**Studying the Neural Substrate of Attention and Visual Awareness**

Consciousness appears to be a bi-stable phenomenon: you are either aware of something, or you aren’t. In addition we have an undeniable feeling that attending to something brings it immediately to awareness. Attention appears to act as a gateway to consciousness and I believe that studying attention is a way to probe the specific mechanisms that translate visual inputs into conscious awareness. To clarify these mechanisms I am building a model of feature-based attention as a part of my research program with Prof. Justin Gardner at Stanford University. Our goal is to build a model of the neural process of feature-based attention that accounts for the evident changes that attention causes for conscious visual perception.

**Inattentional Blindness**

In the early 1990s Arien Mack and Irvin Rock discovered that attention to one feature in an image was sufficient to abolish conscious awareness of other features. They coined this phenomenon “inattentional blindness” noting that it even occurred when participants were specifically fixating (i.e. their eyes were directly centered on) the feature of which they had no perception. However, it was later shown that some features survive inattentional blindness, in particular natural images and faces (Li et al., 2002; Reddy et al., 2004). This finding led researchers like Christof Koch to announce that attention and conscious awareness were two separable processes in the brain (Koch and Tsuchiya, 2007). More recent research has re-opened the debate by suggesting that even scene perception is subject to inattentional blindness when attention is engaged by a sufficiently difficult task (Cohen et al., 2007). I propose that this mixture of results is largely due to an imprecise understanding of attention. **Attention is a specific neural process**. If we knew precisely how attention acts on other neural processes in visual cortex we would have a better grasp on understanding why attention manipulates our conscious awareness.

**Current and Proposed Studies**

Over the past year I have collected data to begin building a model of the effect of feature-based attention on neural processing in the visual cortex. Using an inattentional blindness paradigm I combined two well understood image features: image contrast and motion coherence. We know that the BOLD fMRI signal in early visual cortical areas such as V1 is sensitive to contrast intensity, but not to motion coherence. The reverse is true in the later cortical areas V3a and hMT, where there is response sensitivity to motion coherence but not to contrast intensity. Importantly, visual cortex is organized in a hierarchy where V1 projects more strongly to V3a and hMT than the converse. Based on this knowledge I expected that due to the feed-forward connections in visual cortex attentional effects would be fed to downstream cortical regions, potentially corrupting the downstream representations. Specifically, I expected that attention to contrast, which is known to affect V1, would corrupt or suppress signals in the downstream areas V3a and hMT. In contrast, I expected that attention to motion, which we expected to affect V3a/hMT, would not result in any change in the signals in V1. If discrimination of contrast depended only on V1 and motion only on V3a/hMT, then the behavioral results are clear: attention to motion should affect the perception of contrast but not vice versa. This is precisely the effect that we observed. Our BOLD fMRI results show that the responses in area hMT and V3a are modulated by the type of attention, whereas responses in V1 are not. In parallel we found that discrimination of motion in our task was affected by attention, whereas discrimination of contrast was not.

The model is currently incomplete—although we know from our data that the perception of contrast and motion are asymmetrically related to attention and that BOLD fMRI responses reflect and possibly drive perception, we still have not specified the causal process of attention. My hypothesis is that **attention to contrast corrupts the representation of motion** in the downstream regions. I will test this hypothesis in two ways: First by using a computational model of our current dataset to look at what effect of attention best explains our data, and second in a new experiment using transcranial magnetic stimulation. TMS is a technique that can be used to either abolish neural activity in a region, akin to a temporary lesion, or to boost or suppress activations that are near perceptual threshold. We can take advantage of both of these techniques to test our hypothesis in the following ways: **(1)** as a test of causality, using temporary TMS lesions to test the involvement of each area in contrast and motion perception, and (**2)** by using low-threshold pulses to mimic corrupting attentional signals. If corruption is indeed the cause of our effect than a low-threshold pulse to V1 should introduce similar corruption in downstream regions, mimicking the behavioral effects I have already observed. In this way TMS is a similar tool to the lesion experiments performed in the monkey physiology literature in the 90s. It allows us to test for causal outcomes by both temporarily abolishing activity in a region and inducing increased activation via low-threshold pulses. This is the ideal technique for testing my corruption model and the data we collect will give us considerable leverage in understanding the precise nature of feature-based attention and its impact on the perception of contrast and motion.

**Impact**

This research has the potential to help clarify the debate surrounding attention and inattentional blindness, and ultimately to improve our understanding of the neural processes of consciousness. As I build my model of feature-based attention I continue to think about how this model fits into the larger space of consciousness research. Attention is clearly an integral part of our own conscious experiences, but it remains entirely unclear whether the neural process of attention interacts directly with the neural processes of consciousness. My prediction is that attention is responsible for the bi-stability of consciousness. As a gating function and a form of sensory enhancement attention appears to influence the depth to which perceptual information is processed by the brain. It is likely that only processing that reaches a certain neural system leads to consciousness, but that model is for the moment untestable.

Understanding attention is an indirect solution, as it doesn’t directly address the question of how conscious is evoked by neural processes. I believe that question needs to be held to the side while we clarify attention, memory, and decision making—processes that are often associated with consciousness but with only a vague understanding of their associated neural processes. As these become more clear we will be able to build experiments that more precisely isolate conscious neural processes in the human brain.

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