Effects of rhythmic attention on perceptual weights in multiple observation tasks

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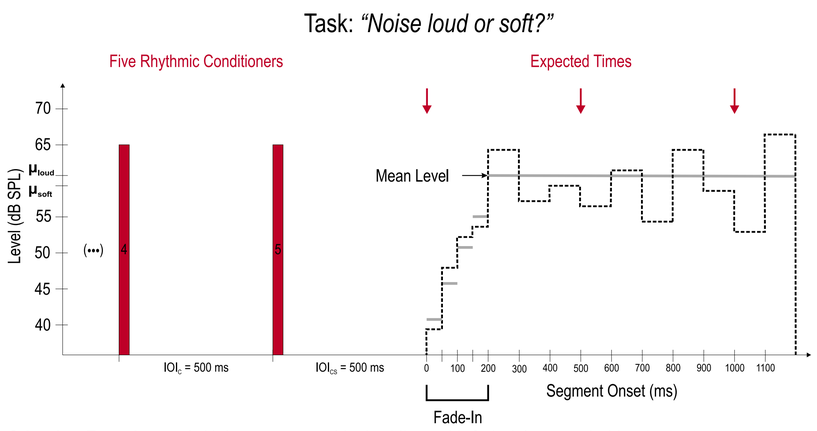
INTRODUCTION

Evidence for rhythmic or anticipatory attending has been reported not only for "temporal tasks" like interval discrimination (e.g., Large & Jones, 1999) but also for pitch discrimination (Jones et al., 2002). The aim of the present study was to gain insight into the effects of temporally directed attention on **intensity perception in a longer auditory stimulus**. In *Experiment 1*, listeners evaluated the overall loudness of a 1200-ms noise stimulus fluctuating in level. In *Experiment* 2, the task was to detect an intensity increment presented in the temporal center of a 500-ms noise ("temporal profile listening"). In both experiments, a **multiple-observation task** was used that allows tracking auditory attention over a time window of several hundred milliseconds (Berg, 1989), rather than measuring it at only a single point in time as in previous experiments.



Stimulus Experiment 1. Noise segments (dashed line; with fade-in), preceded by rhythmic conditioners. The level of each segment was drawn independently from a normal distribution. In each trial, either a "soft" (mean μ_{soft}) or a "loud" distribution was used. Gray lines show mean segment levels for a "loud" trial. Arrows indicate expected times ("on beat").

EXPERIMENT 1: GLOBAL LOUDNESS JUDGMENTS

Purpose and Hypotheses

To answer the question of whether rhythmic attention has an effect on auditory intensity processing, global loudness judgments for a level fluctuating noise consisting of 14 temporal segments were obtained in an absolute identification (AI) task. It has been shown that the initial portion of such a stimulus receives greater weight than the later parts, even if the optimum response strategy would be to weight the level information provided by each temporal segment uniformly (Berg, 1989; Ellermeier & Schrödl, 2000).

The **hypothesis** was that the temporal direction of attention by a conditioner rhythm preceding the target stimulus (**Rhythm Condition**) results in **increased weights** for temporal segments presented on *a rhythmically expected position* ("on beat").

Logistic regression was used to estimate the **relative perceptual weight** with which each of the temporal segments contributed to the decision of the listener. The weights can be taken as indicators of auditory attention. To reduce the primacy effect, each noise started with a fade-in (four 50-ms segments) immediately followed by ten 100-ms segments; a delayed primacy effect (maximum weight assigned to the first unattenuated segment) was expected in both conditions (Oberfeld & Plank, 2005).

METHOD

Stimuli

- Broad-band noise, four 50-ms segments plus ten 100-ms segments (total duration 1200 ms)
- In each trial: level of each segment independently sampled from either a "soft" or a "loud" normal distribution (μ_{soft} = 59.5 dB SPL, μ_{loud} = 60.5 dB SPL, σ = 2 dB)
- Fade in: level of first 4 segments attenuated by 20, 15, 10, and 5 dB, respectively
- Rhythmic conditioners: 30-ms, 1-kHz tones

Apparatus

- Digital stimulus generation (Matlab, RME ADI/S D/A converter), TDT PA5 and HB7
- Diotic presentation via Sennheiser HDA 200 headphones
- IAC single-walled sound proof chamber

Listeners

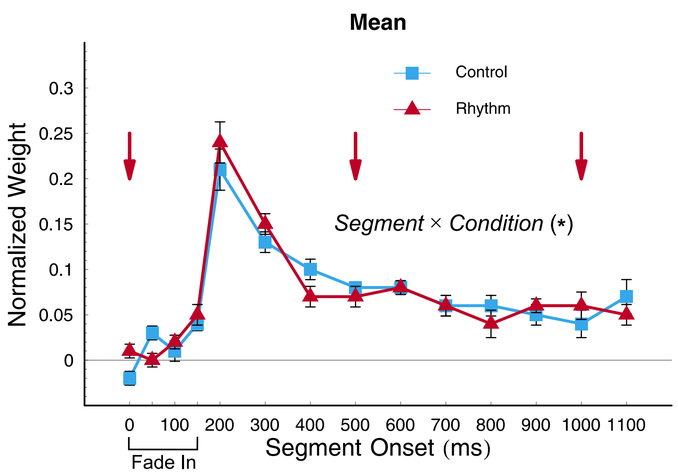
Seven listeners (mean age 21.6 y), all reported normal hearing. Listeners BH, KD, and RD were informed about the aim of the experiment.

Procedure

- Control Condition: no conditioners
- **Rhythm Condition:** five rhythmic conditioners, IOI_C = 500 ms, IOI_{CS} between last conditioner and first noise segment 500 ms. Expected positions: 0, 500, and 1000 ms after noise onset.
- One condition per block of 50 trials, conditions presented in alternating order, 10 blocks/session
- Absolute Identification (1I, 2AFC)
  - In each trial: **soft noise** (mean level 59.5 dB SPL) or **loud noise** (mean level 60.5 dB SPL)
  - Task: **"Noise soft or loud?"**
  - "*Ignore rhythm.*"
  - No trial-by-trial feedback

Weight Estimation

- Logistic regression (independent variables: 14 segment levels, dependent variable: binary loudness judgment). 1000 trials per condition.
- Regression coefficients = estimates of the perceptual weights
- Weights normalized (sum of absolute weights = 1.0)



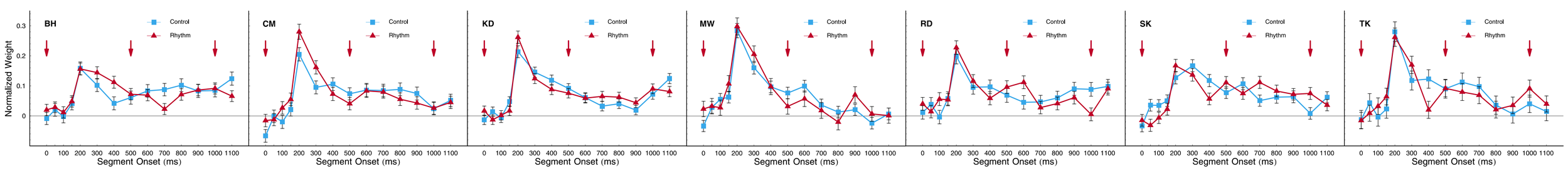
Experiment 1: Mean normalized relative perceptual weights. Individual normalization: sum of absolute values = 1.0. Arrows: rhythmically expected times. Error bars: ± 1 SEM

RESULTS

Control Condition:
- Delayed primacy effect (Oberfeld & Plank, 2005)

Rhythm Condition:
- Increased weights on expected position (500 ms after stimulus onset) for two listeners only (RD and TK)
- Delayed primacy effect more pronounced than in Control Condition

Two-way repeated-measures ANOVA, Huynh-Feldt *df*-correction:
- **Effect *Segment***: significant, $F(13, 78) = 30.09$, $\varepsilon = .369$, $p < .001$
- **Interaction *Segment* × *Condition*:** marginally significant, $F(13, 78) = 1.844$, $\varepsilon = .862$, $p < .062$
- Effect Condition: n.s. (due to normalization)



Experiment 1: Individual weights. Normalization: sum of absolute values = 1.0. Arrows: rhythmically expected times. Error bars: ± 1 SE of the weight estimates.

EXPERIMENT 2: TEMPORAL PROFILE LISTENING

Purpose and Hypotheses

- Experiment 1: Rhythmic attention would have resulted in **impaired performance**
  - An ideal observer would weight the level information provided by each segment *uniformly*

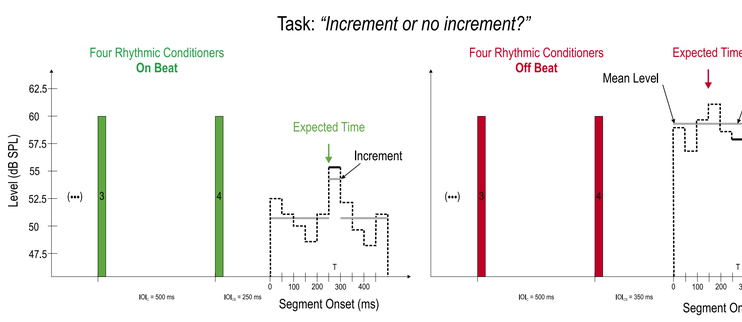
→ *Study a task in which temporally directing attention should* ***improve performance***

Listeners were required to detect a 4-dB level increment on the sixth of ten 50-ms noise segments ("**temporal profile listening**" task, cf. Plank & Ellermeier, 2003).

The target segment was presented either on a **rhythmically expected position** (On Beat), or **100 ms later** than the rhythmically expected position (**Off Beat**), or **no rhythm** was presented (Control Condition).

To prevent the listeners from responding on the basis of overall loudness, a random level rove (± 10 dB) was introduced. The optimum strategy in the task would be to assign a positive weight *a* to the segment containing the increment and a weight of *–a*/9 to the remaining segments.

Hypotheses:
- **On Beat Condition:** The rhythm can be used to direct attention to the target segment → listeners should be more successful in adopting the optimum set of weights → performance expected to be better than in the Control Condition
- **Off Beat Condition:** Attention expected to be involuntarily directed to the segment on the rhythmically expected position (segment 4) → stronger deviation from the optimum set of weights → impairment in performance relative to the Control Condition



Stimuli Experiment 2. Task: detect a 4-dB increment on the target segment *T* (6th segment).
On Beat Condition (left panel): target segment on expected position.
Off Beat Condition (right panel): expected position 100 ms **before** target segment. Note the level rove.

METHOD

Stimuli

- Ten 50-ms broad-band noise segments
- In each trial: level of each segment independently sampled from a normal distribution (μ = 55 dB SPL, σ = 2 dB)
- **Segment 6** (onset at 250 ms): 4-dB **level increment** added with p = 0.5
- Random level rove ± 10 dB

Procedure

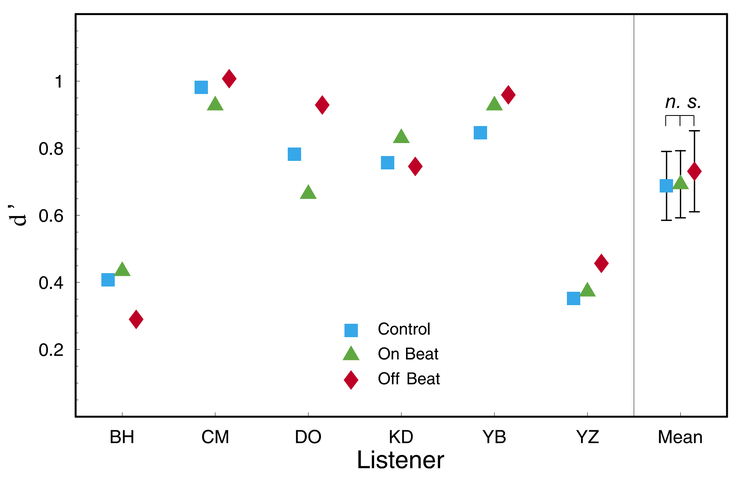
- Control Condition: no conditioners
- **On Beat Condition:** four 30-ms, 1-kHz tones, IOI = 500 ms. Onset of target segment 6 on expected position (500 ms after onset of the last conditioner)
- **Off Beat Condition:** Onset of target segment 600 ms after onset of last conditioner. *Expected position*: onset of segment 4
  - Per session: four successive 50-trials blocks of each condition
- Absolute Identification (1I, 2AFC)
  - In each trial: **increment** or **no increment**
  - Task: **"Increment or no increment ?"**
  - "*Ignore rhythm.*"
  - Visual trial-by-trial feedback

Weight Estimation

- Logistic regression, 1000 trials per condition
- Weights normalized (weight assigned to target segment 6 = 1.0)

Listeners

Six listeners (mean age 25.8 y), all reported normal hearing. Listener DO was the author, the remaining listeners were naïve with respect to the aim of the experiment.



Experiment 2: Individual and mean sensitivity. Error bars: ± 1 SEM

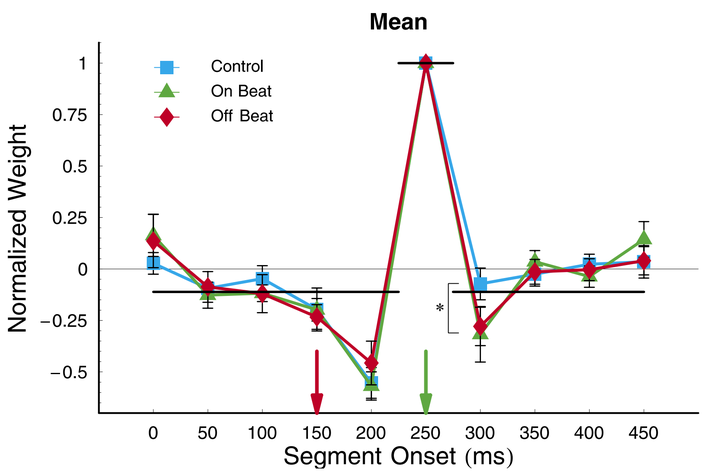
RESULTS

Sensitivity

- **No** significant effect of the rhythmic conditioners, $F(2, 10) = 0.563$.
- Inter-individual differences: Performance better in On Beat than in Control Condition for KD and YB, but worse for CM and DO. Performance superior in Off Beat Condition for CM, DO, and YB, and YZ.

Perceptual Weights

- With **both** On Beat and Off Beat Conditioners: Segment following the target segment received larger negative weight than in the Control Condition, $F(2, 10) = 5.375$, $\varepsilon = .725$, $p < .043$
- Sets of weights: rather large inter-individual variability



Experiment 2: Mean perceptual weights. Weight for target segment (onset at 250 ms) normalized to 1.0. Arrows: rhythmically expected times. Horizontal lines: ideal weights. Error bars: ± 1 SEM.

DISCUSSION AND SUMMARY

Experiment 1: Temporal weighting of loudness
- Only 2 of the 7 listeners showed evidence for rhythmic attention
- Conditioner rhythm resulted in a stronger delayed primacy effect, even though the first unattenuated segment was **not** presented on an expected position

Experiment 2: Temporal profile listening
- No consistent improvement in performance for the target segment presented on an expected position (large inter-individual variability)
- Larger negative weight assigned to the segment following the target segment in **both** rhythm conditions

Remaining questions:
- Streaming due to pure-tone conditioners? → *Use noise conditioners*
- Did listeners learn the (fixed) position of the target segment in Experiment 2? → *Interleave different increment positions*

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