) = 6.169, $p < .000$, respectively]. The interaction between the first marker duration and the factor of IOI was significant [F (10, 80) = 2.025, $p < .041$], but the interaction between the second marker duration and the factor of IOI was not significant [F (10, 80) =.698, $p < .723$]. These interactions suggest that the effect of the second marker duration was similar for all

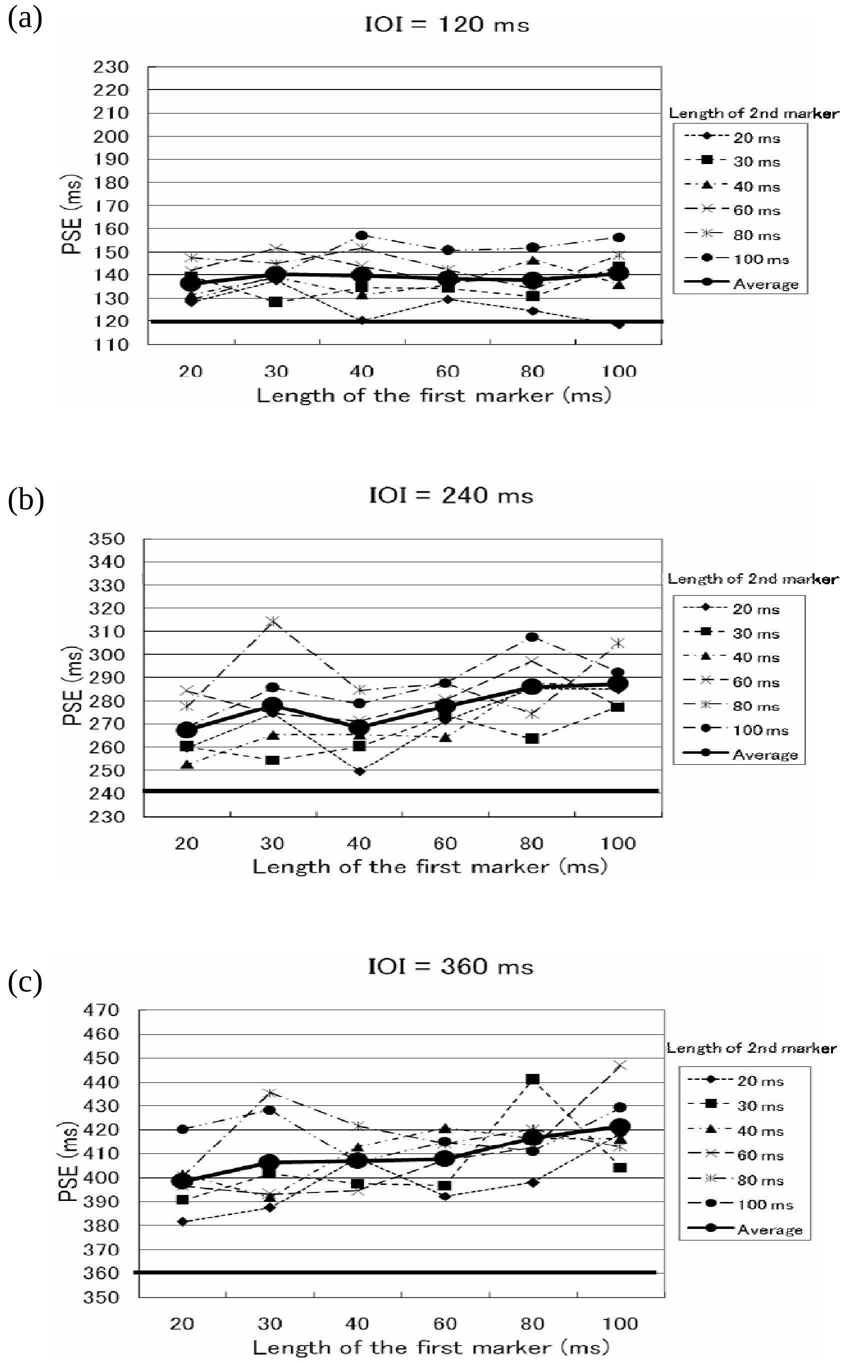
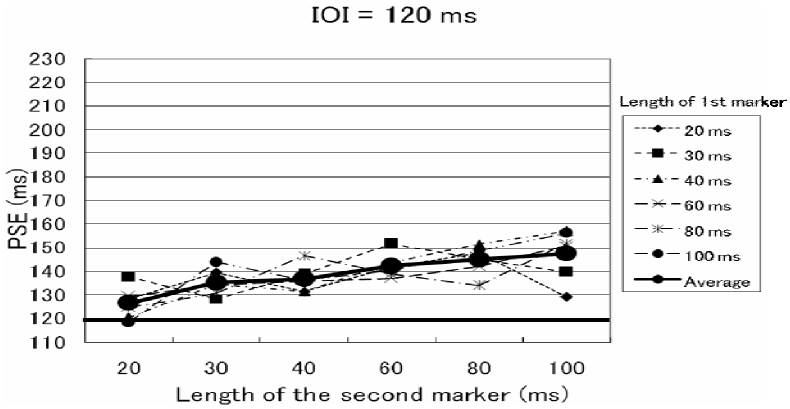


Fig. 3. Mean PSEs plotted as functions of the length of the first marker and the length of the second marker. The horizontal axis shows the duration of the first marker. Closed circles with thick line show the average PSE over the six second marker lengths for each first marker length.

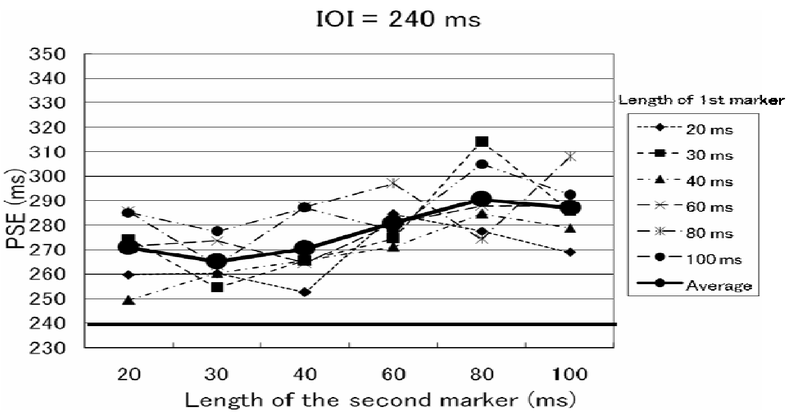
three IOIs, whereas the effect of the first marker duration differed between the three IOI conditions.

Perception of an empty time interval can be explained by the *Processing Time Hypothesis* proposed by Nakajima (1987) (Figure 5; see also Nakajima et al. 2004). This hypothesis claims that the perceived duration of an empty time interval is in proportion to its

(a)



(b)



(c)

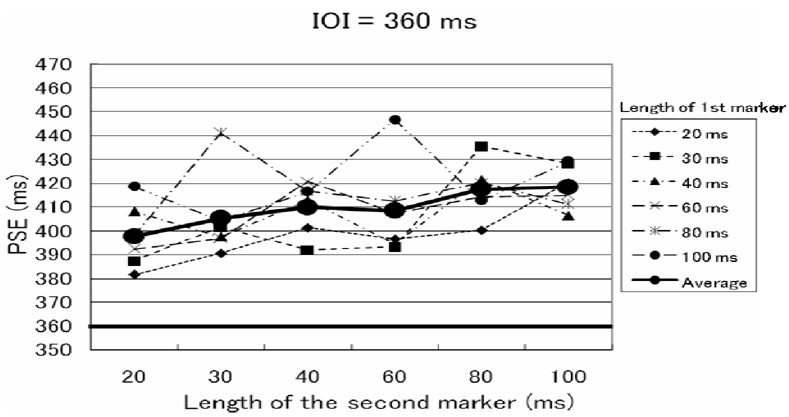


Fig. 4. Mean PSEs plotted as functions of the length of the first marker and the length of the second marker. The horizontal axis shows the duration of the second marker. Closed circles with thick line show the average PSE over the six first marker lengths for each second marker length.

physical duration plus a certain amount of time of about 80 ms, which the perceptual system needs to process the duration after detecting the final marker. According to this hypothesis, an empty time interval is perceived by: (1) detecting the first marker, (2) grasping the time passed after the detection of the first marker, (3) detecting the second marker, and (4) doing additional processing to judge the interval.

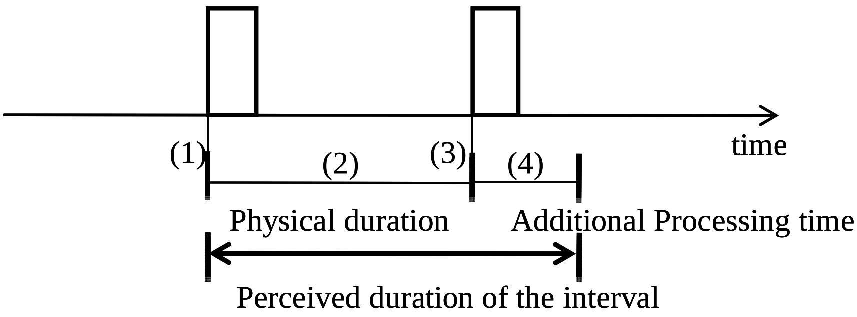


Fig. 5. Processing time hypothesis.

In the present experiment, lengthening the first marker may have affected the process of (2) and caused the physical duration between the first and the second marker to be perceived longer, and lengthening the second marker may have affected the process of (4) by interfering with the additional processing, leading to increase in the time needed for this additional processing. Both of these effects can explain the increase in the PSE as the markers lengthened.

There are reports showing that the perceptual onset of tones is affected by their rise time and maximum levels (Vos & Rasch, 1981). The differences in marker amplitude in the present experiment may have affected the marker detection process of (1) and (3). Although this is not very likely in the present case, we are carrying out a supplementary experiment using markers with equal amplitude and markers with equal total energy to check this issue.

As a summary, it was shown that the perceived duration of an inter-onset time interval increases as the two markers lengthen. Both the first marker duration and the second marker duration influence the perception of the interval but in different manners.

Acknowledgments

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