Collapsing Content and Process: Mental Representations are not Static and the Brain is not a Computer

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The assumption

A widespread assumption in the cognitive sciences that continues to shape theories from low-level perception to high-level reasoning is that cognitive processes are distinct from the representations on which they operate. According to this view, the brain is like a computer in which content (data) is qualitatively separate from process (operations on the data). We will argue that this critical assumption is largely irreconcilable with data from neuroscience and contemporary behavioral studies of perception and attention.

The problem with the assumption

Although there are theoretical, computational, and rhetorical advantages to placing strict divisions between process and content, recent findings from a number of domains belie almost every aspect of such a separation.

First, the process-content separation requires that "content" comprise largely static representations. That is, because content representations are in a sense encapsulated from downstream processes, they should not be affected by them. Thus, regardless of the high level context of the observer, the content should remain the same. This assumption is contradicted by behavioral and electrophysiological findings that context has profound impacts at the earliest levels of perceptual processing. Likewise, there is mounting evidence that visual attention, rather than selecting from underlying static representation, *modulates* representations across multiple levels. For example, Kravitz and Behrmann (2008) have shown that cueing a given object has consequences that extend throughout the visual scene.

Second, the division of process and content requires a complex mechanism by which the process can index the static representations that are assumed to comprise content. Consider this problem in the domain of visual attention. One can rapidly attend to any specific item or group of items in a complex visual scene, ranging in complexity from oriented lines to complex objects. If attention cannot have direct access to perception, then such flexibility necessitates that attention have a very powerful method of indexing its content. We discuss why such indexing is neurally implausible.

Third, the assumption of separation between content and process has encouraged a modular view of brain organization resulting in a binding problem. In vision, cortical areas are thought to be specialized to process particular aspects of visual stimuli (e.g. color in V4, objects in IT). But in order for one to attend to e.g., a red car in a scene, there must be some way to bind together outputs of allegedly modular areas. Recent work has shown that retinotopic position remains an important aspect of visual representations even in far anterior visual regions (Kravitz, Vinson, & Baker, 2008). This and related evidence paints a view of the visual system in which individual regions have some specialization, but still maintain sensitivity to other perceptual dimensions. Thus, a system that appears to be composed of distinct modules may actually be highly interactive, "soft-assembling" dynamic representations of stimuli that span many levels of representation.

The solution and its implications

We argue that content and process must arise within the same system (Lupyan, Kravitz, et al., in prep). One immediate implication of collapsing content and process is that no representations are truly static or veridical. In this view, attention functions *in situ* with perceptual representations. The effects of context and intent can potentially alter all content. All representations, even those contained in early perceptual areas are dynamic and capture a blend of the state of the world *and* the internal state of the observer. Thus, attending to, categorizing, or making a decision about a stimulus—even one that is physically present in the current environment—alters its representation at all levels.

Working on these assumptions, Lupyan and colleagues have shown that even low-level visual processing of familiar items is flexibly modulated by prior knowledge such as the items' conceptual category as well as the verbal label associated with the item.

This approach opens new ways of understanding neural organization: in this view structure is highly reflective of function, rather than being arbitrary or genetically specified.

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