Effects of concurrent and sequential streaming in comodulation masking release

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Introduction

Across-frequency comparisons of temporal envelopes are likely to be a general feature of auditory pattern analysis and may play an important role in extracting signals from noisy backgrounds, or in separating competing sources of sound. Comodulation of different frequency bands in background noise facilitates the detection of tones in noise, a phenomenon known as comodulation masking release (CMR). CMR is usually assumed to depend on comparisons of the outputs of different auditory filters. However, within-channel cues can also facilitate the detection of a signal in modulated noise (e.g., [1]). The present study attempts to clarify the extent to which CMR reflects within- and/or across-channel processes by assessing the influence of concurrent and sequential streaming cues on CMR. The hypothesis is that perceptual grouping may affect across-channel CMR while it should not affect within-channel CMR. If so, the differential effect of grouping cues may provide a functional definition of within- and across-channel.

Method

The signal was a 1000-Hz pure tone, 187.5 ms in duration including 20-ms raised-cosine ramps. The composite noise masker consisted of five bands of noise, each 20 Hz wide. Figure 1 shows the two different stimulus configurations. In the "narrowband" configuration, the noise bands were centered at 794, 891, 1000, 1123 and 1260 Hz representing a sixth-octave spacing around the signal frequency. In the "broadband" condition, the noise bands were centered at 250, 500, 1000, 2000 and 4000 Hz, covering a frequency range of 4 octaves with a one-octave spacing between the bands. The noise bands were generated in the time domain and restricted to the appropriate bandwidth in the Fourier domain.

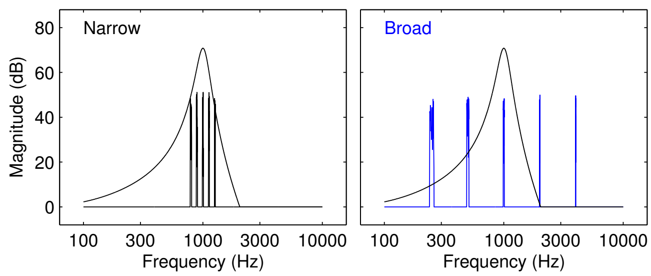

Figure 1: Left: Narrowband configuration where the masker bands were closely spaced in frequency around the signal frequency. Right: Broadband configuration where a larger spacing between the components was used. In addition, the magnitude transfer function of the Gammatone filter at the signal frequency is shown.

Comodulated noises were frequency-shifted versions of the on-frequency band. The level of each of the noise bands was 60 dB SPL

Thresholds for the 1000-Hz tone were measured in nine conditions, many of which are illustrated in Figure 2: (1) Single band condition (SB), where the on-frequency band was presented alone; (2) Random flanking bands (R); (3) Comodulated flanking bands (C); (4) Random flanking bands with fringe (FR), where the flankers were gated on earlier and gated off later (by 100 ms) than the on-frequency band; (5) Comodulated flanking bands with fringe (FC); (6) Random flanking bands, each preceded by four precursor bands (PR); (7) Comodulated flanking bands preceded by the precursors (PC); (8) Random flankers followed by four "postcursors" (PoR), or following bands and (9) comodulated flankers followed by four postcursors (PoC). The four pre- or postcursors were all the same duration as the on-frequency band and were separated by gaps of 62.5 ms, giving an overall repetition rate of 250 ms.

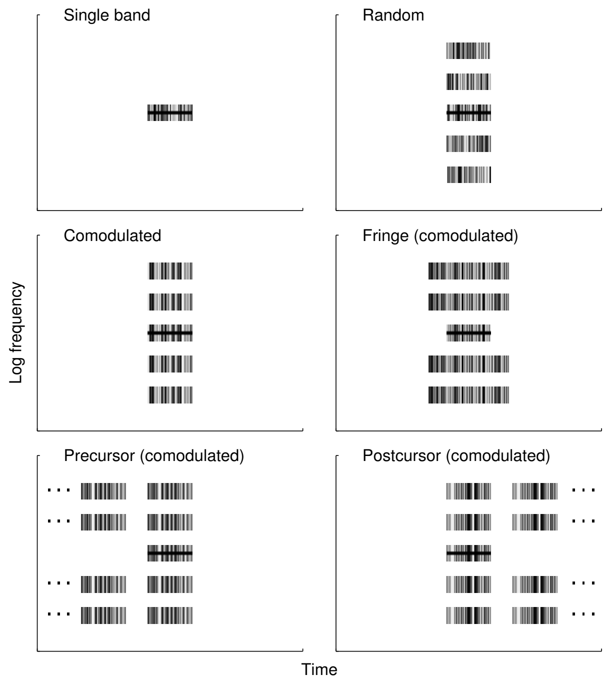

Figure 2: Experimental conditions: The upper row shows the single band (SB) and the standard random (R) condition. The middle row shows the comodulated (C) and comodulated fringe (FC) condition. The bottom row indicates comodulated flankers with precursors (PC) and with postcursors (PoC). The last three conditions promote the perceptual segregation of the on-frequency band.

An adaptive, three-interval, 3AFC procedure was used in conjunction with a 2-down 1-up tracking rule to estimate the 70.7% correct point of the psychometric function.

Results

The left panel of Figure 3 shows the mean data for the nine conditions (five subjects). The circles indicate thresholds obtained for the narrowband configuration and the squares represent thresholds for the broadband configuration. The triangle in the leftmost condition of the left panel represents the threshold for the single on-frequency band (SB). The right panel of Figure 3 shows the threshold differences obtained with random versus comodulated flanking bands. These differences represent the amount of CMR.

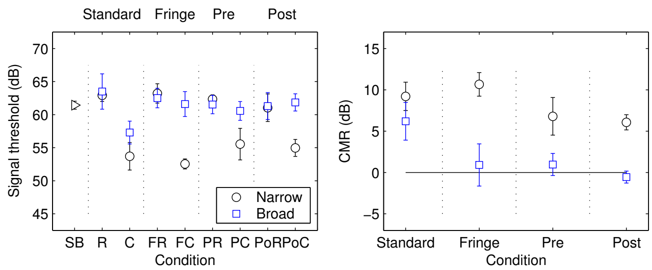

Figure 2: Left: Mean masked thresholds and standard deviations for the signal as a function of the stimulus condition. Thresholds for the narrowband configuration are indicated as circles. The squares represent thresholds for the broadband condition. Right: Threshold differences (CMR) for the standard, fringe, precursor and postcursor conditions.

In the narrowband configuration (circles), thresholds are always lower in the comodulated condition than in the corresponding random condition (left panel), leading to consistently positive CMRs (right panel). Using all conditions except SB, a highly significant main effect was found. In contrast, there were no significant differences between thresholds within either the comodulated conditions or the random conditions.

The results are different for the broadband configuration (squares). While there is a clear CMR effect of about 6 dB in the standard condition, no CMR is observed in any of the other conditions. Using all conditions except SB, the main effect was highly significant. As can be seen by the squares in the right panel of Figure 3, CMR was essentially eliminated in conditions promoting perceptual segregation of the on-frequency and flanker bands.

Discussion

The results from the broadband configuration show a very strong influence of factors designed to affect the perceptual grouping of the masker and flankers. All attempts to perceptually segregate the on-frequency masker from the flankers resulted in a complete elimination of CMR, suggesting that "true" across-channel CMR does not act in isolation from the processes that give rise to auditory object formation. While the effects of asynchronous gating of the masker and flankers, found here and in earlier studies (e.g., [2]) might in principle be explained in terms of some form of peripheral adaptation, such an approach is unlikely to succeed in accounting for the strong influence of the temporally following bands, "postcursors", which seem to influence the perception of the masker and flankers *after* their presentation. In contrast, the results from the narrowband configuration show no effect of grouping manipulation.

These results support the initial hypothesis that two different mechanisms contribute to CMR: results from the broadband conditions reflect across-channel mechanisms, which are susceptible to grouping manipulations, while the results from the narrowband conditions reflect within-channel mechanisms, which do not depend on variations of the acoustical context. It may be a general auditory organizational principle that access to higher-order percepts is via objects rather than outputs of peripheral auditory channels.

Summary and conclusions

The effects of introducing a gating asynchrony or a stream of preceding or following flanker bands were studied for conditions of CMR:

- Using widely spaced flanking bands (broadband configuration), CMR effects were eliminated by introducing a gating asynchrony between the on-frequency masker and the flanking bands, by introducing precursor flanking bands, and by introducing temporally following flanking bands.
- Using narrowly spaced flanking bands (narrowband configuration), CMR was not affected by any of the stimulus manipulations tested here.
- These results suggest two forms of CMR. One is based on within-channel mechanisms (e.g., [1]) determined by the stimulus envelope statistics, which is peripheral in nature and thus may not be susceptible to manipulation by auditory grouping constraints. The other is based on across-channel comparisons and seems dependent on auditory grouping constraints.
- The dependence of across-channel CMR in the broadband configuration on auditory grouping places strong constraints on potential neural substrates for CMR [3]. In particular, it seems unlikely that these effects can be accounted for by processing in auditory brainstem or below.

References

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