DISCRIMINATION OF FREQUENCY TRANSITIONS AS A FUNCTION OF VARYING SPECTRAL CUES AMONG YOUNG AND ELDERLY ADULTS

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Introduction

Next to the changes that are noted in hearing sensitivity loss, the deterioration in speech discrimination is the most commonly recognized characteristic of age-related changes in auditory function. This well-documented reduction in speech discrimination is a pivotal auditory problem associated with aging given that elderly individuals without a high sensitivity loss report difficulty in understanding speech in optimum conditions; that is, speech perception difficulties are greater than would be expected on the basis of pure tone sensitivity levels. One relevant aspect underlying the difficulties that elderly adults experience may be a function of the brevity and rapid spectral changes which characterize some speech segments. Indeed, reduced spectral and temporal resolution has been reported for elderly listeners who demonstrate normal pure tone thresholds (Cranford & Stream, 1991; Maden & Feth, 1992; Robin & Royer, 1989; Trainor & Trehub, 1989). This study investigated how various spectral characteristics influence discrimination of short duration, dynamic signals as a function of age.

Method

Subjects

Subjects were 15 adult undergraduate students from the University of Calgary (mean age 23.8 years; range = 19-38 years) and 11 elderly subjects (mean age 71.4 years; range = 66-75 years) recruited from the community. All the young adults had normal hearing (no greater than +15 dB HL) for .5 to 8 KHz; the elderly subjects had normal thresholds up to 1 KHz with varying degrees of hearing loss from 2 KHz to 8 KHz.

Stimuli

Three continua of 17 signals increasing in 10 Hz steps were generated on a Micro Vax II computer. Stimuli were 60 ms in duration with 5 ms rise/fall times, sampled at 20 KHz, and low passed at 3 KHz To ensure that initial information was identical across continua, a 20 ms 1/3 octave band noise burst was affixed to the beginning of each signal. One continuum had a constant onset frequency of 900 Hz and diverged to varying offset frequencies ranging from 950 Hz to 1110 Hz. A second continuum had a constant rate of change of 3.4 Hz/ms, onset frequencies from 740 Hz to 950 Hz, and diverged to the same offset frequencies (950 Hz to 1110 Hz) as the first series. Onset frequencies of the third continuum ranged from 900 Hz to 1100 Hz and converged on a terminal frequency of 1110 Hz.

Procedure

Subjects were seated in an anechoic chamber and stimuli were delivered monaurally via Kross Pro/4x headphones at 65 dB SPL. A two-alternative forced-choice paradigm designed to determine the smallest discriminable differences that subjects could determine was used. Each trial consisted of two stimuli with an ISI of 500 ms and subjects responded 'same' or 'different'. The first signal in each continuum served as the 'standard' and was present on every trial, though the position as first or second member of the pair was randomly varied. The standard was paired with every other signal 6 times for a total of 96 'different' trials and 40 'same' or catch trials were included to serve as a metric of response bias for a total of 136 trials. Presentation order of of trials was randomized for each subject for each continuum.

Results

Individual psychometric functions were calculated with probit analysis and threshold was defined as the frequency difference corresponding to the 75% correct position. Averaged psychometric functions for all three continua for both age groups are shown in Figure 1. Signals are designated as having a constant onset frequency, constant rate of change, or a constant offset frequency. Functions for the young adults are consistently to the left of those for the elderly subjects indicating a greater degree of sensitivity for discrimination of these signals.

Among the functions for the young adults, the one corresponding to the signals with a constant onset frequency has the steepest slope while the constant offset frequency signals has the shallowest slope. Among the functions for the elderly listeners, there is no difference in the functions for the constant onset frequency and the constant rate of change signals, but these are both to the left of the function for the constant offset frequency series. Neither age group asymptoted at 100 % correct performance for signals converging on the same offset frequency.

A 2 X 3 analysis of variance (ANOVA) of the threshold values revealed significant main effects for age $F(1,22) = 7.21$, $p<.05$, and signal type, $F(2,44) = 27.31$, $p<.001$. The signal type and age interaction was also significant, $F(2,44) = 4.41$, $p<.01$. Planned comparisons showed significant differences between the young and elderly adults for discrimination of signals with a constant onset frequency , $F(1,22) = 12.7$, $p<.025$, and a constant rate of change, $F(1,22) = 6.2$, $p<.025$. Young adults needed smaller differences between the constant onset frequency stimuli ($M = 50$ Hz, $SD = 18$ Hz) compared to the elderly listeners ($M = 86$ Hz, $SD = 31$ Hz). The same pattern was noticed for signals with a constant rate of change where young adults showed smaller jnds (M = 55 Hz, SD = 28 Hz) relative to elderly listeners (M = 84 Hz, SD = 29 Hz). There were no significant differences between the age groups for the jnds associated with the discrimination of signals converging on the same offset frequency (111 Hz for the young adults versus 110 Hz for the elderly adults).

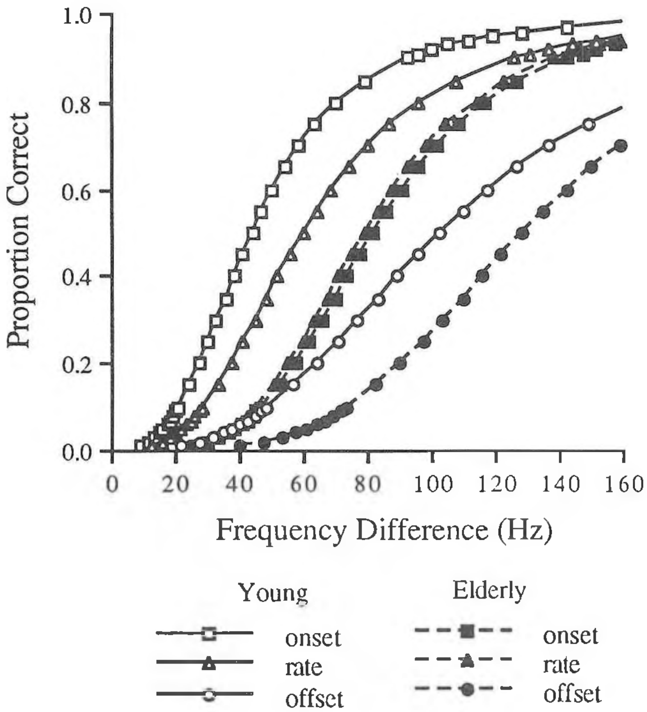

Figure 1. Psychometric Functions For Young and Elderly Adults for Each Signal Type.

Conclusions

The principal finding of this study was that elderly listeners were less able than young adults to distinguish between two sequential stimuli suggesting that elderly listeners have an impaired ability to process rapid information. One important finding was that elderly listeners showed no significant differences among stimuli which had varying offset frequencies regardless of rate of change. This indicates that rate of change information is not utilized as efficiently by the elderly relative to the young adults and potentially represents a reduced ability to integrate temporal envelope modulation in addition to spectral cues when discriminating signals. It is supportive of Schouten and Pols (1989) theory of pitch extraction where the pitch of the terminal frequency is the important information. If the pitch of the terminal frequency was the only cue being used it would be expected that thresholds for signals which have varying offset frequencies would be very similar to each other. Young adults, however, showed smaller threshold values for signals which had differing offset frequencies and varying rates of change relative to signals which had only differing terminal frequencies. Among the elderly listeners pitch/timbre cues appear to be the critical component for differentiating signals.

Pure tone threshold levels are neither the limiting factor in the task, nor an accurate metric of the ability to differentiate signals. These data cannot be interpreted in terms of an associated hearing loss. There was no consistent pattern among the individual data for the elderly subjects. Two elderly listeners who had normal thresholds to 2 KHz reached threshold for the constant onset frequency stimuli when the signals were 100 Hz apart, while another elderly listener who had a moderate loss of 35 dB HL up to 2KHz achieved threshold for the same series of signals at 50 Hz difference. One elderly subject with pure tone sensitivity of 15 dB HL to 3 KHz did not reach threshold at all. The poorer performance of the elderly subjects may be a function of decreased temporal acuity among these individuals consistent with the findings of Robin and Royer (1989).

The age related results may be a function of the greater effect of masking by the noise burst on the elderly relative to the younger subjects. Though this study does not represent a typical masking paradigm (the noise burst and signal were both suprathreshold), the initial noise burst could have reduced the effective listening duration of the signal. This would have impacted upon the temporal resolution ability of the elderly subjects and impaired processing of rapid information.

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