AJA

Research Forum

Temporal Processing Deficits in Middle Age

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Purpose: The purpose of this brief report is to provide a synopsis of recent work, primarily from the authors' laboratory, that points to the emergence of temporal processing deficits relatively early in the aging process.
Method: The approach taken was to provide a descriptive summary of selected published and current experiments focusing on the processing of temporal envelopes and fine structure.
Conclusion: Deficits in both temporal envelope and temporal fine structure processing are evident during middle age even while audiometric hearing sensitivity remains normal.

It is well established that older listeners tend to experience hearing difficulties and that some of these difficulties can occur even in the presence of relatively normal audiometric sensitivity (e.g., Gordon-Salant, 2005). One particular facet of auditory processing with which deficits exist independently of hearing loss in the older population is temporal processing (e.g., Fitzgibbons & Gordon-Salant, 1994; Grose, Mamo, & Hall, 2009). This has led to an interest in the presenescent emergence of temporal deficits. Our laboratory has addressed this by undertaking a series of studies on temporal processing in listeners with normal hearing that have included middle-aged listeners in addition to younger and older listeners. We consider the age range of this intermediate group as spanning approximately 40 to 60 years.

In terms of the temporal characteristics of a sound, it is convenient to consider two aspects of the acoustic waveform: the temporal fine structure (TFS) and its envelope. In a typical situation, the TFS refers to the rapid pressure fluctuations above and below ambient pressure. The gradual changes in TFS amplitude over time are referred to as the envelope; that is, the envelope is carried by the TFS. Our studies have examined both TFS and envelope processing in middle-aged listeners.

Two psychophysical methods that have been employed to gauge TFS processing are the detection of frequency modulation (FM) for low-frequency carriers modulated at slow rates (e.g., 2–5 Hz) and the detection of an interaural phase difference (IPD). Detection of low-rate FM can be interpreted as relying on TFS cues rather than cochlear "place" cues, especially when the low-frequency carrier is roved (Moore & Sek, 1996). We found that middle-aged listeners are poorer at 2-Hz FM detection in the 500-Hz region than younger listeners both when the modulator is in-phase across the two ears and when it is inverted across ears; the latter mode allows for additional binaural beat cues (Grose & Mamo, 2012). Detection of IPDs relies on the comparison across ears of ongoing TFS information encoded in the auditory periphery. We found that the detection of IPDs is also poorer in middle-aged listeners than younger listeners. Using a procedure in which the phase of an amplitude-modulated (AM) carrier is alternated between 0 and π radians across successive cycles of the AM, we found that middle-aged listeners could only follow the carrier frequency phase inversions up to an average frequency of about 1040 Hz, and younger listeners could follow it up to an average frequency of about 1250 Hz (Grose & Mamo, 2010). The same study also used a complementary procedure in which the carrier frequency was held constant and the size of the IPD was varied. Whereas younger and middle-aged listeners had equivalent sensitivity to IPD at low carrier frequencies (250 and 500 Hz), the middle-aged listeners exhibited decreased sensitivity for carrier frequencies 750 Hz and higher. These IPD results suggest a reduced upper limit of neural phase locking for the middle-aged adults as compared to the younger adults. This interpretation arises because IPD sensitivity is thought to rely on interaural coincidence detection of spike trains wherein the synchronization coefficient for interaural coincidence is the product of the synchronization coefficients for phase

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locking in each ear (cf. Batra, Kuwada, & Fitzpatrick, 1997).

These psychophysical results demonstrate that deficits in TFS processing are evident in middle age. Electrophysiological studies also point to presenescent deficits in coding TFS (e.g., Ross, Fujioka, Tremblay, & Picton, 2007; Wambacq et al., 2009). Using a similar stimulus construct for phase inversion of an AM tone, Ross et al. (2007) found that the highest carrier frequency for which interaural phase inversion elicited a cortical potential declined with age. Because the fidelity of TFS coding likely affects segregation and spatialization of competing sound sources, as well as the tracking of target voices in multivoice complexes, deficits in TFS should be detrimental to hearing in competitive listening situations. Several lines of work support this conclusion (e.g., Helfer & Freyman, 2014; Helfer & Vargo, 2009; Ruggles, Bharadwaj, & Shinn-Cunningham, 2012).

In terms of temporal envelope processing, three psychophysical procedures that can be used to gauge acuity are gap detection (or discrimination), masking period patterns (MPP), and forward masking. An early study from our laboratory demonstrated that, for some conditions, middle-aged listeners show poorer gap duration discrimination than younger listeners for both within-channel and across-channel gap markers (Grose, Hall, & Buss, 2006). It is interesting to note that this work also showed that increasing the cognitive demands of the task (by incorporating dual temporal monitoring requirements) could, in some situations, be more disruptive to the performance of middle-aged listeners than younger listeners. In terms of MPP and forward masking, recent work from our laboratory (Grose, Menezes, Porter, & Griz, 2015) assessed these tasks using speech-shaped noise signals and maskers. Whereas younger and middle-aged listeners exhibited equivalent performance in the MPP task, the middle-aged listeners had poorer forward-masked thresholds. This adds to the accumulating evidence that deficits in temporal envelope processing can also be evident relatively early in the aging process. The fidelity of envelope processing is expected to affect the ability to benefit from fluctuations in the background noise in competitive listening situations. In support of this, Baskent, van Engelshoven, and Galvin (2014) have found that differences in masked speech reception thresholds between young and middle-aged listeners depend on the dynamic nature of the masker.

In summary, there is increasing evidence that temporal processing deficits can be observed in middle age both in terms of TFS and envelope processing. Moreover, these deficits are evident in the presence of normal audiometric hearing. There is a solid physiological basis to the expectation that age-related deficits in suprathreshold auditory processing can exist even though audiometric thresholds remain within normal limits. For example, a human temporal bone study of ears that retained a full complement of inner and outer hair cells (suggesting normal cochlear function) showed that the spiral ganglion cell (SGC) count decreased with age more rapidly than did the age-indexed decline in audiometric sensitivity associated with this sample (Makary, Shin, Kujawa, Liberman, & Merchant, 2011). This supports the view that SGC loss begins at a relatively early age and that relatively few surviving auditory nerve fibers are required to maintain threshold sensitivity in quiet. In a similar manner, a study of mice raised in a low-ambient-noise environment demonstrated that the age-related loss of SGCs exhibited a much earlier time course than did the decline in auditory thresholds (Sergeyenko, Lall, Liberman, & Kujawa, 2013). Thus, a disassociation between suprathreshold hearing difficulty and audiometric sensitivity is not surprising. Continued work is required to further characterize the temporal processing deficits present in middle age and assess whether such deficits are amenable to rehabilitation.

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