Effects of signal duration and masker duration on detectability under diotic and dichotic listening conditions

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The detectability of a 500-Hz tone of either 32- or 256-msec duration in a broad-band 50-dB spectrum level noise was measured as a function of the duration of the noise. The noise was continuous or was gated 0, 125, or 250 msec before the onset of the signal. For the gated noise conditions, the noise was terminated approximately 5 msec after termination of the signal. With a homophasic condition (NO SO), the three noise conditions led to approximately the same detectability as did the continuous masker. In an antiphasic condition (NO S π), detectability was poorest when signal and masker began together and improved as the delay between noise onset and signal onset increased. The difference between the simultaneous onset and the continuous noise condition was about 9 dB for the 32-msec signal and about 2 dB for the 256-msec signal. These results are compared to those reported by McFadden (1966).

McFadden (1966) reported on the effects of using either a burst of noise or a continuous noise as a masker in a signal detection experiment. He found, as had Watson (1962) that, when stimuli were presented diotically, there was a negligible difference between detection in burst and continuous noise. These generalizations pertain to masker durations which are at least as long as signal durations and to signals and maskers which are presented simultaneously.

For dichotic conditions, however, McFadden found detection in pulsed noise to be considerably worse than in continuous noise. For the dichotic conditions NO S π , N π SO, NO Sm, and N π Sm, McFadden found that the signal-to-noise ratio for a criterion level of performance with pulsed noise was about 4-5 dB greater than that required when the signals were presented in continuous noise.

McFadden also varied the time between the noise burst onset and signal onset and plotted the masking level difference (MLD) as a function of the duration of this noise "fringe." He found that a fringe of approximately 600 msec was required for detectability to be restored to that obtained with continuous noise. In attempting to explain the advantage of continuous noise over pulsed noise with dichotic conditions, McFadden says, "The advantage of continuous noise . . . may simply be that, due to the presence of noise-alone prior to and subsequent to the observation interval, the subject's 'memory' for the characteristics of the noise-alone activity is better than it is in the burst conditions [p. 1418]." Using the language of the Webster-Jeffress

hypothesis (Jeffress, Blodgett, Sandel, & Wood, 1956), McFadden also suggested that the pulsed noise condition does not allow the listener to take advantage of the initial interaural phase (or time) shift that occurs at signal onset when a dichotic signal is added to a continuous *diotic* masker. There remains as a cue for the pulsed dichotic condition only the ongoing time-varying interaural time difference which occurs while the signal is present.

It may be that signal duration is an important variable in determining the magnitude of the decrement in detectability for the pulsed noise condition. This idea is based upon data obtained by Tucker, Williams, and Jeffress (1968), who investigated detection of short-duration diotic signals in pulsed diotic noise. They found that detection in the pulsed noise condition was superior to that with continuous noise when the signal duration was less than about 100 msec. For longer signals, say 200 to 500 msec, detection in continuous noise was better than that in pulsed noise. McFadden used a 125-msec duration for his signals and thus, based on the Tucker et al findings, was using a duration where no difference between pulsed and continuous maskers would be expected for diotic conditions.

Since the MLD is the difference between a diotic and a dichotic condition, it seemed prudent to reinvestigate the pulsed, fringe, and continuous conditions studied by McFadden, using durations both shorter and longer than those he used. In this manner, changes in detectability between diotic and

dichotic conditions could be measured as a function of changes in both masker and signal duration.

METHOD

The conditions NO SO and NO S π were investigated for two signal durations, 32 and 256 msec, at each of four noise-masker conditions: ϕ -msec fringe (pulsed noise), 125-msec fringe, 500-msec fringe, and continuous noise. (As in the McFadden experiment, the fringe is the time between masker onset and signal onset.)

The 500-Hz signal was gated without respect to phase with a 5-msec rise-decay time. In the pulsed and fringe conditions, the noise was gated with essentially 0-msec rise-decay time and in such a way that noise offset occurred approximately 5 msec after signal offset. The 50-dB spectrum level noise was band-limited between 100 and 3,000 Hz. TDH-39 headphones were employed.

Four Os were tested in the single observation-interval task. Two-point psychometric functions were obtained for the 16 conditions (4 fringes by 2 listening conditions by 2 durations). Psychometric functions were obtained by (1) computing d' for each value of $10 \log (E_S/N_O)$, (2) transforming d' to $P(C)_{\max}$ [the maximum value of $P(C)$ obtainable for that d' , see Egan, 1965], and (3) fitting the function $d' = m(E_S/N_O)^k$ to the two points. Cuts were then made at $P(C) = 0.80$ in order to obtain a value of $10 \log (E_S/N_O)$ for each condition in the experiment.

A trial consisted of a warning light of about 500 msec, a pause of not less than 500 msec between the warning light and signal onset, an observation-interval light which began about 15 msec before the signal interval and terminated at the end of the signal interval, a 1.5-sec response interval, and a feedback light of 500 msec. The time between the end of the warning light and the beginning of the observation-interval light was, of course, not constant, but was varied as a function of the noise fringe.

Data were collected in blocks of 80 trials. On any particular day, Os were exposed to only one signal duration, one value of fringe, and one interaural configuration. Interaural conditions were counterbalanced over two sets of two Os. In this fashion, each O received 400 trials per signal level at each of the two signal levels for each condition. Prior to data collection on each day, the Os were given 20 warm-up trials at an increased signal level.

RESULTS

Figure 1 shows the values of $10 \log (E_S/N_O)$ required for a $P(C)$ of 0.80 as a function of the noise fringe in

Fig. 1. The average values of $10 \log (E_S/N_O)$ required for $P(C) = 0.80$ for the two signal durations and for NO SO and NO $S\pi$ as a function of the noise fringe in milliseconds. Dashed line represents data for NO SO. Solid line represents data for NO $S\pi$; X, 32-msec signal; •, 256-msec signal; □, data from McFadden (1966) for a 125-msec signal.

milliseconds. Data from the McFadden paper are also shown. For the diotic (NO SO) conditions, the required signal levels are essentially independent of the duration of the fringe and show reasonable agreement with McFadden's data.

Performance for the dichotic conditions (NO $S\pi$) varied as a function of both signal duration and masker duration (fringe). For the 32-msec signal, the value of $10 \log (E_S/N_O)$ decreased by about 9 dB from the zero-fringe condition to the continuous noise condition. Over the same fringe durations, the 256-msec signal shows a change of only about 2.5 dB. The data point obtained from McFadden for a 125-msec signal falls between the 32- and 256-msec points for the pulsed noise zero-fringe condition. However, the same comparison for continuous noise is somewhat curious. Apparently, our Os were more sensitive at both shorter

and longer durations than were McFadden's.

Table 1 shows the MLDs obtained by comparing each dichotic condition with its diotic counterpart. It should be noted that, as the fringe is increased, the MLD increases. This effect is largest for the 32-msec signal and smallest for the 256-msec signal. The MLDs obtained by McFadden for a 125-msec signal are intermediate to those obtained with 32- and 256-msec signals. Both Fig. 1 and Table 1 show that, for the dichotic condition, there is an interaction of noise duration and signal duration. For the zero fringe condition, the longer signal is more detectable than the shorter one. The reverse is true for continuous noise. This leads to a greater MLD for the 256-msec signal compared to the 32-msec signal when there is a zero fringe, while this relation is reversed for continuous noise.

DISCUSSION

In order to explain the pulsed vs continuous noise effect, we may argue, as did McFadden, that there are two aspects of interaural temporal difference of import to the binaural system. First, there is the initial interaural temporal shift which occurs at signal onset when the signal is added to the noise. Second, there is the time-varying temporal difference which occurs while the signal is present. The decrement in the pulsed condition relative to the continuous

noise condition may be explained in terms of the lack of the onset cue. We can expand McFadden's hypothesis slightly and suggest that the effect of signal duration on the general "pulsed" effect may be thought of in terms of the "number of looks" at (or the time available to integrate over) the ongoing time-varying temporal difference.

Such an explanation, however, leaves some unsolved problems. Our data suggest that temporal integration appears to differ greatly between diotic and dichotic conditions, as well as within the dichotic conditions, as the noise duration (or fringe) is varied. As was previously noted, the value of $10 \log (E_S/N_O)$ necessary for 80% correct detections does not vary greatly with signal duration or noise fringe for the diotic conditions. Stated otherwise, there appears to be approximately linear integration for the diotic conditions. The dichotic conditions, however, show that integration is effected by noise duration. In agreement with Blodgett, Jeffress, and Taylor (1958) and with Green (1966), there appears to be a slightly greater MLD for short-duration signals (here, 32 msec) than with long (256 msec) signals when these signals are embedded in a continuous noise. However, when these signals and maskers are gated together, the longer signal is much more readily detected, thereby yielding a larger MLD for the longer duration signal.

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Table 1
MLDs Obtained for Three Signal Durations (T_S) and Four Values of Noise Fringe*

(Msec)	Noise Fringe (Msec)			
	0	125	500	∞
32	9.3	13.2	15.6	18.4
125	12.1	13.2	15.3	16.0
256	14.4	15.9	14.5	16.1

*The 125-msec data are estimated from McFadden's data (1966, Fig. 4).