THE OVERSHOOT EFFECT IN OLDER VERSUS YOUNG ADULTS WITH NORMAL HEARING

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INTRODUCTION

The detectability of a short-duration auditory signal improves as the onset of that signal is delayed relative to the onset of a longer-duration masker. This phenomenon has been termed the "overshoot" effect (Zwicker, 1965). The overshoot effect has been well-characterized with respect to its time course and frequency dependent nature (Bacon & Viemeister, 1985; Bacon & Moore, 1986; Bacon & Smith, 1991; Carlyon, 1987; McFadden, 1989), as well as the effect of varying qualities of the masker or signal (Bacon, 1990; Carlyon & White, 1992), in normal hearing young adults.

The magnitude and time course of the overshoot effect in listeners with normal hearing and those with high-frequency hearing loss have also been examined. A permanent, sensorineural hearing loss may disrupt the mechanisms responsible for a large overshoot effect in the frequency region of the hearing loss (Bacon & Takahashi, 1992). Conversely, however, Carlyon and Sloan (1987) have shown that the size of the overshoot effect is not influenced by sensorineural hearing loss. This discrepancy may be due to the fact that two-thirds of Carlyon and Sloan's subjects had a slight hearing loss in the control ears, or due to the use of different masker levels which affect the degree of overshoot. Furthermore, studies have also shown that the detection threshold for a signal near masker onset improved, and thereby reduced overall degree of overshoot, with temporary hearing loss using either intense sound exposure (Champlin & McFadden, 1989) or aspirin (McFadden & Champlin, 1990).

Several explanations for the underlying mechanism for the simultaneous masking phenomenon of overshoot have been proposed. The most common of these is the result of adaptation of auditory neurons tuned to the signal frequency, particularly those with primarily "onset"-like responses. This explanation has been supported by neurophysiological data, which show that primary auditory neurons give a second onset response to an additional short stimulus regardless of the time interval between the first and second stimuli (Smith, 1979; Smith & Zwislocki, 1975). However, by itself, neural adaptation can only partially account for the large overshoot effect observed in normal hearing young adults. Additional mechanistic contributions must therefore be considered to explain overshoot.

Studies by Bacon and Smith (1991) showed that larger overshoot effects are observed in the presence of broadband maskers than maskers of a single critical band width, suggesting the involvement of components remote from the signal frequency. This off-frequency processing may be susceptible to cochlear damage and therefore responsible for the reduced overshoot effect observed in hearing-impaired subjects (Bacon & Takahashi, 1992).

Another hypothesis is based on synchronous across-fiber firing (Champlin & McFadden, 1989; McFadden & Champlin, 1990; Bacon & Smith, 1991). Large overshoot values may be dependent on large pooled responses from groups of auditory fibers. A large pooled onset response would require that the individual onset responses be combined in a synchronous fashion. Desynchronized firing would lead to a reduced pooled onset response and consequently reduced threshold near onset (and hence degree of overshoot).

Finally, more central processes such as neural inhibition may be involved in overshoot (Bacon & Moore, 1987; McFadden & Champlin, 1990).

Several studies have shown that age-related factors other than peripheral hearing loss account for losses in temporal resolving ability, which may contribute to the speech perception difficulties commonly experienced in the aging population, particularly under degraded listening conditions such as background noise and/or reverberation (Lutman, 1991; Snell, 1997; Strouse *et al.*, 1998; Kricos & Lesner, 1995; Gordon-Salant & Fitzgibbons, 1993).

Physiological changes due to aging, particularly the demyelinization and desynchronous firing of auditory nerve fibers, may contribute to poorer temporal resolution. This change in temporal resolving abilities may reduce the degree of overshoot and/or increase the time-course of overshoot in older adult subjects.

This research compared the overshoot phenomenon in older versus young adults with normal hearing sensitivity. More specifically, this research determined what differences existed in the threshold and time-course characteristics of the overshoot effect between normal hearing older adults (55-70 years of age) and normal hearing young adults (20-30 years of age).

METHODS

Subjects

The subject pool consisted of 12 young adults (20-30 years), and 6 older adults (55-70 years) with normal hearing sensitivity (thresholds not worse than 25 dB HL at any of the octave frequencies from 250-8000 Hz), thus minimizing the possible confounding effect of hearing loss. Subjects did not have prior experience with overshoot experiments. Participation was strictly on a voluntary basis, and participants were not paid for their involvement.

Each subject was asked to complete a background information questionnaire relating to general health and other factors that may affect hearing performance. Then, each subject underwent a standard audiometric assessment of hearing sensitivity. Impedance measures were also administered to determine middle ear function.

Stimuli and Apparatus

Sinusoidal signals were 10 ms in duration, with 5-ms cosine rise/fall times. There was no steady state portion of the signals. Signal frequency was either 1000 Hz or 4000 Hz. The onset of the signal occurred near the beginning of the masker (1-ms delay) or near the temporal center of the masker (250-ms delay).

Noise maskers were 475 ms in duration, including 5-ms cosine rise and fall time. For the narrowband condition, white noise was bandpass filtered between 860-1160 Hz for the 1000 Hz condition, and 3440-4640 Hz for the 4000 Hz signal. For the wideband condition, the noise was highpass filtered with a cutoff frequency of 50 Hz. Masker spectrum level was 30 dB SPL, which has been shown to be the level that produces a maximum overshoot effect in most listeners (Bacon, 1990).

Procedure

Quiet thresholds (in the absence of the noise masker) were obtained at both signal frequencies to provide baseline measures of threshold. Subjects were then given a practice run to familiarize them with the stimuli and the task prior to data collection.

Thresholds were then measured using an adaptive two-interval, forced choice procedure that estimates a 70.7% on the psychometric function (Levitt, 1971). Both intervals contained the masker; one also included the signal. Overshoot was determined as the difference in masked thresholds between 250 and 1-ms signal delay conditions.

Four overshoot values were obtained in total: wideband 1000 Hz, wideband 4000 Hz, narrowband 1000 Hz, and narrowband 4000 Hz.

RESULTS

Mean overshoot values for both young and older adult subjects were larger in the wideband cases than the narrowband (Figure 1). This is consistent with results obtained previously in the literature (Bacon & Smith, 1991). Upon comparison of the mean young versus older adult subject results using a split-plot ANOVA (within-subjects and between-subjects design), there was no significant difference between the two groups for any measure.

	Wideband 1000Hz	Wideband 4000Hz	Narrowband 1000Hz	Narrowband 4000Hz
Younger	5.1 (sd=5.3)	6.1 (sd=7.9)	0.19 (sd=4.6)	0.3 (sd=7.8)
Older	8.7 (sd=7.0)	7.7 (sd=9.7)	2.3 (sd=4.7)	0.2 (sd=5.7)

Figure 1. Mean masking overshoot (in dB) for each masking condition.

DISCUSSION

There were considerable individual differences, regardless of age or audiometric threshold. Some normal-hearing young adult subjects showed little or no overshoot; some older adult subjects demonstrated large degrees of overshoot.

In a temporal resolution study of older adults by He *et al.* (1999), gap detection was better for the long-duration stimulus than for the shorter-duration stimulus. The researchers suggested that the detection of a gap in a noise burst in gap detection studies, and the detection of a signal in a masker in overshoot studies may share a common underlying mechanism. Further research by the current authors involved obtaining gap detection thresholds for the same young adult and older adult populations and comparing gap detection vs. overshoot thresholds on an individual basis.

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