EFFECT OF AGE ON SENSITIVITY TO TONALITY

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1. INTRODUCTION

The purpose of our study was to determine if there are differences in how younger and older adults process pitch relations in music, and more specifically tonality.

Pitch may be referred to as the attribute of auditory sensation by which sounds are ordered on a musical scale (Plack, Oxenham, Fay, & Popper, 2005). Tonality refers to the hierarchical organization of pitches around the tonic or key-note of a piece of music. In Western music, this organization has been described as a four-level hierarchy of stability. The hierarchy is theoretically ordered as follows: 1. *Do* (highest level); 2. *Mi, So*; 3. *Re, Fa, La, Ti*; and 4. non-scale notes (lowest level). Krumhansl, & Kessler (1982) have validated this tonal hierarchy using the probe-tone technique with a variety of musical contexts, arriving at a standardized profile of ratings. Sensitivity to the tonal hierarchy is affected by pitch range as well as the periodicity of tones (Cuddy, Russo & Galembo, 2007; Russo, Cuddy, Galembo & Thompson, 2007).

Many older adults, even those with relatively good audiometric thresholds, are believed to have age-related declines in various aspects of auditory temporal processing that may account for the problems that they experience understanding speech in noise (Pichora-Fuller, & Souza, 2003). One such aspect of auditory aging is believed to be a loss of periodicity or synchrony coding. Age-related differences in psychoacoustic measures such as low-frequency frequency difference limens (Abel, Krever, & Alberti, 1990) and in speech measures such as voice fundamental frequency difference limens (Vongpaisal, & Pichora-Fuller, in press) are consistent with the notion that older adults may be less able than younger adults to use periodicity coding. A jitter simulation of loss of synchrony that temporally distorts the fine structure of speech has been used to mimic the effects of aging on intelligibility when younger adults listen to speech in noise (Pichora-Fuller, Schneider, MacDonald, Pass, & Brown, 2007). Reduced ability to code periodicity could have a negative effect on the perception of musical pitch relations, especially for lower frequency notes that are more dependent on temporal coding. Such reductions might be observed in older adults listening to intact music or in younger adults listening to music distorted by the jitter simulation.

In the present experiment, we test sensitivity to tonality using the probe-tone technique. We investigate whether or not there are differences due to age (younger or older), periodicity of the stimulus (normal or jittered), and frequency range (mid- or low-frequency).

2. METHOD

Participants

A total of 30 participants completed the study, including 15 younger adults (18-28 years of age; mean = 20.7; *SE* = 0.67), and 15 older adults (66-79 years of age; mean = 71.2; *SE* = 0.92). All participants had clinically normal audiometric pure-tone air-conducted thresholds (0 to 25 dB HL) across the speech range from .25 to 3 kHz (Mencher, Gerber, & McCombe, 1997).

Musical training was not a criteria for inclusion in the study, although the number of years of formal musical training was recorded for each participant. For the younger adults, musical experience ranged from 0 to 12 years of formal training (mean = 3.27; *SE* = 1.05), with 10 of the 15 younger adults having had some musical training. For the older adults, musical experience ranged from 0 to 10 years of formal training (mean = 2.36: *SE* = 0.88), with 8 of the 15 older adults having had some musical training. To adjust for differences between private and group instruction, if the participant had received training in a group setting (e.g., choir, band) then the number of years of that type of training was halved in calculating the total years of training.

Equipment and Stimulus Presentation

All testing was conducted in a 10 x 12 ft IAC double-walled sound-attenuating booth. A Tucker Davis Technology (TDT) System III was used to present the musical tones which were heard by the participants through Sennheiser HD 265 earphones in both ears.

All tones were produced using the General MIDI Protocol. Both mid- and low-frequency tones were utilized. The mid-frequency piano tones spanned the pitch range from C3 (~ 131 Hz) to E4 (~ 330 Hz). The low-frequency piano tones spanned the pitch range from C1 (~ 33 Hz) to E2 (~ 82 Hz). A trial consisted of a key-defining context (implying either C Major or F# Major) followed by a probe tone. The key-defining context consisted of 4 contiguously presented tones (*Do, Mi, Do, So*). The duration of all tones was 333 milliseconds and an interval of one second separated the probe tone from the context. Each trial was separated by 4 seconds.

Two sets of 4 blocks each were prepared and the order of sets was counterbalanced across participants. The first set of blocks always consisted of normal tones, and the final set always consisted of tones distorted by temporal jittering (i.e., difficulty increased). Each block consisted of 12 probe tones, drawn from the chromatic scale starting on the keynote of the implied key (C for C Major and F# for F# Major). The first two blocks were in the mid-frequency range and the second two were in the low-frequency range (i.e., difficulty increased). Each block consisted of 12 probe tones, representing all 12 chromatic notes starting on the keynote of the key implied by the context.

Task

In each trial, participants were asked to rate the degree to which each probe tone fit with the preceding context. Ratings were made on a 7-point scale that ranged from "Fits very poorly" (1) to "Fits very well" (7). Participants were encouraged to use the entire 7-point scale when assessing each tone. The experiment lasted approximately 20-30 minutes per participant.

3. RESULTS

For each participant and in each block, the set of probe tone ratings was correlated with the standardized profile. The correlation value is referred to as the recovery score and can be interpreted as a measure of tonal sensitivity (Russo et al., 2007). As may be seen in Figure 1, the recovery scores for the younger adults were higher than those for the older adults. Furthermore, the recovery scores for the normal tones were higher than those for the jittered tones. This description was confirmed by an Analysis of Variance with age (young or older) as a between-subjects factor and periodicity (normal or jittered) and frequency range (mid or low) as within-subjects factors. There were significant main effects of age, $F(1, 28) = 5.60, p < .03$, and periodicity, $F(1, 28) = 5.16, p < .04$. No other effects reached significance. Although the effect of frequency range did not reach significance, the trend is as expected with low-frequency tones yielding weaker recovery scores than mid-frequency tones (mean = 0.69; $SE = 0.02$ for the low-frequency range; mean = 0.72; $SE = 0.02$ for mid-frequency range). A Student Newman-Keuls post-hoc test indicated that the recovery scores for the younger adults with jittered tones (mean = 0.72; $SE = 0.03$) did not differ significantly from those of the older adults with normal tones (mean = 0.67; $SE = 0.03$), $p > .1$. The scores for the older adults for normal (mean = 0.67; $SE = 0.03$) and jittered tones (mean = 0.63; $SE = 0.03$) did not differ significantly, $p > .1$, but the scores for the younger adults were significantly better for normal (mean = 0.78; $SE = 0.02$) than for jittered tones (mean = 0.72; $SE = 0.03$), $p < .05$; and for normal tones the recovery scores of the younger adults (mean = 0.78; $SE = 0.02$) were significantly greater than those of the older adults (mean = 0.67; $SE = 0.03$), $p < .05$.

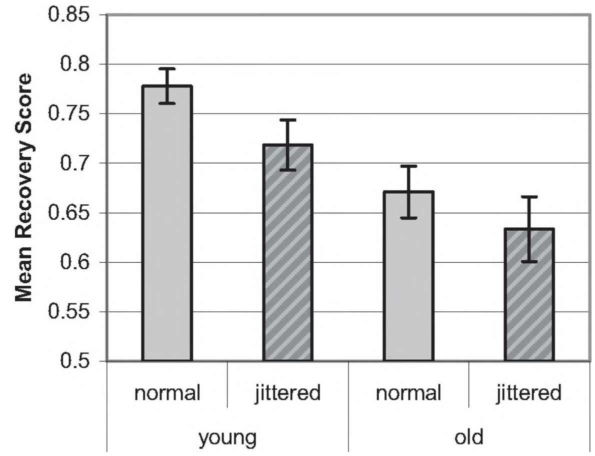

Figure 1. The mean recovery scores for younger and older adults in the normal and jittered conditions.

4. DISCUSSION

We found significant effects of age and stimulus periodicity on tonal sensitivity. The finding that the younger adults were better than the older adults overall in terms of tonal sensitivity provides new evidence of an age-related deficit in periodicity coding. Furthermore, jittering the stimulus to disrupt periodicity negatively influenced tonal sensitivity in both groups.

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