

2pPP8

The effect of fundamental frequency in simulated electric-acoustic hearing

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Introduction

- Individuals with residual hearing restricted to low frequencies are candidates for electric-acoustic stimulation (EAS).
 - When low-frequency acoustic information is added to either real or simulated high-frequency electric stimulation, speech recognition often improves dramatically.
 - This may reflect the availability of fundamental frequency (f0) information in the acoustic region.
- » *The purpose of this experiment was to determine the contributions of f0, as well as amplitude envelope cues, to speech intelligibility in simulated EAS.*

General Framework & Rationale

- In simulated EAS, we replaced the low-pass speech with a tone having a frequency equal to that of the target talker's mean fundamental (184 Hz).
- By applying to the tone the dynamic changes in f0, the amplitude envelope of the low-pass speech, or both, we were able to assess the relative contributions of each cue to intelligibility.
- If EAS benefit can be demonstrated with a low-frequency tone carrying f0 (and/or the amplitude envelope), it is possible that impaired listeners with especially elevated low-frequency thresholds could benefit more from the tonal cue than from speech itself because it may be easier to make the entire narrow band cue more audible than the broader band speech.

Methods

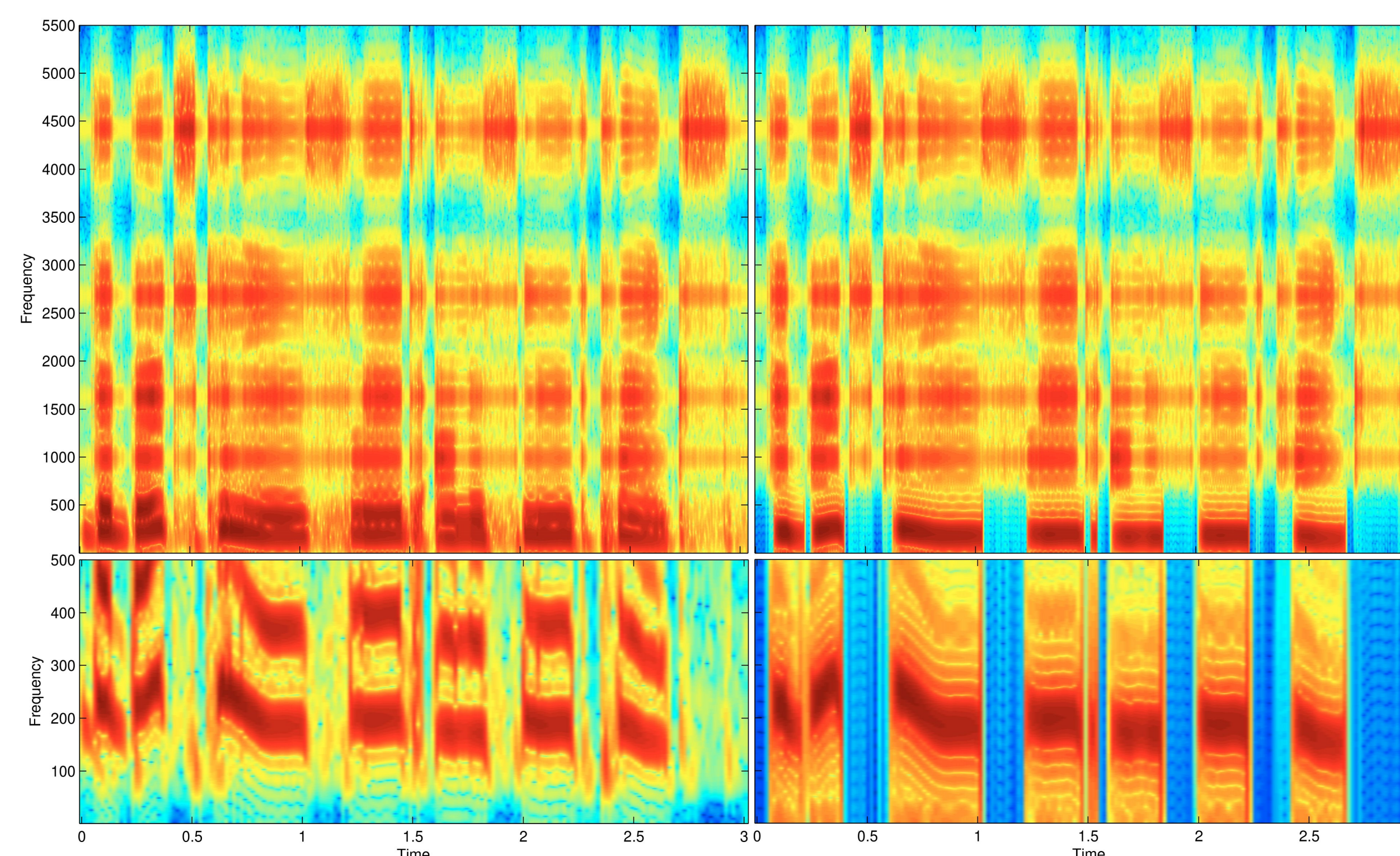


Fig. 1. Spectrograms of the vocoder plus low-pass speech condition (V/500; top left panel) and vocoder plus tone modulated in both frequency and amplitude (V/Tf0-env; top right panel) conditions. The bottom set of panels represents detailed views of the respective low-frequency cues alone.

- 25 individuals with normal hearing participated.
- Prior to testing, the dynamic changes in the female target talker's f0 were extracted using the YIN algorithm¹. Voicing onset/offset information was also extracted.
- Electric listening was simulated using a 4-channel vocoder that employed sinusoidal carriers. The contiguous bands were equally spaced along a log scale between 750 and 5500 Hz.
- 4 backgrounds were used: a different female talker, a male talker, 4-talker babble, and speech-shaped noise.
- Each background was combined with the target at a signal-to-noise ratio of +10 dB, and was presented only in the vocoder region.
- The stimulus in the low-frequency region was either low-pass speech (500-Hz cutoff) or a 184-Hz carrier tone. Voicing was always applied to the tone.
- The tone was unmodulated (except for voicing) and presented at the target talker's mean f0 (f0m), or modulated either in frequency with the extracted f0 (f0), in amplitude with the amplitude envelope of the 500-Hz low-pass speech (f0m-env), or both in frequency and amplitude (f0-env).

Methods (continued)

- The low-frequency cues were presented alone as well.
- Fig. 1 depicts spectrograms of the 4-channel vocoder combined with the 500-Hz low-pass speech (top-left panel) or the tone tracking f0 (top-right panel). The bottom panels show detailed views of the low-frequency cues.

Results

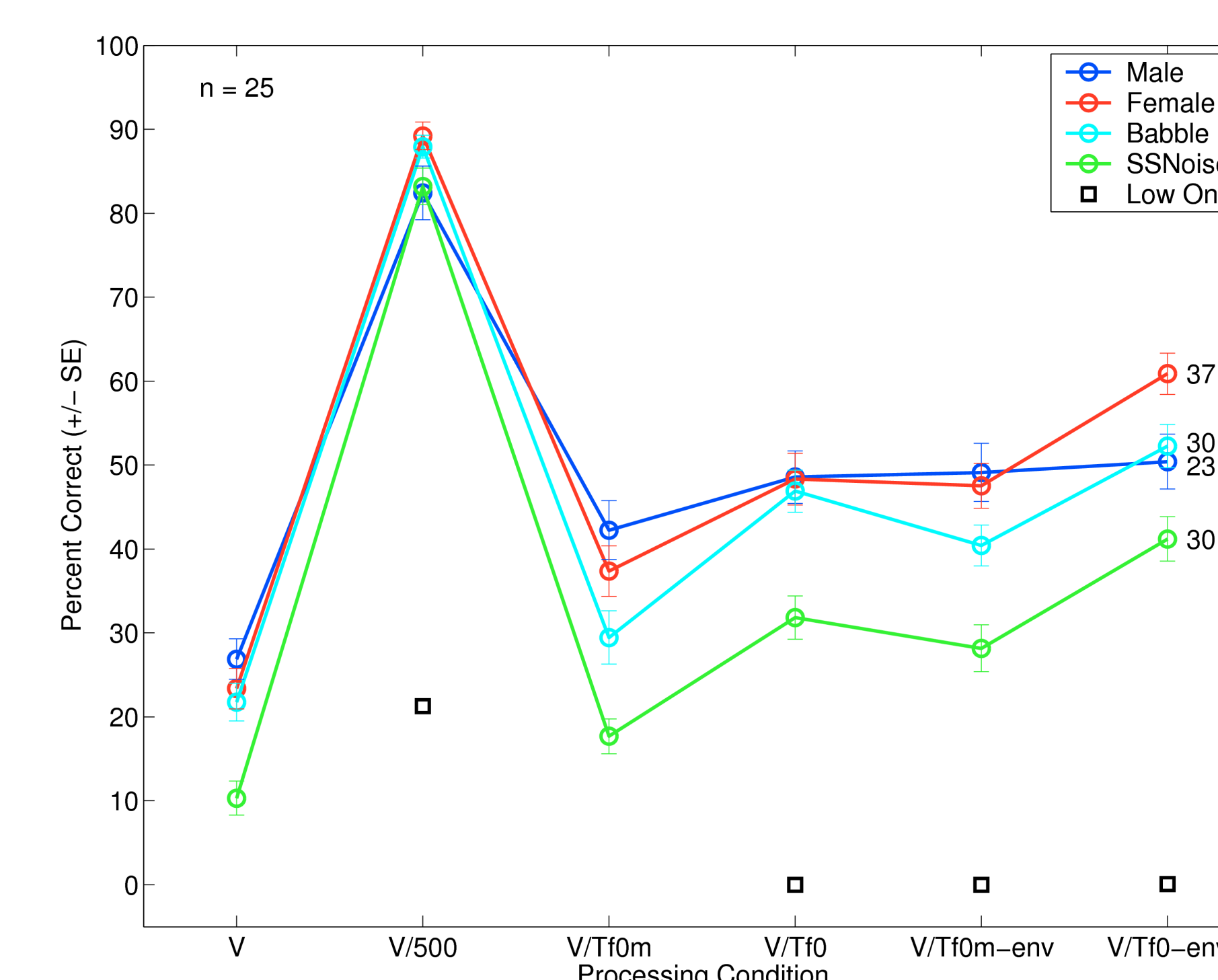


Fig. 2. Mean percent correct scores. Each plot represents a different background, which was present in the vocoder region only. Processing conditions are along the x-axis. The vocoder stimulation was presented alone (V), or with different low-frequency cues, which included low-pass speech (V/500), tone with only voicing applied (V/Tf0m), tone modulated in frequency (V/Tf0), tone modulated in amplitude (V/Tf0m-env), and tone modulated in both frequency and amplitude (V/Tf0-env). Mean intelligibility of the low-frequency cues by themselves is depicted by black boxes. Values to the right of the V/Tf0-env datapoints are percentage points of improvement over vocoder alone in that background.

- The pattern of results was similar across backgrounds.
- The f0 and envelope cues each provided roughly 20 percentage points of improvement over vocoder alone.
- Combining the two cues provided an average of about 30 percentage points of improvement.

Discussion

- A tone that tracks f0 can be combined with simulated electric stimulation in normal-hearing listeners to yield substantial benefit in intelligibility.
- The amplitude envelope provides additional benefit.
- Individuals with severely restricted residual hearing (who are not current EAS candidates) may stand to benefit from EAS.

[1] de Cheveigné, A. and Kawahara, H. (2002). "YIN, a fundamental frequency estimator for speech and music," J. Acoust. Soc. Am. 111, 1917-1930.