Auditory Attention Implements Complementary but Independent Cortical Mechanisms of Enhancement and Suppression

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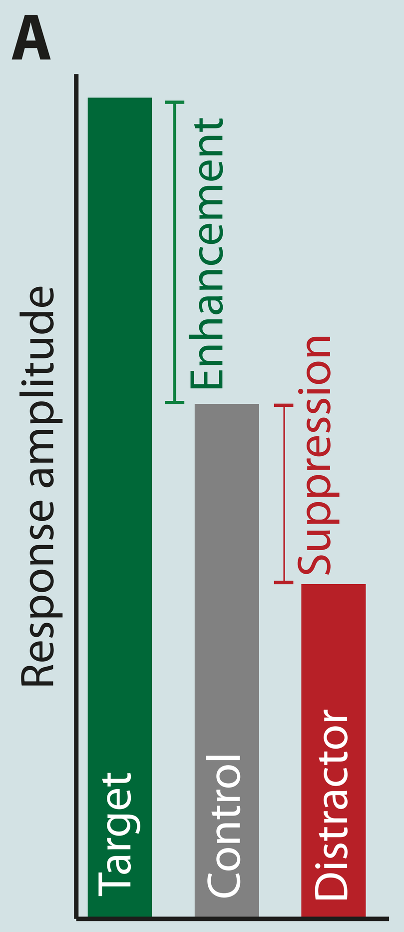
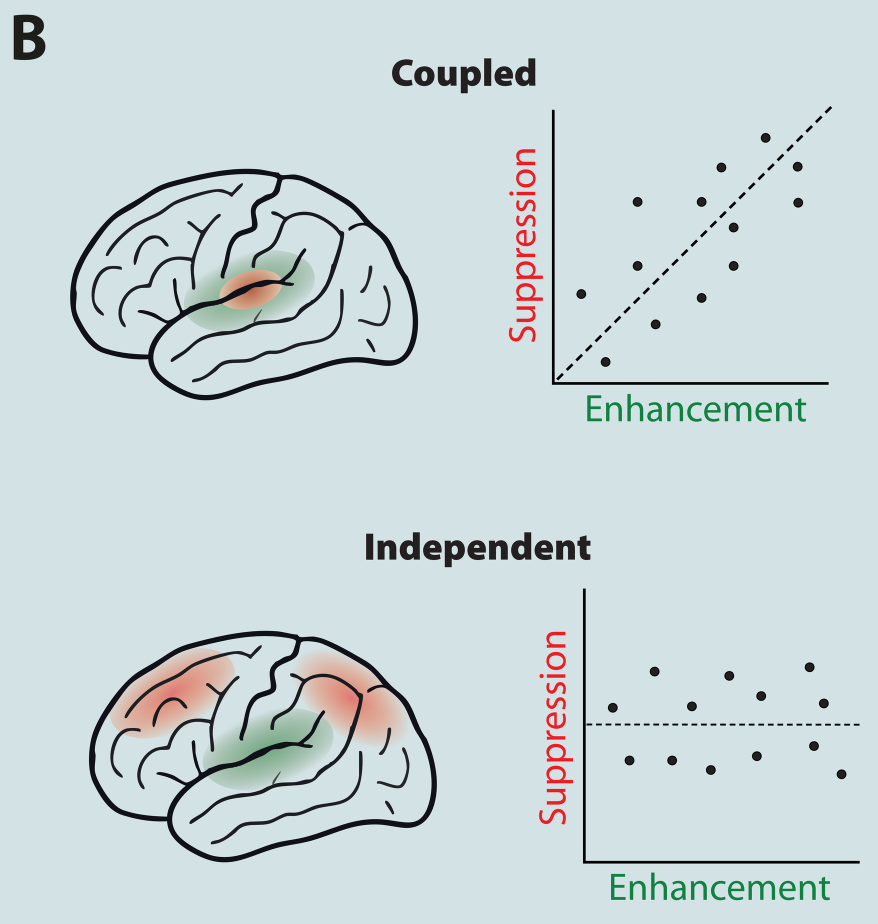
Background and Hypotheses



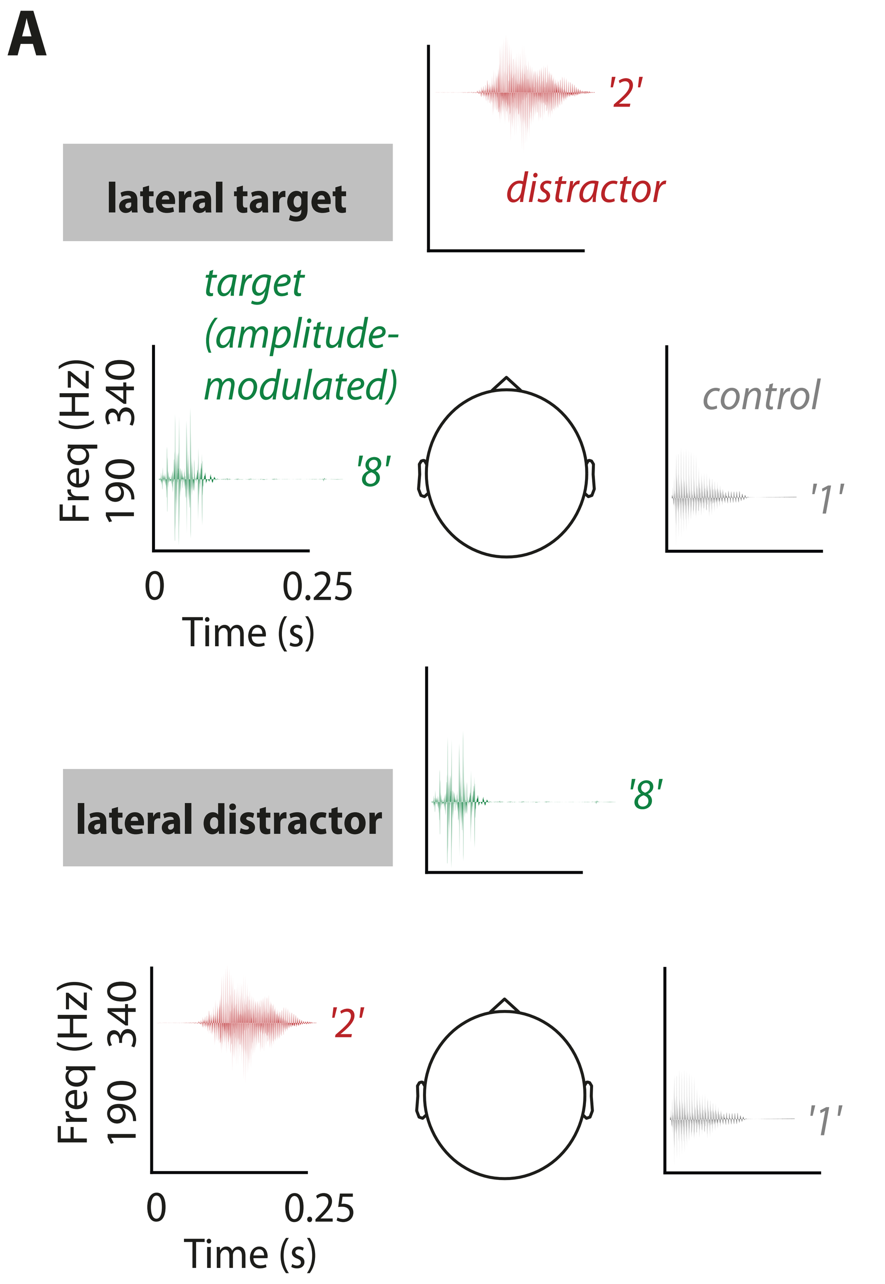


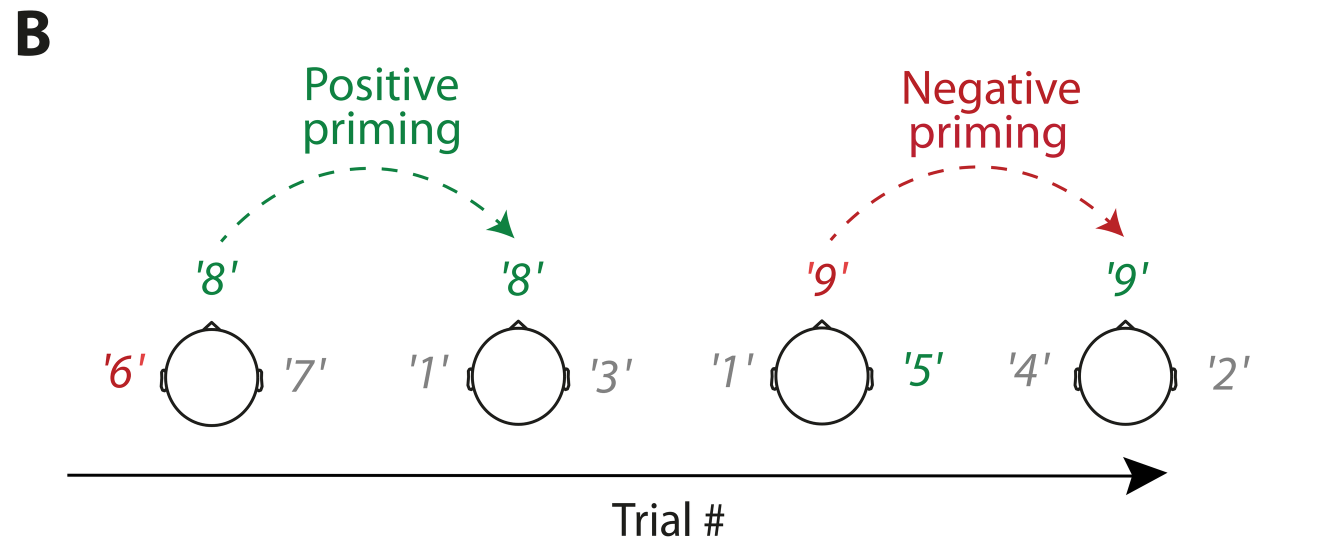
Human environments consist of relevant targets and irrelevant distractors. In auditory attention research, the understanding of capture and suppression is premature, partly because target and distractor effects are often confounded[1].

A) 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** (green) and distractor **suppression** (red).

B) Overlapping neural generators and/or correlation of enhancement and suppression would suggest coupling of the two mechanisms (top). In case of independence, no correlation and spatially separate neural generators would be expected (bottom).

Experimental Design and Target Towardness





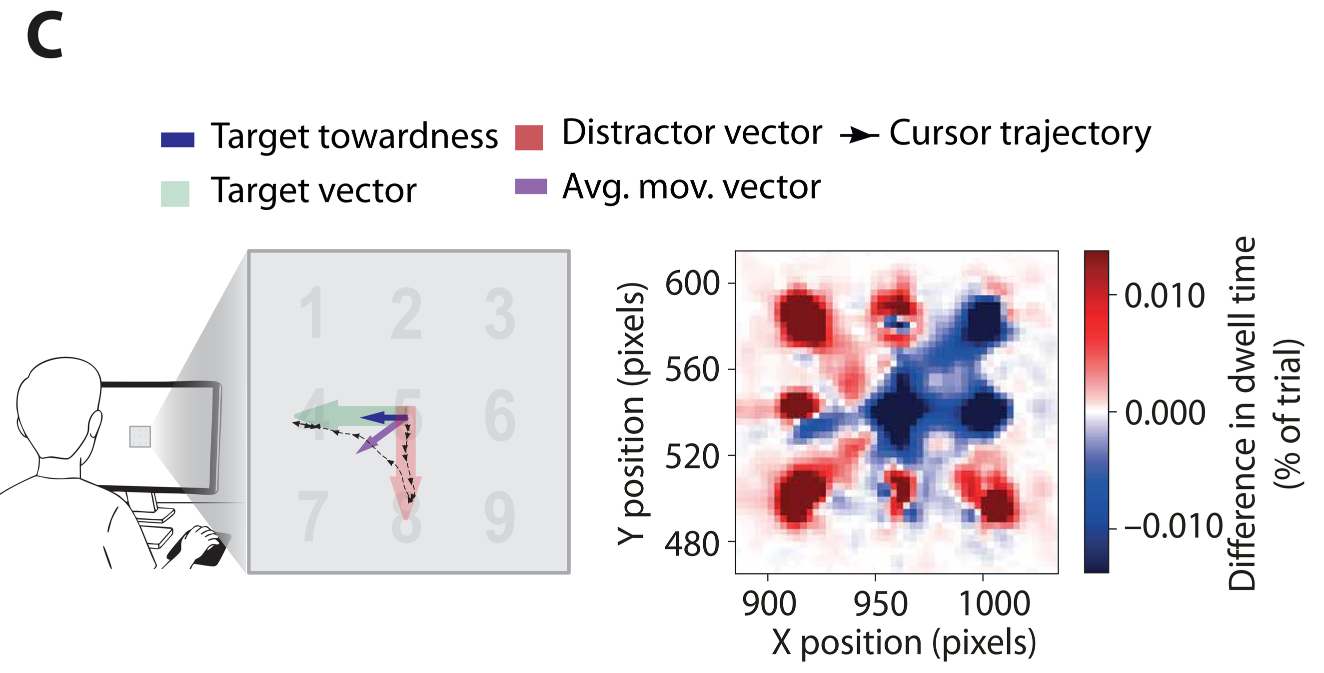


Figure 1. Experimental paradigm and cursor trajectory analysis. **A)** Speaker arrangement and sound characteristics. Three one-syllable numbers were presented simultaneously from three spatial positions (–90°, 0°, and +90° azimuth relative to the participant's head). Experimental conditions included lateral target trials (top) and lateral distractor trials (bottom). **B)** Examples of target repeats (positive priming[2]) and distractor-target switches (negative priming[3]) within a sequence of four consecutive trials. **C)** Left: On every trial, the cursor trajectory used to report the target number (black trace of arrows) was averaged (purple arrow). Target towardness (blue arrow) was calculated as the scalar product of the average movement vector and the target vector (green arrow). The figure shows a trial in which the initial movement direction was aimed towards the distractor (red arrow). Right: Difference of cursor dwell times for correct – incorrect trials.

Target Enhancement

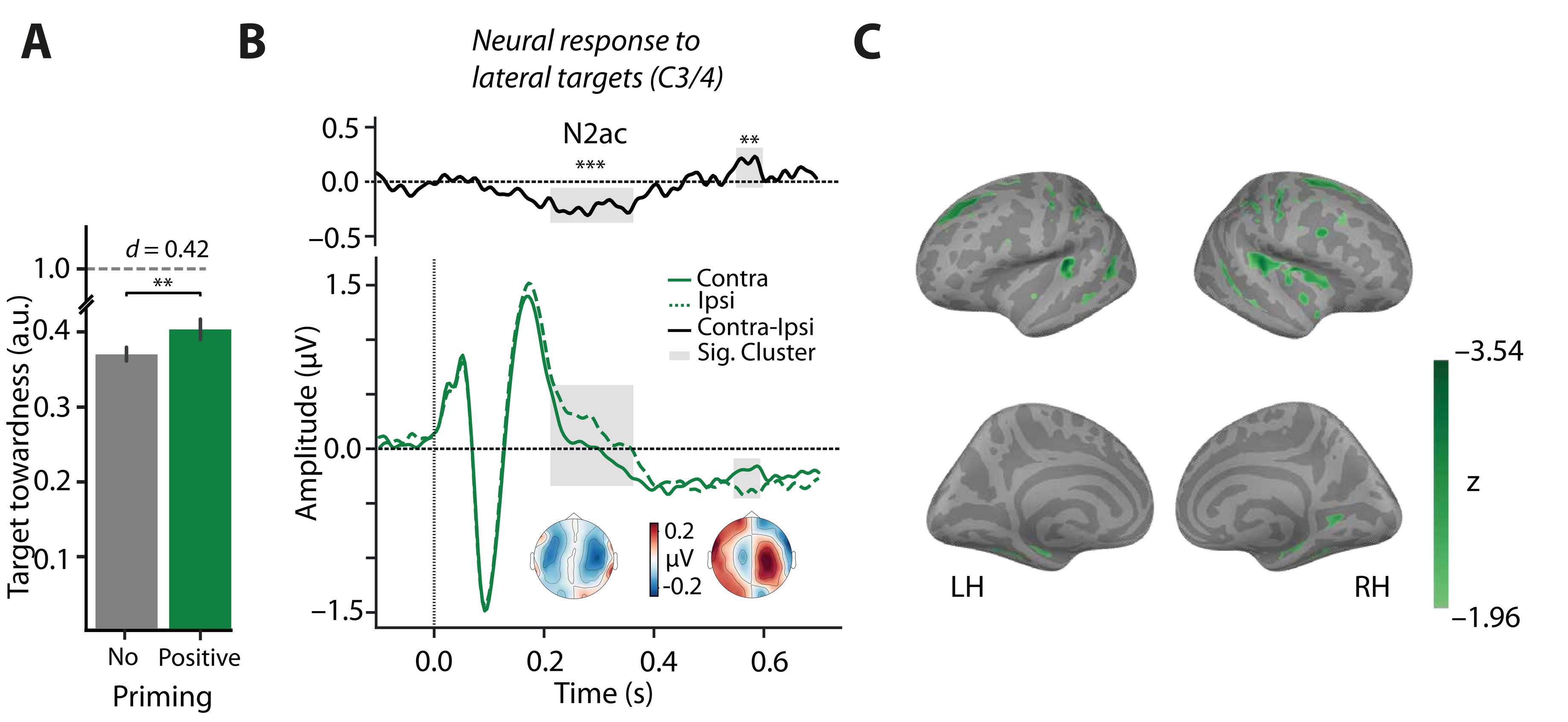


Figure 2. Neural and behavioral signatures of target enhancement. **A)** Bars and error bars show respective average towardness ±1 SEM as a function of priming. The dashed grey line represents optimal target-directed performance. **B)** Ipsi– and contralateral event-related potentials (ERPs) are indicated by dashed and solid lines (green), respectively. The black solid line in the upper panel shows the difference curve (contra-ipsilateral) between electrodes C3/4. Inset topographies show the contra-ipsilateral difference for significant clusters (highlighted in grey). **C)** Z-values for each voxel in the left (LH) and right hemisphere (RH) show the contrast of the source-reconstructed N2ac when the respective voxel is ipsi– vs contralateral to the target.

Distractor Suppression

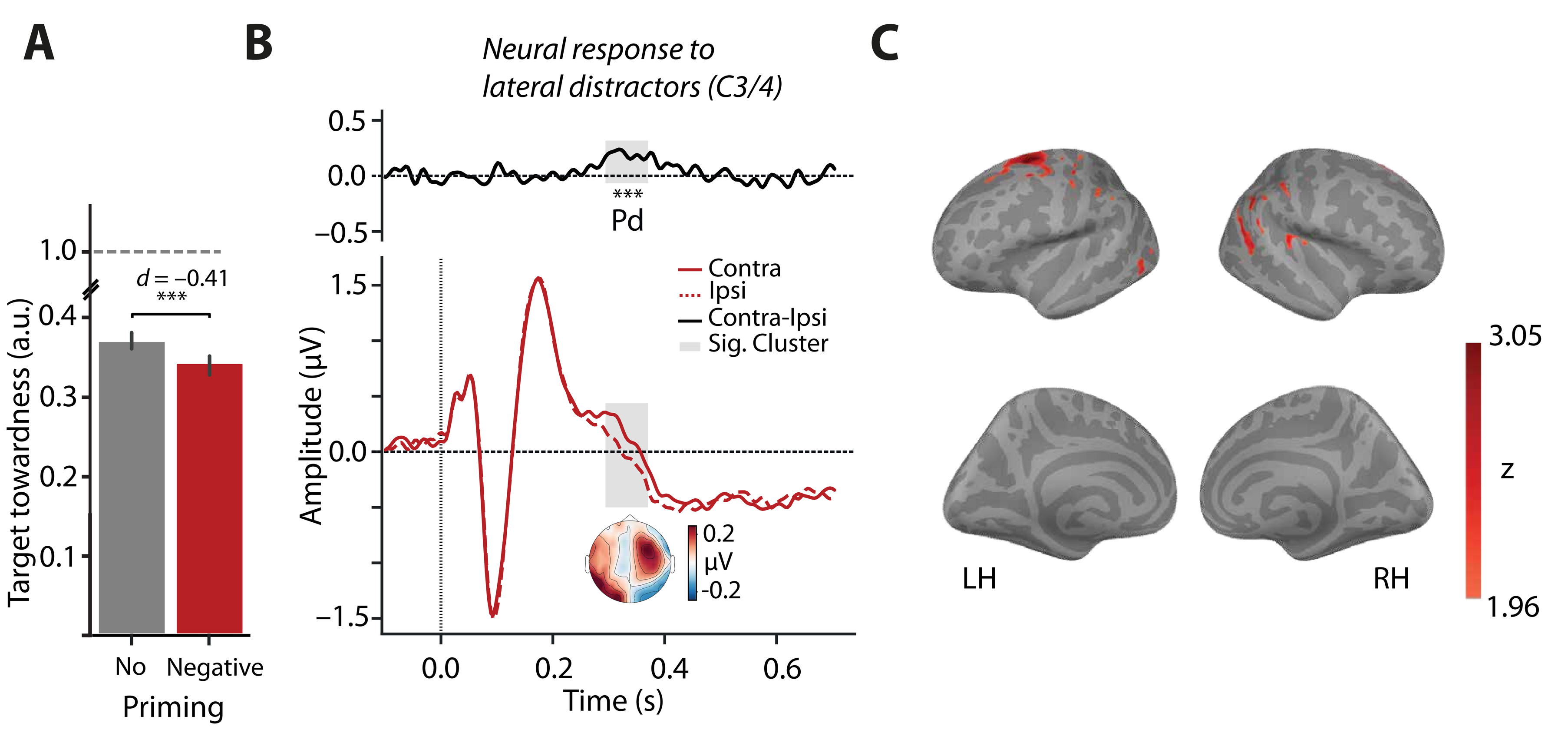


Figure 3. Neural and behavioral signatures of distractor suppression. **A)** Bars and error bars show respective average towardness ±1 SEM as a function of priming. The dashed grey line represents optimal target-directed performance. **B)** Ipsi– and contralateral ERPs are indicated by dashed and solid lines (red), respectively. The black solid line in the upper panel shows the difference curve (contra-ipsilateral) between electrodes C3/4. Inset topographies show the contra-ipsilateral difference for significant clusters (highlighted in grey). C) Z-values for each voxel in the left (LH) and right hemisphere (RH) show the contrast of the source-reconstructed P_D when the respective voxel is ipsi– vs contralateral to the target.

Neural Enhancement Explains Towardness

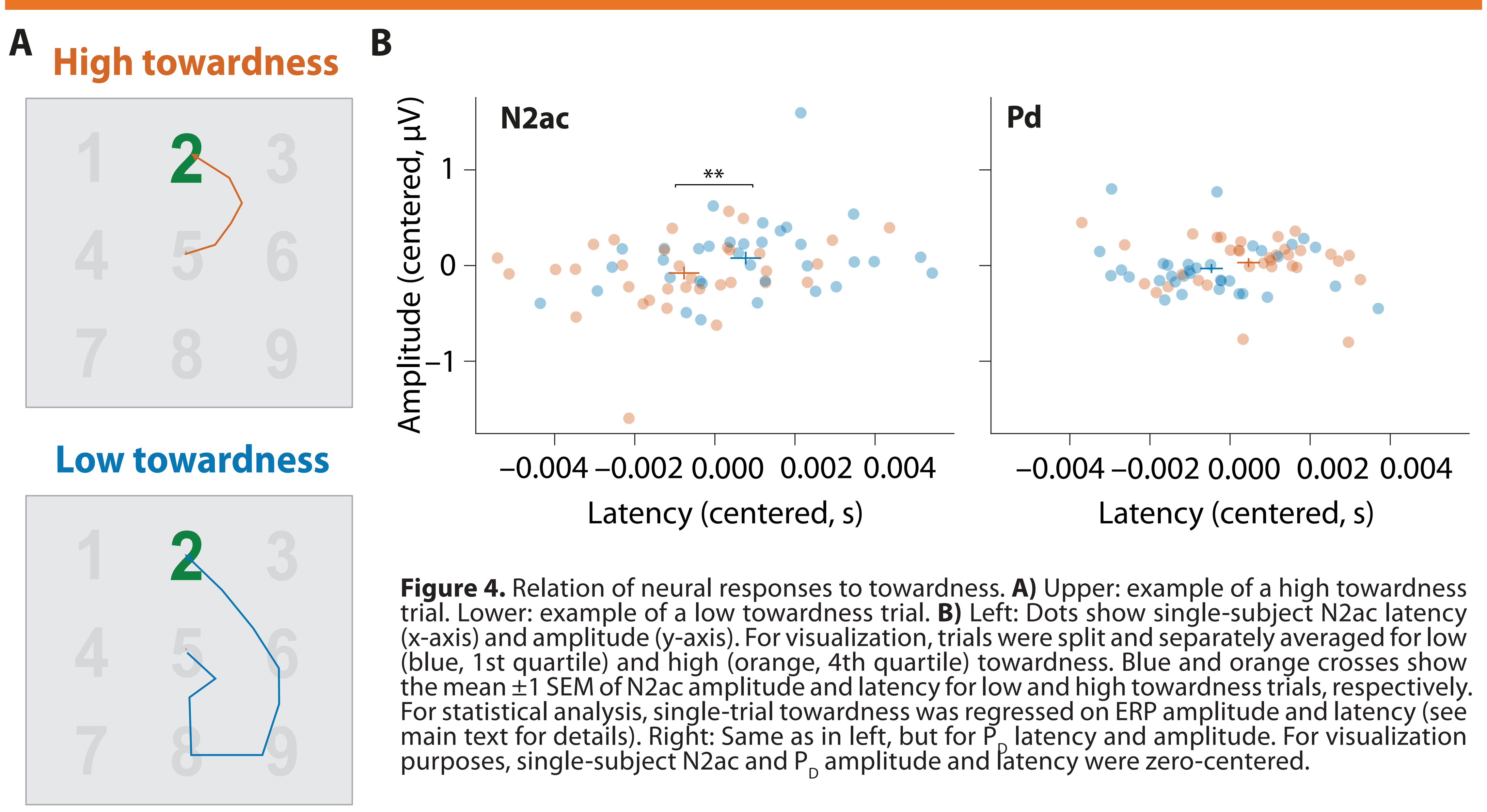


Figure 4. Relation of neural responses to towardness. **A)** Upper: example of a high towardness trial. Lower: example of a low towardness trial. **B)** Left: Dots show single-subject N2ac latency (x-axis) and amplitude (y-axis). For visualization, trials were split and separately averaged for low (blue, 1st quartile) and high (orange, 4th quartile) towardness. Blue and orange crosses show the mean ±1 SEM of N2ac amplitude and latency for low and high towardness trials, respectively. For statistical analysis, single-trial towardness was regressed on ERP amplitude and latency (see main text for details). Right: Same as in left, but for P_D latency and amplitude. For visualization purposes, single-subject N2ac and P_D amplitude and latency were zero-centered.

Conclusion

1. **Reactive attentional suppression**: We here provide first evidence of a distractor-evoked auditory P_D component during auditory attention.
2. **Independence of enhancement and suppression**: Both neural and behavioral indices of up-weighting targets and down-weighting distractors are largely independent[4]. These processes are statistically unrelated and originate from distinct cortical sources.
3. **Neural enhancement predicts behavioral selection**: Target-evoked N2ac – but not the distractor-evoked P_D – explains the directedness of cursor movements towards the attentional target. This suggests complementarity of enhancement and suppression, with the former being the primary determinant of selection performance.

References

[1] Wöstmann et al. (2022), *Progress in Neurobiology*.
[2] Maljkovic & Nakayama (1994), *Memory & Cognition*.
[3] Tipper (1985), *The Quarterly Journal of Experimental Psychology*.
[4] Wöstmann et al. (2019), *Journal of Neuroscience*.