

## Letter

## The Trajectory of Self

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In a recent Opinion article, Sui and Humphreys [1] argue that experimental findings suggest self is 'special', in that self-reference serves a binding function within human cognitive economy. Contrasting their view with other functionalist positions, chiefly Dennett's [2], they deny that self is a convenient fiction and adduce findings to show that a 'core self representation' serves as an 'integrative glue' helping to bind distinct types of information as well as distinct stages of psychological processing. In other words, where Dennett regards self as analogous to a center of gravity, a simplification posited by observers, Sui and Humphreys regard self as a function that modulates mental processes. In practice, however, the concept of 'self' they employ is not unlike Dennett's.

We side with Sui and Humphreys in holding that self-reference modulates mental processes: reference to self during a task can bind memory to source, increase perceptual integration, and link attention to decision making, among other things. What is more, these functions are not reducible to other factors such as semantic coding, familiarity, or reward [3]. But whereas Sui and Humphreys contribute important empirical detail, the binding functions they describe are compatible with Dennett's version of functionalism, which treats self as an artifact of social process.

The problem is that the research they highlight resembles the social process view in critical respects, making self appear nearly as insubstantial as a center

of gravity. Note that, according to Sui and Humphreys, binding functions are evoked when stimuli that are stipulated by experimenters to be self-related, and that seem to 'enhance' coupling among certain brain regions, are introduced by those experimenters within tasks. Here, as with social processes, what matters most is activity that is driven by the designs of other persons and by extrinsic stimuli. But a focus on extrinsic stimuli of this sort that entrain ongoing, integrative mental functions can make self seem derivative of social process, leaving it without a momentum or trajectory of its own, subject to lapses when those processes are absent. It is in this respect that the Sui and Humphreys concept of 'self' is scarcely distinguishable from Dennett's.

Self is less evanescent and more substantial than this view suggests. Indeed, Sui and Humphreys do intimate an approach better suited to explaining self with their observation that, when the perigenual anterior cingulate cortex (PACC) is taken as seed, resting state (RS) activity in the anterior cortical midline structure (aCMS) bears similarities to neuronal activity that occurs when participants respond to self-related stimuli. To go beyond identifying a function for self and explain how it performs that function – to identify wherefrom it derives its trajectory – this observation about the RS warrants scrupulous attention.

We submit that this similarity of pattern affords a unique opportunity to investigate self's neural correlates and preconditions, because neuronal fluctuations can thereby be studied in relative isolation from the social process of responding to experimental tasks. By directing attention to the RS and other pre-stimulus states, progress can be made on identifying the relevant regional, temporal, and biochemical patterns that mediate self. Our point is not that the RS is pristine, untouched by social process [4]; instead, it is that the RS is neither inert nor incapable of sustaining self. On the contrary, the relevant

spontaneous neuronal fluctuations actively shape how stimuli are perceived and interpreted [5,6], and, by concentrating on this shaping process, we can see that self has momentum and trajectory that do not lapse in the absence of external stimuli.

To illustrate this line of investigation, participants were asked to indicate whether emotional photographs were self-related [7]. We discovered that the degree of low-frequency alpha power (8–9 Hz) – even before the photographs were presented – could predict the degree of self-relatedness. That is, a higher degree of alpha power disposes participants to experience pictures as more self-related; a lower degree, as less. In addition, we discovered that the higher the subject's RS concentration of PACC glutamate, the greater the pre-stimulus low alpha power difference between high and low self-relatedness. These findings suggest that PACC glutamate can predispose subjects to spontaneous fluctuations in frequencies, like low alpha, which in turn predisposes those subjects to perceiving stimuli as self-related.

The discovery that RS and pre-stimulus activity shape self-experience creates opportunities for investigating how self accomplishes integration and other functions, in a way that controls for confounding effects of social process. Controlling for the effects of those processes makes possible the development of a more comprehensive, untrammled understanding of self, one that informs about the contents of experience most intimately associated with self [8,9], the binding function when self is absent [10], and circumstances wherein self obstructs rather than binds [11,12]. Sui and Humphreys's affirmation that the 'self' concept can play a functional role is insufficient to distinguish their position from Dennett's. Progress on explaining what is special about self requires scrutiny of intrinsic, spontaneous activity. By attending to that activity we can begin to trace the trajectory of self.

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**Letter****Self-Reference Acts as a Golden Thread in Binding**

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In a recent article in this journal, Glyn Humphreys and I proposed a model of how self-reference enhances binding in perception and cognition [1]. We showed that self-reference changes particular functional processes; notably, self-reference increases binding between the features of stimuli and between different stages of processing. Lane and colleagues [2] provide an interesting comment on our article that suggests our theory of self-reference is compatible with Dennett's philosophical perspective on the narrative nature of the self. Although the nature of the self has attracted the attention of both philosophers and scientists, the two disciplines have generated different perspectives on the functions of the self, largely due to their different methodologies. For example, Dennett argues that the self is constituted through human narration on experience [3]. By contrast, work from psychologists and cognitive neuroscientists focuses on the functional and neural mechanisms of self-reference.

**Hermeneutical Interpretations versus Mechanistic Evidence on the Integrative Self**

The traditional argument of the narrative self in philosophy emphasizes its dependence on narrative and agency

(selves are primarily agents, and agents are understood best in narrative rather than naturalistic terms), although some philosophers are in favor of a binding function for the self (i.e., the concept of center of gravity is not limited to a description). We focus on the mechanistic profile of self: that the self plays the special role of enhancing the binding of information and psychological processes in human beings. The binding function can be parameterized using mathematical models as well as empirical manipulations. For example, when individuals perceive multiple external stimuli associated with themselves, the capacity of information processing can be measured using a capacity coefficient [C(t)] indexing how one responds to the whole configuration of all stimuli rather than the sum of the parts [4]. We argue that self-reference operates as a perceptual glue to bind external stimuli together when facing a complex environment.

**Self-Reference Acts as a Golden Thread in the Brain and Mind**

Lane and colleagues [2] argue that, on a practical level, Dennett and psychologists like us treat self as an artifact of social processes. Indeed, the mechanistic perspective of self-reference has been supported by evidence occurring when people make reference to the self within the task that they are performing. However, one virtue of these manipulations is that they allowed us to test whether there is a specific neural circuit in the brain to support self-reference relative to other-reference. This line of research could provide valuable insight into whether the self is an illusion, a commonly accepted view in philosophy. Substantial evidence shows that thinking in relation to the self strongly activates the ventral medial prefrontal cortex (vmPFC) [5]. As we discuss in our article, researchers claim that the vmPFC is associated with self-representation in the brain [1]. We argue that the vmPFC