DURATION DISCRIMINATION IN YOUNGER AND OLDER ADULTS

Tonya R. Bergeson, Bruce A. Schneider, and Stanley J. Hamstra
University of Toronto

1.0 INTRODUCTION

Older adults, even those with little or no hearing loss, often find it difficult to understand speech when the listening situation is less than ideal (e.g., a noisy or reverberant background) or when the rate of speech is high (e.g., Pichora-Fuller, 1997). Because the temporal modulation of the speech signal has been shown to contribute substantially to speech recognition in younger adults (e.g., Kingsbury, Morgan, & Greenberg, 1998), several researchers have posited that older adults' speech understanding difficulties might stem, in part, from diminished temporal resolution (e.g., Schneider, 1997), although the evidence for this has been mixed. For instance, older listeners who have poor gap duration discrimination abilities have been shown to have more trouble understanding temporally degraded speech (Gordon-Salant & Fitzgibbons, 1993). On the other hand, some studies have suggested that the contribution of age-related changes in temporal resolution to speech recognition are minimal (e.g., Humes, 1996). It is possible that some of the discrepancies across studies may be due to differences in how temporal resolution was measured.

There are several paradigms that measure temporal processing ability. For example, in gap detection studies, listeners try to detect a short period of silence between two sounds. Studies have shown that age-related losses in detecting a gap may only occur when the durations of the tones marking the gap are very short (e.g., Schneider & Hamstra, 1999). If so, we might expect older adults to be generally poorer at processing short-duration stimuli.

Another paradigm used to investigate temporal processing capacity is duration discrimination. In duration discrimination experiments, listeners are asked to detect a change in stimulus duration. Older adults generally have more difficulty discriminating the signal durations than younger adults (Abel, Krever, & Alberti, 1990; Fitzgibbons & Gordon-Salant, 1994; 1995). Moreover, hearing loss or degree of hearing loss does not influence older adults' performance.

Given that the duration of the stimuli that mark a gap has such drastic effects on younger and older listeners' gap-detection performance, perhaps the duration of the stimuli has similar effects on younger and older adults' duration discrimination abilities. In the present experiment, we examined the temporal resolution abilities of younger and older adults in a duration discrimination paradigm in which we systematically varied the standard tone duration from 1.5 ms to 1000 ms. Based on the duration discrimination literature presented previously and the results of Schneider and Hamstra (1999), we predicted that older adults would perform more poorly than younger adults, and that this age effect would be much more pronounced at short standard tone durations, independent of audiometric thresholds.

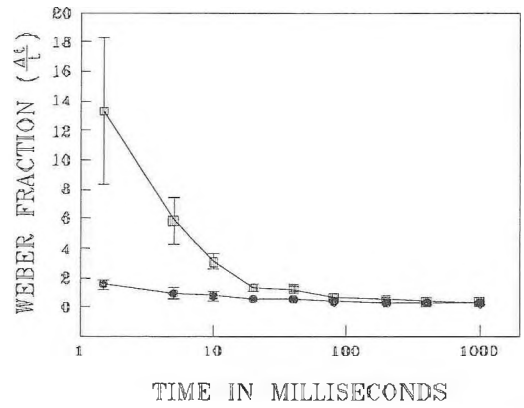
2.0 METHOD

Ten younger adults (mean age = 22.3 years; S.D. = 1.6 years) and ten older adults (mean age = 70.9 years; S.D. = 5.7 years) were paid participants in this experiment. The younger adults were students at University of Toronto at Mississauga; the older adults were recruited from a pool of seniors from the local community. All participants had pure-tone, air-conduction thresholds ≤ 25 dB HL between .25 and 2 kHz.

Stimuli were generated digitally with a sampling rate of 20 kHz and converted to analog form using a 16-bit Tucker Davis Systems (TDS) digital-to-analog converter. The 2 kHz tone was gated on and off by multiplying it by an envelope constructed by summing a series of Gaussian functions (standard deviation ½ ms), spaced ½ ms apart. The duration of the stimulus was defined as the time between the centers of the first and last Gaussian envelopes comprising the sum. The standard tone durations ranged from 1.5 ms to 1000 ms. Stimuli were presented over the left ear over TDH-49 earphones in a single-wall sound-attenuating booth.

Duration discrimination thresholds were determined by presenting stimuli at each standard tone duration in a 2IFC paradigm. A staircase procedure was used to determine the 79.7% point on the psychometric function (Levitt, 1971). At the beginning of a block, a standard tone duration was chosen and the comparison tone duration was set to a previously established value. The standard and comparison tones were randomly assigned to the two intervals. After each trial was initiated by pressing a button, the two tones would occur, separated by a 100 ms silent period. Participants were asked to choose which interval they thought contained the longer tone by pressing one of two buttons that corresponded to the two intervals. Lights on the response box indicated the beginning of the trial and whether the participants' response had been correct. The duration of the comparison tone was adjusted trial-by-trial according to a 3 down, 1 up rule. That is, if participants successfully discriminated between the two tone durations 3 times in succession, the next comparison tone duration would be decreased (closer in duration to the standard tone). However, if the participant responded incorrectly the comparison tone duration would be increased. Each block was terminated after 12 reversals; duration discrimination thresholds were defined as the mean of the last 8 reversals.

The order of standard tone durations was randomly assigned to each participant. Although all participants completed this procedure four times (four 1- to 1.5-hour sessions were required per participant), the first runs at all standard tone durations were treated as practice sessions and were not included in subsequent analyses; only the last three runs were used for the final threshold estimate.



3.0 RESULTS

Figure 1 shows duration discrimination Weber fractions as a function of standard tone duration for younger and older listeners. It is clear that older listeners found duration discrimination much more difficult than younger listeners at the shortest durations tested, although there is considerable variability in the older listeners' performance. In fact, the Weber fractions for the older adults at the shortest duration (1.5 ms) were almost 7 times greater than the younger adults' Weber fractions, compared to just 2 times greater at the 20 ms standard tone duration. This larger difference between younger and older adults' duration discrimination abilities at the 1.5 ms standard tone duration is also much larger than those performance differences found in previous duration discrimination studies (e.g., Abel et al., 1990; Fitzgibbons & Gordon-Salant, 1994; 1995).

To ensure that the variability in the older adults' performance at the shortest duration could not be explained by their audiometric thresholds, we compared the older listeners' Weber fractions to their audiometric thresholds at 2 kHz. Younger and older adults' Weber fractions were not significantly correlated with audiometric threshold at 2 kHz at any of the standard tone durations

The size of the duration discrimination difference between older and younger listeners decreases with increasing standard tone duration, almost converging by 1000 ms.

4.0 DISCUSSION

Duration discrimination is much more difficult for older listeners than for younger listeners at very short standard tone durations, but becomes easier at longer standard tone durations, where the performance of older and younger listeners is nearly identical. Younger listeners' duration discrimination performance also improves with increasing standard tone duration, but the slope is not nearly as steep as that of older listeners. The differential results for older and younger listeners are independent of audiometric thresholds, as expected from similar results reported in most duration discrimination experiments. That is, age-related changes in hearing threshold level most likely have no systematic effect on duration discrimination for older adults with relatively good hearing. Moreover, the independence of duration discrimination and hearing thresholds suggests that older adults' duration discrimination deficits reflect central rather than peripheral auditory dysfunction, as other researchers have also proposed (e.g., Fitzgibbons & Gordon-Salant, 1996).

These results have implications for older listeners' understanding of speech, especially speeded speech or speech in noise. Considering that critical phonemic information in speech often occurs at durations much shorter than 20 ms, older adults would have a very difficult time utilizing such cues to decipher particular words in the speech stream, especially in noisy situations. In addition, Peterson and Lehiste (1960) have shown that, in English, the duration of a vowel is influenced by the preceding or following consonant. For example, the vowel duration in the word "rice" is much shorter than vowel duration in the word "right." Hence, vowel duration can serve as an additional cue to word identification in noisy situations where the consonants may be partially or completely masked. Older adults would be disadvantaged in such situations if they could not easily discriminate differences in vowel duration.

Some studies of older adults' temporal processing have supported this idea. For example, Lutman (1991) found that older adults with extremely poor gap detection thresholds also tended to have diminished speech identification scores. Furthermore, Gordon-Salant and Fitzgibbons (1993) found that gap duration discrimination is related to older adults' ability to recognize reverberant speech, as mentioned earlier. However, they did not find strong correlations between duration discrimination and understanding of temporally distorted speech. Similarly, Abel et al. (1990) did not find that duration discrimination was a factor in the intelligibility of speech.

In conclusion, the present study demonstrates that older adults perform more poorly than younger adults at duration discrimination for short duration stimuli, but older and younger adults perform similarly at longer duration stimuli. This diminished temporal processing capability in older adults could make it more difficult for them to process speech in difficult listening situations where there is noise, reverberation, or when speech is speeded.

5.0 ACKNOWLEDGEMENTS

This research was supported by grants to Bruce A. Schneider from the Medical Research Council of Canada and the Natural Sciences and Engineering Research Council of Canada. We would like to thank Jane Carey for her assistance in recruiting participants.

6.0 REFERENCES

- Abel, S. M., Krever, E. M., & Alberti, P. W. (1990). Auditory detection, discrimination and speech processing in ageing, noise-sensitive and hearing-impaired listeners. Scandinavian Audiology, 19, 43-54.
- Fitzgibbons, P. J., & Gordon-Salant, S. (1994). Age effects on measures of auditory duration discrimination. Journal of Speech and Hearing Research, 37, 662-670.
- Fitzgibbons, P. J., & Gordon-Salant, S. (1995). Age effects on duration discrimination with simple and complex stimuli. Journal of the Acoustical Society of America, 98, 3140-3145.
- Fitzgibbons, P. J., & Gordon-Salant, S. (1996). Auditory temporal processing in elderly listeners. Journal of the American Academy of Audiology, 7, 183-189.
- Gordon-Salant, S., & Fitzgibbons, P. J. (1993). Temporal factors and speech recognition performance in young and elderly listeners. Journal of Speech and Hearing Research, 36, 1276-1285.
- Humes, L. E. (1996). Speech understanding in the elderly. - Journal of the American Academy of Audiology, 7, 161-167.
- Kingsbury, B. E. D., Morgan, N., & Greenberg, S. (1998). Robust speech recognition using the modulation spectrogram. Speech Communication, 25, 117-132.
- Levitt, H. (1971). Transformed up-down methods in psychoacoustics. Journal of the Acoustical Society of America, 49, 467-477.
- Lutman, M. E. (1991). Degradations in frequency and temporal resolution with age and their impact on speech identification. Acta Otolaryngol, Supp. 476, 120-126.
- Peterson and Lehiste (1960
  Pichora-Fuller, M. K. (1997). Language comprehension in older listeners. Journal of Speech-Language Pathology and Audiology, 21, 125-142.
- Schneider, B. A. (1997). Psychoacoustics and aging: Implications for everyday listening. Journal of Speech-Language Pathology and Audiology, 21, 111-124.
- Schneider, B. A., & Hamstra, S. J. (1999). Gap detection thresholds as a function of tonal duration for younger and older listeners. Journal of the Acoustical Society of America, 106, 371-380.