CHANGES IN MELODIC PERCEPTION AS A FUNCTION OF AGE AND LOWEST HARMONIC COMPONENT

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1. INTRODUCTION

Spectral models of pitch resolution explain pitch perception primarily with reference to the place coding of frequency, in which the maximally stimulated point on the basilar membrane of the cochlea depends on the frequency of a tone which is related to its perceived pitch. Temporal models, however, argue that pitch perception is a result of temporal coding, in which the rate of firing of the auditory nerve corresponds to the periodicity of the stimulus. Both views have been influential in our understanding of pitch perception and recent models have attempted to combine the spectral and temporal aspects of auditory processing [1, 2].

Numerous studies have demonstrated the importance of spectral and temporal coding to speech perception. Deficits in spectral coding associated with cochlear hearing loss compromise speech perception in quiet. Furthermore, relative to younger adults, age-related declines in auditory temporal processing abilities may account for the greater difficulties experienced by older compared to younger adults when they listen to speech in noise. For example, difficulties experienced by normal-hearing older adults in understanding time-compressed or reverberant speech are associated with age-related changes in temporal processing [3]. The effects of age-related changes in auditory temporal processing have also been examined with respect to the perception of specific speech cues. Older adults with clinically normal hearing thresholds were less accurate than their younger counterparts in using differences in voice onset time to distinguish between phonemes [4]. Jittering the temporal fine structure of speech to simulate reduced phase-locking resulted in intelligibility scores in younger adults with normal hearing thresholds that resembled those of older normal-hearing adults [5].

Although temporal processing ability seems to decline with age with consequences to speech perception, the issue of age-related changes in temporal processing and consequences for pitch perception in music have not yet been investigated except in two studies. The first found that older adults were more influenced by irrelevant information (i.e., pitch proximity) than were younger adults [6]. The second found that tonal sensitivity of younger normal-hearing adults listening to jittered tones did not differ from that of older normal-hearing adults listening to unaltered tones [7].

The present study investigated age differences in spectral and temporal mechanisms in pitch perception, using a melodic pitch task adapted from a previous study that tested pitch perception in younger adults [8]. In that study, listeners performed better on melodies with a lower fundamental frequency (F_0) and with fewer harmonics resolved by the cochlea compared to melodies with a higher F_0 and more resolved harmonics, which was consistent with the temporal view of pitch processing.

Following predictions from the temporal view of pitch perception, the performance of both age groups in the present study was expected to decline with an increase in the lowest harmonic component of a complex stimulus. In addition, the performance of older adults was expected to be worse than that of younger adults even when lower harmonics were available. Thus, the reduction in performance with increases in the lowest harmonic component was expected to be smaller for older than for younger adults.

2. METHOD

2.1 Participants

Listeners were six younger (21-26 years, M = 22.7) and six older adults (65-75 years, M = 69.5). Older adults with good audiograms were selected to match younger adults' hearing thresholds as closely as possible. Both groups had pure-tone audiometric thresholds of ≤25 dB HL at the octave frequencies from 0.25 to 8 kHz in both ears, except for two older adults who each had a threshold of 30 dB HL at 8 kHz in one ear. None of the listeners spoke tonal languages and musical training was not a requirement for participation. All listeners gave informed consent and were paid at an hourly rate for their participation.

2.2 Task

In each trial, listeners heard two consecutive four-note melodies, with the tonic note of the melodic scale presented twice before each melody. Melodies were identical within each pair except for one note in the second melody that was shifted up or down by one or two semitones, which listeners had to identify.

2.3 Stimuli

Melodies were generated using a custom MATLAB program. In each trial, an F_0 for the tonic of the melody was randomly selected from a range of 126 to 178 Hz (a half octave range centered logarithmically on 150 Hz). Notes for the melody were then randomly chosen with replacement from the first five notes of the diatonic major scale with the selected F_0 as its tonic. Adjacent notes were never identical. All notes consisted of eight successive harmonic components, with the average, lowest component (ALC) manipulated to be the 4^{th}, 8^{th} or 12^{th} with lower components absent. The lowest component was set to rove by one component throughout the study to prevent the listener from using a single sinusoid to complete the task.

2.4 Procedure

Listeners were seated in an IAC double-walled sound booth. Melodies were played using a Creative SB Audigy 4 sound card and presented binaurally at 60 dB SPL through Sennheiser HD 265 headphones, accompanied by bandpass-filtered white noise at 50 dB SPL (*BW* = 50-500 Hz) to mask any combination tones and their harmonics.

Prior to experimental trials, listeners were trained using a similar procedure as Ives and Patterson (2008). Immediately after training, a total of 180 experimental trials were completed, with 60 trials in each of three ALC conditions presented in randomized order. Listeners indicated their answers using a computer interface and received visual feedback on whether or not their answers were correct. No response time limit was imposed. All listeners completed the training and experimental trials in a single two-hour session.

3. RESULTS

Figure 1 shows the performance of younger and older adults across three ALC conditions. To test for age differences in performance at each ALC condition, Mann-Whitney U tests with a multistage Bonferroni correction were conducted. The results showed that younger and older adults differed significantly on ALC 4 ($p = 0.004$) and 8 ($p = 0.002$), but not on ALC 12 ($p = 0.180$). To test for differences in performance between ALC conditions, Friedman's test was conducted separately for each age group. The results confirmed that there were differences between ALC conditions in both younger ($p = 0.006$) and older ($p = 0.011$) adults. Wilcoxon's signed ranks test showed that, in younger adults, ALC 4 and 8 were not different from each other ($p = 0.34$), but they both differed from ALC 12 ($p = 0.028$; $p = 0.027$). In older adults, performance on ALC 8 and 12 was not different ($p = 0.673$), but they both differed from ALC 4 ($p = 0.027$; $p = 0.028$).

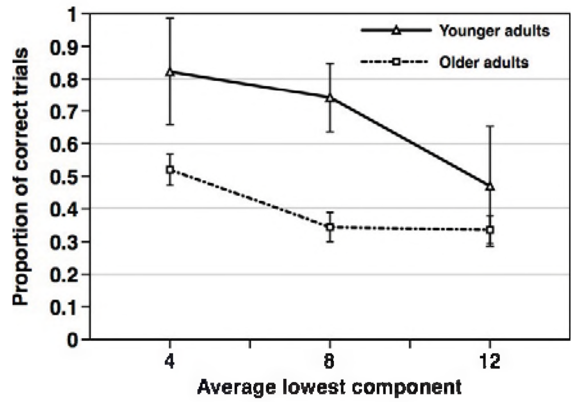

Fig. 1. Average performance of 6 younger and 6 older adults in three ALC conditions. Standard deviations are shown.

4. DISCUSSION

Younger adults performed better than older adults in easier ALC conditions, except in the most difficult condition with the highest frequencies, and the effect of higher frequencies was smaller for older adults than for younger adults. Consistent with the temporal view of pitch perception, task performance declined with higher frequencies. Given that both groups were closely matched on their audiometric thresholds, the results cannot readily be explained in terms of reduced spectral coding due to cochlear damage. This study provides evidence that in addition to speech, age-related declines in auditory temporal processing also reduce the perception of tonality in music.

REFERENCES

[1] Carney LH. Spatiotemporal encoding of sound level: Models for normal encoding and recruitment of loudness. Hear Res. 1994;76:31-44.
[2] Patterson RD, Allerhand MH, Giguere C. Time-domain modeling of peripheral auditory processing: A modular architecture and a software platform. J Acoust Soc Am. 1995;98(4):1890-4.
[3] Gordon-Salant S, Fitzgibbons PJ. Profile of auditory temporal processing in older listeners. J Speech Lang Hear Res. 1999;42(2):300-11.
[4] Strouse A, Ashmead DH, Ohde RN, Grantham DW. Temporal processing in the aging auditory system. J Acoust Soc Am. 1998;104(4):2385-99.
[5] Pichora-Fuller MK, Schneider BA, MacDonald E, Pass HE, Brown S. Temporal jitter disrupts speech intelligibility: A simulation of auditory aging. Hear Res. 2007;223(1-2):114-21.
[6] Halpern, A. R., Kwak, S. Y., Bartlett, J. D., & Dowling, W. J. Effects of aging and musical experience on the representation of tonal hierarchies. Psychol Aging. 1996;11(2): 235-46.
[7] Minghella D, Russo F, Pichora-Fuller MK. Effect of age on sensitivity to tonality. Canadian Acoustics - Acoustique Canadienne. 2007;35(3):58-9.
[8] Ives DT, Patterson RD. Pitch strength decreases as F0 and harmonic resolution increase in complex tones composed exclusively of high harmonics. J Acoust Soc Am. 2008;123(5):2670-9.

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