Trends in
Cognitive Sciences

Spotlight

# Salient distractor processing: inhibition following attentional capture

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**Salient objects often capture attention in a purely exogenous way, followed by inhibition of their locations after a period. Yet, the neural circuits underlying the exogenous attention remain underspecified. Seidel Malkinson *et al.* explore this by uncovering large-scale cortical gradients associated with exogenous attention within the human cortex.**

Salient signals can serve as warnings of imminent danger in crowded environments. These signals grab our attention and force us to rapidly orient attention to detect potential threats (e.g., from predators). However, the innate human tendency to automatically orient toward salient events also makes us susceptible to distraction, as our attention can easily be captured by salient events in our surroundings. For instance, while browsing the internet, many of us have encountered the annoyance of flashing ads appearing in the periphery of the screen, diverting our attention from our intended web search.

Orienting toward salient distractors primarily operates in a bottom-up manner, recruiting the exogenous attention system [1]. Much work has demonstrated that, when a target is presented immediately following the presentation of a salient distractor (i.e., with a short interval between the presentation of the target and the distractor), participants respond to the target more rapidly. However, at longer intervals, exogenous attention becomes disengaged from the location of the salient distractor, triggering subsequent inhibition of these locations. This phenomenon is known as Inhibition of Return (IOR) [2]. IOR results in slower responses to a target presented at the location previously occupied by the distractor. Functionally, the IOR effect promotes spatial exploration, facilitating visual foraging behavior. Despite its functional importance for exogenous attention, the underlying neural mechanisms that modulate these attentional effects remain subject to debate.

In recent work, Seidel Malkinson and colleagues [3] explored the neural mechanisms underpinning exogenous attention using intracranial recordings of electrical signals in humans, uncovering large-scale cortical gradients within the human cortex that are responsive to both early capture and subsequent inhibition of exogenous attention. The authors collected intracranial electroencephalography (iEEG) data from 28 patients undergoing presurgical evaluation for their medication-resistant epilepsy. These participants performed a classic Posner cueing task [4], in which they were asked to detect the letter X presented within one of two placeholders situated peripherally (either left or right of the screen center). One of these placeholders briefly flashed (i.e., the salient cue) either 150 or 600 ms before the target presentation. The target was then presented on either the same side (congruent trials) or the opposite side (incongruent trials) as the cue. Behaviorally, the authors observed slower response times (RTs) in congruent trials compared with incongruent trials at the longer interval (600 ms). Unexpectedly, no facilitation effect was observed at the shorter interval (150 ms), an observation explained by the authors in terms of masking effects.

Importantly, Seidel Malkinson *et al.* delineated the neural processing underlying visual, attentional, and response-related functions in the human brain in response to salient events (cue), offering a detailed portrait of the cortical dynamics involved in exogenous attention [3]. Notably, the spatial coverage of iEEG is known to be limited and heterogeneous across participants, given that electrode implantation primarily serves diagnostic purposes. This poses challenges in identifying responsive contacts (positioned along the electrodes to pick up electrical signals) sensitive to the task design. The authors addressed this limitation in an innovative way that allowed them to cluster contacts together by using an adapted clustering trajectory k-means algorithm.

This advanced data-driven approach revealed three distinct clusters of contacts exhibiting changes in neural activities across time and conditions. Initially, Cluster 1 (comprising 68 contacts) showed rapid visual activation specifically toward contralateral visual stimuli, with separate neural responses to the cue and target. Subsequently, the neural activity in Cluster 2 (comprising 97 contacts) exhibited responses to both ipsilateral and contralateral stimuli, albeit with a stronger bias toward contralateral stimuli, suggesting a degree of spatial sensitivity. Last, the neural activity in Cluster 3 (comprising 67 contacts) exhibited stronger responses to targets than to cues, indicating sensitivity to target identity. Although the clustering algorithm was blind to the location of responsive contacts, the clusters exhibited anatomical grouping, and the contacts within each cluster were structurally connected. This suggests that these clusters are not only functionally, but also structurally distinct.

Notably, in Cluster 2, the significant neural activity of contacts located within the right hemisphere occurred 22 ms later in congruent trials compared with incongruent trials, which the authors note mirrors behavioral IOR. Furthermore, although a significant behavioral facilitation effect was not observed at the short interval (150 ms), the authors conducted an exploratory analysis revealing cue–target summed activity in Cluster 2 that mimicked the behavioral facilitation effect. Given these findings, the authors argued that the neural activity in Cluster 2 has a critical role in exogenous attentional orienting.

Contacts in Cluster 2 were predominately located in the caudal portion of the temporoparietal junction (TPJ), encompassing areas around the angular gyrus, posterior temporal cortex, and prefrontal cortex. However, intriguingly, as shown in Table 2 of Seidel Malkinson *et al.* [3], 41 out of 97 responsive contacts in Cluster 2 were situated within the temporal lobe. This underscores the crucial role of the temporal lobe in processing salient signals, which may be intricately involved in the exogenous attention system, aligning with previous studies [5–7].

Furthermore, contacts within the three clusters spanning over 20 brain regions exhibited corresponding neural activities during exogenous attentional orienting. The authors propose that various types of response could be defined across these clusters, forming a spatiotemporal gradient from the visual cortex to frontoparietal areas [8]. Instead of discrete sequential processes across the brain (e.g., transmitting signals from visual to motor regions), attention arises simultaneously across large cortical gradients comprising multiple brain regions, integrated into cortical topography. This provides causal evidence that the brain may coordinate information via a global framework [9], incorporating specific brain regions to regulate behavior.

Overall, with iEEG recordings, Seidel Malkinson *et al.* introduced a novel approach of clustering responsive contacts to explore the neural circuits underpinning exogenous attention [3]. Within these clusters, they identified one (Cluster 2) as being crucial for exogenous attention, spanning numerous brain regions. This underscores the significance of large-scale cortical gradients in reacting to salient objects, suggesting that exogenous attention engages multiple brain regions simultaneously. These findings promise to greatly advance our understanding of the functional hierarchical organization of the human brain.

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## Declaration of interests

Neither author declares a conflict of interest.

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## References

1. Theeuwes, J. (2019) Goal-driven, stimulus-driven, and history-driven selection. *Curr. Opin. Psychol.* 29, 97–101
2. Klein, R. (2000) Inhibition of return. *Trends Cogn. Sci.* 4, 138–147
3. Malkinson, T. *et al.* (2024) Intracortical recordings reveal vision-to-action cortical gradients driving human exogenous attention. *Nat. Commun.* 15, 2586
4. Posner, M.I. and Cohen, Y. (1984) Components of visual orienting. In *Attention and Performance X: Control of Language Processes* (10) (Bouma, H. and Bouwhuis, D. G., eds), pp. 531–556, Erlbaum
5. Lin, R. *et al.* (2024) Neural evidence for attentional capture by salient distractors. *Nat. Hum. Behav.*, Published online March 27, 2024. https://doi.org/10.1038/s41562-024-01852-5
6. Sani, I. *et al.* (2021) The human endogenous attentional control network includes a ventro-temporal cortical node. *Nat. Commun.* 12, 360
7. Stemmann, H. and Freiwald, W.A. (2019) Evidence for an attentional priority map in inferotemporal cortex. *Proc. Natl. Acad. Sci. U. S. A.* 116, 23797–23805
8. Huntenburg, J.M. *et al.* (2018) Large-scale gradients in human cortical organization. *Trends Cogn. Sci.* 22, 21–31
9. Deco, G. *et al.* (2021) Revisiting the global workspace orchestrating the hierarchical organization of the human brain. *Nat. Hum. Behav.* 5, 497–511