Quality Estimation of Human Frequency-Following Responses

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INTRODUCTION

- The frequency-following response (FFR) is widely used to study speech and music perception, auditory processing disorders, and neural plasticity. It captures sustained neural phase-locking to sound but remains challenging to interpret due to its small amplitude and susceptibility to EEG noise (Krizman & Kraus, 2019).
- FFR recordings typically use fixed-sweep averaging to enhance the signal-to-noise ratio (SNR). However, this does not guarantee response quality, as neural synchrony and EEG noise vary across individuals and sessions. This variability limits clinical and research applications.
- A statistical metric is needed to assess FFR quality. A similar challenge in auditory brainstem response (ABR) recordings led to the Fsp algorithm (Don et al., 1984; Elberling & Don, 1984), which evaluates response reliability. Since ABR and FFR share characteristics, adapting Fsp for FFR could provide an objective quality assessment.
- The algorithm can be expressed: $F_{sp} = \frac{VAR(\bar{S})}{VAR(SP)}$
  - Where VAR(S) is the variance of the averaged signal,
  - VAR(SP) is the variance of the SP values across N number of sweeps
- We hypothesize that a robust FFR quality metric would enable:
  1. More reliable interpretation of responses
  2. Adaptive control over sweep numbers
  3. Enhanced automation of data collection

METHODS

Participants
- 15 college students (22.7 ± 1.7 years old) with normal hearing

Acoustic Stimuli
- ABR:
  - Rarefaction clicks, 33.7 clicks/s
  - 0, 20, 40, 60 dB nHL to the right ear
  - Pre-control and post-control conditions
- FFR
  - An English vowel /i/ with a rising frequency contour (F0 ranging from 102 to 140 Hz)
  - The stimulus has a duration of 150 ms (experimental condition), with a silent interval of 150 ms (control condition) at 60 dB nHL to the right ear.

EEG Recordings
- 3 gold-plated surface recording electrodes
- 8000 accepted sweeps for each recording

Fsp Parameters
- Time window
  - ABR: 1-11 ms for high intensities, 4-14 ms for low intensities and control conditions
  - FFR: 10-150 ms (experiment) and 160-300 ms (control)
- SP locations
  - ABR: 2, 3, 4, 5, 6, 7, and 8 ms
  - FFR: 20, 40, 60, 80, 100, 120, and 140 ms

Statistical Analyses
- ABR: Three-way ANOVA (intensities x N sweeps x SP locations)
- FFR: Three-way ANOVA (conditions x N Sweeps x SP locations)

Behavioral Measurements

Shorter Reaction Times to Mother Voice and Disyllables

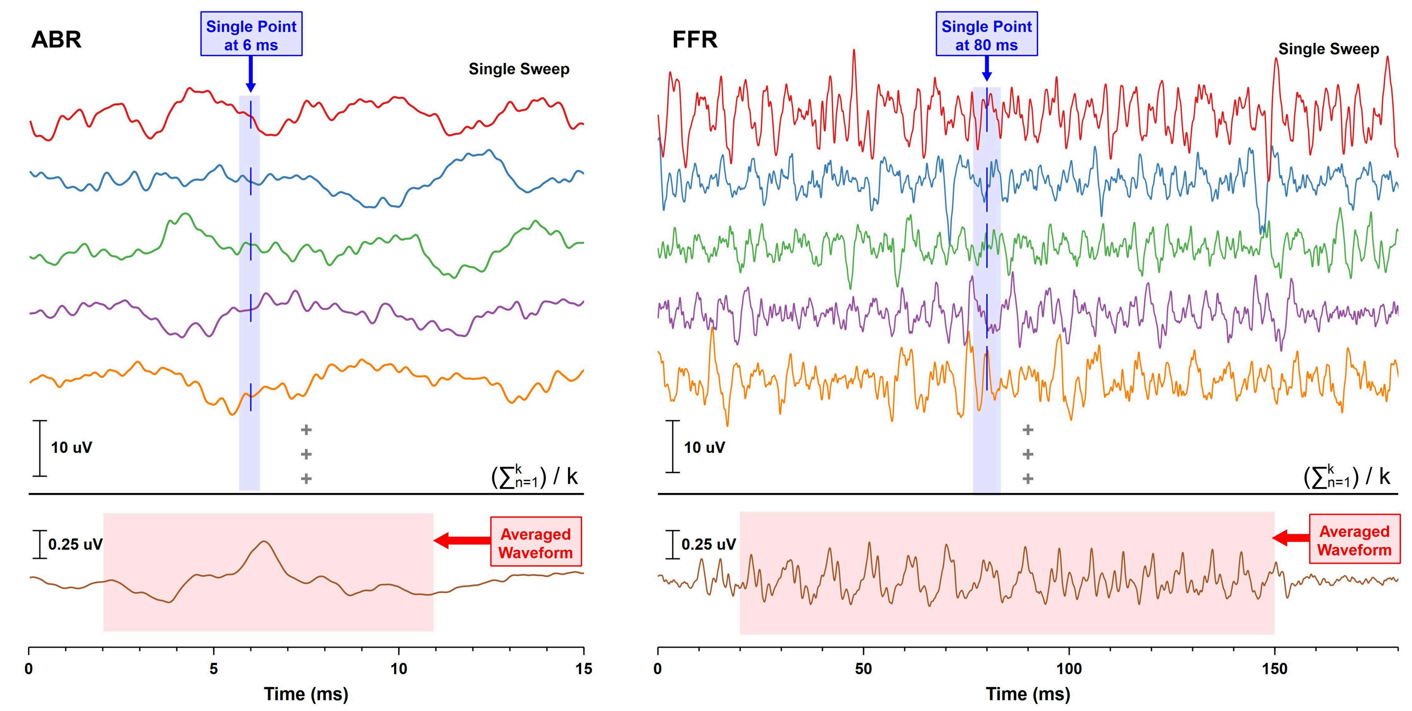
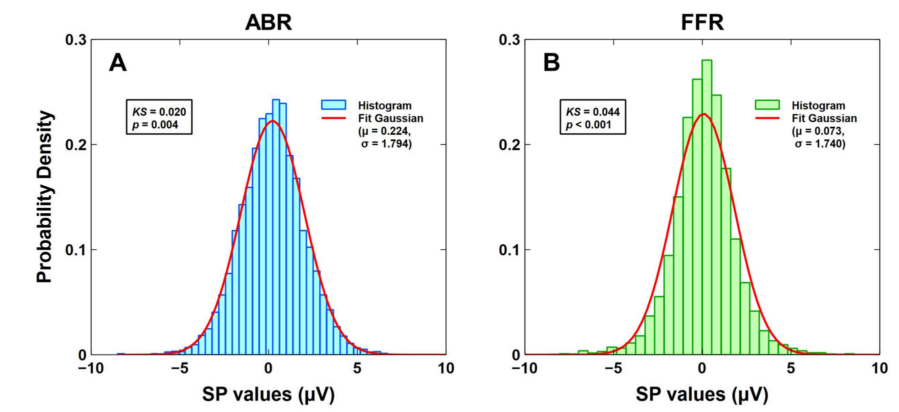
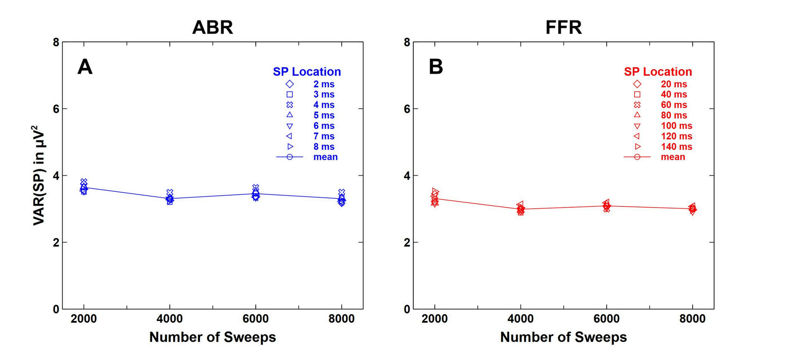


Figure 1. Behavioral reactions times were obtained from each participant (top left) by using custom-built software (top right). During the practice round of the behavioral portion, adult child participants are instructed to select whether they believe the randomized speech stimuli was their mother or a stranger. Incorrect responses produced an 'X' (bottom left) while correct responses produced a check mark (bottom right).

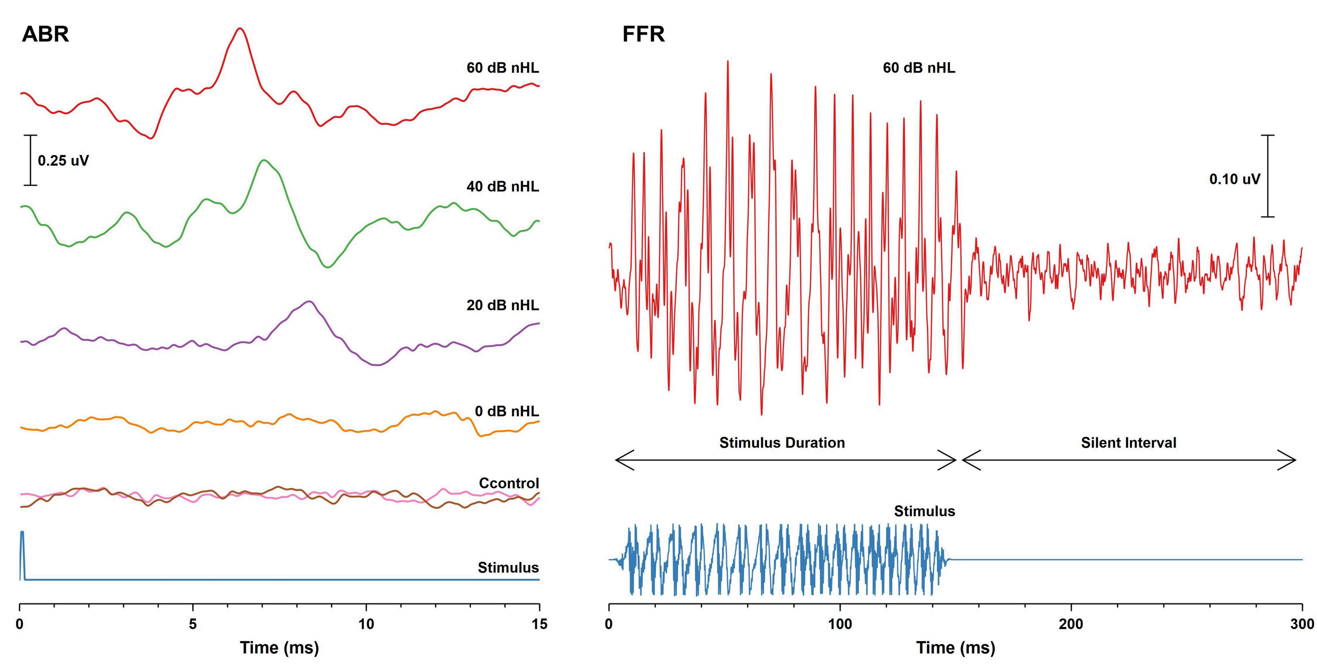


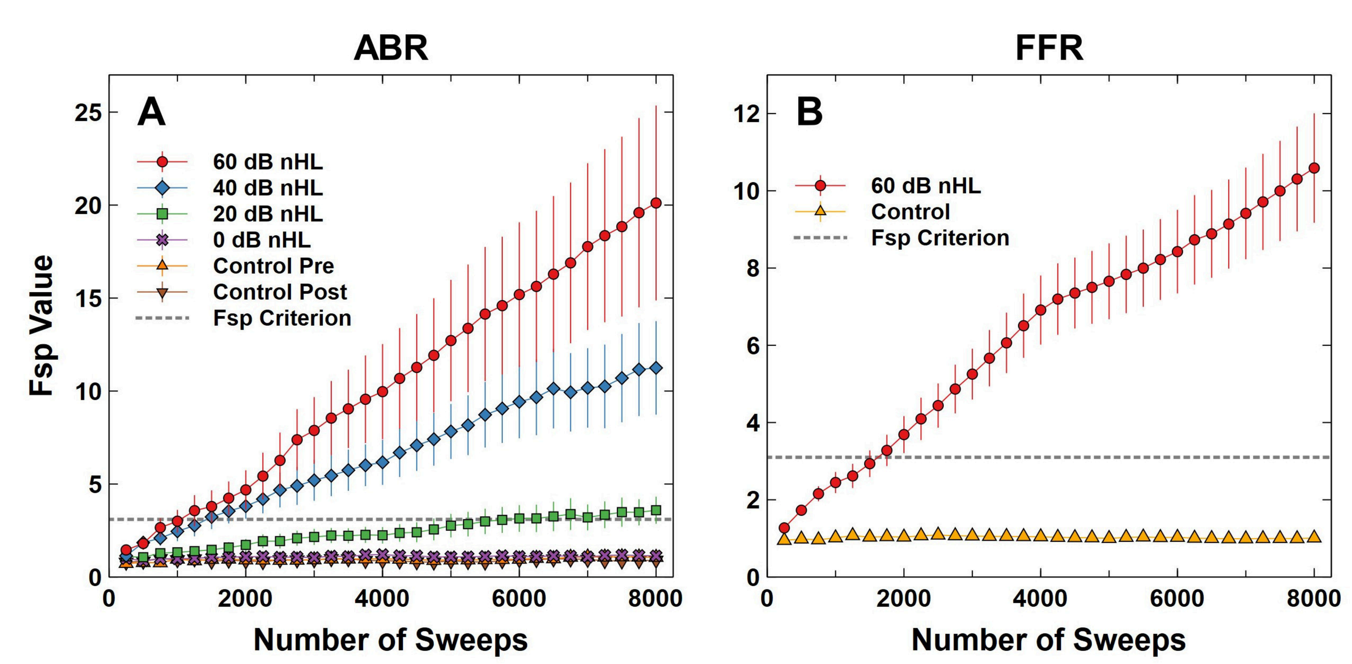


- The Fsp algorithm can be expressed:
- $F_{sp} = \frac{VAR(\bar{S})}{VAR(SP)}$
- Where VAR(S) is the variance of the averaged signal/response, VAR(SP) [illegible] across N number of sweeps

Figure 2. Behavioral responses are plotted for each of the 16 tokens for mother and stranger. [illegible] *into monosyllables and disyllables (left) and furthermore into mother versus stranger (right).*

Electrophysiological Assessment





Electrode Placement

Figure 4. Gold plate electrodes were placed on the high forehead, right mastoid, and low forehead to pick up neural activity elicited from hearing a speech stimuli through an insert ear tip placed in the right ear. Participants were encouraged to remain relaxed and still throughout testing.

Electrophysiological Respo[illegible] Findings

Figure 5. The spectrogram and time [illegible] *left indicates results from the mother* [illegible] *is on the right. The effective regions of* [illegible] *produced by the mother and stranger* [illegible]

[illegible] *ices were found to be* [illegible] *uency error (fe), slope* [illegible] *a), spectral amplitude* [illegible] *ot mean square (rms)*

	Paired Samples T-Test					
	Measure 1		Measure 2	t	df	p
fe	fe.mother		fe.stranger	0.081	10	0.937
se	se.mother		se.stranger	0.843	10	0.209
ta	ta.mother		ta. stranger	0.48	10	0.641
sa	sa.mother		sa.stranger	0.762	10	0.464
ps	ps.mother		ps.stranger	-1.405	10	0.19
rms	rms.mother		rms.stranger	0.956	10	0.361

DISCUSSION

- A significant difference ($p < 0.05$) was observed when comparing mothers' voices to female stranger voices. These findings show a cognitive advantage to processing familiar female, specifically maternal, voices.
- Additionally, disyllables show an improved behavioral response (e.g. shorter reaction time) to speaker identification.
- Our overall findings provide additional insight on how the brain is more efficient at processing familiar speech versus unfamiliar speech stimuli.
- There was no significance found in the electrophysiological assessment testing. A paired samples t-test was conducted for each of the six indices. When comparing the mother and stranger voice data for each index, the p value indicated non-significance for all findings.
- FFR findings and the behavioral mean reaction time were correlated using Pearson's r, but no significant correlation was found.
- Limitations of this study and future directions
  - A sample size of eleven college students limited generalizability of findings. With a larger sample size, findings could be further explored in subdivisions such as gender, age, etc.
  - While our study focused primarily on monosyllabic and disyllabic words, future studies could incorporate words of varying linguistic complexities.
  - We found significance between mother and female stranger voices, but excluded other familiar voices such as fathers, siblings, and other family members.

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