Canadian Audiologist
The Official Publication of the Canadian Academy of Audiology

A Fast Note about Slowed Temporal Processing in Older Adults

Published February 26th, 2025

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Some comments of older listeners about their experiences of hearing problems that we need to think about more:

> *"Most TV or radio speakers are too fast and while I am trying to make sense of the first statement they are away onto the third or fourth sentence so I soon have to drop out and so lose interest."*
>
> *"For me, distinct enunciation helps greatly, in completely sounding each word, the speaker goes more slowly and therefore gives the recipient time to assimilate and adapt the sounds to meaning."*
>
> *"When asking for repetition of statements it seems to be a way of giving the brain cells time to put sounds into meaning."*
>
> *"Using a photographic term, I have a very shallow depth of field and sounds are soon out of focus."*

Why do older adults with (near-)normal audiograms describe speech as unclear and too fast?

Audibility:

It is well known that the prevalence of audiometric hearing loss increases markedly as adults age. The hallmark of age-related hearing loss (ARHL) is elevated audiometric thresholds in the high-frequencies. Reduced audibility of high-frequency speech cues can result in difficulties understanding speech because of misperceptions, including errors resulting from confusions among low-energy voiceless consonants (e.g., *p-t-k*; *f-th*). Amplification provides a good solution to problems in speech understanding that are attributable to reduced audibility. Nevertheless, temporal processing problems may continue to contribute to difficulties understanding speech in noise even when amplification has been provided (Humes, 2007).

For those younger than 65 years of age, the number who self-report hearing loss is greater than the number who have impaired hearing based on their audiometric thresholds (Bainbridge & Wallhagen, 2014). Despite having (near-)normal audiometric thresholds and little difficulty in quiet listening conditions, these older adults frequently complain about difficulties understanding speech in noisy everyday sitatuions. Many who are seeking hearing help from audiologists for the first time are told that they are not yet candidates for hearing aids because their audiograms are "too good". More needs to be done to help them address listening difficulties that likely involve declines in supra-threshold auditory temporal processing.

Supra-threshold Auditory Temporal Processing:

Many auditory spectral cues are important for speech perception. Spectral patterns, as displayed in spectrograms, correspond to speech cues such as vowel formants, consonant transitions, or consonant frication noise. In addition to spectral cues, many different auditory temporal cues serve speech perception (Phillips, 1995; Pichora-Fuller & Souza, 2003). Different temporal cues are involved in the perception of speech cues at various linguistic levels. Periodicity coding of voice fundamental frequency and harmonic cues enable voice identification (e.g., cues used to differentiate female from male voices). The period (duration of one cycle of the fundamental frequency) of adult voices is about 5 ms for females and about 10 ms for males. Gaps in speech provide phonemic cues that signal the presence of stop consonants that are necessary to differentiate words (e.g., *split* vs. *slit*; *catch* vs. *cash*). Word-level phonemic contrasts based on gaps are in the range from about 20 ms in fast speech to about 40 ms in slow speech. Sentence-level speech envelope patterns, such as changes in pitch and rate, provide prosodic cues to syntax (e.g., *You like that?* vs. *You like that!),* with typical syllable durations around 250 ms. In contrast to spectral cues, temporal cues are more robust over a wider range of signal levels from just above threshold up to uncomfortable levels of speech. For speech intelligibility, spectral cues contribute more for the higher frequencies (above 1500 Hz) whereas temporal cues contribute more for lower frequencies (below 1500 Hz). Spectral cues become less helpful but temporal cues become especially helpful when listeners must segregate multiple simultaneous voices during listening in noise.

Importantly, there are different types of ARHL. The sensory type (resulting from outer hair cell damage in the cochlea) and the metabolic type (resulting from changes in the stria vascularis of the cochlea that affect endo-cochlear potentials) or a combination of sensory and metabolic ARHL are characterized by elevated audiometric thresholds at high-frequencies (Dubno et al., 2013). In contrast, neural ARHL may result in declines in temporal processing in the absence of elevations in audiometric thresholds (Liberman & Kujawa, 2017). About half of 60-year old men and half of 70-year-old women have (near-)normal audiometric thresholds that are no more than 25 dB HL at frequencies up to and including 3 kHz (ISO 7029:2017). Compared to younger adults, most of these older adults with (near-)normal audiograms perform more poorly on tasks using non-speech or speech stimuli to measure temporal processing.

Compared to younger adults, older adults have poorer pure-tone frequency difference limens and they benefit less from differences in voice fundamental frequency when identifying vowels spoken concurrently by two talkers (e.g., Vongpaisal et al., 2007) or when identifying words in sentences spoken by a talker when the voice of a competing talker is different from rather than the same as the target talker's voice (Besser et al., 2015). To detect the presence of a gap, older adults need longer gaps between two tones of the same frequency and they also need longer gaps between a noise and a tone (Pichora-Fuller et al., 2005). Similarly, for speech signals, older adults need longer gap durations than younger adults to detect phonemically significant gaps between two identical vowels (*u_u* heard as *upu*) or between a fricative and a vowel (*s_u* heard as *spoo*). The minimum gap needed to differentiate words, with or without a stop consonant (e.g., *spoon* vs. *soon*), is larger for older than for younger listeners, with both age groups needing a smaller gap in fast speech than in slow speech (Haubert & Pichora-Fuller, 1999). An experiment measuring the signal-to-noise ratio (SNR) threshold for word recognition in three-word nonsense sentences illustrates the abilities of younger and older listeners to segregate target speech from various maskers depending on the presence of competing voices (Ezzatian et al., 2015). Not surprisingly, across all masking conditions, younger listeners recognized words at more challenging SNRs than older listeners. Both younger and older listeners had the least difficulty when the masker was steady-state noise (i.e., when the masker provided no competing temporal speech cues). Both age groups had the most difficulty recognizing key words in the three-word nonsense sentences when the masker was intact two-talker speech. Notably, when the masker was intact two-talker speech, the performance of both groups was worse on the first than the third word of the target non-sense sentence such that, as the sentence unfolded in time, both age group improved in segregating the speech of the target talker from the competing two-talker masker (masker had both competing voice and envelope cues). For older adults, but not younger adults, stream segregation was also improved from the first to the third word in the nonsense sentences when 16-band vocoding was used to distort the masker (masker voice cues were impoverished but competing envelope cues remained), suggesting that younger listeners could rapidly segregate the target from the masker when there were competing envelope cues, but the presence of competing envelope cues slowed older adults in segregating the target from the masker.

Conclusion

In summary, compared to younger adults, most older adults with (near-)normal audiograms have multiple declines in auditory temporal processing that may undermine speech understanding in noise. Older adults are less able to use periodicity cues to differentiate voices; they need longer gaps to detect phonemic contrasts; they are slower in segregating speech and maskers with competing voice and/or speech envelope cues. Such age-related declines in temporal processing likely explain their common complaints of difficulty understanding speech and self-reported hearing problems that are not predictable from audiometric thresholds. Age-related declines in temporal processing can also undermine music perception (Russo et al., 2012; Pichora-Fuller, 2020) and the identification of vocal emotion (Dupus & Pichora-Fuller, 2015; Goy et al., 2018). Furthermore, reduced supra-threshold auditory temporal processing may diminish cues that facilitate cognitive processes involved in comprehension, memory and attention (Pichora-Fuller et al., 2017). Audiologists could use existing assessment tools such as the LiSN-S test (Cameron et al., 2011) to gain insight into whether or not listeners benefit from voice differences between target and competing voices (e.g., Besser et al. 2015). They could also use questionnaires such as the SSQ (Gatehouse & Noble, 2004; Banh et al., 2012). Most importantly, audiologists should discuss the everyday listening needs of older adults that could be addressed by using assistive technologies or environmental modifications or communication strategies to improve communication accessibility in challenging listening situations, even if their audiograms seem to be “too good” for them to be candidates for hearing aids (Humes et al., 2020).

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