Frequency-Following Responses Elicited by Chinese Consonant-Vowel Combination

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Introduction

- Voice pitch is important for listeners to process speech (Krishnan, Yisheng, Gandour, & Cariani, 2005), appreciate music (Wong, Skoe, Russo, Dees, & Kraus, 2007) and is related to reading (Chandrasekaran, Hornickel, Skoe, Nicol, & Kraus, 2009) as well as speech-in-noise processing (Hornickel, Skoe, Zecker, & Kraus, 2009).
- Frequency-following response (FFR), a scalp-recorded objective measure, has shown potential to help better understand the speech processing mechanisms and neural plasticity of the human brain.
- Scalp-recorded FFR, has been reported for normal-hearing adults who speak a tonal (Krishnan et al., 2005); (Swaminathan, Krishnan, & Gandour, 2008), and non-tonal language (Galbraith et al., 2004); (Aiken & Picton, 2006).
- Two types of stimuli have been used to record FFR response, the consonant vowel combination such as /da/ with equivalent pitch (Skoe & Kraus, 2010) and vowels such as /i/ with superimposed Mandarin intonation (Jeng, Chung, Lin, Dickman, & Hu, 2011).
- Given the success of recording FFRs using the stimuli mentioned above, it was **hypothesized** that combining the two stimuli would still be a feasible method in delineating the FFR trends for people who speak a tonal and non-tonal languages. It was also **hypothesized** that using this combined method would provide both an onset response and FFR response in the same recording thus eliminating the need for two separate recordings.

Methods

Participants

- 12 normal-hearing Chinese adults
  - Mandarin as a native language
  - Between 20 and 40 years of age
  - Non-musicians
- 12 normal-hearing American adults
  - English as a native language
  - Between 20 and 40 years of age
  - Non-musicians

Stimulus

- Combined the consonant /d/ and English vowel /i/ with a rising pitch contour

Procedure

- 3 gold-plated surface recording electrodes (High forehead, low forehead, and the right mastoid)
- Participants rest quietly or fast asleep prior to recording.
- Stimulus presentation : 75 dB SPL to the right ear
- Silent interval set to 200ms.

Data Analysis

- Recordings were examined in both time and frequency domains.
- Amplitude, Latency and Slope of the onset responses were examined.
- For the steady state response, three objective indices (Frequency Error, Tracking Accuracy and Pitch Strength) were used to estimate neural phase locking and frequency-encoding acuity.

Results

The Stimulus and Response in Time Domain

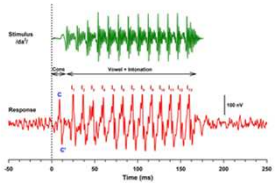

Figure 1 Temporal waveform of Frequency-following responses elicited by the consonant-vowel combination /da/ with a rising pitch contour. Both the onset response to the consonant and steady state response to the vowel are visible within the same waveform.

Spectral Response and Output

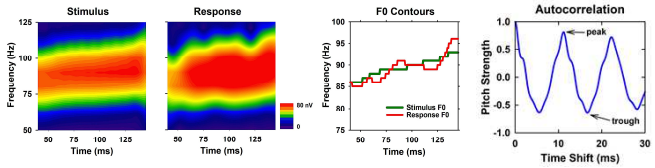

Figure 2 Spectral FFR trends for Frequency-following response elicited by /da/ compared to the stimulus (left). **Figure 3** Shows the F0 contour and autocorrelation output of a frequency-following response elicited by /da/ with a rising pitch contour (right).

FFR Trends with Respect to the Different Objective Indices

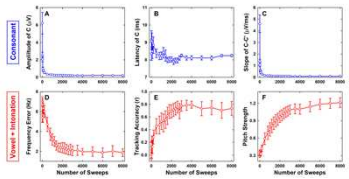

Figure 4 FFR trends for the Amplitude (A), Latency (B) and Slope (C) of responses to consonant portion of stimulus with increasing number of sweeps (top). FFR trends for Frequency Error (**D**), Tracking Accuracy (**E**), and Pitch Strength (**F**) with increasing number of sweeps for the vowel portion of stimulus (bottom).

Exponential Modeling of FFR Trends

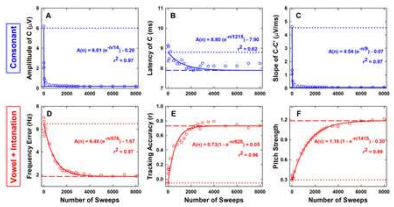

Figure 4 Exponential modeling of the FFR trends for the consonant (top) and vowel with intonation (bottom) with respect to the objective indices: Amplitude (A), Latency (B), Slope (C), Frequency Error (D), Tracking Accuracy (E) and Pitch Strength (F).

Findings

- Results demonstrated that it is possible to record brainstem responses to consonant and vowel sounds with intonation simultaneously.
- Combining the onset and steady state recording can save time and provide a rich representation of brainstem responses than consonant-vowels and intonation alone.
- Distinct response trends faithfully reflect acoustic aspects of the speech signal at the brainstem level and indicate the neural circuits for consonants and vowels with intonation may be different.

Conclusions

- Although English is a non-tonal language, speech cues such as voice pitch and intonation prove to be important to speech understanding.
- Stop consonants like /d/ contribute important phonetic information and pose great perceptual challenges to individuals with hearing loss, auditory processing disorders and learning impairments.
- FFR screenings with emphasis on speech and phase-locking synchrony could prove useful for early identification of children and adults who are at risk for auditory based difficulties.
- Knowing the acoustic properties of the syllable can provide a foundation for more precise programming strategies in hearing devices for individuals with hearing impairment.

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