Adaptive Suppression and Enhancement in Auditory Search

Max Schulz, Jonas Obleser & Malte Wöstmann

Department of Psychology, University of Lübeck, Germany
Center of Brain, Behavior and Metabolism, University of Lübeck, Germany

max.schulz@uni-luebeck.de; malte.woestmann@uni-luebeck.de; jonas.obleser@uni-luebeck.de

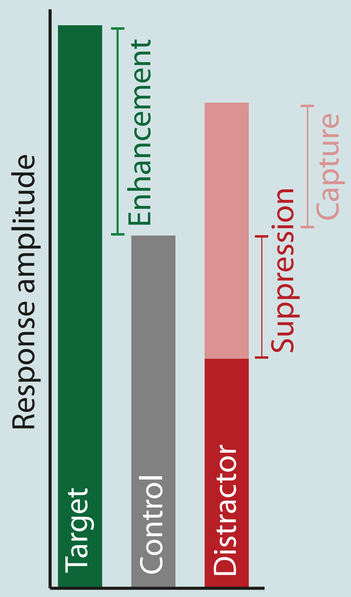
UNIVERSITÄT ZU LÜBECK

DFG Deutsche Forschungsgemeinschaft

Background

Human environments consist of relevant targets and irrelevant distractors. In auditory attention research, the understanding of capture and suppression is premature, partly because target and distractor effects are often confounded[1].

Research goal: We introduce a baseline to directly compare neural and behavioral responses between control versus target and distractor sounds, inferring mechanisms of target **enhancement**, distractor **suppression** and **capture**[2].



Design and Target Towardness

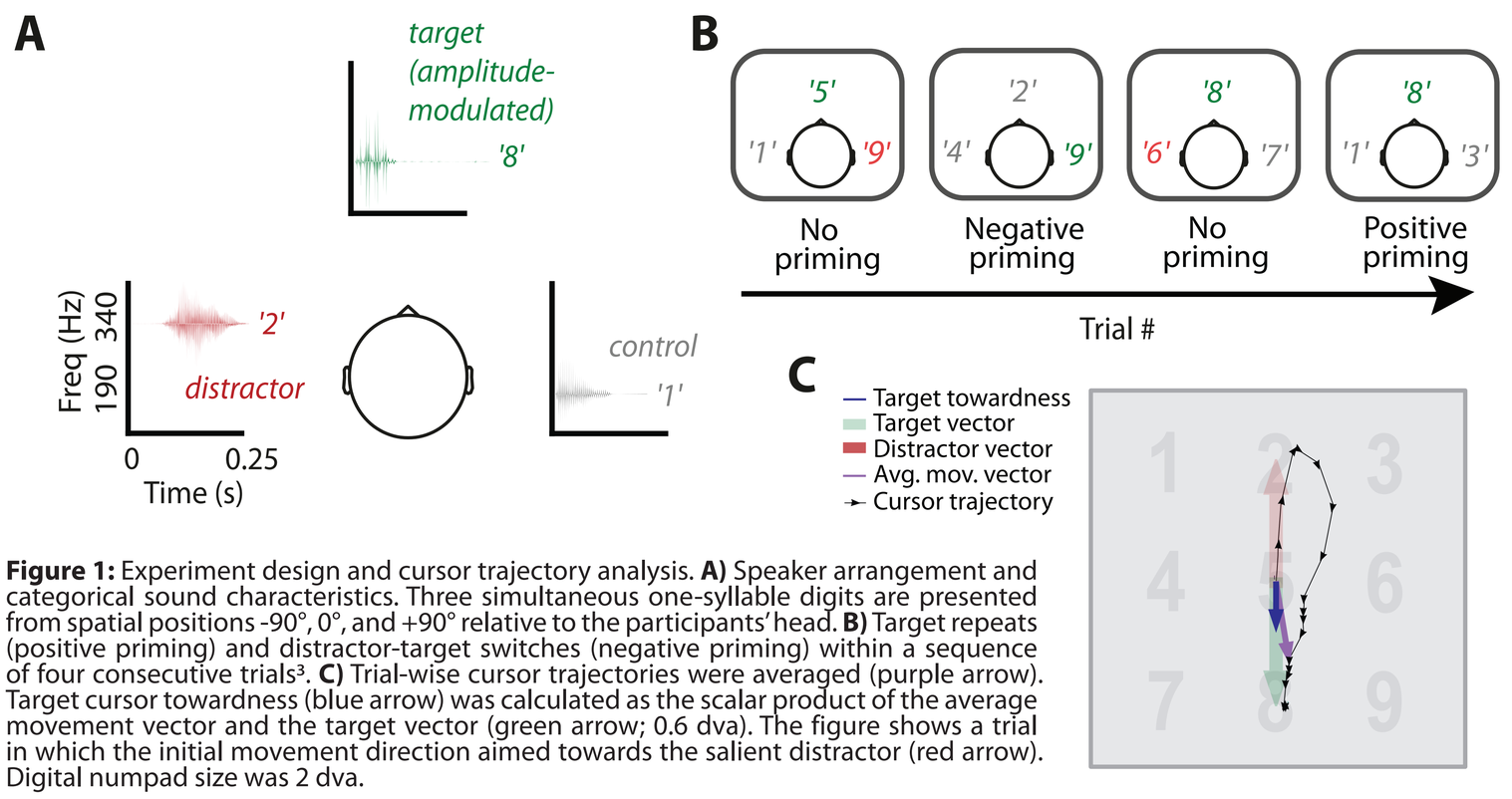


Figure 1: Experiment design and cursor trajectory analysis. **A)** Speaker arrangement and categorical sound characteristics. Three simultaneous one-syllable digits are presented from spatial positions -90°, 0°, and +90° relative to the participants' head. **B)** Target repeats (positive priming) and distractor-target switches (negative priming) within a sequence of four consecutive trials[3]. **C)** Trial-wise cursor trajectories were averaged (purple arrow). Target cursor towardness (blue arrow) was calculated as the scalar product of the average movement vector and the target vector (green arrow; 0.6 dva). The figure shows a trial in which the initial movement direction aimed towards the salient distractor (red arrow). Digital numpad size was 2 dva.

Results

Target Enhancement

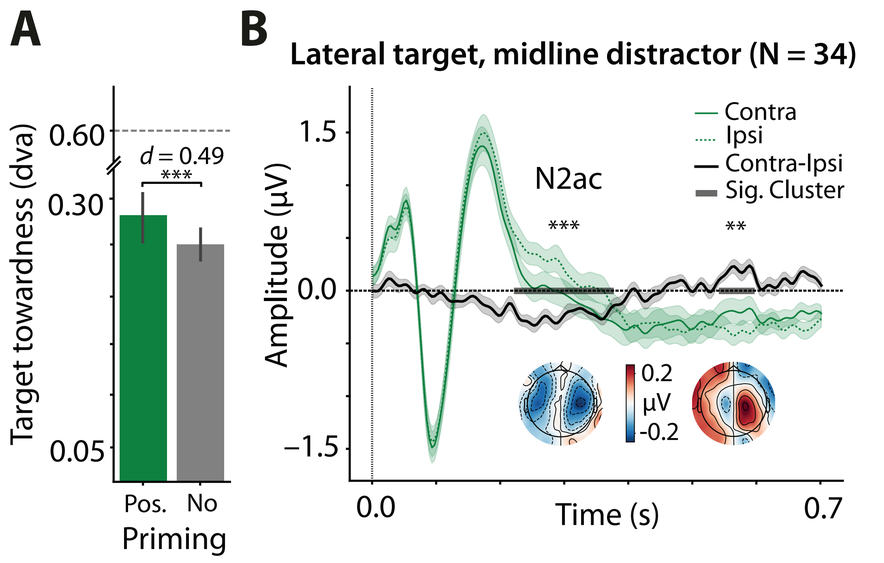


Figure 2: Signatures of target enhancement. **A)** Behaviorally, target enhancement was expressed as heightened target towardness in target-repeat trials ($p < 0.001$). Dashed grey line represents optimal performance. **B)** In the EEG, target enhancement was observed by N2ac emergence in lateralized target trials at electrode pair C3/4 ($p = 0.001$). A later component was observed ($p = 0.006$), possibly reflecting spatial reorienting[4,5]. Inset topographies show difference wave distribution for significant cluster. Shades areas represent ± 1 s.e.m.

Distractor Suppression

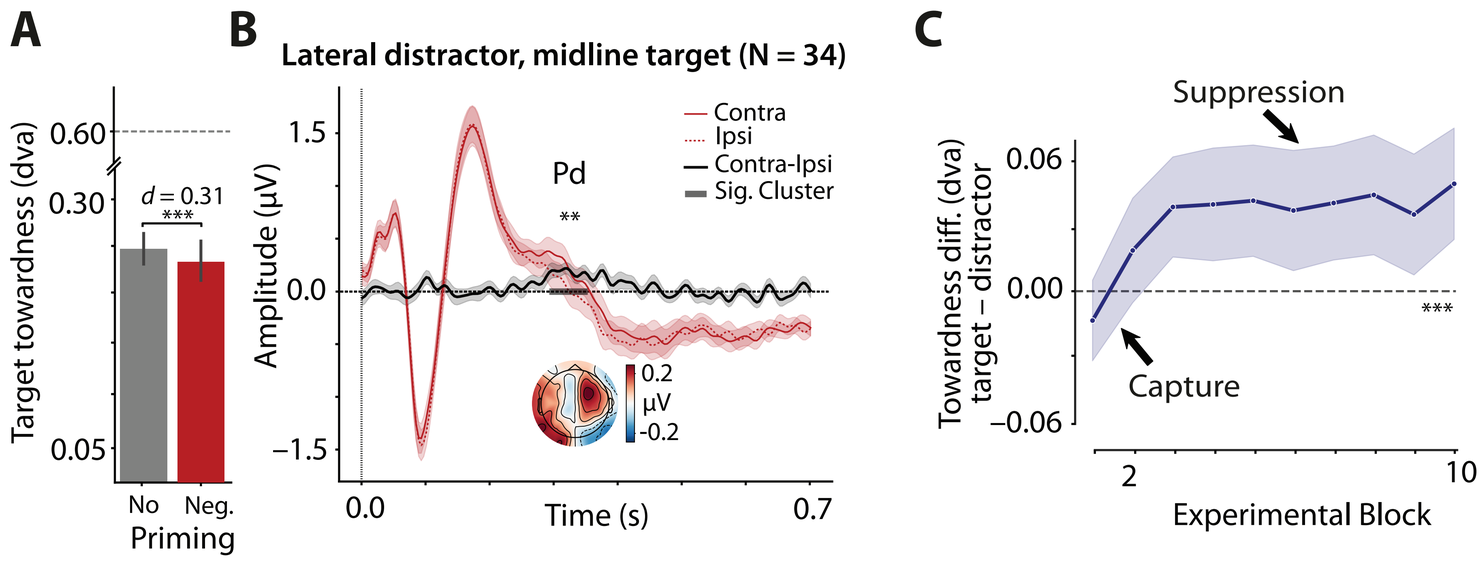


Figure 3: Signatures of distractor suppression. **A)** Behaviorally, distractor suppression was expressed as decreased target towardness in distractor-target-switch trials ($p < 0.001$). Dashed grey line represents optimal performance. **B)** In the EEG, distractor suppression was observed by Pd emergence in lateralized distractor trials at electrode pair C3/4 ($p = 0.004$). Inset topographies show difference wave distribution for significant cluster. **C)** Over the course of the experiment, target towardness relative to distractor towardness increased, indicating a gradual transition from attentional capture to more successful distractor suppression[6] (Page's trend test: $L = 10758$, $p < 0.001$). Shaded areas in **B)** and **C)** represent ± 1 s.e.m.

Neural Activity Relates to Target Towardness

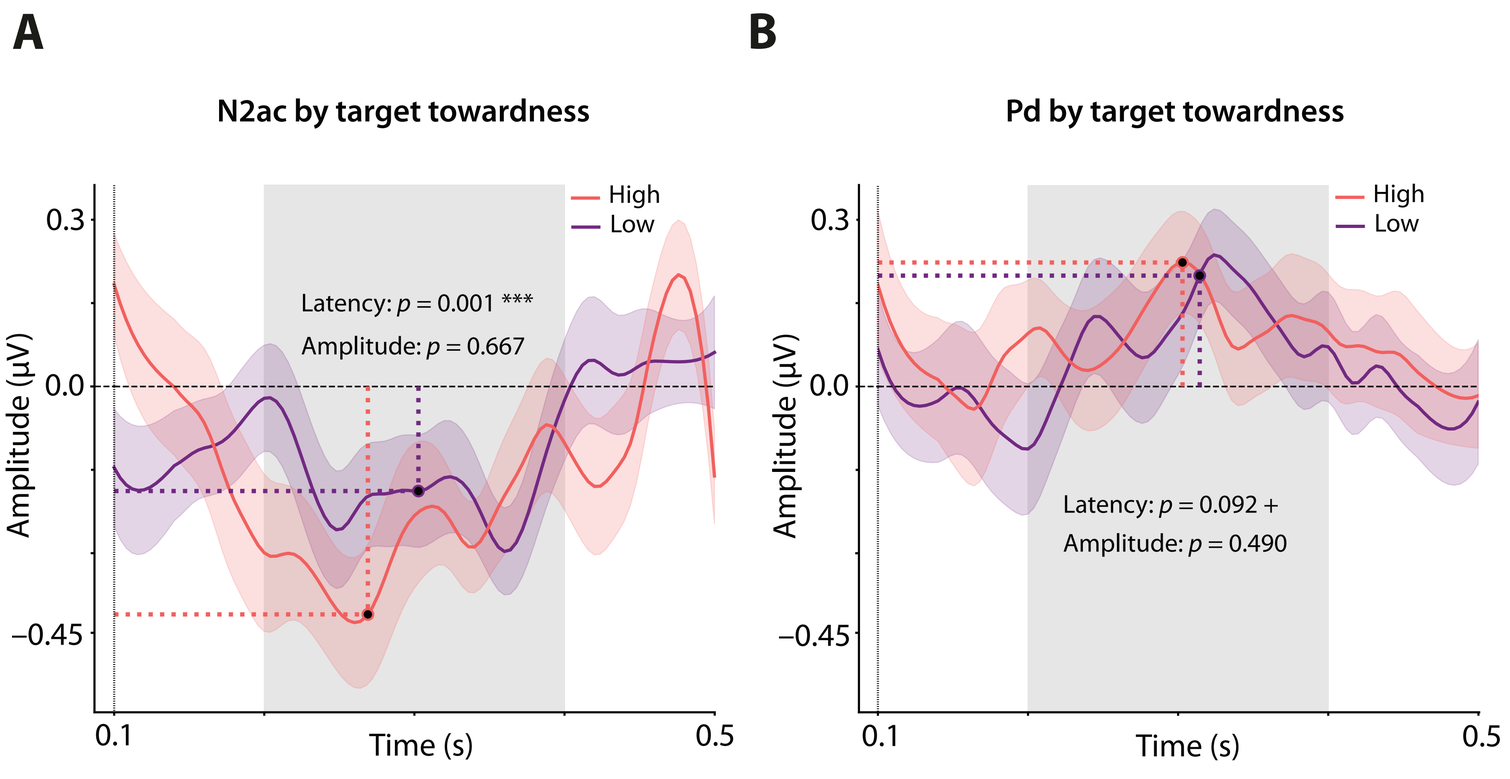


Figure 4: Target towardness relates to ERP components. Note that both panels visualize identical analysis on lateralized target (N2ac) and distractor (Pd) trials, respectively. Single-trial component latencies and amplitudes were retrieved between 0.2 - 0.4 s post-stimulus onset as the absolute 50% cumulated voltage. P values were estimated by a linear mixed-effect model and equated target_towardness ~ (1|Subject ID) + trial number + amplitude + latency. The median-split target towardness serves solely illustration purpose. A Savitzky-Golay filter (order: 3; frame length: 21) was applied to the waveforms before visualization to improve the visibility of effects. **A)** Small N2ac latencies relate to greater target towardness compared to large N2ac latencies. The same trend can be observed for lateralized distractor trials in **B)**. Shaded areas in both panels represent ± 1 s.e.m.

Conclusion

1. Our design includes **salient and non-salient distractors**, offering a novel approach that translates the established visual search paradigm into the auditory modality.

2. We establish a novel metric, **target towardness**, directly capturing selection of relevant against irrelevant items. This metric reflects target enhancement as well as the transition from distractor capture to suppression during **auditory reactive attention**.

3. Mechanistically, participants exhibit differential ERP amplitude lateralization for lateral targets versus distractors, which relate to **successful selective auditory attention** (see also [7]).

References

[1] Wöstmann et al. (2022), Progress in Neurobiology.
[2] Orf et al. (2023), iScience.
[3] Tipper (1985), The Quartlerly Journal of Experimental Psychology.
[4] Gamble & Luck (2011), Psychophysiology.
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[6] Gaspelin & Luck (2017), Journal of Experimental Psychology.
[7] Gaspelin et al. (2023), Journal of Cognitive Neuroscience.

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