Intensity effect on discrimination of auditory duration flanked by preceding and succeeding tones

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1. Introduction

This letter reports on an intensity effect found in the duration discrimination of auditory stimuli temporally flanked by other sounds. Such intensity effect has not been observed in previous studies which have employed an isolated duration.

Kato *et al.* (1992, 1993) found that perceptual sensitivity to durational change is dependent on the intensity using speech segments as stimuli. Up to that time, no clear evidence showing intensity-dependency on duration discrimination had ever been reported (see *e.g.* Allan and Kristofferson, 1974, for a detailed review). The difference between the previous studies and Kato *et al.*'s studies is that the former usually dealt with a non-speech signal presented only in isolation while the latter used a segment in spoken words; *i.e.* the target is preceded and succeeded by adjacent segments. This difference has two major aspects; one is concerned with whether the stimulus is speech or non-speech and the other is concerned with whether the target is isolated or flanked by other sounds. In the current study, we are going to address to the latter aspect. An experiment using non-speech stimuli was designed to test whether an intensity effect on duration discrimination can be clearly observed in the presence of flanking sounds. For this purpose, the performance on temporal discrimination is evaluated for tones in several levels (including silence) preceded and succeeded by long tones.

2. Method

2.1 Subjects

Six adults with normal hearing participated in the experiment.

2.2 Stimuli

—Flanker Condition— The target level was 79, 76, 70, 67, 55 dB SPL, or silence. The standard duration of each target was 170 ms including rise and fall slopes. The comparison duration was 7, 22, 37, or 52 ms longer or shorter than the standard, which was chosen on the basis of preliminary experimental results. As shown in Fig. 1, each target stimulus (T) was temporally flanked by two tones (F_1 and F_2). There was no interval either between F_1 and T, or between T and F_2 .

The durations of F_1 and F_2 were 1,400 and 1,100 ms, respectively. Both had a level of 73 dB SPL.

—No-flanker Condition (Control Condition)— In this condition, only the target was presented. The target stimuli were the same as in the flanker condition excluding those at 76 and 70 dB SPL which were not employed. For the silent target level, an empty 170-ms interval marked by two identical tone bursts was used; the marker tones each had a duration of 21 ms and a peak level of 79 dB SPL.

All signals were 1,000-Hz sinusoids with 10-ms linear rise and fall slopes; they were digitally generated by a workstation (SPARC Station 2 or 10, SUN microsystems) at a 12-kHz sampling rate and with 16-bit precision. The presented levels of the stimuli were adjusted using a sound level meter (Type 2231, Brüel & Kjær) mounted on an artificial ear (Type 4153, Brüel & Kjær).

2.3 Procedure

Each subject listened to a pair of standard and comparison sequences, and was required to judge which target was longer. The interstimulus interval between the standard sequence and comparison sequence (ISI) was 1,500 ms in the flanker condition and 4,000 ms in the no-flanker condition to make the interval between the two target durations constant in both conditions. The durations of flanking tones and ISIs were chosen so as to be sufficiently longer than the target durations and also to not be simple integer proportions of each other. The paired stimuli were randomized and fed diotically to the subjects through a D/A converter (MD-8000 mkII, PAVEC), a low-pass filter (FV-665, NF Elect. Instruments, $f_c=3,000$ Hz, 96 dB/octave), and headphones (SR-1 Professional, driven by SRM-1 MkII, STAX) in a sound-treated room. The order of presentation of the standard and comparison sequences was random but equiprobable within each session.

In this experiment, there were fourteen sessions for each of the flanker and no-flanker conditions, the first one being for training. In each session, each pair of standard and comparison sequences was repeated four times. Thus, each point on the psychometric function comprised 52 judgments for each subject. The dis-

Fig. 1 Schematic diagram showing the amplitude contour of a stimulus sequence used in the flanker condition. All signals were 1,000-Hz sinusoids with 10-ms linear rise and fall slopes.

crimination threshold was estimated as the point of 75% correct on the approximation line, fitted according to the least-squares criterion with Müller-Urbach weighting, for the obtained probability of a correct response plotted on normal coordinates. Then, the upper and lower 75%-discrimination thresholds were pooled.

3. Results and discussion

The obtained 75%-discrimination thresholds for each subject and for each experimental condition (flanking $\times$ target level) are shown in Table 1. The data indicates a general tendency in the flanker condition, *i.e.*, for the thresholds to increase as the target levels decrease. However, the range of thresholds varies widely among the subjects. Therefore, each of the discrimination thresholds was normalized by the mean and the standard deviation calculated for each subject. The normalized thresholds are pooled over six subjects and plotted as a function of the target level in Fig. 2 for both conditions. A one-way ANOVA with the factor of target level was performed for the normalized data separately for each of the two flanking conditions.

In the flanker condition, the significant effect of the target level was found [$F(5, 30)=35.28$, $p<0.001$]. Multiple comparisons for all pairs using Tukey-Kramer HSD indicated the discriminability for silent targets to be significantly worse than that for other conditions and also the discriminability for the 55-dB target to be

Fig. 2 Normalized discrimination thresholds pooled over six subjects as a function of target level.

significantly worse than that for targets at higher levels ($p<0.01$ for both).

In the no-flanker condition, the target level had no significant effect [$F(3, 20)=0.42$, $p=0.74$].

The results in the no-flanker condition showing no intensity effect and Weber fractions around 10%, are in agreement with other published results (*e.g.* Abel, 1972). In the flanker condition, on the other hand, a clear intensity effect could be observed even for a 12-dB difference in levels; no effect could be found in previous studies with no flankers for 20-dB difference (Abel, 1972). Clearly, the observed effect is due to the existence of preceding and succeeding tones and might not be predicted by conventional types of duration discrimination models (*e.g.* Creelman, 1962) which take no account of influences from flanking sounds. Further studies should be undertaken to investigate how the flankers function in the perceptual measurement of target durations.

Table 1 Individual and pooled discrimination thresholds in ms, and Weber fractions for pooled data.

Condition	Level	Subject						Mean	Weber fraction
		A	B	C	D	E	F		
With flankers	79 dB	21.6	11.1	49.4	24.3	20.5	14.9	23.6	0.139
	76 dB	22.4	10.8	64.9	23.9	17.7	15.9	25.9	0.153
	70 dB	27.8	12.2	64.2	25.8	26.8	20.6	29.6	0.174
	67 dB	32.7	14.3	74.4	30.7	30.9	20.0	33.8	0.199
	55 dB	50.4	15.7	170.4	88.8	27.5	26.5	63.2	0.372
No flanker	silent	103.7	22.5	153.3	74.3	55.0	39.8	74.8	0.440
	79 dB	21.5	12.9	22.5	16.3	14.7	15.8	17.3	0.102
	67 dB	17.1	14.3	23.6	18.2	13.3	20.2	17.8	0.105
	55 dB	14.5	12.9	27.4	22.6	14.1	21.9	18.9	0.111
	silent	19.7	12.3	21.7	17.6	19.2	23.4	19.0	0.112

4. Summary

An intensity effect has been found on auditory duration discrimination using a short target tone between long preceding and succeeding flanking tones. The measured discrimination thresholds significantly increased with decreasing target levels; the largest discrimination threshold was obtained in the silence condition where the target portion was an empty interval. Such a systematic intensity effect could not be observed in the control condition where the target was presented with no flanking sound.

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