Forward-Masked Intensity Discrimination: Evidence From One-Interval and Two-Interval Tasks

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Introduction

Non-simultaneous masking produces a rather complex pattern of effects in intensity resolution. With an intense forward masker, difference limens are strongly elevated for a midlevel standard, relative to the jnd in quiet. On the other hand, the masker has only a small effect on jnd's for standards presented at low and high levels, respectively [1], resulting in the so-called *midlevel hump* in intensity discrimination. In experiments varying the masker-standard level difference while keeping the standard level constant, the jnd elevation caused by a forward masker was larger for *intermediate* than for *large* masker-standard level differences (*mid-difference hump,* [2]). These observations are evidence for the *similarity model* proposed by Oberfeld ([2, 3]), which assumes that the masker degrades or biases the memory representations of the target tones [4, 5], and that the *perceptual similarity* of masker and standard is crucial for the effect of the masker on intensity discrimination. Maskers strongly differing from the standard in at least one dimension (e.g., loudness, duration) are assumed to have only a relatively small effect on the memory representations and thus on intensity resolution. The model therefore predicts the jnd elevation to be a non-monotonic function of the masker-standard level difference.

Intensity resolution in forward masking has been measured in two- and three-interval paradigms exclusively. Most frequently, adaptive procedures have been used, the notable exception being [6]. It is therefore not impossible that the previously reported effects of forward masking on intensity resolution are –at least in part– related to the experimental procedure. First, the effect could depend on the task requirements in a two-interval paradigm. If the memory representation of the target tone presented in the first interval was systematically biased by the masker (e.g., remembered target loudness shifted towards masker loudness, [3]), the resulting response bias would lead to larger difference limens measured in an adaptive procedure. Second, the dynamics of the adaptive procedure could play a role. There is evidence for the remembered loudness of the standard being shifted towards masker loudness ("loudness enhancement", [5]). Therefore, the initially large increment used in most studies may have resulted in loudness of the standard being enhanced by more than loudness of the standard-plus-increment, due to the different level differences between masker and target tone. Such an effect would result in the two tones sounding more similar and thus in a reduction in performance.

In order to gain insight into potential procedural effects, the present experiment measured intensity resolution in both a two-interval (2I) and a one-interval (1I) paradigm for the same listeners. In the 1I paradigm, the level increment was constant within a given block. To study the effect of the masker-standard level difference, a 25-dB SPL standard was presented in quiet and combined with a 55-dB SPL and an 85-dB SPL masker, respectively. Additionally, a 55-dB SPL standard was presented, either in quiet or combined with an 85-dB SPL masker. The latter combination resulted in the largest jnd elevations in previous studies.

Method

Stimuli and apparatus

The standard and the masker were 1-kHz pure tones (steady-state duration 20 ms, 5-ms $\cos^2$-ramps). The silent interval between masker offset and standard onset was 100 ms. In the 2I paradigm, a masker was presented in both intervals; the interval between the offset of the first target tone and the onset of the second target tone was 650 ms. The stimuli were generated digitally, played back via one channel of an RME ADI/S D/A converter, attenuated (TDT PA5), buffered (TDT HB7), and presented to the right ear via Sennheiser HDA 200 headphones.

Listeners

Six normal-hearing volunteers participated in the experiment (age 20 – 33 years). One of them (DO) was the author; the remaining participants were students at the Universität Mainz. All except the author were naïve with respect to the hypotheses under test.

Procedure

Two-interval paradigm

A 2I, 2AFC, adaptive procedure with a 3-down, 1-up tracking rule was used to measure difference limens ($\Delta L_{DL} = 10 \log_{10}[1 + \Delta I/I]$). In one of the intervals (selected randomly), an in-phase increment was added to the standard. Listeners indicated the interval containing the louder target tone. Visual trial-by-trial feedback was provided. Step size was 5 dB until the fourth reversal, and 2 dB for the remaining six reversals. For each track, the arithmetic mean of the pressure-increment levels ($10 \log_{10}[\Delta I/I]$) at the last six reversals was computed. The resulting mean value was then converted to ΔL_{DL}. In each block, two randomly interleaved tracks were presented. For each condition, at least three blocks were run.

One-interval paradigm

Intensity resolution was measured in a 1I, 2AFC, absolute identification procedure. In each trial, the standard or the standard plus a level increment was presented with identical a-priori probability. Listeners decided whether the soft tone or the loud tone had been presented. The increment was constant in each block of 100 trials. The interval between the onset of the standard in trial n and $n + 1$, respectively, was 3930 ms. Only one masker-standard level combination was presented in a given block. For each level combination ($L_S \times L_M$), three different level increments were presented, selected to obtain d' values between 0.5 and 3 in each condition. The level increment ranged between 1 dB and 9 dB. Per level condition, at least two blocks of 100 trials were run with the intermediate increment and at least one block with each of the two remaining increments.

Results

Two-interval paradigm

Individual results from the two-interval paradigm are displayed by the filled squares in the left panels of Fig. 1.

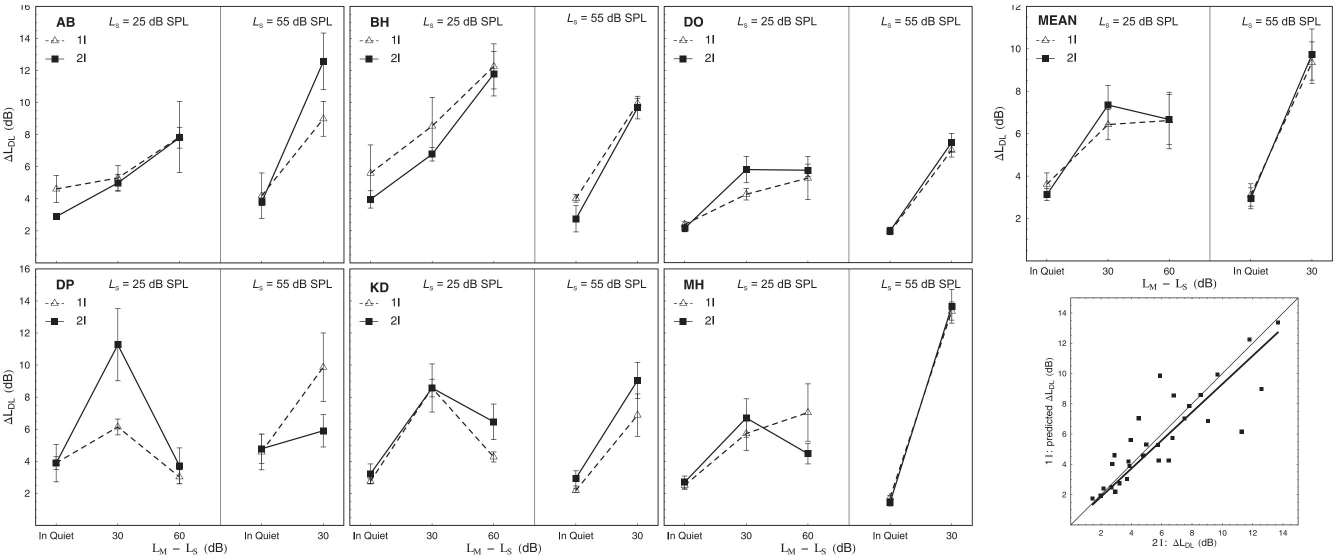

Fig. 1: *Left panels*: level increments corresponding to $d' = 1.16$, as a function of the masker-standard level difference. Panels represent listeners. Open triangles: 1I paradigm. Filled squares: 2I paradigm. In each panel, the left lines show the data for the 25-dB SPL standard, the right lines show the data for the 55-dB SPL standard. Error Bars: ± 1 SEM. *Right upper panel*: Mean data. *Right lower panel*: Scatterplot of ΔL_{DL} estimated in the 2I (x-axis) and the 1I paradigm (y-axis). Each data point represents one listener and one masker-standard level combination. The thick line shows the best-fitting linear function passing through the origin ($R^2 = .70$).

At the 25-dB SPL standard level, three of the six listeners showed a clear *mid-difference hump*. For listener DO, ΔL_{DL} did not continually increase with the masker-standard level difference, either: performance was identical with the 55-dB SPL and the 85-dB SPL masker. A repeated-measures ANOVA indicated a significant effect of the masker-standard level difference, $F(2, 10) = 6.07$, $\tilde{\varepsilon} = .56$, $p = .05$. Pairwise comparisons showed that the difference limens obtained in the two forward-masking conditions did not differ significantly ($t[5] = 0.38$), indicating that mean ΔL_{DL} did not continually increase with the level difference between masker and standard.

One-interval paradigm

For the 3-down, 1-up rule used in the 2I task, the intensity difference limen ΔL_{DL} corresponds to 79.4% correct or $d' = 1.16$. To compare intensity resolution in the 1I and the 2I paradigm, the level increment corresponding to $d' = 1.16$ was estimated for each block in the 1I task. First, resolution-per-dB was computed ($\delta' = d'/\Delta L$). Next, the arithmetic mean of δ' obtained in all blocks presenting a given condition (level combination and increment) was calculated. The increment corresponding to $d' = 1.16$ was then computed as $\Delta L_{DL} = 1.16/\delta'$. The open triangles in Fig. 1 show the estimated values, which for most listeners and conditions closely followed the difference limens measured in the 2I, adaptive procedure.

1I versus 2I paradigm

At the 25-dB SPL standard level, an $(L_M - L_S) \times$ Task repeated-measures ANOVA confirmed the similarity between the just-noticeable level increments estimated for the two tasks. Neither the main effect of task ($F[1, 5] = 0.11$), nor the $(L_M - L_S) \times$ Task interaction ($F[2, 10] = 1.32$) was significant (Fig. 1, upper right panel). At the 55-dB SPL standard level, there was also neither a significant main effect of task ($F[1, 5] = 0.041$), nor an $(L_M - L_S) \times$ Task interaction ($F[1, 5] = 0.25$).

The lower right panel of Fig. 1 shows a scatterplot of ΔL_{DL} estimated in the 2I and the 1I paradigm, respectively. The relation between the two estimates can be described reasonably well by linear regression through the origin (thick line), $R^2 = .70$.

Conclusions

Results from both tasks are compatible with previous data [2], again showing that the effect of a forward masker peaks or saturates at intermediate masker-standard level differences. The similarity of the jnd's obtained in the two paradigms indicates that the previously reported effects of a forward masker on intensity resolution cannot be attributed to the use of a 2I, adaptive procedure. Note that in principle, the listeners might have used across-trial comparisons in the 1I task, effectively transforming the identification into a discrimination task. Such a strategy is unlikely, however, given the inter-trial interval of nearly 4 s [7]. A critical test of this assumption would be to compare intensity resolution in a 2I paradigm with and without a level rove [8].

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