Aging effects on neural representation of vowel duration speech cues

Lindsey Roque, Logan Fraser, and Samira Anderson*
Department of Hearing and Speech Sciences, Program in Neuroscience and Cognitive Science
University of Maryland, College Park, MD, USA
*lroque@terpmail.umd.edu

INTRODUCTION

- Older adults experience increased speech perception difficulties compared to younger adults, especially in adverse listening environments.
- Behavioral and electrophysiological studies have demonstrated such difficulties may be attributed to age-related degradation in auditory temporal processing.[1-4]
- Reduced encoding of temporal envelope modulations and fine structure, and therefore limited access to temporal and spectral speech cues, respectively, contribute to older adults' increased difficulty distinguishing one word from another.[5]
- The Frequency-Following Response (FFR) reflects the temporal characteristics of the stimulus and may provide insight into the neural mechanisms underlying age-related temporal processing deficits.[6]

Does aging affect the subcortical representation and perception of vowel duration cues in speech?

METHODS

Participants

- Two participant groups: younger (YNH, n= 18, avg= 21 yrs) and older (ONH, n= 27, avg= 64 yrs) normal-hearing adults
- Audiometric thresholds ≤ 20 dB HL from 125 to 4000 Hz bilaterally
- Scores on the Montreal Cognitive Assessment (MoCA) ≥ 22

Stimulus presentation

- Contrasting word pair Wheat and Weed
- Stimuli are extrema of a Wheat-Weed continuum created by increasing vowel duration from 93 to 155 ms in increments of 7-8 ms

Auditory Midbrain EEG Recording

- Stimuli presented to the right ear at 75 dB SPL using alternating polarities
- Minimum of 3000 sweeps obtained for each stimulus
- Responses were recorded using the Biosemi ActiABR-2000 acquisition system and digitized at 16,384 Hz
  - Offline bandpass filtered from 70-2000 Hz using zero-phase, 4th order Butterworth filter and averaged over 660 ms

Perceptual Identification Functions

- 2-alternative forced-choice identification task for stimuli along Wheat-Weed continuum of vowel duration from 93 to 155 ms
- Stimuli presented to the right ear at 75 dB-A

Data Analysis

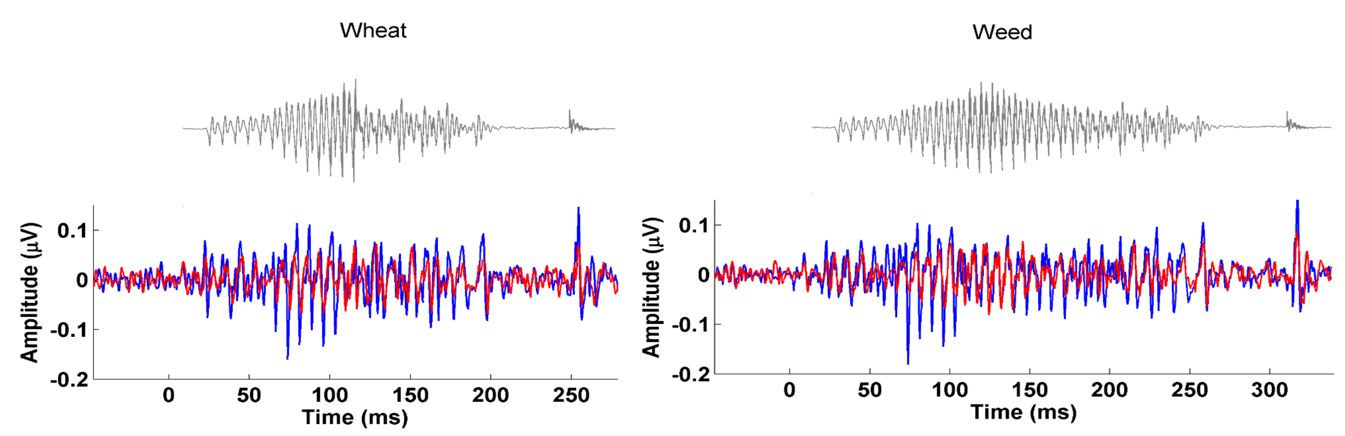
- EEG
  - *Stimulus-to-response correlation (STR):* Cross-correlation was performed by shifting the stimulus waveform in time relative to the response waveform until a maximum correlation was found between the stimulus and region of the response from 10-300 ms.
  - *Phase-locking factor: Temporal envelope (PLF_{ENV}):* Morlet wavelets were used to decompose the signal from 80 to 800 Hz. Individual PLF_{ENV} values to the f0 of stimulus vowel /i/ (100 Hz) were calculated and averaged for each group.
  - *Phase-locking factor: Temporal fine structure (PLF_{TFS}):* Morlet wavelets were used to decompose the signal from 300 to 1500 Hz. Individual PLF_{TFS} values to the F1 of stimulus vowel /i/ (400 Hz) were calculated and averaged for each group.
- Perceptual
  - *Identification Function:* Slope and 50% crossover points were calculated to determine the boundary for stimulus categorization

Statistical Analysis

- Pearson's correlations assessed relationships among the following: FFR STR values, FFR PLF_{ENV} and PLF_{TFS} during the vowel and final consonant intervals, and identification function crossover points and slopes.

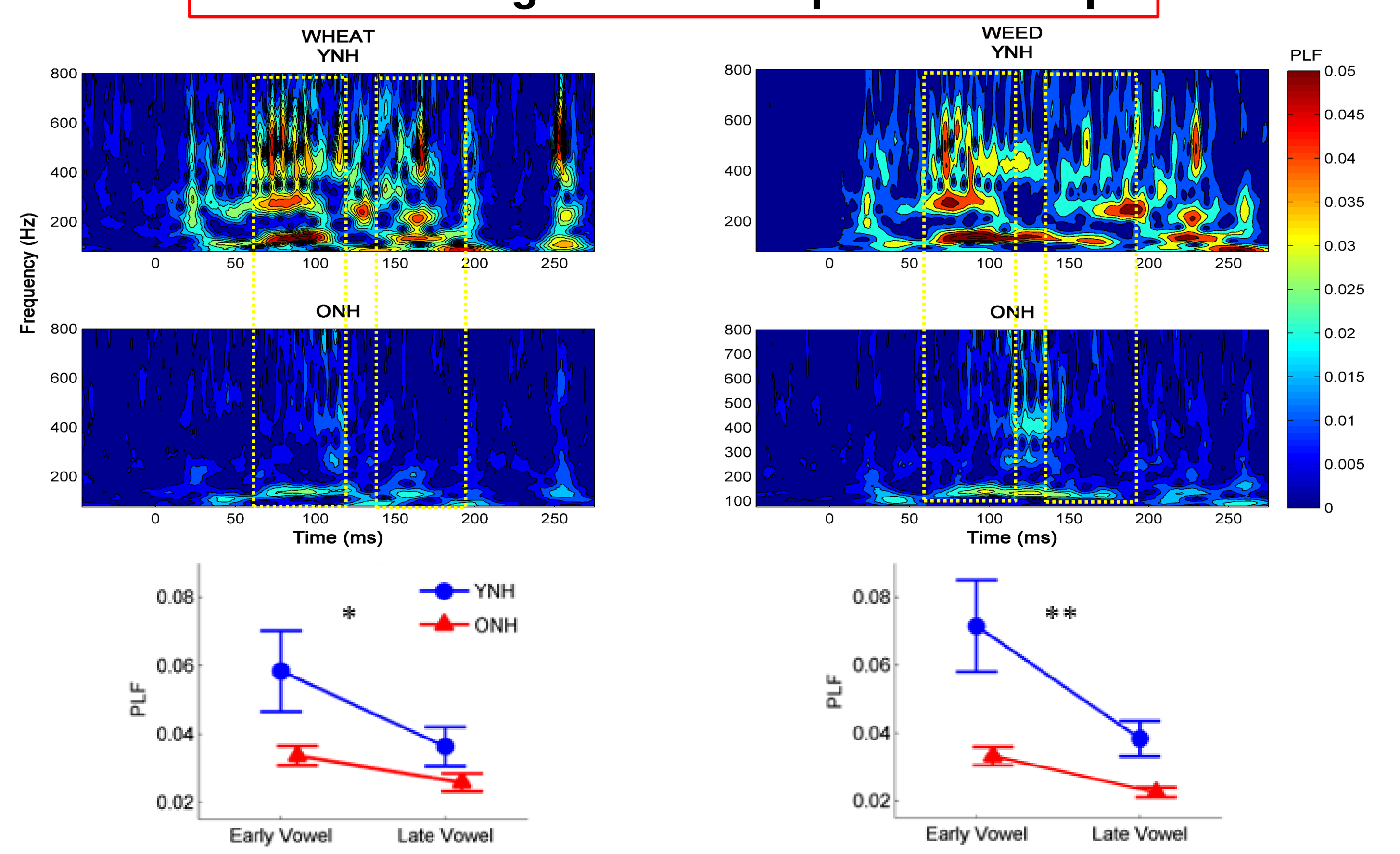
EEG RESULTS

Stimulus-to-Response Correlation



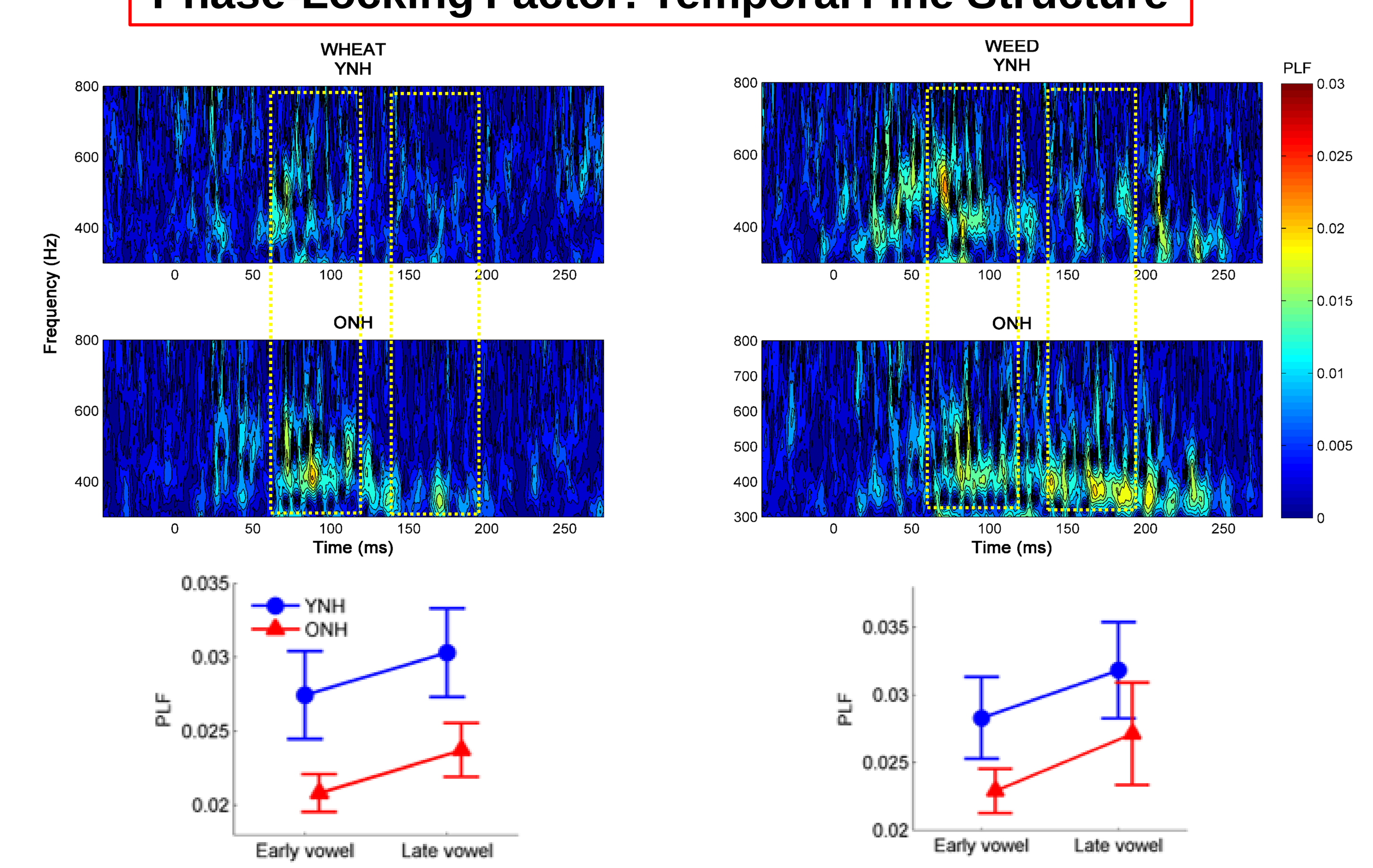
- Response waveforms in individual YNH and ONH mirror stimulus waveforms
- No significant group difference is observed to Wheat waveform ($p > .05$)
- YNH response waveforms better approximate Weed waveform than ONH ($p = .001$)

Phase-Locking Factor: Temporal Envelope



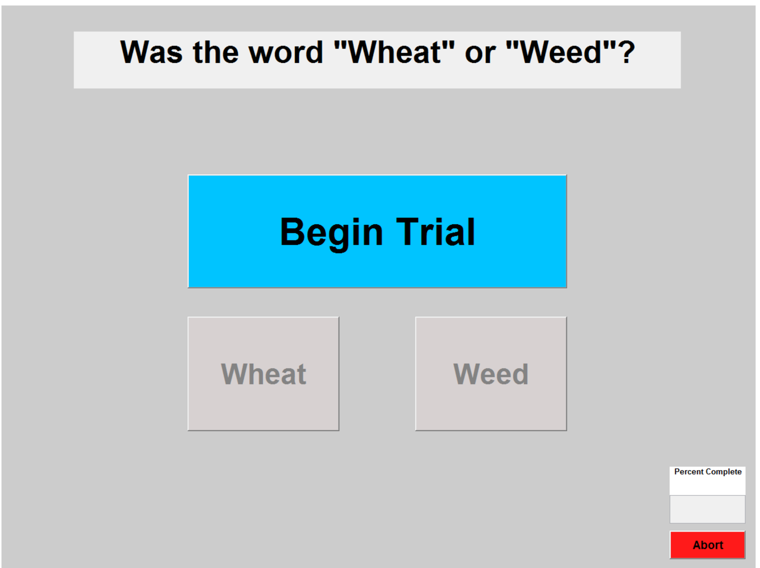
- YNH has more robust phase locking to both early and late regions of the vowel /i/ to temporal envelope of both Wheat and Weed compared to ONH (all p values < .05)
- Early and late vowel regions outlined by dashed yellow rectangles

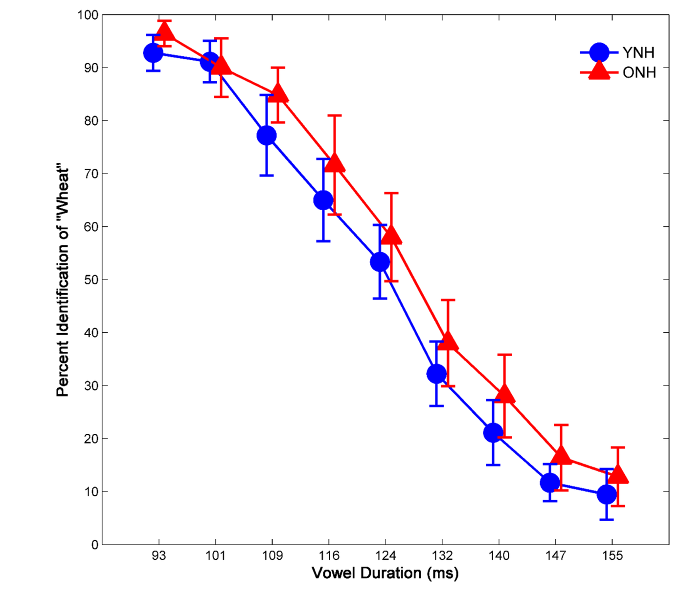
Phase-Locking Factor: Temporal Fine Structure



- YNH has more robust PLF values to both early and late regions of the vowel /i/ to fine structure of both Wheat and Weed compared to ONH (all p values < .05), except for the late vowel region in Weed ($p > .05$)
- Early and late vowel regions outlined by dashed yellow rectangles

PERCEPTUAL RESULTS





- No group differences are observed on slope or 50% perceptual crossover (all p values > .05)
- Higher STR correlations and PLF relate to the 50% crossover point in the identification functions

DISCUSSION

- **FFR**: Younger adults had more robust FFRs than older listeners, which may be attributed to age-related temporal processing deficits.
  - Decreased numbers of duration-tuned neurons in the inferior colliculus, accompanied by delayed neural recovery in the rostral brainstem, may inhibit older adults' ability to follow the temporal waveform of speech.[7]
- **Perceptual**: No significant group differences were observed for slope or 50% crossover point. Behavioral performance, however, was variable across participants.
  - Procedures replicated those in Gordon-Salant et al. (2006) and found similar group patterns.[4]
- **FFR-Perceptual Relationship**:
- **Future Directions**: Future analyses will examine the contributions of auditory nerve, early brainstem and cortical processing on these findings. Future studies will investigate aging effects on other temporal contrasts in speech.

References

1. Fitzgibbons PJ, Gordon-Salant S (1994). *J Speech Lang Hear Res* 37:662-670
2. Grose JH, Mamo SK (2010). *Ear Hear* 31:755-760.
3. Presacco A, Jenkins K, Lieberman R, Anderson S (2015). *Ear Hear* 36:e352-63
4. Gordon-Salant S, Yeni-Komshian GH, Fitzgibbons PJ, Barrett J (2006). *J Acoust Soc Am* 119:2455-2466
5. Walton JP (2010). *Hear Res* 264:63-69.
6. Skoe, E, & Kraus, N. (2010). *Ear Hear,* 31:302-324.
7. Walton JP, Frisina RD, O'Neill WE (1998). *J Neurosci* 18:2764-2776
8. Parthasarathy A, Bartlett EL (2011). *Neuroscience* 192:619-630
9. Schneider BA, Pichora-Fuller MK (2001). *Semin Hear* 22:227-240.

Acknowledgements

The authors wish to thank Alanna Schloss and Veronica Yevsukov for their assistance with data collection. Research in this presentation is supported by the American Hearing Research Foundation (Anderson) and the National Institute on Deafness and Other Communication Disorders of the National Institutes of Health (NIH) under Award number R21DC015843A (Anderson). The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

http://www.hearingbrainlab.umd.edu