Purpose: In this study, the author sought to investigate if and when the ability to process temporal-fine-structure (TFS) cues deteriorates with age in adults with audiometrically normal hearing sensitivity.

Method: Using a cross-sectional design, the author assessed TFS sensitivity in 102 normal-hearing adults sampled from across the entire range of adulthood (ages 18–90 years), using 2 psychophysical tests for the assessment of within- and across-ear TFS processing.

Results: Both types of TFS sensitivity (monaural and binaural) declined gradually starting in young adulthood, with the earliest significant deficit already apparent in early midlife (i.e., between ages 40 and 49 years). TFS sensitivity was not correlated with absolute sensitivity at the test frequency.

Conclusions: Some suprathreshold auditory processing abilities decline throughout adulthood, even when an individual’s peripheral hearing is clinically normal. These deficits are not captured by a conventional, audiometric hearing assessment but may contribute to the increasing difficulties with age to identify speech in noisy environments. From a methodological point of view, the existence of such age effects warrants the use of age-matched participant groups when comparing normal and impaired peripheral hearing.

Key Words: aging, audiometrically normal hearing, suprathreshold auditory processing, temporal fine structure

Most difficulties in speech-in-noise identification reported by older persons are caused by age-related changes in the peripheral hearing organ, leading, for example, to reduced audibility and frequency selectivity. However, suprathreshold auditory processing abilities that are not captured in an audiometric assessment can also contribute to speech identification. If these “central” processing abilities decline with age, then an older adult’s listening difficulties are the result of cochlear and retro-cochlear deficits. Indeed, recent findings (see, e.g., Moore, Glasberg, Stoev, Füllgrabe, & Hopkins, 2012) have indicated that sensitivity to the temporal fine structure (TFS) of acoustic signals—which seems to be important for successful speech identification in complex and noisy listening conditions (for a review, see Moore, 2012)—is reduced in older adults. Surprisingly, many (even recent) studies on the perceptual consequences of sensorineural hearing loss did not use age-matched participant groups; that is, they compared young, normal-hearing (NH) participants to older participants with hearing impairment. This article describes the preliminary results from a cross-sectional experiment assessing differences in suprathreshold temporal auditory processing across the adult life span in the absence of peripheral hearing loss.

Method

Participants

Thus far, 102 participants have been recruited from the adult population (ages 18–90 years), with at least 10 participants per age group (corresponding to age decades up to 70 years; above that age, only 18 eligible participants have been identified to date); no participants ages 30–39 years were tested. All participants had NH sensitivity, defined as audiometric thresholds ≤ 20 dB hearing level at octave frequencies between 0.125 kHz and 4 kHz, as well as at 0.75 kHz and 3 kHz, either unilaterally (UNH) or bilaterally (BNH). The exact number of participants per age group for each experimental test is indicated in Figure 1 (see Results section). Participants age ≥ 60 years were also tested on the Mini
Mental State Examination (Folstein, Folstein, & McHugh, 1975); all scored ≥ 28 points (of 30).

Materials and Stimuli

Sensitivity to monaural and binaural TFS cues was measured using two psychophysical tests. In the first (Moore & Sek, 2009), UNH and BNH listeners discriminated a monaurally presented harmonic tone complex from an inharmonic tone complex, obtained by shifting all components of the first complex upward in frequency. A fundamental frequency (F0) of 182 Hz was used, and the spectral envelope was fixed by applying a filter with a bandwidth of 1 F0 centered on the 11th harmonic (corresponding to 2002 Hz) to minimize the possible use of excitation pattern cues to perform the task. In the second test (Hopkins & Moore, 2010), BNH listeners discriminated a diotic 850-Hz pure tone from the same pure tone, with a phase difference between the two ears. In both tests, tones were presented over Sennheiser HDA200 headphones at a sensation level of 30 dB, based on absolute thresholds that were measured at the beginning of the test session using a similar experimental procedure and stimulus parameters. Threshold-equalizing noise was presented at 15 dB below the tone level in the monaural test. Both TFS tests used a 2-interval, 2-alternative forced-choice (2I, 2AFC) method with feedback. Each interval contained four successive tone bursts. All tones in one interval, selected at random, were identical, whereas in the other interval, the first and third tones differed from the second and fourth tones due to a frequency shift (monaural TFS test) or a phase shift (binaural TFS test). The participant’s task was to identify the interval containing the change in pitch or lateralization. Each tone was 400 ms long, including 50-ms onset and offset ramps, and was separated from the next tone by a silent gap of 20 ms. The gap between intervals was 500 ms. Both tests used a two-down, one-up adaptive procedure. Whenever a participant was unable to complete an adaptive run, a constant-stimuli procedure was used for a frequency or the phase shift was set to the maximum value of F0/2 Hz (half the fundamental frequency) and 180°, respectively. Three estimates were obtained for each experimental condition. To allow thresholds from the adaptive procedure and percent-correct performance from the constant-stimuli procedure to be compared, all scores were transformed into the detectability index $d’$.

Results

Data for the monaural (left panel) and binaural (right panel) TFS tests are shown in Figure 1. Although the ability to process TFS cues within a given age group varied markedly, there was a significant negative correlation between TFS sensitivity and age for the monaural and binaural tests ($rs = –.49$ and –.60, respectively; both $ps < .001$). When averaged within age groups, mean monaural and binaural TFS sensitivity differed across the different age groups, $F(4, 79) = 6.79$ and $F(4, 65) = 9.75$, respectively (both $ps < .001$). Sensitivity in the youngest age group was significantly better than in all other age groups (all $ps ≤ .032$ and ≤ .029 for the monaural and binaural test, respectively), but the other age groups did not differ from one another (all post hoc tests were Bonferroni corrected for multiple comparisons). Although the pure-tone average (measured between 0.125 kHz and 4 kHz) increased slightly with age group, neither monaural nor binaural TFS sensitivity was significantly correlated with absolute thresholds at the test tone frequency.

Conclusion

This article reports preliminary results from a still-ongoing study on the age-dependent changes in the sensitivity to monaural and binaural TFS cues. Even for participants with audiometrically normal hearing, it was shown that (a) sensitivity declined with age and (b) a significant deficit, compared with the youngest age group, could already be observed in early midlife—that is, in participants ages 40–49 years. Confirming and extending previous findings on generally smaller and audiometrically less well-controlled or sensitive participant groups (see, e.g., Grose & Mamo, 2010; Ross, Fujioka, Tremblay, & Picton, 2007), these results illustrate the importance of using age-matched participant groups when studying the effect of peripheral hearing loss on speech perception to exclude age as a confounding variable. Currently, NH participants aged 30–39 years are being tested to assess if TFS sensitivity is already affected at that age. Another (still open) question is the role of TFS sensitivity in speech-in-noise identification. Some authors (see, e.g., Lorenzi & Moore, 2008) have claimed that reduced TFS sensitivity associated with peripheral hearing loss could explain why listeners with hearing impairment show less...
release from masking (i.e., less benefit in intelligibility due to the “glimpsing” of target speech cues during the energetic minima of a fluctuating background noise). In a recent study involving young (< 30 years) and older (≥ 60 years) participants with normal individual and matched mean audiograms, Füllgrabe, Moore, and Stone (2012) showed that TFS sensitivity was reduced in the older participants and was indeed associated with the ability to identify speech in noise, but not without the amount of masking release. It will be of interest to establish whether the early midlife reduction in TFS sensitivity observed here coincides with difficulties in speech identification, as suggested in subjective reports (Leigh-Pfaffenroth & Elangovan, 2011).

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References


Moore, B. C. J. (2012). The importance of temporal fine structure for the intelligibility of speech in complex backgrounds. In T. Dau, J. Dalsgaard, M. Jepsen, & T. Poulsen (Eds.), *Speech perception and auditory disorders* (pp. 21–32), Denmark: Centrertyrk A/S.

