Effects of Frequency Compression on the Neural Encoding of Complex Sounds in the Human Brainstem

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Nonlinear Frequency Compression

- 2 parameters
  - Compression Ratio:
  - Start Frequency:
    - Decrease in bandwidth between signal spectra
    - Where compression begins
    - Everything below this limit is left "untouched"

Efficacy of NFC

- Perceptual studies with hearing-impaired individuals are not uniform and improvement is generally seen only for consonant identification, especially for the fricative /s/.
  - (Alexander, 2012; Glista et al. 2009; Glista et al., 2005; Simpson et al., 2009; Simpson et al., 2006)
- However, some perceptual results indicate that benefits for consonant identification might come at the expense of detriments in vowel identification as start frequency is lowered.
  - (Alexander, 2012; Parsa et al. 2013)
- While perceptual data exists, few physiologic methods have been employed to examine the effects of this frequency lowering technique

Specific Aim of the Study

- The specific aim of the current study is to characterize the changes in the neural encoding, examining both spectral and temporal attributes, in response to an incoming stimulus manipulated by nonlinear frequency compression.

Frequency Following Response (FFR)

- The FFR reflects sustained phase-locked activity in a population of neurons within the rostral brainstem, presumably at the level of the inferior colliculus.
  - (Worden & Marsh, 1968; Smith et al., 1975; Sohmer et al. 1977; Krishnan, 1999)
- EEG scalp recording
- FFRs assumed to be generated at the IC

FFRs assumed to be generated at the IC

- (Krishnan)
**Methods**

- **Participants**
  - 10 NH individuals

- **Stimuli**
  - Monaurally presented complex tones with a duration of 100 ms
  - Differed in parameters of start frequency (SF), compression ratio (CR), and fundamental frequency (F0)

- **Exp. 1: Compression Ratio (CR)**
  - Varied CR (Control, 1.75, 3.5) with a fixed SF of 1400 Hz

- **Exp. 2: Start Frequency (SF)**
  - Varied SF (Control, 1400, 1000, 600 Hz) with the CR fixed at 1.75

**RESULTS**

**Exp. 1: Effects of changing CR**

- Reduction in spectral magnitude for both envelope and temporal fine structure (TFS) information with increasing amounts of frequency compression.

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**FFR Acquisition**

- Monaural presentation through magnetically shielded inserts (Etymotic, ER-3A) at 80 dB SPL intensity at a repetition rate of 3.13/sec.
- Both condensation and rarefaction polarity to yield a total of 3000 sweeps

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- Reduction in spectral magnitude for both envelope and temporal fine structure (TFS) information with increasing amounts of frequency compression.
Exp. 1: Effects of changing CR

- Decrease in envelope and TFS pitch strength with increasing amounts of frequency compression.

Exp. 2: Effects of changing SF

- Reduction in spectral magnitude with decreasing start frequencies.

Exp. 2: Effects of changing SF

- Decrease in envelope and TFS pitch strength with decreasing start frequencies.
### Conclusions

- Results suggest that neural phase-locking to both envelope and TFS deteriorates when frequency compression of the stimulus has a deleterious effect on both the envelope periodicity and spectral resolution of the stimulus harmonic components.
- These stimulus manipulations also introduce envelope modulations which smear phase locked neural activity at the lower harmonics proximal to F0.
- Possible distortion products originating from the compressed region could also degrade neural encoding of the stimulus.
- These detrimental effects may have implications for the optimal representation of speech sounds with low second formant frequencies, which are important to distinguish vowels.
- Caution should be exercised with CR and SF settings aimed at improving speech intelligibility.

### References


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### Resources