Variable-Duration Notched-Noise Experiments in a Noise Context

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Abstract: A variable-duration notched-noise experiment was conducted in a noise context. Broadband noise preceded and followed a tone and notched noise of similar duration. Thresholds were measured at four durations (10, 30, 100, and 300 ms), two center frequencies (0.6, 2.0 kHz), and five relative notch-widths (0.0, 0.1, 0.2, 0.4, 0.8). At 0.6 kHz, 10-ms thresholds decrease 6 dB across notch widths while 300-ms thresholds decrease over 35 dB. These durational trends are similar but less pronounced at 2 kHz. In a second experiment, the short-duration notched noise was replaced with a flat noise which provided an equivalent amount of simultaneous masking and thresholds dropped by as much as 20 dB. Thus, the elevated thresholds at short durations are dependent on the spectral shape of the simultaneous masker, which may imply reduced frequency selectivity.

MOTIVATION

Short-duration speech signals, such as plosives, are often confused in noisy environments. To model these confusions, it is necessary to characterize our ability to resolve the spectral components of short-duration stimuli in background noise. Previous notched-noise masking experiments using a short-duration tone and long-duration notch suggest that frequency selectivity develops nearly instantaneously (3), (5). However, other noise-masking studies which use a broadband noise-masker suggest decreased frequency selectivity at short-durations (2), (4). To assess the discrepancy between these studies, a variable-duration notched-noise experiment was conducted in a broadband-noise context.

EXPERIMENT 1

Figure 1 shows a schematic spectrogram of the stimuli used in the experiment. Both the notched-noise and the surrounding white-noise had a spectrum level of 36 dB. To reduce the effect of spectral splatter, all stimuli where gated on an off with raised-cosine windows of 10 ms. Signal durations of 10, 30, 100, and 300 ms were defined from the half-rms level (i.e.-6 dB). The experiment was conducted at tone frequencies of 0.6 and 2 kHz. All notches were symmetric (in frequency) around the tone and characterized by $\Delta f/c_f$, where c_f is tone frequency, and Δf is the frequency difference between the tone and either edge of the notch. Thresholds were measured for $\Delta f/c_f$ equal to (0.0, 0.1, 0.2, 0.4, 0.8). To measure the amount of non-simultaneous masking by the surrounding white noise, additional data points were collected using a wide notch-width from 50 to 7950 Hz. Four audiometrically normal subjects participated in the experiments. Masked thresholds were determined using a 2I, 2AFC paradigm with no feedback.

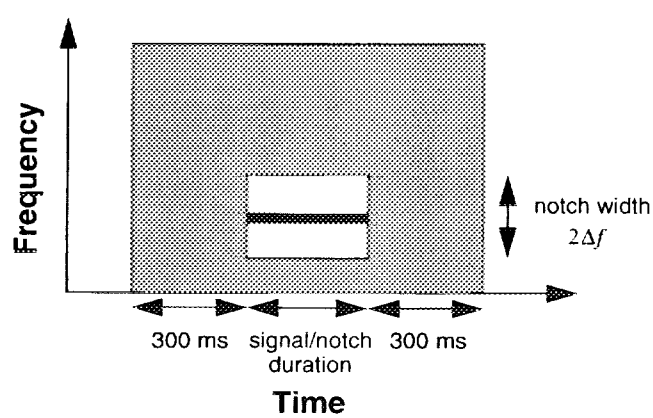

FIGURE 1. Schematic spectrogram of the experimental stimuli.

Figures 2 (a) and (b) plot mean thresholds of the 0.6 kHz and 2.0 kHz tones, respectively, as a function of the relative notch-width, ($\Delta f/c_f$), with signal duration as a parameter. Standard deviations are expressed by the error bars and are only shown above the average thresholds. Wide-notch-width thresholds, corresponding to a notch from 50 to 7950 Hz, are denoted by "wide" on the horizontal axes. At short durations, thresholds decrease less with notch width. For

the 0.6 kHz data, 10 ms-thresholds decrease 6 dB between notch widths of 0.0 and 0.8, while 300-ms thresholds decrease over 35 dB. At 2 kHz, these durational trends are similar but less pronounced.

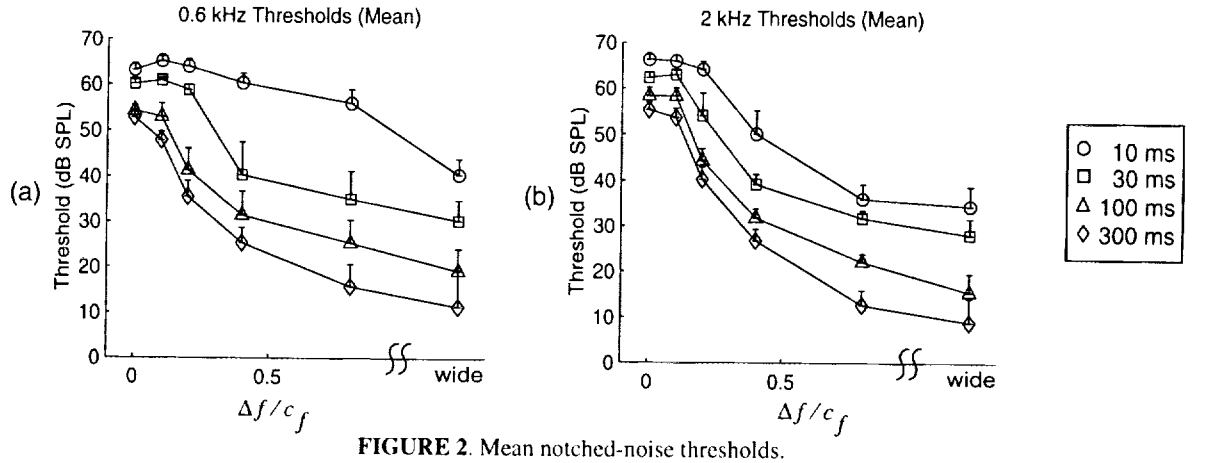

FIGURE 2. Mean notched-noise thresholds.

EXPERIMENT 2

It is possible that the results of Experiment 1 are due to a non-linear combination of simultaneous and non-simultaneous masking. A simple modification of the first experiment was conducted to assess this possibility. In experiment 2, the simultaneous notched noise was replaced with a flat noise (0 - 8 kHz). Assuming a roex-filter shape derived from previous (long-duration) notched-noise data (1), the level of the simultaneous flat noise was set to provide the same amount of simultaneous masking as the notched noise in Experiment 1. Tone thresholds were measured for equivalent noise levels, N_{eq}, corresponding to notches of 0.2, 0.4, and 0.8. In Figures 3 (a) and (b), the 10-ms thresholds from Experiment 2 (squares) are compared to the corresponding notched-noise thresholds from Experiment 1 (circles). Thresholds were averaged across four subjects with standard deviations represented by the error bars.

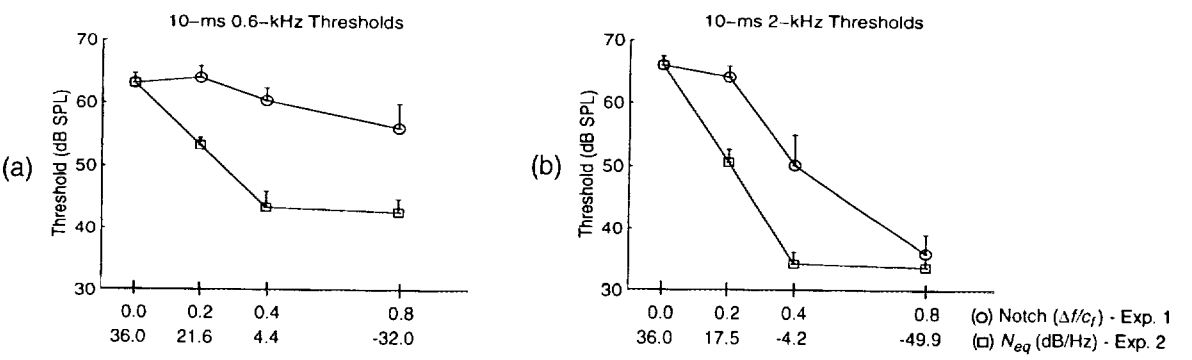

FIGURE 3. 10-ms thresholds for Experiments 1 and 2.

Despite a similar combination of simultaneous and non-simultaneous masking, thresholds with a flat-noise simultaneous masker (Experiment 2) are lower than those with a notched-noise masker (Experiment 1). A simple combination of simultaneous and non-simultaneous masking cannot predict both results. Instead, the elevated thresholds at 10 ms are dependent on the spectral shape of the simultaneous masker, which may imply reduced frequency selectivity. [Work supported in part by NIH-NIDCD and the Whitaker Foundation.]

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