Detektion gradueller Intensitätsänderungen in auditiven Stimuli

[Auditory detection of gradual changes in intensity]

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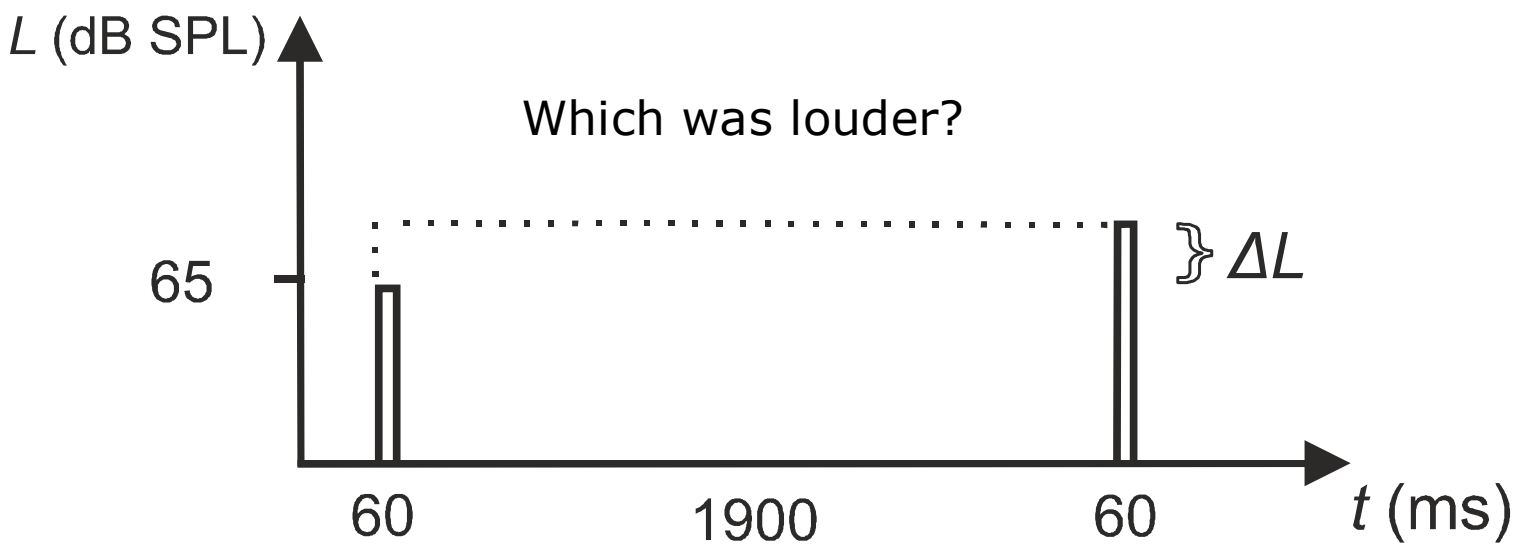
Auditory intensity discrimination

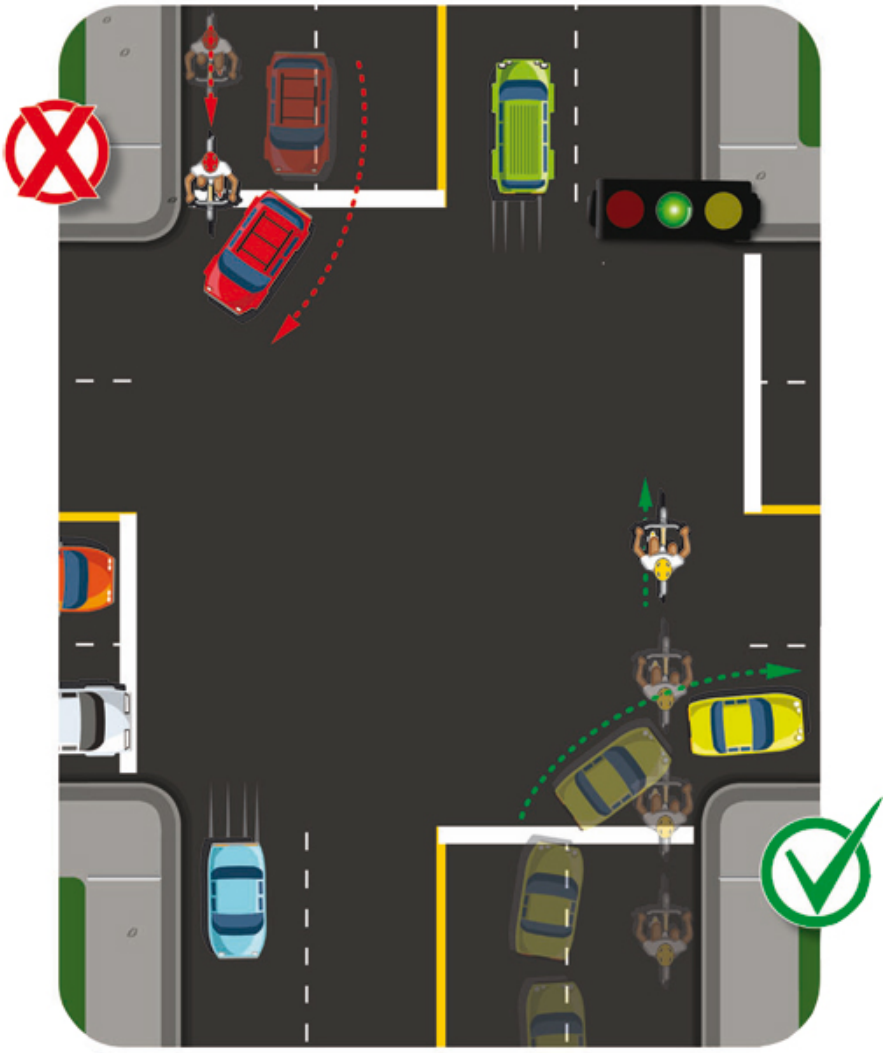
- How do listeners judge the intensity of a sound?



- Huge literature: How does the intensity difference limen depend on the sound pressure level, frequency spectrum, duration, monaural/binaural etc.?
  - Many effects accounted for by models of the auditory periphery (cochlea and auditory nerve)
- Also well studied: Detection of abrupt intensity changes in an ongoing sound

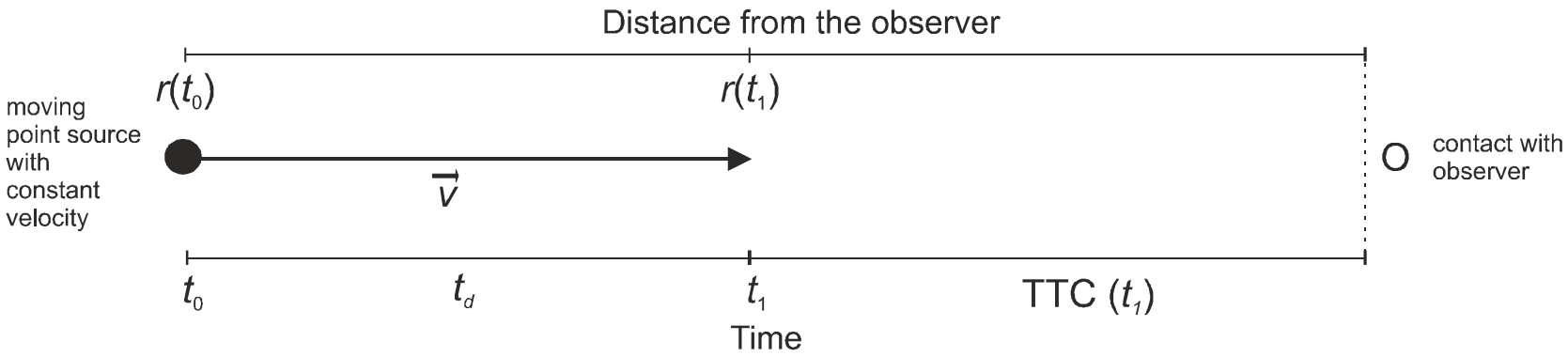
Gradual changes in level

- In our environment, approaching sound sources are signaled by **gradual** changes in acoustic intensity

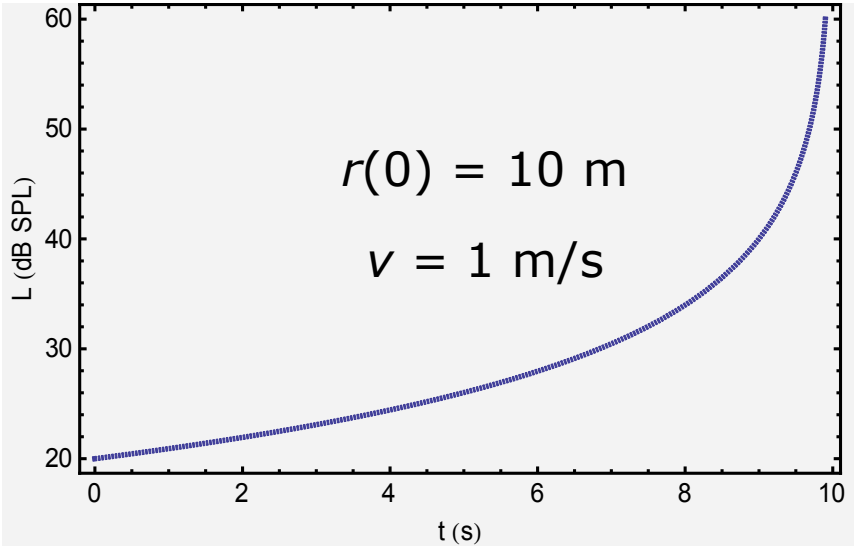


Gradual changes in level

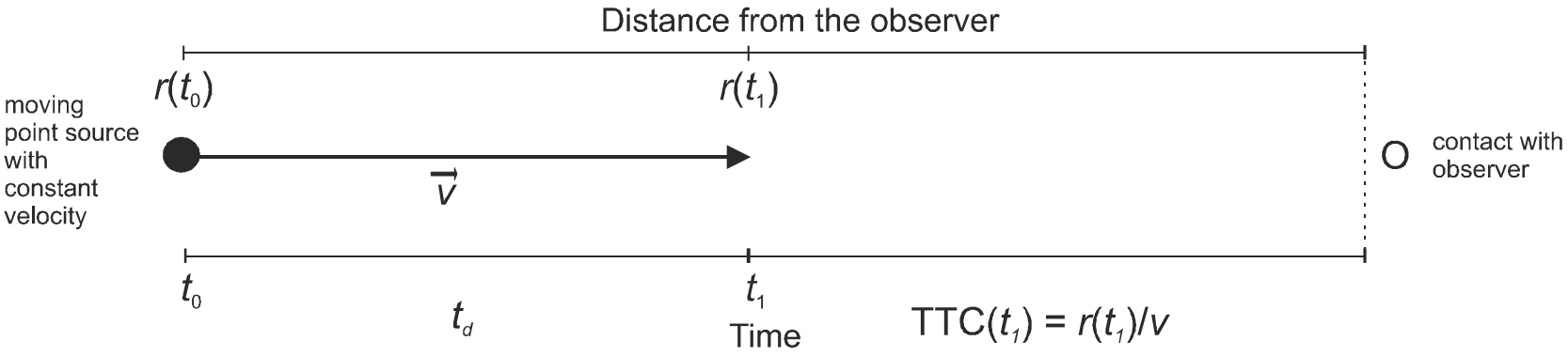
- In our environment, approaching sound sources are signaled by **gradual** changes in acoustic intensity
- Example: sound source approaches with constant velocity



- "Inverse law": sound pressure $p(t) \propto 1/r(t)$ [free field] -> characteristic level profile



Auditory time-to-contact judgments



- Time-to-contact (TTC) judgment: *How long will the object take until it hits me*?

- The pressure/level change across the time interval t_d can be used to compute an **absolute** estimate of TTC

$$\beta = \frac{t_d}{p(t_1)/\,p(t_0) - 1} = \frac{t_d}{10^{\Delta L/20} - 1} = \mathrm{TTC}(t_1)$$

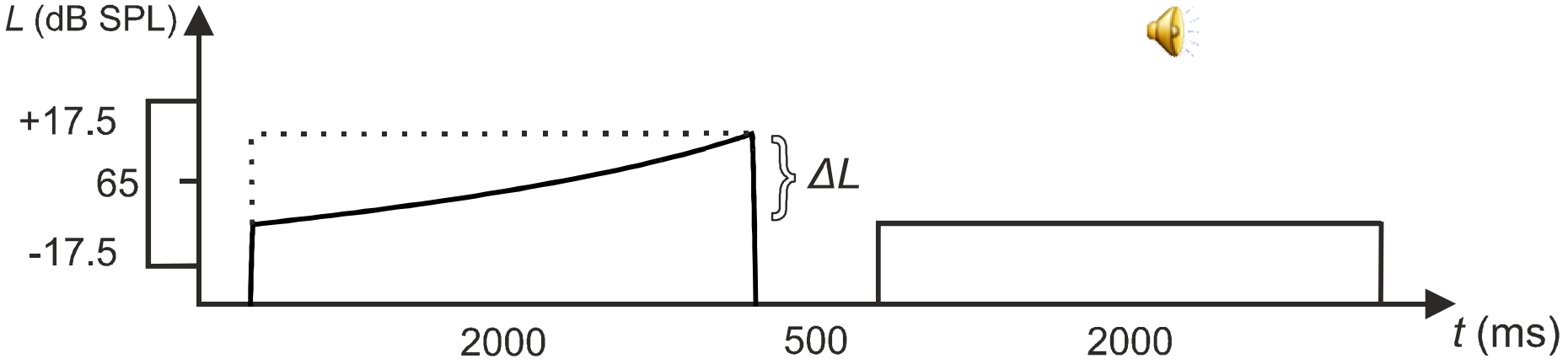
  - No information about the velocity / the distance / the acoustic intensity required

  ⇒ Being sensitive to gradual intensity changes is useful!

- But surprisingly, next to nothing is known about the sensitivity to **gradual** changes in intensity

How do listener judge gradual intensity changes?

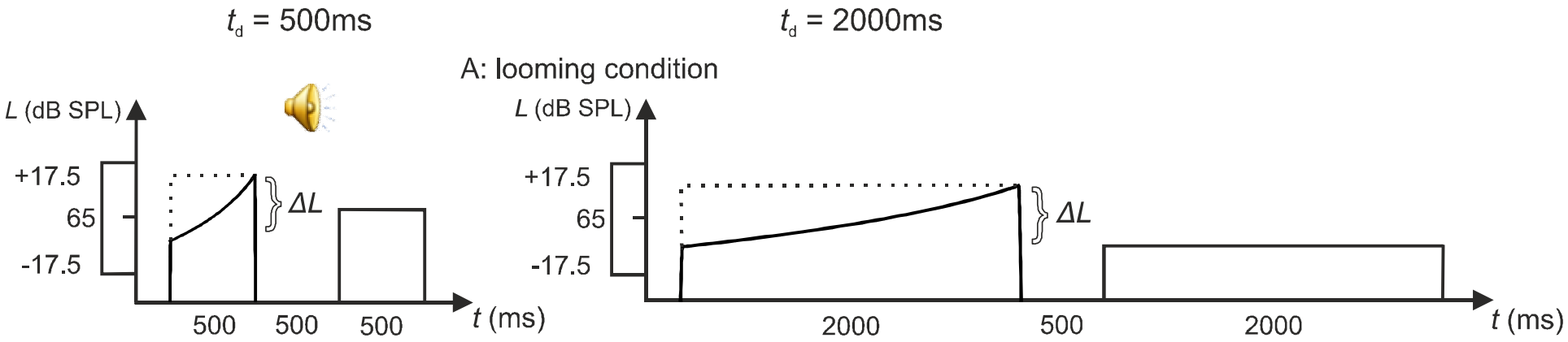
- First step: If we listen to a sound for a given duration (t_d), what is the minimal change in level that can be detected?
- **Our experiment**: two-interval task, 1 kHz tones, one with a „looming“ level profile, monaural



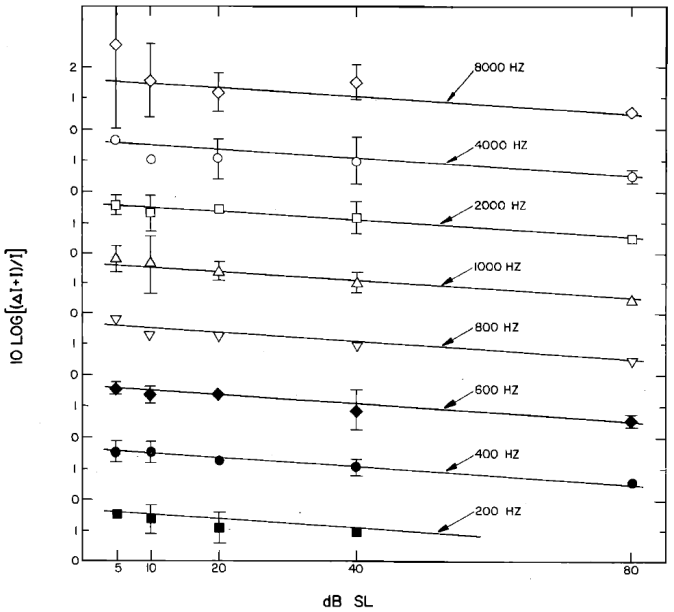
  - Listener decides which sound (1st or 2nd) contained a change in level (ΔL)
  - Random within-trial level rove (±17.5 dB) -> task could not be solved by judging only the peak level

Experimental parameters

- Duration varied (t_d = 500 ms or 2000 ms)
  - Higher rate of change in brief sounds -> this might make the level change easier to detect



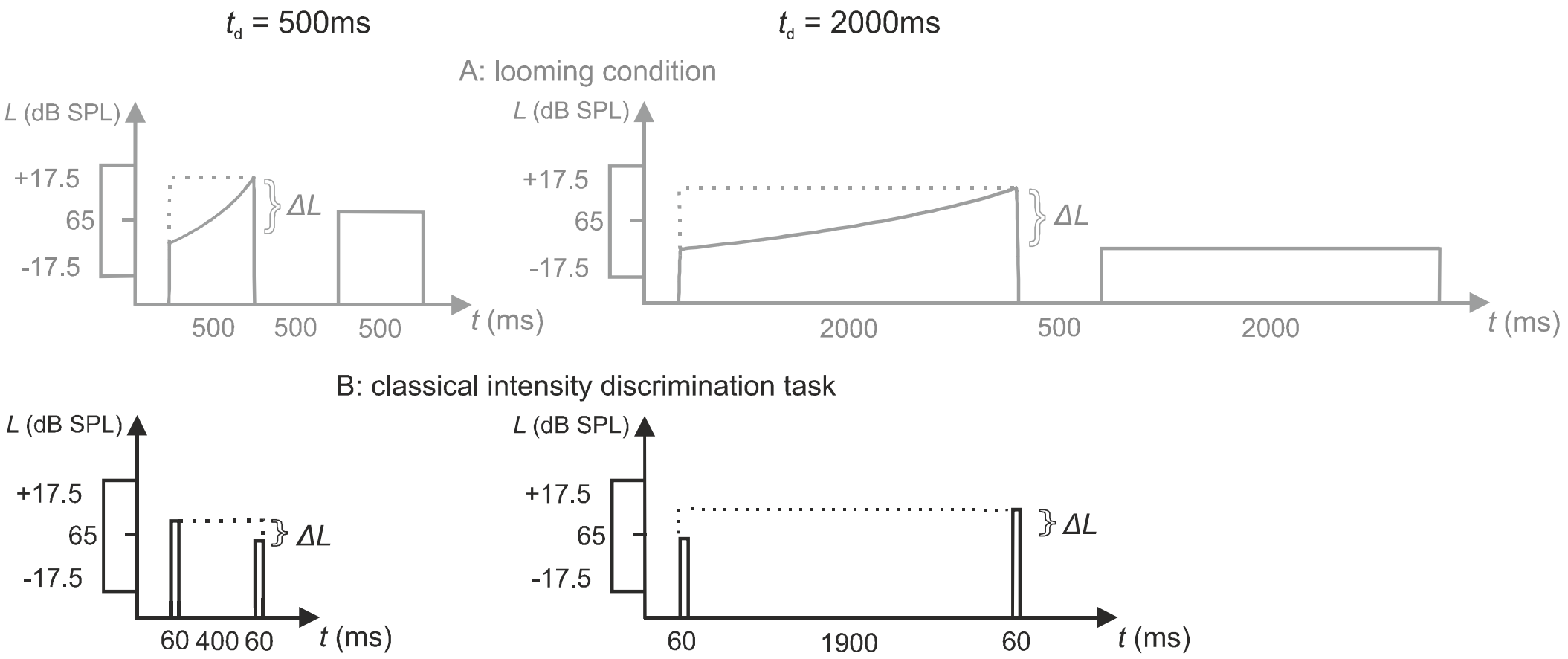
- Peak level varied (40 or 65 dB SPL)
  - Intensity discrimination: near-miss to Weber's law
  - ⇒ higher sensitivity expected at the higher peak level



Jesteadt et al. (1977)

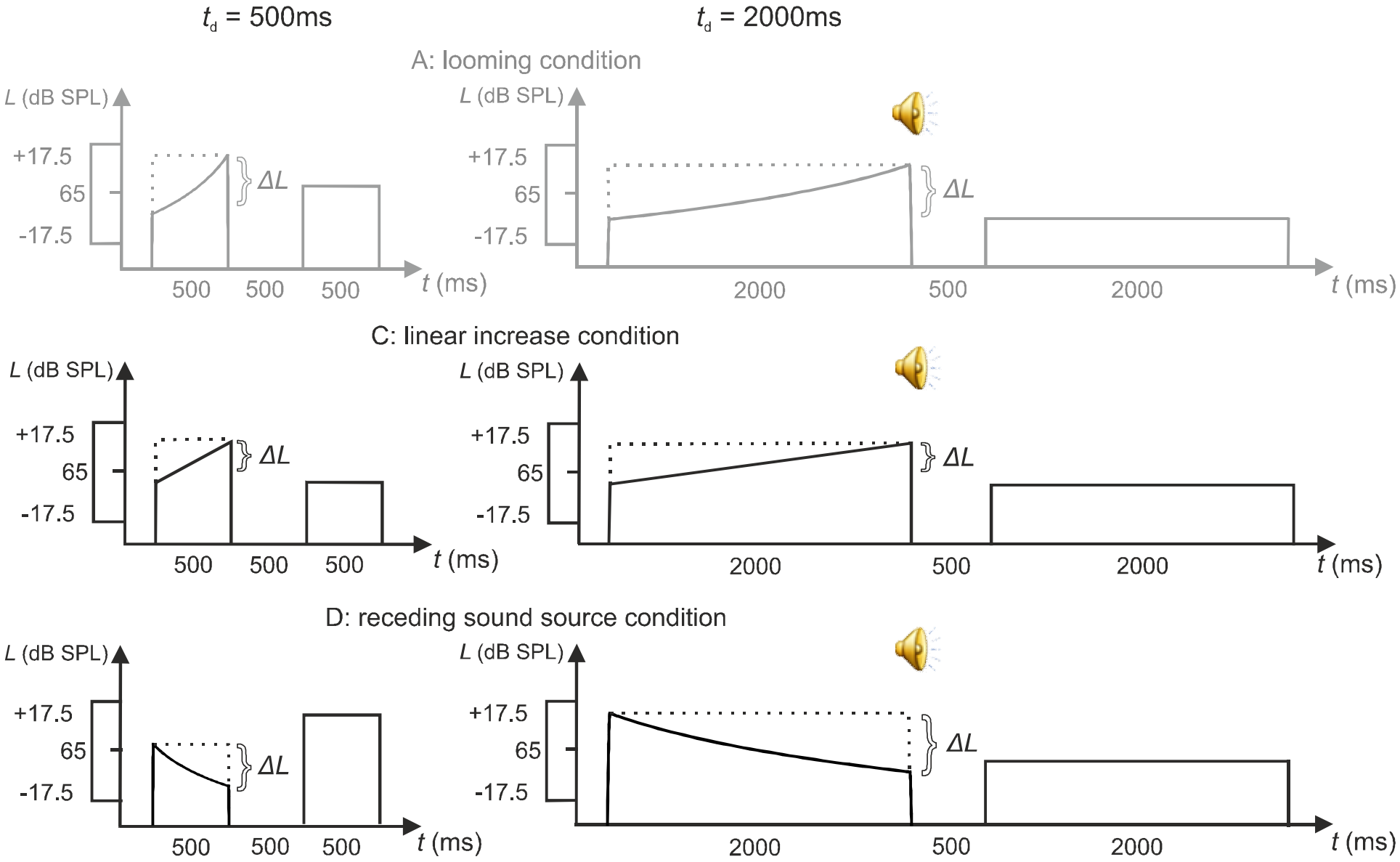
Control conditions

- The task might be solved by comparing the levels of the *initial* and *final* portion of the sound -> included a *classical intensity discrimination task*



Is „looming“ special?

- Higher sensitivity for a „**looming**“ gradual change in level (John Neuhoff) than for a **linear** increase in level or a „**receding sound source**“?



Design

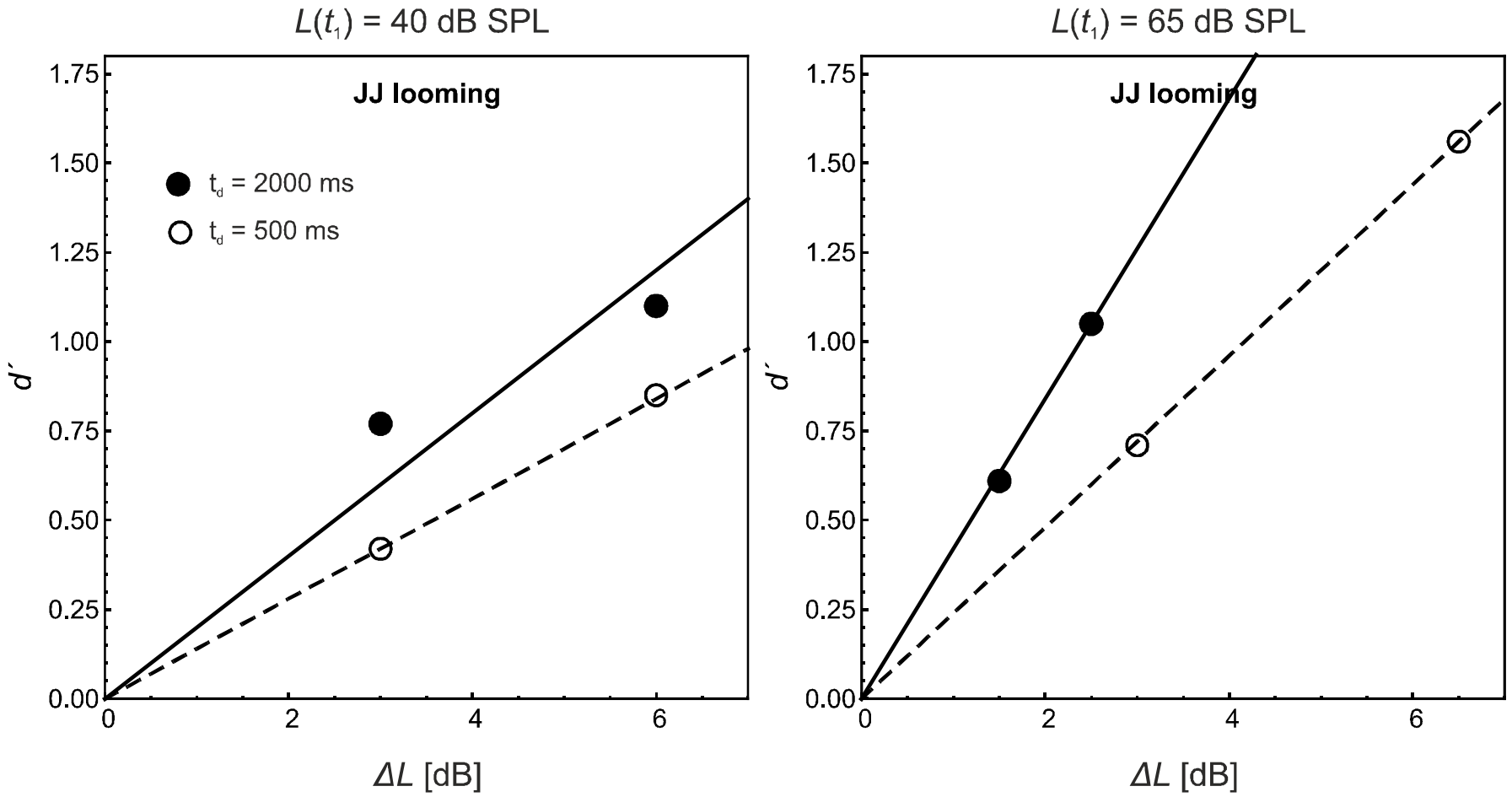
- 8 normal-hearing listeners

- Two values of the level change (ΔL) individually selected per combination of task × duration (t_d) × peak level (-> $d' \approx 0.75$ and 1.5)

- Per listener: two blocks of 100 trials each per combination of task × duration (t_d) × peak level

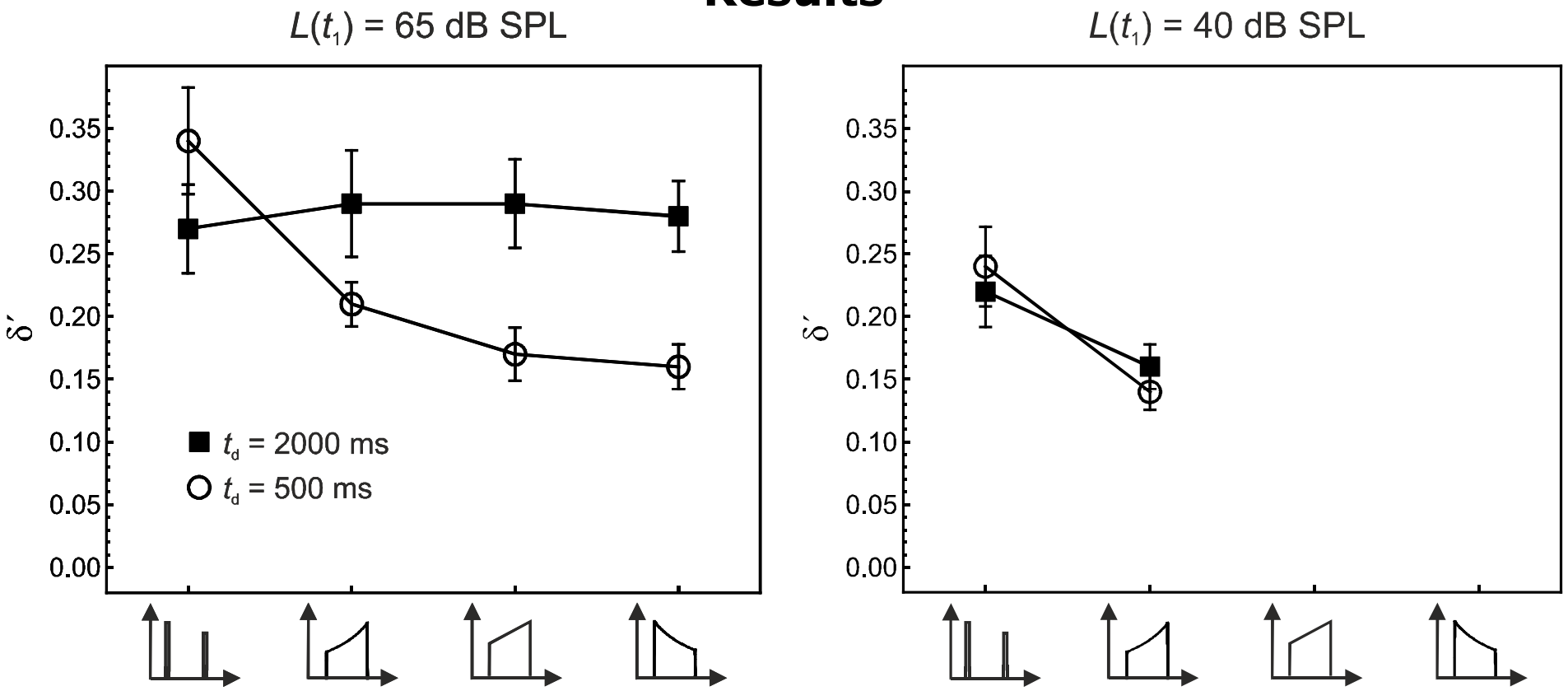
Psychometric functions

- Data analysis: computed d' for each listener and condition (100 trials per data point)
- Slope of the psychometric function = measure of sensitivity



- Slope: $\delta' = d'/\Delta L$ (resolution-per-dB)

Results



- Long t_d: No effect of task
- Short t_d: Higher δ´ for classical discrimination (expected), but lower δ´ for detection of gradual changes (unexpected!) (*, $p < .05$)
- Conditions with gradual intensity changes: no effect of task, no task × duration interaction ⇒ looming is **not** special, at least not at longer durations!
- Lower δ´ at the lower peak level (*), particularly for looming at the long duration (level × duration *)

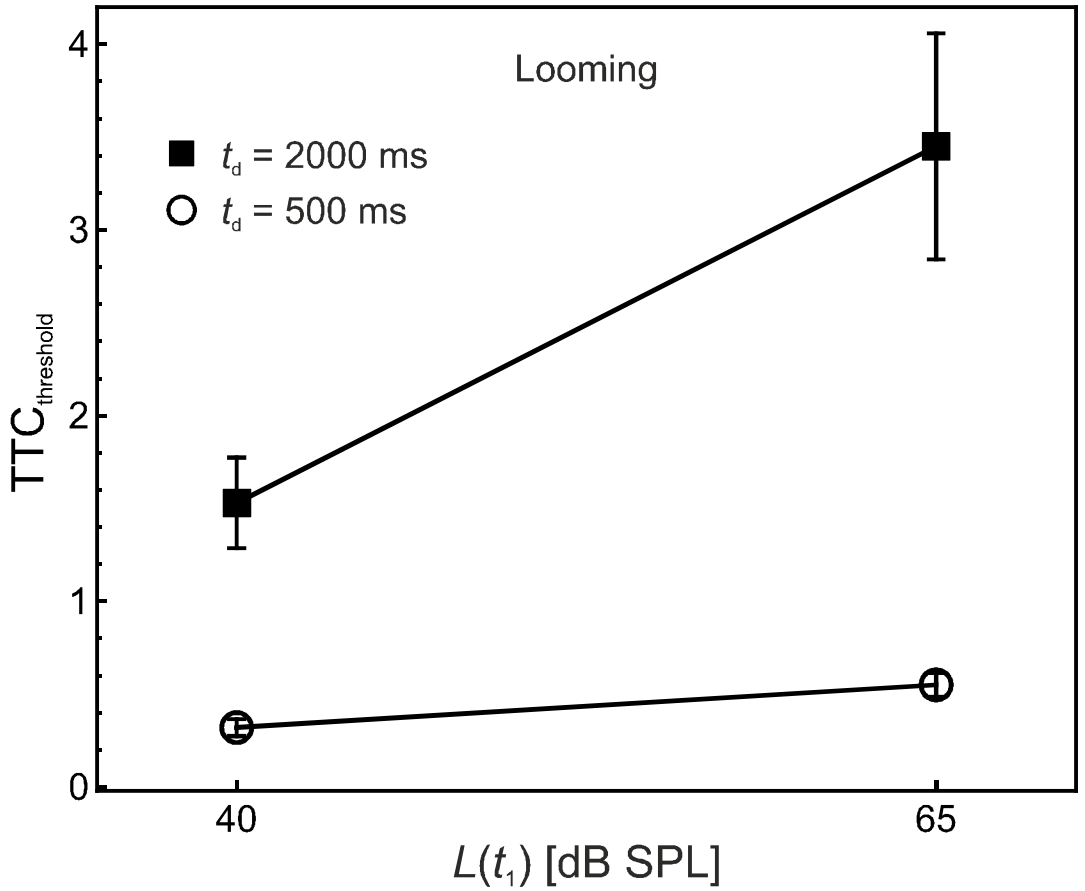
Relation to TTC estimation

- The minimal level change that can be detected corresponds to a TTC:

$$\beta = \frac{t_d}{p(t_1)/p(t_0) - 1} = \frac{t_d}{10^{\Delta L/20} - 1} = \mathrm{TTC}(t_1)$$

  ⇒ Shorter TTC -> stronger change in level across the presentation duration

- What is the maximal TTC that results in a noticeable level change?



Discussion and summary

- No 1:1 relation between intensity discrimination and the detection of gradual changes in intensity

- For the same ΔL, the change in level is more difficult to detect in **short** compared to **longer** sounds, despite the stronger rate of change for short sounds
  - Listeners do not seem to use the rate of change
  - Open question: can the higher sensitivity at longer durations be explained by "multiple looks"?

- Evidence for preferential processing of „looming" sounds at the most for short sounds

- Future research:
  - Can the observed effects be explained by models of auditory processing (neural encoding in the auditory nerve, template matching…)?
  - **Discrimination** of intensity changes, relation to TTC estimation performance?

Danke für Ihre Aufmerksamkeit!

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