Cuing effects for modulation informational masking

Christopher Conroy and Gerald Kidd, Jr.
Department of Speech, Language & Hearing Sciences and Hearing Research Center Boston University

Background

The detectability of target sinusoidal amplitude modulation (SAM) can be reduced if masker SAM of a similar rate is present in the same carrier region (Bacon and Grantham, 1989), presumably reflecting limitations imposed by relatively "peripheral," rate-selective channels (Dau et al., 1997). In a recent study, we showed that this reduction can be made much worse if the masker rate is uncertain, presumably reflecting limitations imposed by more central mechanisms (Conroy and Kidd, 2021; see Fig. 1). We termed this finding "modulation informational masking" and speculated that modulation informational masking, by way of analogy to "spectral informational masking" (cf. Durlach et al., 2003), reflects an adverse effect of masker AM rate uncertainty on the ability to focus selective attention on the target AM channel.

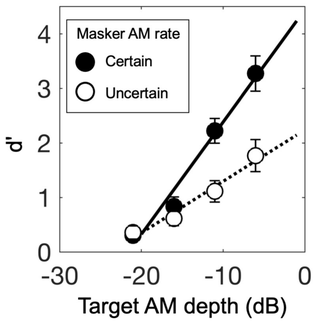


Fig. 1: Adapted from Conroy and Kidd (2021). Psychometric functions for the detection of target SAM (32 Hz) in the presence of simultaneous masker SAM (8 to 128 Hz, two octave "protected zone") imposed on a broadband noise carrier. Masker rate was either certain (i.e., fixed) or uncertain (i.e., random) on each yes-no detection trial. Symbols give the mean *d′* +/- 1 standard error across eight observers. Lines are average psychometric functions based on fits to the individual *d′* data.

Current study

We examined the effectiveness of a pretrial acoustic cue to either the target or masker AM rate in reducing modulation informational masking (cf. Richards and Neff, 2004). **Hypothesis:** We hypothesized that both cue types would be effective in reducing the effects of masker AM rate uncertainty, and therefore in reducing modulation informational masking, potentially by promoting selective attention to the target AM channel.

Methods

Task and observers: **Task:** Yes-no target SAM detection in the presence of simultaneous masker SAM imposed on the same (noise) carrier (i.e., a "tone-on-tone" modulation masking task; cf. Bacon and Grantham, 1989). **Observers:** N=4.

Stimuli: **Target:** 32 Hz SAM (random phase) at one of two depths: a "low" depth [*m*=0.30, ~-10 dB in terms of 20log(m)] and a "high" depth (*m*=0.48, ~-6 dB). **Masker:** Single SAM component (random phase, *m*=0.52, ~-6 dB) with a rate selected at random on each trial from 18 possible rates spanning the range 4 to 256 Hz (excluding 16 Hz protected zone). +/-10% jitter applied after rate selection. **Carrier:** 500-ms broadband noise. **Other details:** Masker SAM or target SAM+masker SAM applied to the entire 500-ms carrier duration. Following the application of AM, the waveform was filtered (250 to 4000 Hz), gated (5-ms cosine^2 ramps), and scaled to an overall level of 80 dB SPL.

Procedures: **Conditions:** (1) No cue, (2) target cue, and (3) masker cue. **Trial structure:** In cue conditions, a cue interval preceded each yes-no trial interval by 500-ms (silence). The cue interval was matched to the trial interval in all relevant respects: for example, on masker cue trials, the cue interval was 500-ms and the carrier, the masker rate, and the masker phase were the same as in the trial interval; it was 80 dB SPL. **Data collection:** Six estimates of *d′* were obtained for each condition-by-target depth combination for each observer to arrive at the final *d′* estimate for each observer.

Results

Fig. 2: **Left panel:** *d′* for all conditions. Bars give the mean *d′* for each condition (abscissa) and target AM depth (parameter). Error bars are standard errors of the mean (SEM). Small symbols give individual data. **Right panel:** Mean cue benefit (cued minus uncued performance) in *d′* units. **Stats:** two-way, repeated-measures analysis of variance (ANOVA): significant main effects of cue type (no cue, target cue, masker cue; p<0.05) and target depth (low, high; p<0.05) but no significant interaction.

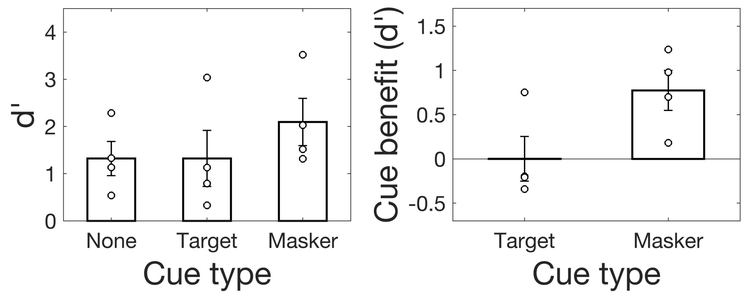
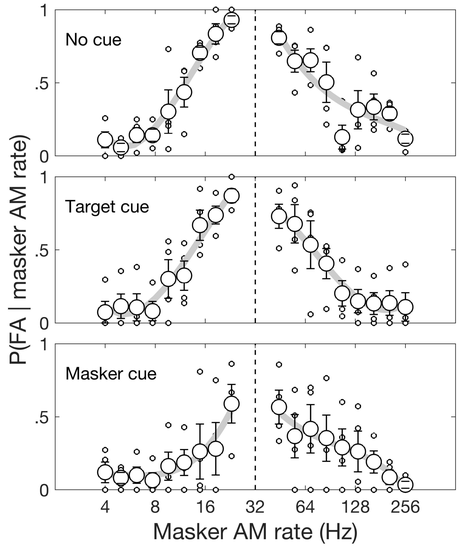


Fig. 3: As in Fig. 2 but averaged across target depths following the results of the ANOVA. **Stats:** Post-hoc t-tests indicated that a cue to masker rate yielded a significant *d′* benefit relative to the no cue condition (p<0.05), but that a cue to target rate did not.

Results cont'd

Fig. 4: Probability of a false alarm (FA) conditional on masker AM rate plotted as a function of masker AM rate for each condition (panels). Large symbols give the mean and SEM across listeners; small symbols give individual data. Solid lines are least-squares fits to the data, fit separately to the data below and above the protected zone. The dashed lines mark the target AM rate (32 Hz). These functions can be conceptualized in terms of the distribution of attention across the AM spectrum. Attention to a particular region should yield high probabilities for masker rates in that region. In all conditions, FAs were more frequent for masker rates close to the target rate vs. for those that were not, suggesting focused attention in the region of the target AM channel. FA rates were reduced, however, for nearby maskers in the masker cue condition, suggesting a narrowing of attention about the target AM channel.



Discussion

Summary: We tested the effects of a pretrial acoustic cue to either the target or masker AM rate in a tone-on-tone modulation masking experiment characterized by a high degree of masker AM rate uncertainty. We assumed that this uncertainty produced modulation informational masking and were interested primarily in the extent to which the different cue types reduced its effects. A pretrial cue to masker rate was effective in reducing modulation informational masking, yielding a small, but significant improvement in *d′*; a cue to target rate, however, was not, and did not (Fig. 2 and 3). An analysis of the attentional strategies used by the observers (Fig. 4) suggested that the masker cue effected a narrowing of selective attention about the target AM channel.

Interpretation: At a qualitative level, the results of the current study lend credence to the hypothesis that modulation informational masking reflects an adverse effect of masker AM rate uncertainty on the ability to focus selective attention on the target AM channel, and that a cue to masker AM rate can reduce this effect. Alternatively, it is possible that adaptation of the masker AM (i.e., "adaptation of masking"; Viemiester, 1980) played a role in the masker cue benefit. Such an account would also be consistent with the lack of an effect of a cue to target rate, although it could also be argued that such a cue would do little to counteract masker AM rate uncertainty. Work designed to tease apart these interpretations is ongoing.

References

- Bacon, S. P., and Grantham, D. W. (1989). Modulation masking: Effects of modulation frequency, depth, and phase. *The Journal of the Acoustical Society of America, 85*(6), 2575-2580.
- Conroy and Kidd (2021). Informational masking in the modulation-frequency domain. *The Journal of the Acoustical Society of America, submitted.*
- Cousineau, D. (2005). Confidence intervals in within-subject designs: A simpler solution to Loftus and Masson's method. *Tutorials in quantitative methods for psychology, 1*(1), 42-45.
- Dau, T., Kollmeier, B., and Kohlrausch, A. (1997). Modeling auditory processing of amplitude modulation. I. Detection and masking with narrow-band carriers. *The Journal of the Acoustical Society of America, 102*(5), 2892-2905.
- Durlach, N. I., Mason, C. R., Kidd Jr, G., Arbogast, T. L., Colburn, H. S., and Shinn-Cunningham, B. G. (2003). Note on informational masking (L). The Journal of the Acoustical Society of America, 113(6), 2984-2987.
- Richards, V. M., and Neff, D. L. (2004). Cuing effects for informational masking. *The Journal of the Acoustical Society of America, 115*(1), 289-300.
- Viemeister, N. F. (1980). "Adaptation of masking," in *Psychophysical, Physiological and Behavioural Studies in Hearing*, edited by G. van den Brink and F. A. Bilsen (Noordwijkerhout, The Netherlands), pp. 190–199.