Auditory temporal resolution: Gap detection as a function of interpulse frequency disparity

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Gap detection thresholds, defined by the minimum temporal disparity between the offset of one pulse and the onset of a second, were used to describe auditory temporal resolution. Temporal resolution, as defined by the gap threshold, was observed to decrease as the frequency disparity between the successive pulses increased. These results cannot be accounted for in terms of a simple temporal masking hypothesis.

Monaural temporal resolution has been frequently defined by the minimum detectable temporal disparity between the onsets of two successive auditory events. Using very short duration wide-band pulses (clicks), investigators have reported onset disparities ranging from 1 to 3 msec as detectable (Wallach, Newman, & Rosenzweig, 1949; Gescheider, 1966). On the other hand, Pollack (1967, 1968a, b) has shown that interpulse intervals differing by only a few microseconds can be appreciated monaurally, if the temporal information is included within a pulse train. It seems clear that there is no single value which represents the temporal resolving capacity of the auditory system. While it is obvious that differences in psychophysical procedure probably influence any function defined, tasks which use either two successive pulses or pulse trains likely describe fundamentally different functions. With the first task, temporal disparity is defined by differences in signal envelopes (macrostructural disparity), whereas with pulse trains, the interpulse interval disparity can be readily described as part of the microstructure of the stimulus. Pollack (1968b) has suggested that the highly precise temporal resolution demonstrated with auditory pulse streams is achieved by a conversion from a temporal to a spectral analysis. With pulse streams, Ss can be instructed to respond to the tonal color, pitch, or roughness of the signal.

The following study was performed to investigate temporal resolution in a two-pulse task (gap detection) in which the microstructure of the stimulus pulses was varied systematically. Temporal resolution was defined as the period elapsing between the offset of one tonal pulse and the onset of a second.

SUBJECTS

Five experienced Ss were used in this experiment. All had demonstrated

normal auditory function.

APPARATUS

Sinusoids were led from two audio oscillators (General Radio, Models 1302A and 1304B) through separate electronic switches (Grason-Stadler, Model 1229). The output of each switch was led to a precision attenuator (Hewlett-Packard, Model 350D), then to a mixer, amplifier, and impedance matching network, and finally to an earphone (TDH-49) which was located in an audiometric test chamber (Industrial Acoustic Co., Model 1200) where S listened. Programming was provided with a six-channel Teletype tape fed through a modified tape reader (Frieden, APT), which in turn set a logic control unit (BRS/Foringer, 200 series). The logic control unit operated the audio switches and

controlled all signal and nonsignal periods, as well as recorded Ss' responses. Signals were calibrated and checked on line.

STIMULI

Tonal pulses, 100 msec in duration, were delivered to S at 35-dB sound-pressure level (re .0002 dynes/cm²). In order that both the onset and offset of stimuli could be readily defined, signal envelope (1-msec rise/decay) was calibrated in terms of the acoustic response of the earphone. The tonal pulses were presented in pairs (either f_1 then f_2 or f_2 then f_1) in which $f_1 = f_0 + a$ and $f_2 = f_0 - a$, where $f_0 = 1,000$ Hz (i.e., center frequency) and $a = 0, 3, 10, 30, 100$, or 300 Hz. The following stimulus sequence was used: Two pulses were presented, followed by a silent interval of 500 msec (the intercomplex interval), and finally a second pair of pulses in either the same or reverse order. Between one of the pulse pairs, an interevent disparity period was present (IED = 5, 10, 20, 40, or 80 msec). Each IED appeared with each pulse-pair combination 40 times in a randomized sequence. The probability that the IED period occurred between the first pulse pair or the second was .5.

PROCEDURE

S was instructed to listen to two pairs of tonal pulses and to indicate whether the IED interval occurred between the first (early) or second (late) pair of pulses. A two-alternative forced-choice task, where S had to choose between the pulse pairs

Fig. 1. Interevent disparity (IED) threshold for 75% correct detection (auditory gap threshold) in a two-alternative forced-choice task as a function of the frequency disparity from f_0 (hertz).

whether or not he could detect the IED, was used. A self-paced system was used in which S's response initiated a 1,200-msec delay interval, during which the next presentation sequence was set by the logic unit. Only a single value of (a) was used in any given run.

RESULTS

The gap threshold was defined by the IED that could be detected on 75% of the trials. Individual thresholds were determined from a least-squares analysis of the data (Guilford, 1936) for each value of (a) and pulse order for each S. The results of an analysis of variance on the obtained thresholds indicate a significant interpulse frequency difference effect ($F = 17.03$, $df = 6/24$, $p < .001$). With no frequency difference between the successive pulses ($a = 0$ Hz), the IED for 75% correct detection was only 6.03 msec; however, as (a) increased, the IED for the two-pulse threshold also increased ($a = 300$ Hz, two-pulse threshold = 26.05 msec).

The order in which the pulses appeared (f_1 , IED, f_2 or f_2 , IED, f_1) had no effect. Figure 1 presents the obtained thresholds collapsed across

pulse order. On a log/log plot, the function is readily described by a single straight line with a slope, $m = .25$. An examination of individual functions indicates a high degree of agreement between four of the five Ss. One S has a function which is systematically elevated above the others.

DISCUSSION

It is obvious from the present data that the spectral information contained in the tonal pulses interact with the temporal analysis of successive signal envelopes. The effects of interpulse frequency differences on gap threshold cannot be readily reduced to a spectral analysis as appears to be the case with auditory pulse trains. In the present experiment, a pitch change was not correlated with interevent disparity. For example, if (a) were sufficiently large, a change in pitch could always be detected, even with the standard pulse pair (IED = 0 msec). In addition, pulses were of sufficient duration to ensure good frequency resolution (100 msec) under all conditions.

At present, the data are too limited to support a specific hypothesis. The

direct relation between the gap threshold and the interpulse frequency difference (a) does, however, argue against a simple temporal masking hypothesis as suggested earlier by Hirsh (1959). Temporal masking would not be expected to increase as the interpulse frequency difference increased.

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