Deutsche Gesellschaft für Akustik (Ed.) (2003): Fortschritte der Akustik - DAGA `03. Oldenburg: DEGA; pp. 606-607.

Intensity Discrimination and Loudness in Forward Masking: The Effect of Masker Level

Daniel Oberfeld

Inst. für Psychologie und Arbeitswissenschaft, Technische Universität Berlin; Email: oberfeld@gp.tu-berlin.de

Introduction

If a brief sound is presented in close temporal proximity to another sound (e.g., a forward masker), both intensity resolution and perceived intensity (loudness) are altered by the masker.

Zeng, Turner, and Relkin [1] were the first to report the "midlevel hump" in non-simultaneously masked intensity discrimination. In the presence of an intense forward masker (90-100 dB SPL), just-noticeable differences (jnd's) were considerably elevated at intermediate standard levels (40-60 dB SPL). At low and high standard levels, however, jnd's remained approximately as small as in quiet.

As to loudness, the presence of an intense tone preceding or following a target tone causes the perceived intensity of the target tone to be larger than in quiet ("loudness enhancement"; e.g., [2]). Conditioners presented at a level below target tone level result in a reduction of perceived intensity ("loudness decrement"). Again, the effects are more pronounced at intermediate standard levels [7,8].

Previous models proposed for the midlevel hump in intensity discrimination (the recovery-rate model [1], and the referential-encoding hypothesis [3,4]) can not explain similarity effects reported in [5] and [6]. Moreover, the effects of various parameters on both phenomena are very similar (cf. [4]), and jnd's and loudness enhancement have been found to be correlated [7,8]. These findings suggest a common process or a causal link between the phenomena [4]. The models mentioned above can not account for loudness enhancement, however. In the present paper, I formulate an alternative model and present data from two experiments designed to test the model.

Model

I propose that the effects of non-simultaneous masking can be understood by a two-level model that

1. combines the "mergence hypothesis" [2] (which can explain loudness enhancement) and the "loudness enhancement hypothesis" [4] (which assumes a causal link between enhancement and the jnd elevation)
2. extends the mergence hypothesis by introducing a similarity effect.

The mergence hypothesis assumes that a listener 'combines' loudness of masker and standard, resulting in loudness matches reflecting a weighted average between masker and standard loudness. However, the model predicts enhancement to increase monotonically with the level difference between masker and standard, which contradicts the finding of a midlevel hump in loudness enhancement [7,8]. In the new model, a **similarity effect** is introduced. It is assumed that less mergence will occur if the tones are perceptually different (e.g., in spectral content, duration, or intensity). This idea is compatible with previous studies demonstrating, e.g., that the midlevel hump is most pronounced if masker and standard are of the same duration [5]. Now, for a 90-dB SPL masker and a 90-dB SPL standard, the weighted average between the two perceived intensities is just the same as the loudness of each interactor presented alone (*no enhancement*). A 30-dB SPL standard and a 90-dB SPL masker are perceptually too different for strong mergence to occur (*virtually no enhancement*). A 60-dB SPL standard and a 90-dB SPL masker, however, are sufficiently similar perceptually for their loudness to be merged (*pronounced enhancement*). Obviously, the similarity effect results in the prediction of a midlevel hump in loudness enhancement. In a second step, the new model predicts jnd's: according to the loudness-enhancement hypothesis, enhancement causes a jnd elevation by introducing loudness variability. Consequently, the model predicts the two effects to be correlated.

The model was tested by independently varying masker level and standard level and measuring jnd's and loudness matches. Unlike previous models, the new model predicts a **mid-difference hump**, i.e., jnd's and loudness enhancement are expected to be non-monotonic functions of the masker-standard level difference at each standard level.

Experiment 1: Intensity Jnd's

Stimuli

The standard was presented at 25 dB SPL, 55 dB SPL, and 85 dB SPL, respectively. The level difference between masker and standard ($L_M - L_S$) was varied between −60 and +60 dB in 15-dB steps; masker level ranged between 10 dB SPL and 100 dB SPL. Standard and masker were 1-kHz pure tones with a steady-state duration of 20 ms, gated on and off with 5-ms $\cos^2$-ramps and presented to the right ear via Sennheiser HDA200 headphones.

Procedure

A 2I, 2AFC adaptive procedure (2-down, 1-up; [9]) was used to measure jnd's ($\Delta L_{DL} = 10 \cdot \log_{10}[1 + \Delta I/I]$). Standard and standard-plus-increment were presented in two observation intervals in random order. In forward masked trials, a masker was presented in both intervals (ISI = 100 ms). Listeners selected the interval containing the increment. Visual feedback was provided after each trial. Step size was 5 dB for the first four reversals and 2 dB for the remaining eight reversals. The jnd was computed as the arithmetic mean of the increments presented at the last eight reversals. At least three runs were obtained for each data point.

Listeners

Six listeners participated in the experiment. One of them (DO) was the author; the others were paid an hourly wage. All had thresholds better than 10-dB HL in the frequency range between 125 Hz and 6000 Hz.

Results

Fig. 1 shows the individual data. For masker levels smaller than standard level ($\Delta L = L_M - L_S \leq 0$), forward masked jnd's were approximately as small as in quiet. As the level difference increased, jnd's were elevated at each standard level. At a standard level of 25 dB SPL, there was evidence for a **mid-difference hump** for four listeners. The maximum jnd's were observed at level differences of 15 to 45 dB. With further increase in the level difference, jnd's became smaller again, resulting in non-monotonic functions. For BS, jnd's strongly increased with ΔL. For DO, no jnd decrease, but also no sizeable jnd increase was observed at the largest ΔL. At a standard level of 55 dB SPL, only SD and YS showed a decrease in the jnd elevation at the largest level difference. In accordance with previous findings, jnd's were not elevated for the 85-dB SPL standard combined with an 85-dB SPL masker.

Deutsche Gesellschaft für Akustik (Ed.) (2003): Fortschritte der Akustik - DAGA `03. Oldenburg: DEGA; pp. 606-607.

At a level difference of +15 dB, jnd's were elevated even for the high-intensity standard, however. From the jnd's obtained with an 85-dB SPL masker at the different standard levels, it is obvious that a 'midlevel hump' was present for all listeners except BS.

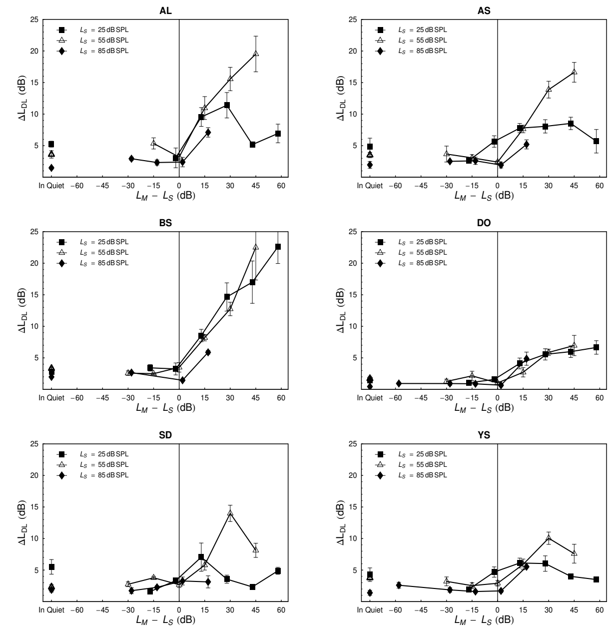

Fig. 1: Jnd's (10 log$_{10}$[1 + Δ*I*/*I*]) as a function of the level difference between masker and standard. Each panel shows data for one listener. Boxes: 25-dB SPL standard. Triangles: 55-dB SPL standard. Diamonds: 85-dB SPL standard. Errorbars show ± 1 SEM.

Experiment 2: Loudness Matches

Stimuli

The same stimuli as in Experiment 1 were used.

Procedure

The standard was always presented in the first interval, followed by a comparison tone after an ISI of 650 ms. In forward-masked trials, a masker was presented in interval 1 only (ISI = 100 ms). Listeners responded whether the test tone in interval 1 (the standard) or the test tone in interval 2 (the comparison tone) had been louder. Comparison tone level was adjusted in two randomly interleaved tracks [10]. The upper track (2-down, 1-up rule) tracked the 70.7% point on the psychometric function. In the lower track, a 2-up, 1-down rule was used to track the 29.3% point of the psychometric function. Step size was 5 dB until the fourth reversal and 2 dB for the remaining eight reversals. No feedback was provided. In each run, the arithmetic mean of the level differences between comparison tone and standard ($L_C - L_S$) at the last eight reversals was computed for the upper and for the lower track. The arithmetic mean of these two values was taken as the loudness match. At least three runs were obtained for each data point.

Listeners

The same listeners as in Experiment 1 participated, with the exception of listener AS.

Results

Fig. 2 shows individual loudness matches. Positive values of $L_C - L_S$ denote loudness enhancement. As expected, there was loudness decrement if masker level was smaller than standard level. As $L_M - L_S$ increased above 0 dB, an increasing amount of loudness enhancement was observed. The maximum amounts of enhancement were present for level differences between 15 and 45 dB. At larger level differences, loudness enhancement decreased again, resulting in non-monotonic functions. This pattern was observed for all listeners except BS at the 25-dB SPL standard level, and for all listeners except BS and SD at 55 dB SPL. For listener BS, the masker had a very strong effect again. Intense maskers produced loudness decrement in several cases.

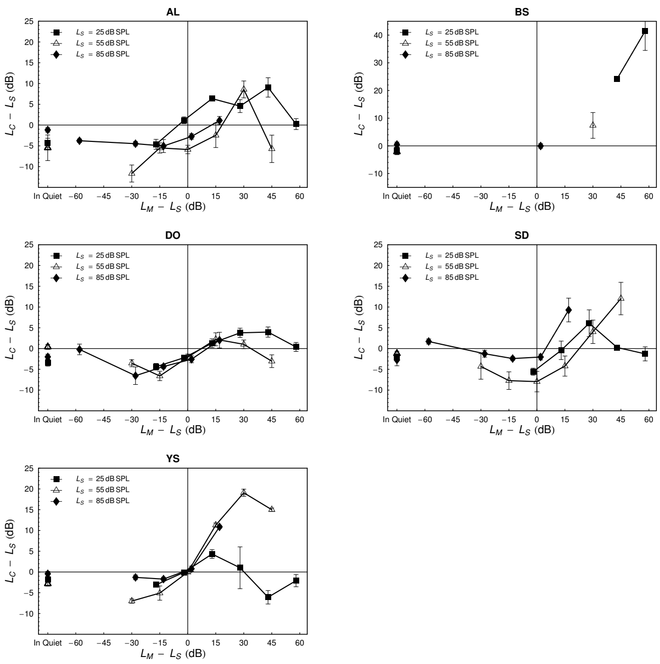

Fig. 2: Loudness matches ($L_C - L_S$) as a function of the level difference between masker and standard. Same format as Fig. 1.

Summary

The non-monotonic functions observed in both experiments are evidence supporting the new model that predicts jnd's and enhancement to increase with the masker-standard level difference up to a point where the perceptual distance between masker loudness and standard loudness becomes sufficiently large for the weight assigned to masker loudness to decrease again. The differences between the functions at the 25-dB SPL and the 55-dB SPL standard level were not predicted by the model, however. It also remains unclear why intense maskers produced loudness decrement in some cases.

[1] Zeng, F.-G., Turner, C. W., & Relkin, E. M. (1991): Recovery from prior stimulation II: Effects upon intensity discrimination. Hear. Res. **55**, 223-230

[2] Elmasian, R., Galambos, R., & Bernheim, A. (1980): Loudness enhancement and decrement in four paradigms. J. Acoust. Soc. Am. **67**, 601-607

[3] Plack, C. J., & Viemeister, N. F. (1992): Intensity discrimination under backward masking. J. Acoust. Soc. Am. **92**, 3097-3101

[4] Carlyon, R. P., & Beveridge, H. A. (1993): Effects of forward masking on intensity discrimination, frequency discrimination, and the detection of tones in noise. J. Acoust. Soc. Am. **93**, 2886-2895

[5] Schlauch, R. S., Lanthier, N., & Neve, J. (1997): Forward-masked intensity discrimination: Duration effects and spectral effects. J. Acoust. Soc. Am. **102**, 461-467

[6] Schlauch, R. S., Clement, B. R., Ries, D. T., DiGiovanni, J. J. (1999): Masker laterality and cueing in forward-masked intensity discrimination. J. Acoust. Soc. Am. **105**, 822-828

[7] Zeng, F.-G. (1994): Loudness growth in forward masking: Relation to intensity discrimination. J. Acoust. Soc. Am. **96**, 2127-2132

[8] Plack, C. J. (1996): Loudness enhancement and intensity discrimination under forward and backward masking. J. Acoust. Soc. Am. **100**, 1024-1030

[9] Levitt, H. (1971): Transformed up-down methods in psychoacoustics. J. Acoust. Soc. Am. **49**, 467-477

[10] Jesteadt, W. (1980): An adaptive procedure for subjective judgments. Perc. Psychophy. **28**, 85-88