Effects of Aging and Spectral-Shaping on Brainstem Differentiation of Consonants

THE UNIVERSITY of TENNESSEE HEALTH SCIENCE CENTER

Starkey Hearing Technologies

Dania A. Rishiq[1], Ph.D., Ashley W. Harkrider[2], Ph.D., Mark S. Hedrick[2], Ph.D.

[1]Audiology Research, Starkey Hearing Technologies; [2]Department of Audiology and Speech-Language Pathology, The University of Tennessee Health Science Center

Introduction & Rationale

Older listeners even with normal hearing (NH) often present with poor temporal resolution. Due to such impairment, time-varying spectral cues that distinguish consonants might not be fully captured by the aging auditory system. Specifically, aging might disrupt the encoding of the second formant (F2) transition, an imperative speech cue for identifying place of articulation in stop consonants.

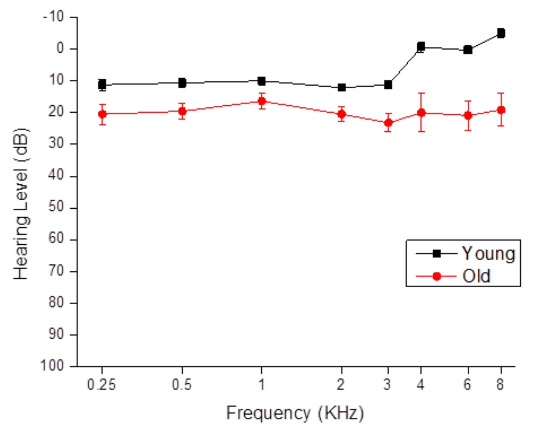
Because discriminating consonants is vital for speech understanding, it is important to understand how the aging brain discriminates among consonant sounds, while isolating the effects of hearing sensitivity. Factors such as aging and other than hearing status must be explored to explain performance differences between listeners with NH and those with hearing loss.

Further, it is imperative to understand how the brain processes frequency-specific gain that aims to enhance important spectral cues such as the F2 transition. Providing spectrally-shaped gain, by improving audibility of the F2 formant in relation to the rest of the signal, may overcome performance difficulties in NH elderly, as opposed to flat frequency-independent amplification. Providing the elderly with the latter kind of amplification may increase susceptibility to deleterious effects of upward spread of masking, hence making feature identification even more difficult.

The Purpose of this Study: For the reasons above, this investigation aimed to (1) study the effects of aging on the brainstem differentiation of contrastive stop consonant; (2) determine whether spectrally-shaped (i.e. frequency-specific) gain can reverse potential age-related brainstem alterations, if existed.

Subjects

Eleven older adults (mean = 58.60 years; range = 51 – 72 years; 4 males) with "near-normal" to NH and 16 younger controls (mean = 20.94 years; range = 18 – 33 years; 6 males) with NH participated in this study. For both groups, younger and older adults, average audiometric thresholds for the tested (i.e. right) ear are illustrated in the following figure.



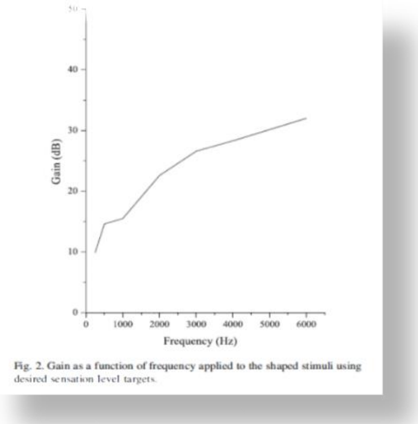
Stimuli

For Behavioral Testing: (Harkrider et al. 2005)

- A /ba/-/da/-/ga/ perceptual continuum of 15 steps (Klatt 1980).
- The starting frequency of the F2 formant ranged from 900 to 2300 Hz in 100 Hz steps creating the fifteen tokens.

Spectral Shaping: (Harkrider et al. 2005):

- Cool Edit Pro (Adobe) was used to spectrally-shape the stimuli in order to enhance audibility of F2 transition in relation to the rest of the signal.
- Specifically, spectral shaping delivered amplification to the stimuli similar to that delivered by the Desired Sensation Level fitting method (DSL v4.1 software, 1996) to conversational speech for a listener with a mild-to-moderate SNHL. This older DSL version was used to facilitate direct comparisons of our results to that of previous studies by Harkrider and colleagues (2005; 2006; 2009)



↑Gain in mid to high freq's (i.e. frequency region of F2 transition)
↓Gain at the low freq's (to minimize upward spread of masking).

For Electrophysiological Testing:

- 6 exemplars (2 shaping conditions X 3 phonemes)
  The exemplars had 900, 1700 and 2300 Hz for their F2 onset frequencies.
- 80 dB SPL (e.g. Hornickel et al. 2009)

Behavioral Testing and Analysis

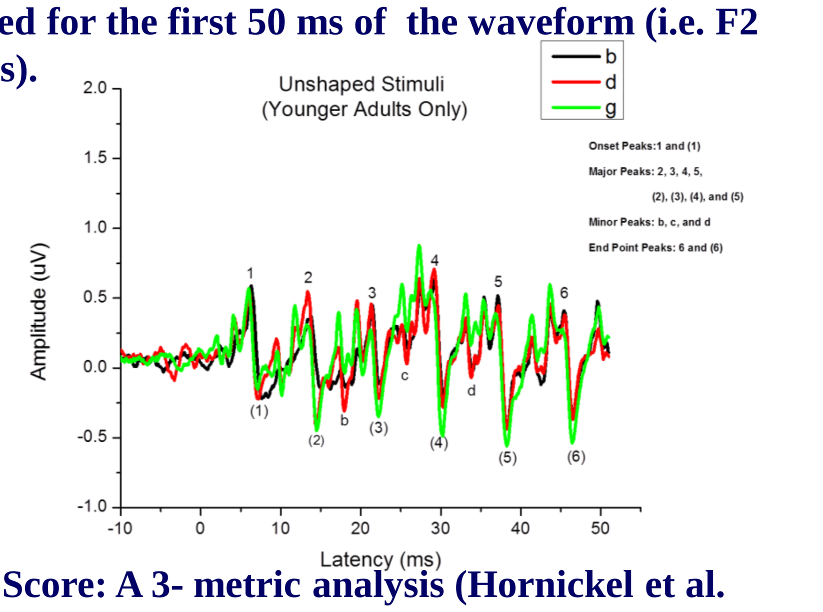
- 20 blocks (30 tokens each) = a total of 600 responses
- Presented randomly
- Psychometric functions* were generated to assess behavioral identification of 15-step perceptual unshaped and shaped /b-d-g/ continua.

*The percentage of phoneme identification as a function of onset frequency.

Area Under the Curve	Phonemic Boundaries
• Adding the number of % responses for each phoneme (b, d, g) collected across the continuum of F2 onset transitions. • The sum was divided over the total # of transition steps for the continuum.	• The 50% point was defined by converting the % unshaped /b/ (for example) scores to Z scores and using linear least-squares fit to get an estimation of the 50% point which is the phonemic boundary of this stimulus. • Measured in Hz

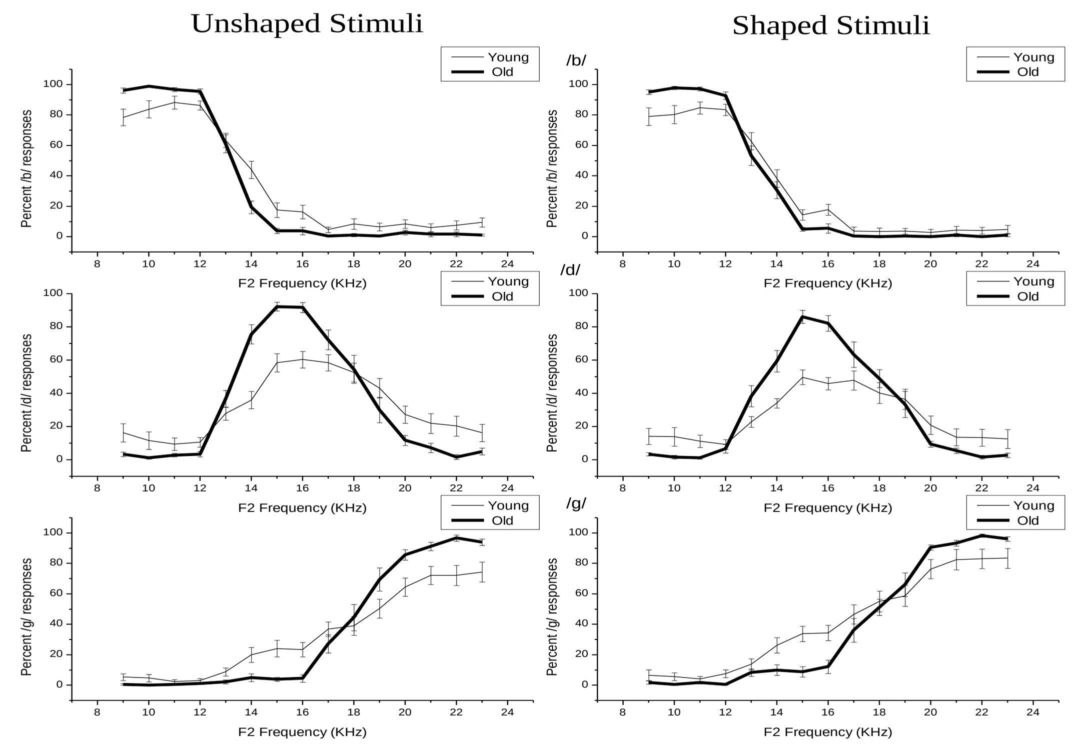
Electrophysiological Testing and Analysis

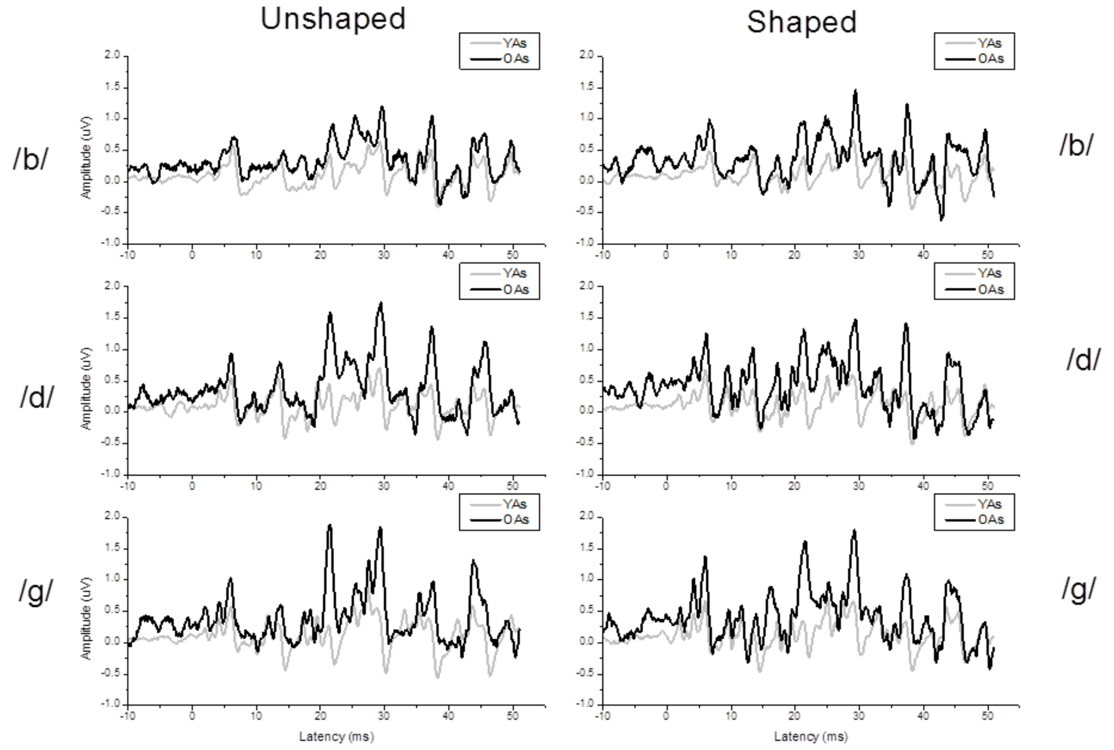
- Speech-ABRs were recorded using Intelligent Hearing Systems (IHS) via the SmartEP Advanced Auditory Research Module.
- Stimuli were presented monaurally to the right ear via an insert earphone.
- Vertical electrode montage: Cz (non-inverting), the ipsilateral earlobe (inverting) and the forehead (ground).
- Rate: 4.35/s, 4000 sweeps, alternating polarity.
- A total of 6 speech-ABR waveforms [3 phonemes X 2 shaping conditions].
- Peak latencies and peak amplitudes were identified for 15 speech-ABR peaks [The onset peaks: 1, and (1); the major peaks: 2, 3, 4, 5, (2), (3), (4), and (5); the minor peaks: "b", "c", and "d"; and the endpoint peaks: 6 and (6). Latencies were identified for the first 50 ms of the waveform (i.e. F2 transition duration is 40 ms).

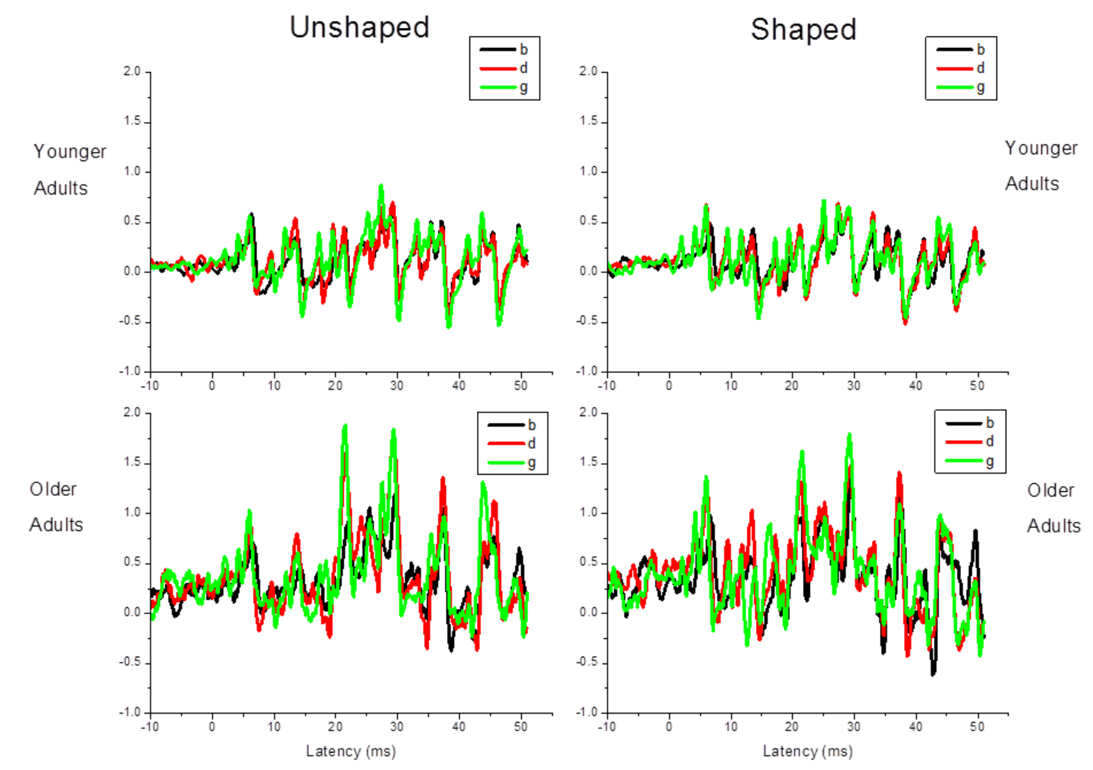


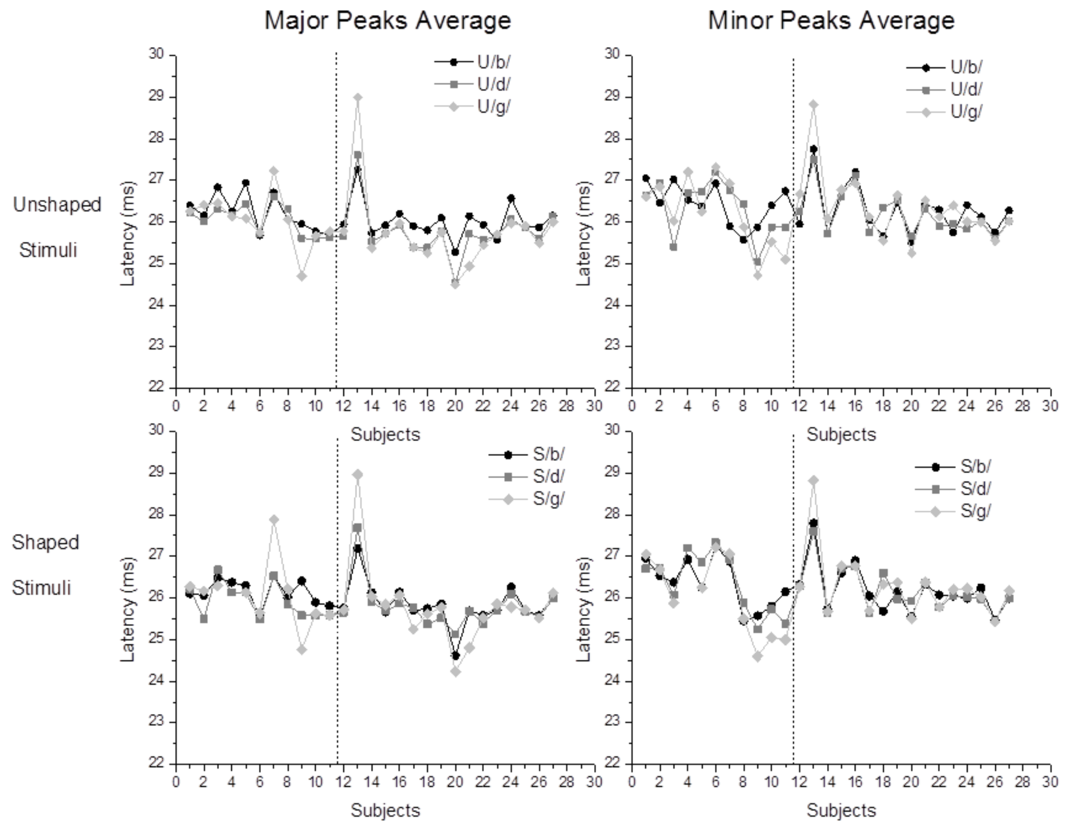
- Consonant Differentiation Score: A 3- metric analysis (Hornickel et al. 2009) was conducted to generate differentiation scores for major and minor peaks. It was expected that the stimuli with the highest F2 will elicit the earliest responses due to brainstem tonotopicity. Hence, the following latency pattern is expected: [ga] < [da] < [ba]. The analysis took into account the presence of this latency pattern as well as the magnitude of the latency difference in order to generate the differentiation scores. A higher differentiation score indicated a better brainstem differentiation of the stimuli.

Results









OAs: from 1 - 11, YAs: from 12 - 27 (The two groups are seperated by a dashed line)

Stop Consonant Differentiation Score

The average differentiation scores and standard deviations for each shaping condition and each group.

Score of		Major Peaks		Minor Peaks	
		Unshaped	Shaped	Unshaped	Shaped
Younger Adults	Mean	13.25	7.94	5.81	3.81
	SD	11.41	10.18	5.62	3.76
Older Adults	Mean	6.20	11.70	6.00	6.60
	SD	9.00	12.46	6.38	4.79

Discussion

- Normal-hearing older listeners showed robust categorical perception, or better defined categories than younger controls.
- Subtle brainstem differences were obtained between the two groups (older vs. younger adults):
  1) Older listeners showed larger amplitudes for the minor wave "d" than younger adults.
  2) The amplitude of the negative major peak (5) increased from /b/ to /d/ and from /b/ to /g/ in younger, but not in older adults.
- The brainstem changes detected in our older listeners do not seem to influence their behavioral identification of stop consonants. However, these subtle deficits seen at the sub-cortical level might have been over-ridden by cortical top-down compensation strategies in our older listeners. Therefore, whether or not these changes are adequate to cause poor performance on the behavioral speech perception tasks utilized in this study cannot be teased out using our current data.

  Further cortical assessments will be needed to evaluate possible decline-compensation patterns.
- When compared to that of the controls, individual data of older adults showed weaker latency distinctions among the /b-d-g/ brainstem responses, particularly for speech-ABR major peaks. The brainstem responses in almost all older listeners did not follow the expected latency pattern for major peaks.
- Spectral shaping improved the stop consonant differentiation score for major peaks in older listeners, such that it moved older adults in the direction of the younger adults' responses. However, due to a possible ceiling effect, improvements to the originally robust perception of older adults, at the behavioral level, were not found.

Conclusion

Results indicate that aging reduces the brainstem responsiveness to dynamic spectral cues. Further, the enhancement of the F2 transition cue seems to diminish the age-related deficits detected at the sub-cortical level. Hence, spectral-shaping may reduce the listening effort of older listeners and free up their sub-cortical resources for other tasks.

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Contact Information

Dania A. Rishiq[1], Ph.D. (Research Audiologist): Dania_Rishiq@Starkey.com

Ashley W. Harkrider[2], Ph.D. (Faculty Advisor and Chair): aharkrid@uthsc.edu

Mark S. Hedrick[2], Ph.D. (Professor): mhedric1@uthsc.edu

[1]Audiology Research, Starkey Hearing Technologies

[2]Department of Audiology and Speech Pathology, University of Tennessee Health Science Center