THE EFFECT OF INTENSITY ON DURATION DISCRIMINATION

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ABSTRACT

This paper reports on several experiments carried out to find the effects of intensity difference on duration discrimination in pairs of pure tones. Pure-tone signals were presented with the modification of amplitude and duration. Duration-discrimination thresholds for the musical tones and the signals that were varied in amplitude were investigated together with those of the fixed signals. From the results, it was found that the duration discrimination tasks are affected by an intensity difference of 20 phons.

1. INTRODUCTION

The effect of duration on loudness has been studied extensively [1-6] and it has been found that, at a given intensity, loudness increases with duration. Boone [7] found that, for a frequency of 1 kHz, the loudness was related to the total energy of the tone burst.

How then is intensity related to the threshold of duration? From Abel's study [8] it can be seen that, for signals of 3.5 kHz frequency, a change in intensity from 85 to 65 dB did not affect discrimination performance when the standard stimulus duration, T, was 5, 40 and 320 msec. Creelman [9] also examined the effect of signal level on duration discrimination in the presence of noise. In his first experiment (*Effects of signal voltage on duration discrimination*), he found duration discrimination improved with an increase in signal voltage, the dependence becoming negligible as the signals were made loud and clear above the noise background. In another study Creelman [3] used two levels and varied T from 40 to 640 msec (Experiment 4: *Discrimination as a function of standard duration and signal voltage*). He found an interaction between signal level and T. The difference in duration discrimination, as a function of tone level, was greater as the value of T became shorter.

Carbotte and Kristofferson [10] showed that for T equal to 50, 200 and 250 msec, changing the intensity by 37 dB (which was larger than the 17 dB in Abel's study) resulted in the same small change in performance at 50 msec as that obtained at 250 msec, *i.e.*, there is a discrepancy between the results of Creelman and Carbotte and Kristofferson. The experiments in this paper are mostly concerned with the question of how the unequal intensity might affect duration judgements.

Allan and Kristofferson [11] showed in their investigations, using trained subjects, that the amount of practice a subject has with a particular set of duration values is a critical variable. Spiegel and Watson [12] used musicians or trained subjects for studies of the auditory system. As Spiegel and Watson pointed out, use of trained musicians may eliminate a subpopulation that has not yet learned how to, or who cannot, listen carefully. Presumably, the non-sensory influences on threshold measurement, such as time-order-error, alternative number in answering procedures, etc., would be minimized with trained musician subjects.

This work is of importance because it has relevance to speech recognition. The amplitude envelope of the speech waveform has been considered as an important parameter that can be used as an effective auditory supplement to speechreading in tactile devices by representing the time/intensity variations of the amplitude envelope.

2. TWO INTENSITY CASES (59 & 78 dB)

This experiment was undertaken to investigate the effect of intensity on duration judgements. Responses from all subjects were shown as mean values of correct judgements, P(C), on the sound pairs with different frequencies. In this experiment standard stimuli durations were from 100 to 800 msec.

2.1 Experimental design

Thirteen university students and staff were selected as subjects. The subjects were tested individually in an anechoic room. Each received the same schedule of stimulus presentation from a tape recorder (REVOX A77) and loud speaker. They listened to 24 pairs of sounds which were repeated four times, *i.e.*, 96 pairs in different orders through four test sequences. The four test sequences were recorded by random sampling of the 24 pairs of sounds. The ability to discriminate the durations was judged using 75 % correct scores. Responses of the subjects were recorded on answer sheets by the subjects themselves.

Stimulus pairs were used with loudnesses of 80 phons and 60 phons. For the condition in which pairs had a 20 phon difference in loudness, the sound pressure levels of the 80 phon and the 60 phon stimuli were maintained at 78 dB and 59 dB, respectively. The 1 kHz frequency tone was maintained for the two sound pressure levels. The range of $\Delta T/T$ was from 0.16 to 0.32, as shown in Table 1. The Interstimulus Interval (ISI) for each pair of sounds was 0.5 sec while the time between pairs of sounds was around 2.5 sec. Subjects were asked to identify which of the two continuous pure tones was longer when the sounds had different intensities (shown in Table 2).

TABLE 1 The standard and comparison stimulus durations used for this experiment.

Standard stimulus duration (msec)	Comparison stimulus duration (msec) for $\Delta T/T$ of 0.16	0.24	0.32
100	116	124	132
200	232	248	264
400	464	496	528
800	928	992	1056

TABLE 2 Classification of the cases by intensity difference in the standard and comparison stimuli.

Case No.	Standard Stimuli Freq. (kHz)	SPL (dB)	Duration (msec)	Comparison Stimuli Freq. (kHz)	SPL (dB)	Duration (msec)
1	1	78	100	1	59	116-132
			200			232-264
			400			464-528
			800			928-1056
2	1	59	100	1	78	116-132
			200			232-264
			400			464-528
			800			928-1056

2.2 Results and discussion

Responses from all subjects were averaged as proportions of correct responses, P(C)s. Fig.1 shows comparison of mean values of correct judgements obtained from thirteen subjects, in Cases 1 and 2 (referred to in Table 2), using standard stimuli durations of 100 to 800 msec, as a function of duration increment, *ΔT/T*. The results are compared with those of Exp. 1, which was previously undertaken under the same experimental situation arrangement, to be used as reference data for the equal frequency/intensity case.

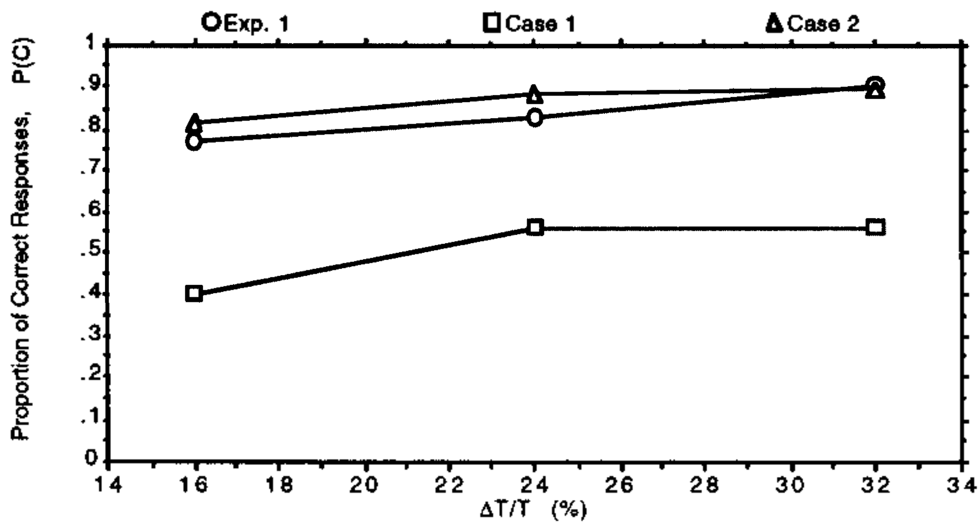

FIG. 1 Comparison of mean values of correct judgements obtained from thirteen subjects, in Cases 1 and 2, using standard stimuli durations of 100 to 800 msec, as a function of duration increment rate, *ΔT/T*. The results are compared with those of the equal frequency/intensity (1 kHz / 70 dB) case represented as Exp. 1.

From Fig. 1, it can be seen that the proportion of correct responses, P(C), when the comparison stimulus has a lower intensity, as in Case 1 (*i.e.*, when the shorter duration signal has higher intensity), is smaller than the P(C) of Exp. 1 (*i.e.*, when the two signals in a pair have equal intensity). On the other hand, the proportion of correct responses, P(C), when the comparison stimulus has a higher intensity, as in Case 2 (*i.e.*, when the longer duration signal has higher intensity), is bigger than the P(C) of Exp. 1 (*i.e.*, when the two signals in a pair have equal intensity). This result reveals that the intensity difference does affect the judgement of subjects. It seems that the subjects tend to select a signal of higher intensity as a signal of a longer duration. Therefore, it can be concluded that subjects are affected in their duration discrimination tasks by intensity differences of 20 phons.

3. FOUR AMPLITUDE CASES (32, 50, 71 & 100 %)

The relative amplitude could be represented and adjusted (only in percentages) by the sound generating software system used in the experiments of this paper. To confirm more precisely the previous experimental results which showed the intensity effect on duration judgement, it would be necessary to train subjects, to confine the experimental conditions and to increase the number of test sequences. An experiment which does this is described below.

3.1 Experimental design

There were two female subjects (N.J. and K.C.) and two male subjects (H.J. and S.K.). All had thresholds within 10 dB of the ISO-1964 standard at all audiometric frequencies. The subjects ranged in age from 20-30 years, with most being university students. They had previously taken part in other experiments on auditory duration assessments, for at least 20 hours. The subjects were tested individually in an anechoic room as in the previous experiments. Each received the same schedule of stimulus presentations from a Macintosh IIci computer through headphones. The rise/fall time for each stimulus was 5 msec.

Stimulus pairs were used with four different intensities. For the condition in which pairs had 0, 3, 6 and 10 dB differences in intensity, the amplitudes of stimuli were maintained at 100, 71, 50 and 32%, respectively. The 1 kHz frequency and 200 msec tone was maintained for the four sound pressure levels.

The subjects were presented with $\Delta T/T$ = 0.025, 0.075 and 0.125. The ISI and the time between pairs of sounds were the same as in the first experiment. The 2AFC method was employed in this experiment. Subjects were presented with a pair of stimuli composed of high and low intensity pure tones and asked to discriminate differences in duration between the two tones, ignoring differences in the intensity of the tones. All the stimuli pairs were presented 40 times. The order of the longer and shorter duration stimuli was equally distributed. Responses of the subjects were recorded on answer sheets by the subjects themselves.

3.2 Results and discussion

As shown in Fig. 2, when C was lower intensity than S (Cases IV and VI), duration judgements were poorer than for equal intensities (Cases I and VIII). In cases II and III there was little difference in the correct responses because the sound level difference of two signals was only just perceptible (3 dB). When comparing Case VI with Case I, the difference of correct responses, with a 10 dB difference in intensity, was as large as 0.15. However, even though the intensity of S became lower than C (from Case I to Cases III, V and VII), the proportion of correct responses was almost constant at 0.79 to 0.82.

From the comparison of Case I with Case VIII, it can be seen that the difference in performance as a function of tone amplitude is not great, even though there is large variation in amplitude (100-32 %, 10 dB difference). There is a difference (as small as 0.05 in the P(C) value) between Case I and Case VIII which suggests that detectability is of little importance. The result again supports Abel's [8] data and does not support Creelman's [9] or Carbotte and Kristofferson's [10] researches. The subjects' discriminations were more likely to be affected by the amplitude of signals than detectability or intensity bias. If the subjects mainly based their judgements on detectability (*i.e.*, a high intensity), Case VIII should have had much lower P(C)s than Case VII.

The result suggests that duration discrimination of tone pairs is affected by variations in amplitude as much as by the apparent duration difference in the signals. This hypothesis might be further tested by investigating the thresholds on duration judgements (the duration JNDs) but for the same intensity range in the variable intensity case.

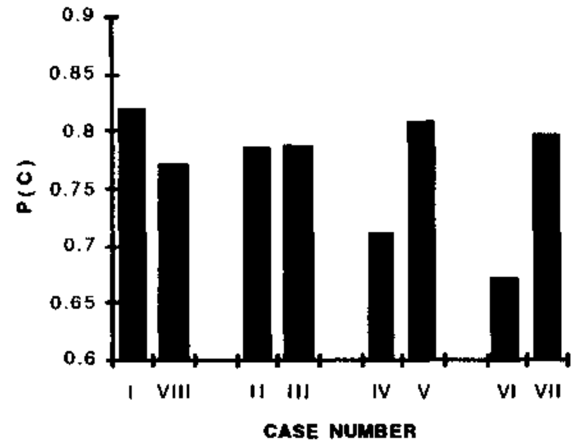

FIG. 2 Proportions of correct responses, P(C), averaged from four subjects, in eight cases of amplitude differences from 32 to 100% of the standard stimulus amplitude (As) and the comparison stimulus amplitude (Ac), using a standard stimulus duration of 200 msec. Case I As:Ac = 100%:100%, Case II As:Ac = 100%:71%, Case III As:Ac = 71%:100%, Case IV As:Ac = 100%:50%, Case V As:Ac = 50%:100%, Case VI As:Ac = 100%:32%, Case VII As:Ac = 32%:100% and Case VIII As:Ac = 32%:32%.

4. DISCUSSION AND CONCLUSIONS

From the results of experiments to investigate the effect of intensity on duration discrimination, it was found that subjects are affected in their duration discrimination tasks by an intensity difference of 20 phons when the higher intensity falls on the longer duration stimulus. As the standard stimulus duration becomes longer, from 200 to 800 msec, the duration judgement difference between the shorter-duration, higher-intensity case and longer-duration, higher-intensity case gets smaller. Garner and Miller [13] assumed that the ear performs as an integrator and shows 3 dB reduction of the auditory threshold for each doubling of a signal duration. This theory described the data within the range from 20 to 100 msec, but very short durations yielded an even steeper slope (about 4.5 dB per doubling, for signals briefer than about 20 msec). Very long durations produced a slope of about 1.5 dB per doubling for signals longer than 100 msec.

The results obtained are somewhat different from those of some previous researchers [7, 9], who have considered that duration discrimination is independent of the intensity of the stimuli, as long as the stimuli are easily detectable. Creelman [9] mentioned that "duration discrimination depends on sufficient intensity to mark the time unambiguously; it depends on detectability but not on loudness." However, when Abel [8] varied both the duration and the amplitude (70-85 dB) of noise bursts from 0.63 to 640 msec, Abel found that the amplitude of the signal did appear to be an important variable. Discrimination performance was better, for a 10 msec, 85 dB stimuli than for the 10 msec, 70 dB stimuli. The results of the present work support the Abel's study; variations in discriminability as a function of amplitude are considerable.

The experiments of this chapter are mostly concerned with the question of how the unequal intensity might affect duration judgements. It would be good to look for this effect in music too., *i.e.*, that passages marked '*pp*' or '*p*' are played longer than passages marked '*f*' or '*ff*'. Certainly this is a natural tendency (and well known) but it has not been quantified.

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