PERIPHERAL VERSUS CENTRAL PROCESSING OF A GAP BETWEEN TWO COMPLEX TONES IN YOUNG AND OLD ADULTS

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1. INTRODUCTION

Older adults often report difficulties in understanding conversations in noisy environments, especially in the presence of multiple talkers. These difficulties are likely due to age-related losses in both spectral and temporal resolution (e.g., Pichora-Fuller, 1997; Schneider, 1997; Stuart & Phillips, 1996). This study explores the nature of age-related losses in the ability to detect a gap between two complex tones differing in spectral content and perceived fundamental frequency.

1.1 Gap detection with simple tones

In a gap detection task, the listener is asked to detect a period of silence between two sounds, the leading and lagging marker. When each marker is composed of a single frequency, the frequencies can be identical or dissimilar. If these frequencies are identical, the markers stimulate the same region on the cochlea and the listener can perform the gap detection task by detecting a gap or discontinuity in a single auditory channel (within-channel). Several studies suggest that gap thresholds in this condition are generally small for all listeners, yet age differences exist between young and old adults (e.g. Schneider et al. 1994). When the spectral content of the two markers does not overlap, the task becomes one of detecting a gap between different auditory channels (between-channel). Studies that investigated gap detection thresholds in between-channel tasks found that gap detection thresholds are larger for between-channel gap detection tasks than for within-channel gap detection tasks (e.g. Formby et al., 1998). Nothing is known about the extent of age differences in between-channel tasks. In contrast to within-channel tasks, it has been suggested that the gap information from different auditory channels is recovered centrally (Formby et al., 1998).

1.2 Gap detection and complex tones

Vowels consist of a fundamental frequency, f_0, and its overtones or harmonics. Hence, in order to understand how age differences in temporal resolution might affect speech, it might be useful to employ complex tones as markers in gap detection task. Complex tones possess two properties that can potentially influence gap detection: 1) The degree of overlap of the spectral content between leading and lagging marker and 2) the harmonic structure of the markers. Regarding the first characteristic, if spectral content is not overlapping, the task is essentially a between-channel one and high thresholds should be expected. With respect to the second property, Oxenham (2000) used harmonic tone complexes to investigate the effect of a change in the fundamental frequency (f_0) between leading and lagging marker on gap detection thresholds and found elevated gap detection thresholds when f_0 was changing.

In the present study we investigated age differences in gap detection performance when the two markers differed with respect to whether or not 1) they had a frequency in common (both markers had energy at 1 kHz), and 2) whether the two markers shared a common f_0 (e.g., marker 1 had energy at 250, 500, 750, and 1000 Hz, and marker 2 at 1000, 1250, 1500, and 1750 Hz). We hypothesized that the presence of a common frequency should improve gap detection if the listener could make use of the discontinuity information in a more central auditory channel that processes tones having the same perceived pitch. Note that because one of the markers does not have energy at the common fundamental frequency, this pitch channel must be central rather than peripheral.

2. METHOD

2.1 Subjects

Ten young adults (mean age: 21.2 years; SD: 1.81) and ten older adults (mean age: 74.5; SD: 4.35) participated. All participants had good hearing (hearing thresholds below 30 dB up to 3000 Hz).

2.1 Apparatus and stimuli

The stimuli were generated digitally with a sampling rate of 20 kHz, and played using TDT System II. In each condition, the leading marker had energy at 250, 500, 750, and 1000 Hz (f_0.= 250 Hz). Four different lagging markers were employed in a 2 (presence versus absence of a common fundamental) by 2 (presence versus absence of a common frequency) design. The lagging markers defining these four conditions were : 1.) Common f_0 and overlap at 1000 Hz (lagging marker had energy at 1000, 1250, 1500, and 1750 Hz); 2.) Common f_0 and no overlapping frequency (lagging marker had energy on 1250, 1500, 1750, and 2000 Hz); 3.) Different f_0's but energy overlap at 1000 Hz (lagging marker had energy on 1000, 2000, 3000, and 4000 Hz); 4.) Different f_0's and no overlapping frequency (lagging marker had energy on 2000, 3000, 4000, and 5000 Hz). All participants were tested in each of these four conditions. In addition, we also tested them in a condition in which there was no frequency overlap and the lagging marker did not have a recognizable f_0 (lagging marker had energy on 1300, 1900, 2100, and 4100 Hz). The latter condition served as a check to see whether having a perceptually identifiable f_0 in the first marker but not the second marker had the same effect on gap detection threshold as having two perceptually different f_0's in the two markers defining a gap. Both leading and lagging markers were 20 ms long. The no-gap stimulus was created by filling in the gap between the two 20 ms markers, with the gap and the no-gap stimulus having the same energy throughout the experiment. The presentation level was 90 dB SPL.

2.1 Procedure

Gap detection thresholds were determined in a 2IFC paradigm and a staircase procedure was used to determine the 79.4% point on the psychometric function. The beginning gap size was 300 ms. The inter-stimulus interval was 100 ms. Each participant was tested in all conditions. The testing order of the conditions was counterbalanced across participants.

3. RESULTS AND DISCUSSION

We first checked to see whether having a perceptually identifiable f_0 in the first but not the second marker had the same effect on gap detection thresholds as having perceptually-identifiable f_0's in both markers. (This analysis only included the 3 conditions in which no frequencies were common to the two markers.) A 2 (Age) by 3 second-marker f_0 condition (second marker f_0 absent, the same, different from first marker f_0) found a significant main effect for second marker f_0 ($F(2,34)=7.71$, $p=0.002$) but no main effect for age, and no significant age by second marker condition interaction. Post hoc analysis revealed that the absence of an identifiable second marker f_0 had the same effect on gap detection thresholds as when the second marker f_0 was the same as that of the first marker. Hence, there does not appear to be an appreciable advantage in having a common fundamental frequency between the two markers when there is no overlapping frequency content. However, thresholds for the condition where the lagging marker had a different f_0 than the first marker were signifcantly higher than in the other two conditions, indicating that when there is no overlapping frequency content, having identifiably different f_0's interferes with gap detection. To evaluate the relative contribution of having overlapping frequencies versus same or different f_0's, we conducted a 2 age (young vs old) by 2 frequency overlap (presence vs absence of shared energy at 1 kHz), by 2 fundamental frequency (same or different f_0 in leading and lagging markers) ANOVA. We found significant main effects for frequency overlap ($F(1,52)=20.94$; $p=0.000$) and f_0 ($F(1,52)=5.16$; $p=0.027$), and a significant interaction between f_0 and frequency overlap ($F(1,52)=5.38$; $p=0.024$). There was no significant main effect of age, nor did age interact with any other factor. Post hoc analyses indicated that gap detection thresholds were elevated only when leading and lagging markers differed in perceived fundamental frequency and did not share a frequency in common. Hence, the pattern of results indicates that gap detection thresholds are only elevated when the two markers do not share a common frequency, and have identifiably different fundamental frequencies. One possible reason for this might be that the presence of a different f_0 in the second marker might have led the participant to focus on the frequencies regions associated with the two f_0's, thereby ignoring information that might be available at other frequencies. However, when the two markers contain at least one frequency in common, the presence of the common frequency prevents this from happening.

In all conditions there was no indication of age differences in gap detection thresholds. This was somewhat surprising given the evidence in the literature for age differences when leading and lagging markers are identical. This suggests that age differences might be limited to situations in which there is substantial spectral overlap (more than a single frequency) between leading and lagging markers. .

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ACKNOWLEDGEMENTS

This research was supported by grants from the Natural Sciences and Engineering Research Council of Canada and Canadian Institutes of Health Research. The first and second author was supported, in part, by a Canadian Institutes of Health Research Training grant.