THE RELATIONSHIP BETWEEN A PSYCHOPHYSICAL MEASURE OF COMPRESSION AND OVERSHOOT

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ABSTRACT

The threshold for a brief pure-tone signal masked by a broadband noise is often higher when the signal is near the onset than near the temporal center of the masker. This temporal effect is referred to as "overshoot". It has been hypothesized that overshoot is related to basilar membrane compression. There are typically large individual differences in the magnitude of overshoot. The purpose of the present study was to determine whether these individual differences are related to individual differences in the degree of compression. Thus, an estimate of compression and a measure of overshoot were obtained in 10 normal-hearing subjects. Compression at 4 kHz was estimated as the ratio of the slope of an off- to an on-frequency growth-of-masking function in forward masking. Overshoot was determined as the difference in threshold for a 4-kHz signal located at the onset vs. the temporal center of a broadband noise masker. Although there were individual differences in the magnitude of compression and the amount of overshoot, there was no significant correlation between the two. Thus, it appears that the large individual differences typically seen in overshoot experiments are not due to individual differences in the magnitude of compression.

INTRODUCTION

- The threshold for a brief pure-tone signal masked by a broadband noise is often higher when the signal is near the onset as compared to the temporal center of the masker. This is referred to as "overshoot".
- It has been suggested that overshoot is related to basilar membrane compression, and more specifically that the decrease in threshold reflects a reduction in compression over time through the influence of the efferent medial olivocochlear bundle (MOCB) on the outer hair cells (OHCs).[1, 2]
- This is consistent with the fact that the amount of time it takes the efferent system to reach its strongest effect is similar to the time required for the signal threshold to reach its minimum. [3, 4]
- There are typically large differences in the magnitude of overshoot across subjects due to large differences in threshold at masker onset.

The purpose of this study was to determine whether these individual differences in overshoot are related to individual differences in the magnitude of compression.

STAGE 1: COMPRESSION

On-frequency and off-frequency forward-masked growth-of-masking (GOM) functions were measured in order to obtain a psychophysical estimate of compression.

Methods

- 10 normal-hearing listeners
- 2IFC procedure, 3-up, 1-down adaptive rule
- f_s=4000 Hz; f_m=2000 Hz or 4000 Hz
- Signal level ranged from 30 to 50 dB SPL.
- Masker level was varied adaptively.
- Masker-signal delay was determined individually so that masker levels ranged from 30-70 dB SPL; delay values ranged from 5 to 30 ms.
- Masker duration was 200 ms and signal duration was 10 ms. Durations include 5-ms cos^2 onset and offset ramps.
- An ipsilateral high-pass background noise with a 4800-Hz cut-off frequency was used to prevent off-frequency listening. A contralateral background noise with a bandwidth from 3200-4800 Hz was used to prevent cross-ear hearing.

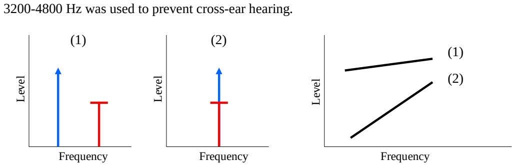

Fig. 1. Schematic of GOM procedure (left panel) and hypothetical results (right panel).

•The left panel displays a schematic of the off-frequency GOM condition. The center panel displays a schematic of the on-frequency GOM condition. In both cases, the masker is represented in blue, and the signal is represented in red.

•The right panel displays the hypothetical GOM function for each condition. In the off-frequency case (1), the signal is being compressed but the masker is not. In the on-frequency case (2), the masker and signal are being equally compressed.

Results

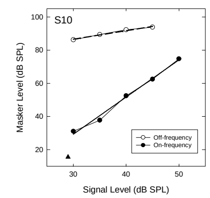

Fig. 2. GOM functions for S10. The open circles represent the off-frequency function, and the filled circles represent the on-frequency function. Quiet threshold for the 4-kHz signal is indicated by the filled triangle. Regression lines fit to the functions are represented by bold lines (dashed for the off-frequency function, and solid for on-frequency function).

•Fig. 2 displays a GOM function for a representative subject.

•Each GOM function was fit with a linear regression line. The regression line is denoted by the bold line (dashed for the off-frequency function, solid for the on-frequency function).

•The ratio of the off-frequency to on-frequency slope was taken as the estimate of compression for each subject.

•Compression estimates ranged from 0.12 to 0.50.

STAGE 2: OVERSHOOT

Simultaneous-masked GOM functions were measured with the signal at the onset and temporal center of a broadband-noise masker in order to obtain an estimate of overshoot.

Methods

•10 normal-hearing listeners

•2IFC procedure, 3-down 1-up adaptive rule

•f_s=4000 Hz

•The masker was 10 equivalent rectangular bandwidths wide (1720-6280 Hz), centered at the signal frequency.

•Masker spectrum levels were 10, 20, and 30 dB SPL.

•Signal level varied adaptively

•Masker duration was 400 ms and signal duration was 10 ms. Both include 5-ms cos^2 onset and offset ramps.

•The signal was located at either the onset (0-ms delay) or the temporal center (195-ms delay) of the masker.

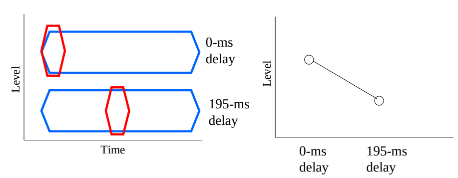

Fig. 3. The left panel displays a schematic of overshoot conditions. The blue shapes represent the masker, and the red shapes represents the signal. The right panel displays a schematic of expected results. Note that the threshold for the 0-ms condition is higher than that for the 195-ms delay.

Results

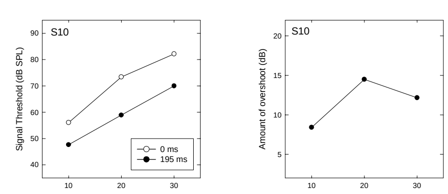

Fig. 4. The left panel displays the masking functions for S10. Open circles represent the 0-ms delay condition, filled circles represent the 195-ms delay condition. The right panel displays the amount of overshoot (0-ms threshold minus 195-ms threshold for each masker level) for the same subject.

•The left panel of Fig. 4 displays a masking function for a representative subject. Note the elevation of the 0-ms delay thresholds above the 195-ms delay thresholds.

•An estimate of overshoot was determined by subtracting the 195-ms delay threshold from the 0-ms delay threshold. The right panel of Fig. 4 displays the amount of overshoot for the three masker levels for the same representative subject.

•For seven subjects, the maximum amount of overshoot was obtained with the 20-dB masker. For the remaining subjects, it was at the 10-dB masker. Because overshoot declined at 30 dB, the average amount of overshoot for each subject was determined by averaging the amount of overshoot at masker levels of 10 and 20 dB.

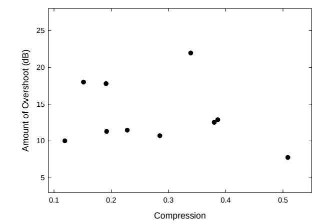

Fig. 5. Overshoot v. compression for S1-S10.

•Fig. 5 shows a scatter plot of overshoot versus compression. To evaluate the relationship between overshoot and compression, a Pearson correlation coefficient was computed. The correlation was small and non-significant ($r=-0.223$, $p=0.53$).

MODEL FITS

•The results show no relationship between overshoot and compression. To determine whether the changes in compression observed here would be expected to yield clear changes in overshoot, the equation

$$l_{out} = (0.5+(x\times 0.1))\times l_{in}+50-(x\times 10)+8.5\times(1-(\frac{1}{1+\exp(-0.09\times(l_{in}-60))}))$$

was used to approximate the basilar membrane input-output function for a tone at characteristic frequency, where x=amount of compression; l_{in}=input level in dB; l_{out}=output level in dB. [5,7]

•This equation was used to model the amount of overshoot expected for a decrease in compression over the course of masker stimulation. The centered x was held constant, and expected amount of overshoot was determined as a function of varying onset x values.

•For the range of compression seen here, a 33 dB change in overshoot was predicted in a systematic relationship where as compression grows stronger, more overshoot is present.

CONCLUSIONS

1) *The magnitude of compression at 4000 Hz as measured by forward-masked GOM functions ranged between 0.12 and 0.50.*

2) *The amount of overshoot at 4000 Hz (averaged at masker levels of 10 and 20 dB SPL) ranged from approximately 8-22 dB.*

3) *There was no significant relationship between overshoot and compression, suggesting that individual differences in the amount of overshoot can not be explained by individual differences in compression.*

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