

GAP DETECTION WITHIN AND ACROSS AUDITORY CHANNELS IN YOUNGER AND OLDER LISTENERS

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1. INTRODUCTION

A common way to investigate the properties of auditory temporal processing is by means of gap detection. In the standard paradigm the subject is required to decide, which of the two stimuli presented in a trial contains a silent gap. In the target stimulus, a leading and a trailing marker, which can be similar or dissimilar in spectral content, bound the gap. The comparison tone comprises the same markers but without a gap. The sound can be a broadband or bandpass noise, or a pure tone. Several studies have used pure tones as stimuli to investigate gap detection thresholds of young adults. Results show that gap detection thresholds are quite small (2-5 ms) when leading and trailing markers are identical in center frequency. Moreover, gap detection thresholds appear to be relatively independent of center frequency when both markers are similar in spectral content (Moore & Glasberg, 1988). When frequency disparity between leading and trailing marker increases, the task becomes more difficult and the shortest detectable gap can be lengthened to 10 – 50 ms (Boehnke & Phillips, 1999; Lister, Koehnke, & Besing, 2000). Hence, the spectral characteristics of the markers bounding the gap exert great influence on the magnitude of the gap threshold. These results suggest that there is something fundamentally different about perceptual processes involved in within and across frequency gap detection tasks. Several researchers suggested an auditory channel theory to explain the discrepancies in threshold (Formby, Gerber, Sherlock, & Magder, 1998; Phillips, Taylor, Hall, Carr, & Mossop, 1997). According to this theory, identical markers constitute a simple discontinuity detection task within a given auditory channel. In this case, the information can be carried by any or all of the afferent nerve fibers serving that channel. On the other hand, when the markers differ in spectral content, each marker activates different populations of peripheral neurons and higher-order processes are required to compare the relative timing across the different perceptual channels subserving the leading and the trailing markers. These cross-channel timing operations exhibit poorer temporal acuity than within-channel gap detection.

A few studies have investigated the relationship between age and gap threshold. In general, these studies found an elevated gap threshold for older listeners in within channel conditions (Schneider, Pichora-Fuller, Kowalchuk, & Lamb, 1994; Snell, 1997). We are not aware of any study

that has examined older listeners' gap detection threshold in the across frequency case. Because audiometric thresholds and gap detection thresholds are uncorrelated, at least in the within channel case, these age effects cannot be attributed to age-related hearing losses (Moore & Glasberg, 1988; Schneider & Hamstra, 1999). Thus, age rather than audiometric loss appears to be the main reason for the significant age effects.

In the present study young and old adults were tested in within and between channel gap detection tasks using pure tones of two different center frequencies.

2. METHOD

Twenty four young (age range 19 to 25 years of age) and 24 older adults (65 years and older) participated in the study. Stimuli were generated digitally with a sampling rate of 20 kHz and converted to analog form using a 16-bit Tucker Davis System (TDS) digital-to-analog converter. The amplitude envelopes for the leading and trailing markers were constructed by summing a series of Gaussian envelopes (standard deviation = 1 ms) whose centers were spaced 1 ms apart to form a flat top envelope with oval rise and decay times (Schneider & Hamstra, 1999). The end of the leading marker was defined as the time at which the envelope (expressed in units of power) of the leading marker declined to 0.9 of its peak value. The beginning of the lagging marker was defined as the point in time where the envelope of the lagging marker reached 0.9 of its peak power. Gap duration was defined as the time difference between these two points. Because the rise-fall time of the envelopes (time difference between the .1 and .9 power points) was 2.45ms, tone were only reduced in amplitude rather than being completely turned off at the shorter durations. Two different kinds of comparison tones were used. In the adjusted condition the number of Gaussian envelopes added to construct the standard equaled the combined sum of Gaussians in both markers plus the omitted or reduced Gaussians in the gap. In the fixed condition the comparison tone had a fixed length equaling the sum of the two marker durations. This way, the comparison tone had the same rise and decay times as the leading and trailing markers, but without the gap. One and two kHz tones, aligned in cosine phase with the peaks of the Gaussians, were multiplied by the amplitude envelopes to obtain target and comparison stimuli. Before multiplication

the envelopes were normalized so that after the multiplication the total energy in each stimulus was equal to the total amount of energy in the stimulus defined by multiplying two widely separated Gaussian envelopes with the appropriate tone. Thus all stimuli were identical with respect to total energy. The tones, after being multiplied by the marker envelopes were presented at 90 dB SPL to the left ear over TDH-49 earphones in a single-wall sound-attenuating booth. The duration of leading and trailing markers were kept constant within each block but varied in between blocks between 10 and 20ms. A 2IFC method was used to determine the gap detection threshold in each condition. A three-down / one-up adaptive tracking procedure (after Levitt, 1971) was used to determine the 79.4 % point on the psychometric function. Starting gap durations were 32.4 ms in the within frequency and 62.4 ms in the across frequency condition. Marker durations of 10 and 20 ms were used. The within channel conditions used leading and trailing markers of identical frequency (1 or 2 kHz, respectively); the across channel conditions used markers of different frequencies (1 and 2 kHz or 2 and 1 kHz for leading and trailing marker, respectively). Subjects were tested four times under each condition and the four thresholds were averaged to compute a final threshold estimate.

3. Results and Discussion

In agreement with other hearing studies (Moore, Peters, & Glasberg, 1992; Schneider et al., 1994; Snell, 1997) the present study found larger and more variable gap thresholds for older normal hearing listeners in within-channel comparisons. As Schneider & Hamstra (1999) pointed out, the age-related differences in threshold may have been especially pronounced due to the rather short marker durations and may vanish eventually for marker durations over 200 ms. No such age-difference was detected in the across-channel conditions. Gap thresholds did not vary systematically with marker duration in the within or between channel task.

The aging auditory system is characterized by accumulating deficits especially in peripheral processes. Within channel gap detection tasks are assumed to engage peripheral temporal processing mechanisms. The age differences found in this task emphasize once again the gradual decline of the peripheral auditory system with age. Across frequency tasks engage more central processes and thus reveal the developmental course of central mechanisms. In accordance with other recent studies the lack of an age difference in the between channel case is interpreted as showing that older adults appear to be able to compensate for sensory deficits on a more central level and minimize age-related sensory losses (Schneider, Daneman, Murphy, & Kwong See, 2001). Hence, it seems to be most likely that the age-specific impairment for older listeners occurs on a peripheral processing level.

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