Psychometric Functions for Gap Detection

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Abstract: To determine the form of psychometric functions for gap detection, three normal listeners were tested at octave frequencies from 0.25 to 8 kHz using a constant-stimulus procedure with a cued Yes-No paradigm. The gaps were carried by bandpass noises with an overall level of 85 dB SPL and a bandwidth equal to three auditory-filter bandwidths. The slopes of the psychometric functions were quite similar for the three listeners. They increased as the test frequency increased up to 2 kHz, but remained constant at the higher frequencies. The results and modeling indicate that stimulus variability is not important in determining gap-detection thresholds at 2 kHz and above.

INTRODUCTION

This paper presents psychometric functions for gap detection in bandpass noises. Gap detection in bandpass noise is a relatively simple task that provides a frequency-selective measurement of temporal resolution in the auditory system (e.g., 1, 3). Although extensive data exist on the effects of frequency, level, and bandwidth of the bandpass noise on gap-detection thresholds (e.g., 1, 2, 3, 9), little is known about the form of the psychometric functions. Knowledge of the psychometric functions is important for several reasons. First, if gap detection is to be used as a test of temporal resolution, efficient procedures must be developed. The most efficient procedures such as a Maximum-Likelihood, Yes-No procedure (4, 8) require knowledge of the approximate form of the psychometric function. Second, psychometric functions also show how the cue used to detect a gap (i.e., the listeners' decision variable) depends on the duration of the gap. Therefore, psychometric functions for gap detection may provide important insight into the mechanisms underlying gap detection and temporal resolution in the auditory system.

Whereas psychometric functions for gap detection have been measured for broadband noises (5, 6) and sinusoids (7, 10), no data are available for bandpass noises. Although their inherent variability affect gap thresholds (e.g., 1, 2), bandpass noises are likely to be useful stimuli to assess temporal resolution because their variability makes them somewhat similar to the time-varying sounds encountered in everyday listening situations. Therefore, the present study investigates psychometric functions for gap detection in bandpass noises.

METHOD

Stimuli: The signals were 85-dB-SPL bandpass noises with center frequencies, CFs, between 0.25 and 8 kHz. The bandwidth was three auditory-filter bandwidths, ERBs [calculated as 0.11*(f+165 Hz)], and the cutoffs were essentially infinitely steep. The gap was produced by setting samples of the bandpass noise to zero for the duration of the gap, which started 250 ms after the onset of the noise. To prevent listeners from hearing spectral splatter caused by the gap, the bandpass noise was presented with a complementary bandstop masker, whose spectrum level was 10 dB lower. The combined noises were filtered with a nine-ERB-wide filter to limit the bandwidth and loudness of the stimulus ensemble while keeping the spectral splatter inaudible. The filter characteristic ensured that the rise and fall of the gap was fast enough not to increase listeners' gap-detection thresholds appreciably.

Procedure and Listeners: Psychometric functions for gap detection were measured in three young listeners with normal hearing using a constant-stimulus procedure with a cued Yes-No paradigm. For each listener and CF, five (six at 0.25 kHz) gap durations were chosen to encompass the range of the psychometric function. In addition, a 0.5-ms gap was tested to provide an estimate of the false-alarm rate. Each trial consisted of two 786-ms intervals separated by 500 ms. The first interval never contained a gap. The second interval always contained a gap. The listener responded "Gap" if it was heard and "No Gap" if it was not. No feedback was given. Each point on an individual listener's psychometric function was based on 100 trials.

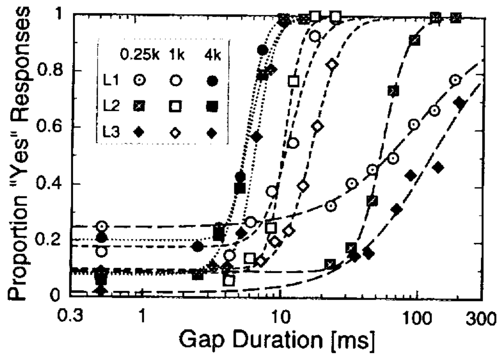

FIGURE 1. Psychometric functions for gap detection are shown for individual listeners tested at 0.25, 1, and 4 kHz as indicated by the legend. The best fitting logistic functions are shown by the dotted (0.25 kHz), short-dashed (1 kHz), and long-dashed (4 kHz) lines.

<u>Data Analysis</u>: To summarize the psychometric functions, the data for each listener and CF were fit by a logistic function ($P_{yes}=\alpha+[1-\alpha]/[1+\exp\{-k\cdot[\log(x)-\log(m)]\}]$, where α is the false-alarm rate, m is the midpoint of the psychometric function, and k is a free parameter).

RESULTS AND DISCUSSION

Fig. 1 shows examples of psychometric functions for the three listeners. As shown by the various lines, the logistic functions describe the data well. Except at 0.25 kHz, the psychometric functions are relatively similar across listeners. For L1 and L3, the slopes increase systematically with CF, but for L2 they are relatively similar at 0.25 and 4 kHz and steepest at 1 kHz. Nevertheless, taken across all listeners and CFs, the average slope increases with CF up to about 2 kHz as shown in Table 1. The false-alarm rate is relatively independent of CF, but varies considerably across listeners as shown in Fig. 1 (at 0.5 ms) and by the standard deviations in Table 1. The just-noticeable gap duration, defined as the midpoint, m, of the fitted psychometric function decreases systematically as CF increases. These gap thresholds are in excellent agreement with those obtained in our earlier study (1, 3).

These findings are mostly consistent with a model in which the decision variable is the decrease in the output of channels in which a short-term integrator is fed by the compressed output of the auditory filter. This model predicts the frequency dependency of the gap thresholds, except at 0.25 kHz where the predicted threshold is somewhat lower than that obtained. It also predicts psychometric functions that are similar in shape to those obtained, but the slopes of the predicted functions vary only slightly with frequency, contrary to the data. The model also indicates that the stimulus variability should have almost no effect on the gap thresholds at and above 2 kHz. The frequency dependency of the psychometric-function slope can to some extent be modeled if the compression increases with frequency. In any case, the data show that the slope of assumed psychometric functions for Maximum-Likelihood gap-threshold procedures can reasonably be constant at high CFs, but should decrease at lower CFs.

TABLE 1. Averages and standard deviations (in parentheses) of parameters for the logistic functions used to describe the psychometric functions. The range of plus and minus one standard deviation for m is the mean multiplied and divided by the error factor shown in parenthesis.

CF	α	k	m
0.25 kHz	0.12 (±0.12)	5.8 (±4.6)	88.1 (⋇1.54)
0.5 kHz	0.11 (±0.07)	11.1 (±2.7)	20.3 (⋇1.45)
1 kHz	0.12 (±0.05)	12.4 (±4.2)	12.7 (⋇1.28)
2 kHz	0.15 (±0.06)	15.2 (±2.4)	8.4 (⋇1.23)
4 kHz	0.12 (±0.07)	14.4 (±2.7)	5.9 (⋇1.09)
8 kHz	0.10 (±0.08)	15.1 (±5.8)	4.6 (⋇1.05)

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