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Guided Search is associated with modulated neuronal excitability to Target and Distractor features in early visual regions

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Feature guidance in visual search

Visual search models have long suggested that search is facilitated by a "priority" or "activation" map, guiding attention towards items having Target (T) features and away from items having Distractor (D) features[1,2]. In this MEG study, we use Rapid Invisible Frequency Tagging (RIFT) in a classic visual search paradigm, to understand the neuronal mechanisms underlying feature guidance. RIFT is a novel technique to probe neuronal excitability in primary visual cortex (V1)[3-5].

Hypotheses:

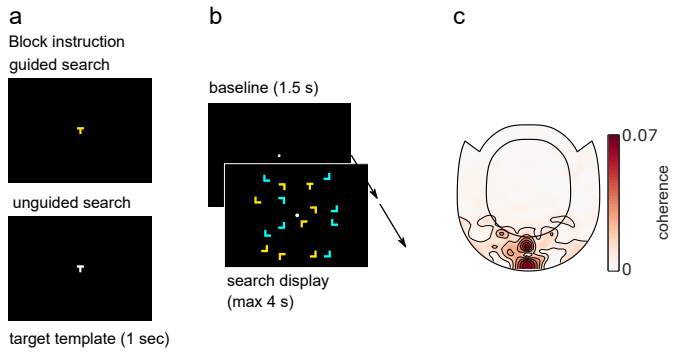
1.Neuronal excitability (RIFT response) to the T feature is enhanced and response to D features is reduced in guided (pre-defined T and D) compared to unguided (undefined T) search.

2. Faster reaction times are preceded by enhanced alpha power.

3.1. Pre-display alpha power reflects a targeted inhibtion and is only enhanced in the guided search condition. OR

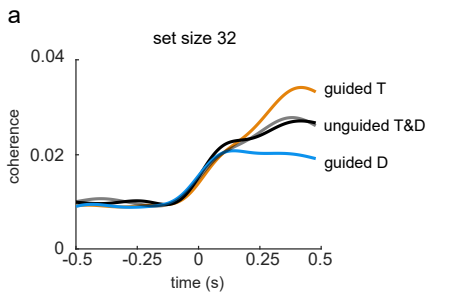
3.2. Pre-display alpha oscillations impose an untargeted "blanket" inhibition in guided and unguided search.

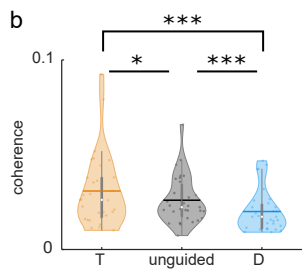
Visual Search: Rapid Frequency Tagging & MEG

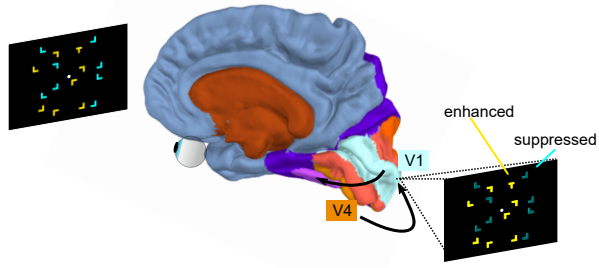


a Instruction at beginning of the block: T color known (guided search) vs randomized (unguided search). **b** Trial structure. The T and D colors were randomly tagged at 60 and 67 Hz; set sizes (16 & 32) were randomized over blocks. **c** RIFT response in one participant, planar gradiometers.

Target features are boosted & Distractor features are suppressed in primary visual cortex



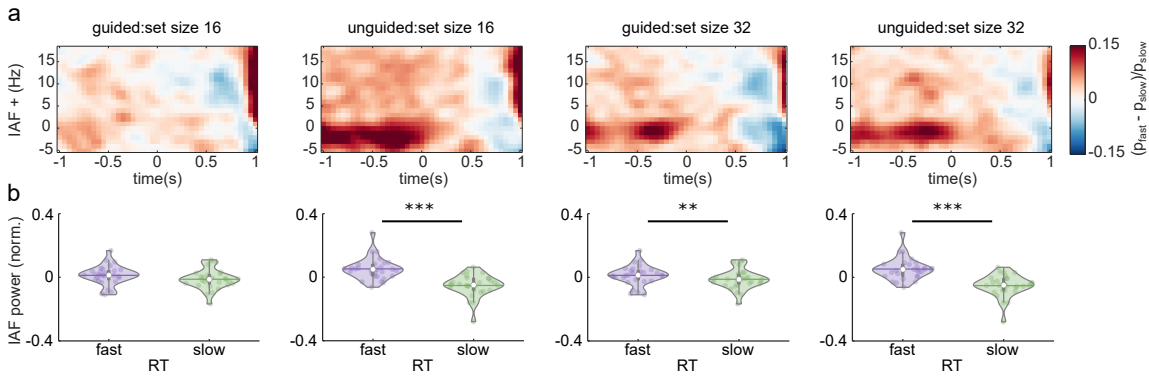




Coherence between MEG signal (gradiometers) and tagging signal for set size 32‡. **a** The response to the guided T and D color are modulated after ~150 ms. **b** Coherence averaged over the 200 ms to ~500 ms time interval (minimum reaction time; RT). RIFT response to the known T color is significantly enhanced (T_{28} = 2.36, p = .025, d = 0.41), and the response to the known D color is signifcantly reduced (T_{28} = -4.28, p = $3e^{-4}$, d = -0.75) compared to unguided search. Consequently, there is a strong, significant difference between the responses to the known T and D (T_{28} = 4.8, p = $1e^{-4}$, d = 0.84; p-values Benjamini-Hochberg-corrected).

Model: Target enhancement and Distractor suppression in V1. The latency of the modulation (~150 ms) suggests that the neuronal excitability in V1 underlies top-down control, e.g. by color-sensitive area V4. Modulation of V1 excitability results in a dimmed retinotopic representation of the items in the D color and an enhanced representation of the items in the T color. Brain regions colored according to the visuotopic PALS atlas[97].

Stronger pre-search alpha power predicts faster reaction times



***T_{28} = 4.1, p = .00032, d = 0.76

**T_{28} = 2.86, p = .008, d = 0.53

***T_{28} = 4.14, p = .00029, d = 0.77

a Power contrast fast vs slow RT, aligned to each participants' individual alpha frequency (IAF; grandaverage, combined gradiometers). Power at IAF is visibly enhanced for fast vs. slow trials, for set size 16:unguided and set size 32:unguided and guided.

b Power at IAF for fast vs slow trials, normalized to the mean across trials. A three-way rmANOVA on normalized IAF power (guided/unguidedxsetsizexRT) reveals a significant main effect for RT ($F_{1,28}$ = 12.18, p = 7e-5, η2 = .25) (pairwise-comparisons are Bonferroni-corrected). The results suggest that the visual system prepares for difficult searches (set size >=16) by increasing alpha power.

Conclusions

We propose that visual search is guided by an interplay of alpha inhibition, boosting of Target features and inhibition of Distractor features. Alpha oscillations impose a pulsed "blanket" inhibition on the upstream signal from V1 along the visual hierarchy. The excitability of V1 neurons is modulated by a higher-order area, e.g., V4, based on whether they encode Target or Distractor features.

Attention will be guided to objects whose representations are strong enough to overcome the inhibition, here, objects sharing the Target color.

‡ Coherence was not significantly modulated for set size 16.

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