Perceptual Cue Robustness of Consonants under Noise Masking

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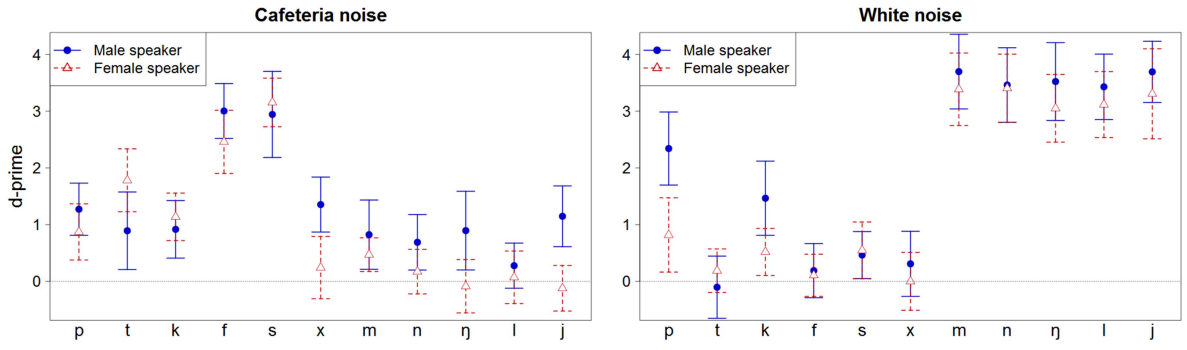
BACKGROUND: The unusual distributional patterns of sibilant fricatives in onset consonant clusters (e.g., [st]) pose challenges to sonority-based accounts of syllable structure. It has been proposed that sibilant fricatives have higher robustness of perceptual cues than other obstruents, allowing them to be positioned further away from nucleus without sacrificing correct identification [2]. The current study attempts to examine one of the proposed aspects of perceptual cue robustness: resistance of cues to environmental masking [3].

METHODS: An AX discrimination experiment was conducted to investigate consonant detection sensitivity under different types of masking noise. Auditory stimuli pairs were presented to subjects for "same or different" judgements and d-prime values were calculated. Presented stimuli were either a different pair [Cta]-[ta] or a same pair [Cta]-[Cta], where [C] denotes one of 11 target consonants ([p] [t] [k] [f] [s] [x] [m] [n] [ŋ] [l] [j]) cross-spliced to the same [ta] sequence, separated by a 50ms silence. The targets were recorded from 2 trained phoneticians (1 male, 1 female), and then equalized in pitch (to speaker mean F0), duration (to the shortest consonant), and intensity (to 60dB after A-weighting). White noise and cafeteria noise with 70dB(A) intensity were used for masking. Cafeteria noise was generated by summing 8 different cafeteria noise recordings and mixing with a 100-speaker-babble. A total of 512 trials were presented with noise type set as a between-subject factor in order to obtain sufficient responses for each consonant's d-prime calculation. Thirty subjects participated in the experiment (15 white noise).

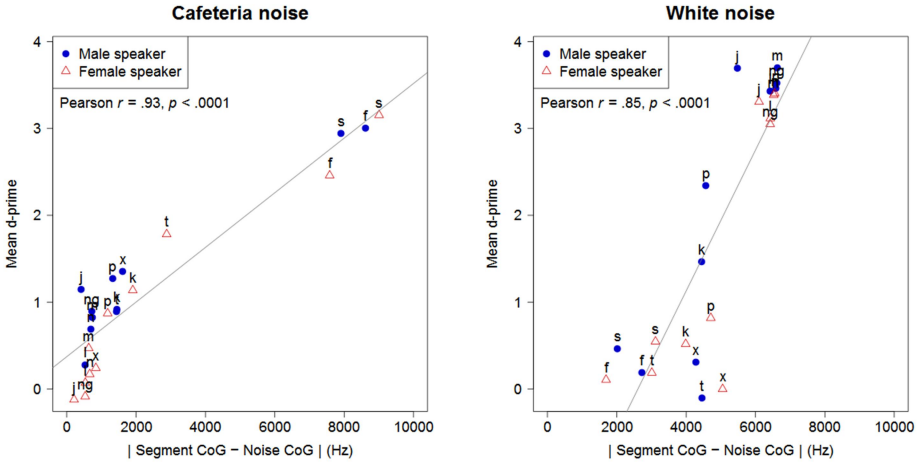
RESULTS: The resulting data fitted through linear mixed-effects modelling revealed several findings (Figure 1): (1) in cafeteria noise, [s] and [f] had significantly higher detection sensitivities than most other consonants ($p < .0001$); (2) in white noise, [s] and [f] had similarly poor performance as other obstruents; (3) sonorants were easy to detect in white noise but not in cafeteria noise.

Figure 1. Consonant detection sensitivity (d-prime) in two types of noise. Whiskers represent 95% confidence intervals.



Additional acoustic analysis revealed that the absolute difference between a target consonant's center-of-gravity (CoG) and a noise's CoG highly correlated with d-prime (Figure 2) in both cafeteria noise (CoG = 1068Hz, Pearson $r = .93$, $p < .0001$) and white noise (CoG = 6959Hz, $r = .85$, $p < .0001$). This |ΔCoG| is considered to be a gross measure of "acoustic difference" between a target consonant and a given noise, and appears to be a major contributing factor to the d-prime results.

Figure 2. Correlation of target consonant's mean d-prime and the absolute difference in CoG between consonant and noise.



DISCUSSION: The results partly support the view that sibilant fricatives have higher cue robustness than other obstruents, though only in cafeteria noise. This property serves to facilitate sibilant fricative detection even in syllabic positions where no other cue encoding mechanisms (such as formant transitions) are available. The high detection sensitivity of [f] in cafeteria noise could be a by-product of stimuli intensity equalization [1], and may not necessarily indicate high cue robustness in noise. On the other hand, sonorant consonants' spectral energy concentration in the lower frequencies may be responsible for their low detection sensitivities in cafeteria noise, which has a low CoG. However, this does not preclude sonorants from maintaining better cue robustness when a flanking vowel is present. Whether the current findings extend to other sibilants and a wider range of segments in different noise environments would call for further research.

References

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[3] Wright, R. (2004). A review of perceptual cues and cue robustness. In Hayes et al. (eds.) *Phonetically Based Phonology*, 34-57. Cambridge University Press.