Tracking covert attention over space and time using RIFT

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Abstract

When navigating through the visual world, we constantly shift our attention from one point to the other. We often do this in a covert manner, without any clearly visible signature (such as moving our eyes). This makes these shifts difficult to study, and therefore we know relatively little about how they actually operate. How does our attention move from one point to another? Here, we use Rapid Invisible Frequency Tagging (RIFT) in an EEG experiment to track the allocation of spatial attention over time and space during covert attentional shifts, showing a suppression of attention at the location between the shifts around 150ms after it begins.

Keywords: Visual attention; Covert Attention; EEG; Rapid Invisible Frequency Tagging (RIFT)

Introduction

As we navigate the world and process complex visual scenes, we continuously shift our visual attention from one place to the next. Although we can simply look towards a location or object to process it better (overt attention), we can also shift our attentional focus alone without making an eye movement (covert attention). Covert shifts of attention form a fundamental component of research in vision science (Carasco, 2011). The properties of a covert shift of spatial attention are typically inferred from behavior, using responses to target stimuli at this location (Posner, 2016), or neural markers such as the lateralization of alpha oscillations (Worden et al., 2000).

Though such signatures can identify when or to what destination attention has (covertly) shifted, this still leaves unanswered questions about how attention moves from one point to another. When shifting from point A to B, does a hypothetical spotlight of covert attention travel linearly between these two points? Or does attention disengage entirely from the visual scene and re-engage directly at point B? In other words, is the processing of locations in space *between* point A and B also boosted? Or is such enhancement limited only to the start and end location of the covert shift of attention? Furthermore, how long does this shift take?

Figure 1: How does covert attention move from point A to B?

To answer this, we would ideally want to have some measure of covert attention at different locations along an attentional shift. Here, we achieve this goal by using Rapid Invisible Frequency Tagging (RIFT), where the neural response to *invisible* stimuli forms a spatial tracker of attention over time. Using RIFT and EEG, we track the allocation of spatial attention over time and space during a covert attentional shift.

Methods (1/2) - What is RIFT?

Steady-State Visual Evoked Potentials (SSVEPs) are a characteristic neural response to rhythmically varying sensory inputs (Norcia et al., 2015). When flickering a visual stimulus at a fixed frequency, the amplitude of this frequency in the neural response forms a time-varying measure of how much attention is directed to the location where this stimulus is presented, even if gaze remains unchanged.

Recent progress in display technology has given rise to a new avenue: Rapid Invisible Frequency Tagging (RIFT), wherein stimuli are flickered at frequencies higher than 60Hz (Seijdel et al., 2023). Though traditional SSVEP flickers are visible, flickers in the RIFT range are not perceived despite evoking a low-level neural response. Thus, using RIFT, we can track the allocation of covert attention to stimuli that appear otherwise static, eliminating any confounds arising from flicker-caused distractions.

Methods (2/2) - The Task

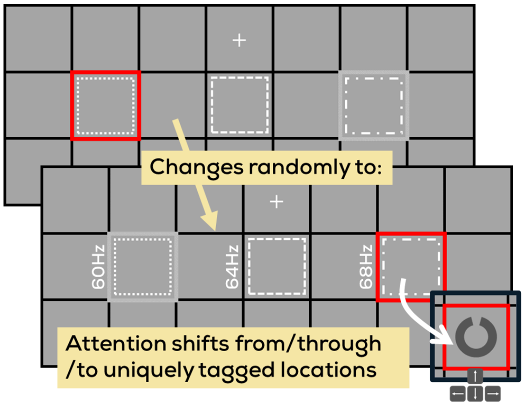

Figure 2: Task schematic (Dotted lines indicate tagging, were not shown on actual display)

We ran an EEG experiment with 24 healthy human participants. A grid of squares is presented in 90 20-sec trials. Gaze is fixed at the screen's center (the plus). Two squares (left/right) are highlighted with grey/red outlines, and landolt Cs are occasionally shown in both. The outlines are swapped at several random moments throughout a trial, following which participants must immediately switch their attention from one to the other to report the orientation of targets in the cued square.

The start, middle, and end points of the shift are uniquely tagged, such that we obtain a RIFT trace (measure of attention allocation) for each of the three locations independently over time.

Results

First, we confirmed that our oscillatory stimulation can be measured in the neural response (Figure 3), as shown by peaks at our selected frequencies (60Hz, 64Hz, 68.57Hz) in parietal/occipital electrodes. We also confirmed that participants indeed switch their attention from one square to the other, using lateralized alpha oscillations and horizontal gaze biases.

When looking at the RIFT signal locked to the switch cue (Figure 4), the tagging signal from the endpoint is significantly higher than that of the startpoint, confirming the attentional shift. Interestingly, attentional allocation to the midpoint of the switch is *reduced*. This is neither what a linear movement of attention would predict (enhancement at the midpoint) nor what a disengaging account would predict (no effect at the midpoint). We also see an enhancement at the start point location. This is unexpected, but is likely caused by the visual transient - change in outline colour - at this location.

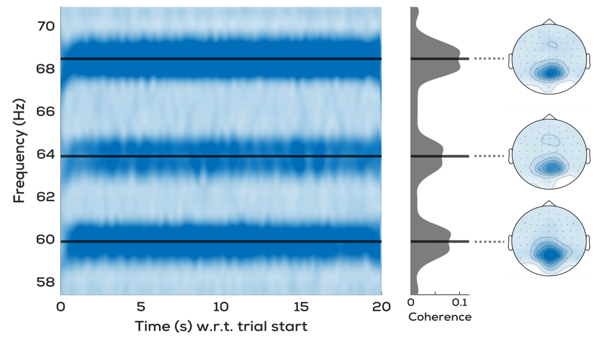

Figure 3: RIFT signal observed in the EEG response as measured by coherence

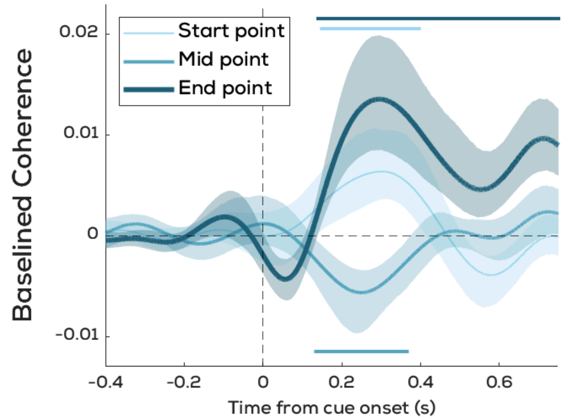

Figure 4: Attentional Modulation to the RIFT coherence amplitude at different locations.

Conclusion

We find reduced attentional allocation at the midpoint of covert attentional shifts. This suggests that when shifting attention we actively suppress either the whole visual field, or specifically the region between the shifts. We are currently conducting a follow-up experiment with more tagged locations to determine whether this dip at the midpoint is global suppression or suppression specific to the area between the shift using an auditory cue to avoid the effects of the visual transients.

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