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Forward masking of amplitude modulation detection includes a large perceptual effect

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Background

Forward masking of amplitude modulation (AM) detection is tuned: target sinusoidal AM (SAM) is masked more easily, for example, by masker SAM with a similar, rather than dissimilar, AM rate [Wojtczak and Viemeister, J. Acoust. Soc. Am. **118**, 3198-3210 (2005)]. **Two hypotheses:** Two hypotheses have been offered to account for this finding: **(1)** it is a sensory effect related to interference between the target and masker within a modulation channel tuned to the target's AM rate; **(2)** it is a perceptual effect related to the perceived similarity of the acoustically similar AM. The purpose of this study was to examine these two alternative possibilities.

Approach

We manipulated the perceived similarity of the target and masker modulators in a forward masking of AM detection paradigm. We reasoned that if the pattern of forward masking that was observed across maskers differed from what was expected based on within-AM-channel interference, it would indicate that the perceived similarity of the target and masker modulators was an important factor in producing masking. More specifically, we examined whether a square-wave masker modulator would produce as much masking of its third harmonic as a masker modulator comprising the third harmonic alone, the former being perceptually dissimilar from, and the latter being perceptually similar to, the third-harmonic target [cf. Nachmias et al., Vis. Res. **13**, 1335-1342 (1973)]. **Predictions of the two hypotheses:** The within-AM-channel interference hypothesis (1) predicts that the square-wave masker should produce at least as much masking as the third-harmonic masker; the perceptual similarity hypothesis (2) predicts that the square-wave masker should produce less.

Methods

- **Task:** AM detection with and without a forward masker modulator
- **Observers:** Three (highly experienced in psychophysical tasks)
- **Carrier:** Broadband noise (650 ms total duration, 60-dB SPL overall level)
- **Target:** 96-Hz SAM staring 540 ms after carrier onset (6-cycles/62.5 ms total duration)
- **Maskers:** Applied to initial 500 ms of carrier (see **Fig. 1** and **2** for details)
- **Procedure:** 3I-3AFC adaptive; three-down one-up stepping rule

Conditions

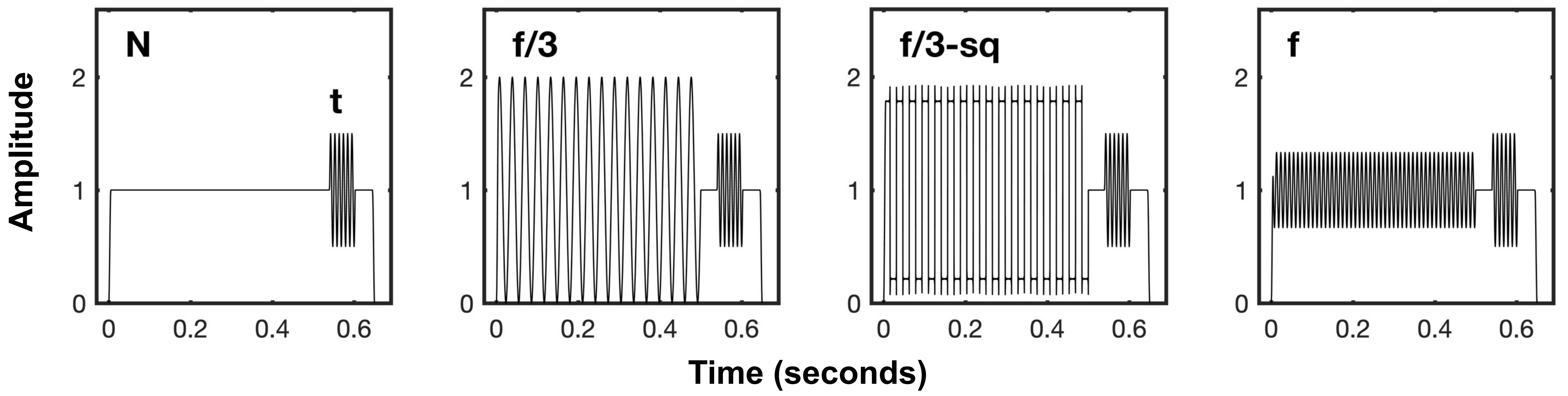

Fig. 1: Example envelopes for the different conditions. Each panel shows the envelope for a different condition with the condition names given by the inset text. **N:** No masker; **f/3:** 32 SAM with a modulation index (m) of 1. **f/3-sq:** 32-Hz square wave with a fundamental that had a modulation index of 1. Note that the square wave only included the first 99 odd harmonics of 32 Hz, hence the imperfect square shape. **f:** 96-Hz SAM with a modulation index of 0.33, i.e., the modulation index of the 96-Hz third harmonic of the 32-Hz square wave (cf. **Fig. 2**). The target (**t**) was 96-Hz SAM. In the experiment, the masker modulators had the modulation indices shown here; the modulation index of the target was the independent variable but in these examples is 0.5.

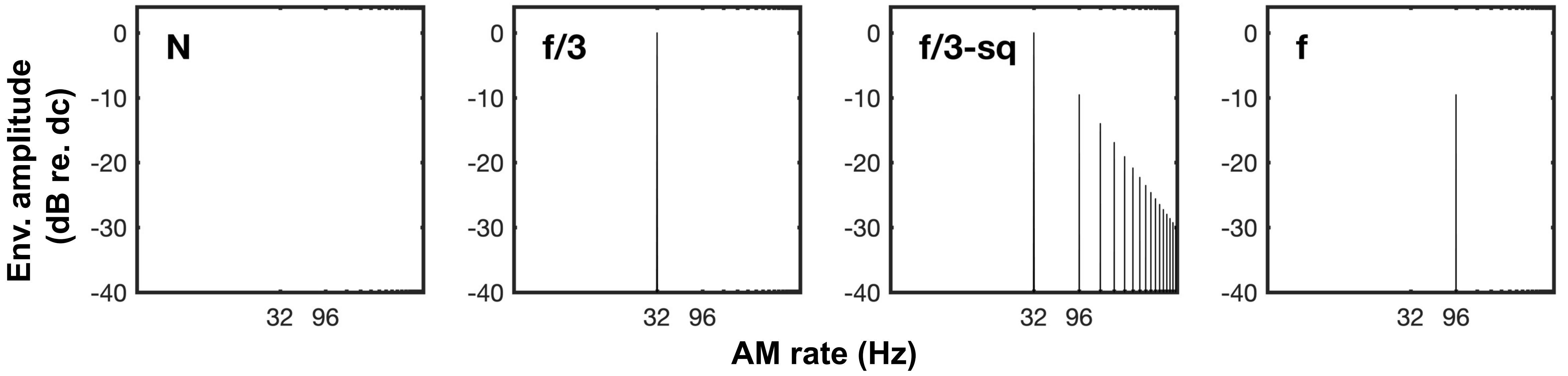

Fig. 2: Amplitude spectra of the masker envelopes, i.e., the first 500 ms of the envelopes shown in **Fig. 1**.

Results

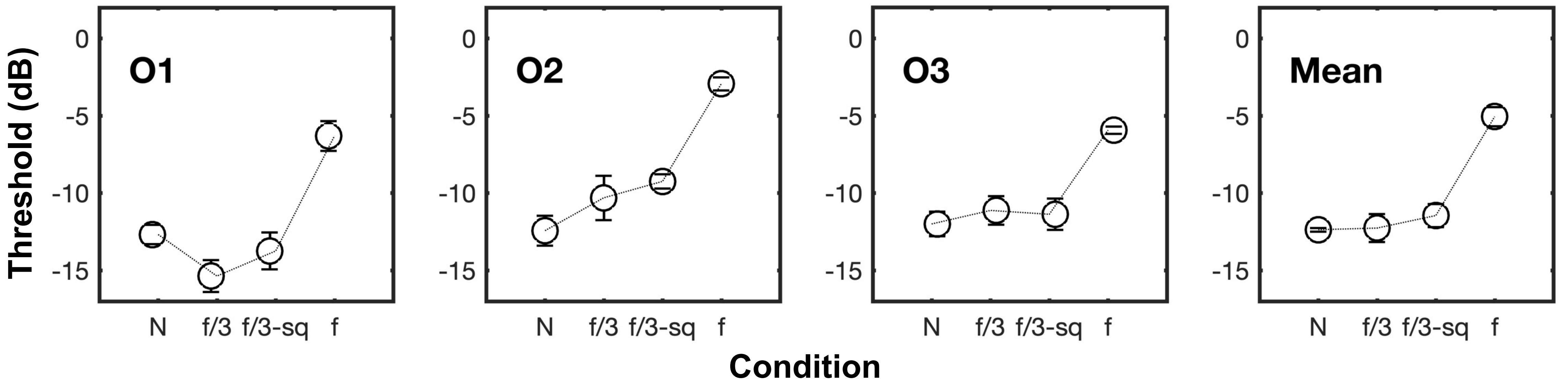

Fig. 3: Target-modulation-detection thresholds for the three observers and the mean across observers (different panels, see inset text) for all conditions. Error bars in the individual observer plots give +/-1 standard deviation across the four threshold replicates provided for each condition. Error bars in the group-mean plot give +/-1 standard error of the mean.

Discussion

The square-wave masker (f/3-sq) did not produce as much masking of its third harmonic as the masker comprising the third harmonic alone (f). **Returning to the two hypotheses:** The results, therefore, were more consistent with the perceived similarity hypothesis (2) than the within-AM-channel interference hypothesis (1). For example, one potential mechanism of interference is adaptation of a modulation channel tuned to the target's AM rate [e.g., Malone et al., J. Neuro. **35**, 5904-5916 (2015)]. If adaptation was the primary factor responsible for producing masking, masking should have increased with the power of the masker at the output of the target-AM channel. This is not what we found (**Fig. 4**).

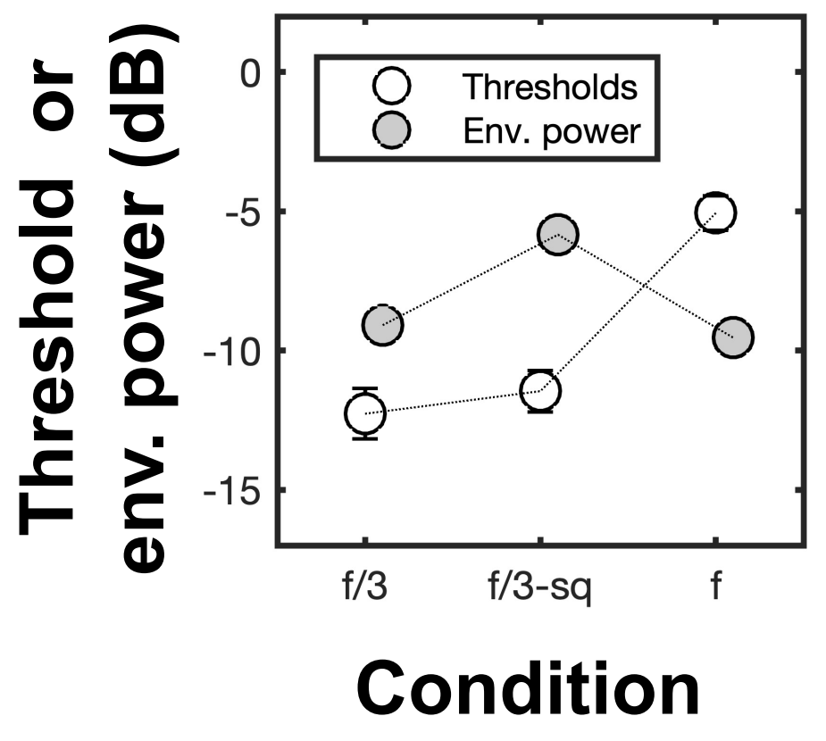

Fig. 4: Envelope power in dB at the output of a modulation channel tuned to the target's AM rate (96 Hz) for the different maskers plotted along with the mean thresholds (+/-1 standard error) for the same maskers (cf. **Fig. 3**). Estimates of envelope power were obtained using the model described by Ewert and Dau [J. Acoust. Soc. Am. **108**, 1181-1196 (2000)] and an AM channel with a Q value of 1.

Conclusions

The results suggested that forward masking of AM detection includes a large perceptual effect: masking did not conform to expectations based on within-AM-channel interference. Similar findings have been reported previously [Wojtczak and Viemeister (2005); Fullgrabe et al., Hear. Res. 405, 108244 (2021)]. An important new finding reported here, however, is that masking decreased with target-masker dissimilarity, despite an increase in masker envelope power. Dissimilarity may not have been the only factor driving this effect, however; across-AM-channel suppression, for example, could have played a role [cf. Shannon, J. Acoust. Soc. Am. **59**, 1460-1470 (1976)].

Acknowledgements

This work was supported by NIH-NIDCD grants No. R01DC004545 and F31DC019819