

Thinking about the Self from a Social Cognitive Neuroscience Perspective

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In this paper Kashima et al. develop an interesting model of self that attempts to simulate several psychological processes critical to an amalgamated James-Mead theoretical conceptualization of self. More specifically, the authors use a connectionist framework to model temporal, cultural and social aspects of self which may give rise to the enculturated stream of consciousness which is seen the essential experience of self in such a model. This approach is important as so much of behavioral research has focused on the self as known, in relatively static form, in contrast to the dynamic aspects of the self that unfold in each moment and as a function of context. Simple associative and declarative models of self-representations are not well equipped to handle these nonlinear dynamics, but connectionist models excel at capturing such dynamics (Hopfield, 1982).

Although the authors are primarily interested in using connectionism as a tool to model artificial neural architecture that is capable of supporting self-processes, they also stress that such models should be biologically plausible at the neural level. An interest in how the self is neurally instantiated in the living human brain has been investigated in recent years by a growing number of social neuroscientists, who have used functional imaging techniques to attempt to isolate the neural correlates of self-processing. Although the effort to understand how the self is represented in the brain is still in its infancy, such investigations have nonetheless already proven informative and seem well worth reviewing here. Due to the inherent complexities of discussing a phenomena as multifaceted as the self, it may be useful to consider this body of research by parsing it into the follow categories: self-processing versus other social processing, internally-focused versus externally-focused self-processing, and controlled versus automatic aspects of self-processing.

Self Versus Social Processing

An unresolved question in social psychology is the degree to which the self is a unique knowledge structure whose characteristics differ qualitatively from other kinds of mental representations. This debate was partly sparked by the discoveries that information is better remembered when encoded with reference to the self (Rogers, Kuiper, & Kirker, 1977) and when it is judged to be self-descriptive (Derry & Kuiper, 1981). While some researchers have suggested that these findings constitute evidence for the unique nature of

self-representations (Rogers et al., 1977), others have argued that self-reference effects can be explained by the operation of ordinary memory processes such as elaboration and depth of encoding (Greenwald & Banaji, 1989). In a more recent meta-analysis, it was found that the memory advantage of self-reference is diminished but not eliminated when it is compared to conditions in which participants encode information with reference to another individual, particularly if the target is well-known (Symons & Johnson, 1997).

The advent of functional imaging has afforded researchers a new tool for investigating whether the self is represented uniquely in the brain. One manner of addressing this question is to examine whether brain regions that are recruited by self-processing are distinct from those which are involved in the processing of other similar social information. These studies have generally employed paradigms in which the self-processing condition consists of participants making self-reflective judgments about whether trait words or sentences are self-descriptive or not. Brain activation in response to this condition is then compared to activation generated by comparable judgments of other individuals and/or semantic tasks such as judging the letter case of a trait adjective.

A clear, robust finding that has emerged from this line of research is that cortical midline structures are consistently engaged when subjects are asked to make judgments about their own psychological processes, especially when compared to semantic processing (Northoff et al., 2006). In particular, medial prefrontal cortex (MPFC) appears to be heavily recruited during self-reflective processing. In one of the first fMRI studies to directly examine the neural correlates of self-reflection (rather than the monitoring of internal states), Johnson and colleagues (2002) found activation in anterior MPFC (BA 9/10) when comparing self-reflective judgments (e.g., "I am a good friend") to semantic knowledge processing (e.g., "You need water to live"). Recruitment of MPFC for self-judgments compared to semantic judgments has since been well replicated (D'Argembeau et al., 2005; Fossati et al., 2003; Heatherton et al., 2006; Johnson et al., 2005; Kelley et al., 2002; Phan et al., 2004; Schmitz, Kawahara-Baccus, & Johnson, 2004; Zysset, Huber, Ferstl, & von Cramon, 2002). The degree of self-relevance of the target stimuli may be an important moderator of this effect, as MPFC has been shown to activate more strongly to material judged to be self-descriptive than material deemed non-self-descriptive (Macrae, Moran, Heatherton, Banfield, & Kelley, 2004;

Moran, Macrae, Heatherton, Wyland, & Kelley, 2006). In contrast, stimulus valence does not appear to be a significant moderator of MPFC activation induced by self-processing, in that MPFC has been shown to be recruited similarly for self-referentially processing both negative and positive stimuli (Moran et al., 2006).

Furthermore, MPFC involvement during self-processing may be responsible for the previously described memory advantage observed for self-referenced stimuli. In a specific investigation of the neural correlates of the self-reference effect, MPFC activation in response to judging trait adjectives was shown to predict subsequent memory for the material (Macrae et al., 2004). This finding prompted investigators to suggest that MPFC may facilitate the encoding into memory of self-relevant material in much the same way that the amygdala is thought to enhance the encoding of emotional stimuli. A study by Fossati and colleagues (2004) dovetails nicely with this finding by demonstrating selective MPFC activation during retrieval of adjectives that had been previously encoded with reference to the self compared to those which had been encoded semantically or phonemically.

Although the ubiquitous involvement of MPFC in self-reflective processing seems clear, it is much less obvious whether MPFC (or a specific region of MPFC) is *selectively* activated for self-judgments. Several studies have found essentially no differences between neural activity in response to trait self-judgments and trait judgments of others, including both personally unknown and close others (Craik, 1999; Ochsner et al., 2005; Schmitz et al., 2004; Seger, Stone, & Keenan, 2004). However, other studies which compare these same conditions evidence greater activation of MPFC during self-processing compared to other-processing (D'Argembeau et al., 2005; Heatherton et al., 2006; Kelley et al., 2002; Ochsner et al., 2004). In a recent developmental study, Pfieler and colleagues (under review) found that in both children and adults MPFC was more active when judging the descriptiveness of traits for the self versus a familiar other.

The existing literature suggests several possible ways of understanding how self-processing and other social processing may occur in the brain. The first possibility is that MPFC is generally recruited to the same extent whenever metacognitive evaluation of social information is required, be it about the self or another individual. This would suggest that there is little neural difference between the processes used to psychologically evaluate oneself or another individual (Bem, 1967). A second possibility is that both self-and other-reflection evoke MPFC activity but to a different extent, which would imply that differences between these two kinds of processing are indexed quantitatively in the brain. A third possibility is that there are functionally discrete areas of MPFC that make dissociable contri-

butions to self-and other-processing in the brain. Such a model implies that there are qualitative differences in how the two processes are neurally instantiated.

The latter possibility seems to be most fruitfully informed by examining the potentially separable contributions of ventral and dorsal regions of MPFC to self-processing. In general, ventromedial prefrontal cortex (VMPFC) has been linked to emotion and affective processing while dorsomedial prefrontal cortex (DMPFC) has been associated with cognitive operations and executive function (Stuss & Levine, 2002). Phillips and colleagues (2003) have proposed a model that mapped appraisal theories of emotion perception onto distinct ventral and dorsal neural circuitry. The authors suggest that a ventral affective system (consisting of ventral prefrontal cortex, amygdala, insula, ventral striatum, and ventral anterior cingulate gyrus) may be important for identifying the emotional import of stimuli and producing appropriate affective responses. In contrast, the dorsal neurocognitive system (made up of dorsal prefrontal regions, dorsal anterior cingulate, and hippocampus) is involved in the regulation of the affective response produced by the ventral route. Northoff and Bermpohl (2004) recently proposed an analogous model which is specific for self-processing. In this model, VMPFC continuously represents self-referential material and DMPFC subsequently evaluates the representations generated by VMPFC. In related work, Schmitz and Johnson (2005) found that self-processing activated both ventral and dorsal MPFC when compared to making decisions about target valence. However, when the investigators conducted connectivity analyses of MPFC activation, they found VMPFC was coupled to amygdala, insula and nucleus accumbens activity, while DMPFC activity was coupled to dorsolateral PFC and hippocampus. The authors interpret these findings to mean that the ventral route is responsible for generating the affective experience of self-related processes, while the dorsal route contributes to the cognitive evaluation of the stimuli under consideration. To the extent that the self is a more intrinsically affect-laden structure than knowledge about others persons, it may turn out to be the case that self-processing could preferentially recruit more ventral regions of MPFC while other-processing could evoke stronger dorsal MPFC activity.

In a slightly different approach, Mitchell and colleagues (2006) have argued that self-processing generally recruits VMPFC rather than DMPFC, but that mentalizing about others may differentially involve either VMPFC or DMPFC depending upon the situational context. The authors propose that the neural networks involved in thinking about the minds of others will depend upon the extent to which using the self as a template for understanding others is situationally appropriate. That is, the self may be a useful model only if the other under consideration is

very similar to oneself. In support of this hypothesis, the authors observed a double dissociation in which making judgments about the self and similar others commonly activated VMPFC but making judgments about dissimilar others selectively activated DMPFC.

It is interesting to note that in some ways this theory is the converse of that proposed by Kashima et al.: one model suggests that the self is created through appropriating the experiences of others, while the other argues that we use our own experiences as a vehicle for understanding the minds of others. Other data are supportive of the target article's view. In the study by Pfeifer et al. (under review), adults were found to activate DMPFC more when making social judgments about another person than when making self-referential judgments (for which VMPFC was more active). In contrast, the young children in the study activated DMPFC during both social and self-referential judgments. These findings may suggest that prior to have well-established self-knowledge, children may rely more on social knowledge processes when making self-judgments than they do later in life.

Internal Versus External Self-Focus

Although we have thus far limited our discussion of the neural correlates of self-processing to MPFC, it is important to note that posterior midline structures such as posterior cingulate, retrosplenial cortex, and precuneus are also frequently activated in response to self-processing (Northoff et al., 2006). This co-activation has prompted some investigators to suggest that cortical midline structures may be diffusely involved in self-representation and can even be thought of as a single functional unit (Northoff & Bermpohl, 2004).

Lieberman (2006) recently reviewed evidence which suggests that this remarkably robust pattern of midline activity may have less to do with the target of mental processes per se (e.g., self versus other) but rather may depend more critically upon the aspect of the target being considered. In this review, Lieberman argues that we usually think about ourselves and others in one of two general ways and that each may be distinctly represented in the brain. The first way is termed internally-focused. In this mode, attention is directed to intangible aspects of the self or others, such as thoughts, feelings or other contents of the mind. In contrast, externally-focused refers to when the target under consideration is viewed as a physical object in the world whose characteristics are available to us through sensory-mediated channels. It is important to recognize that it is the nature of the goal of the perceiver that determines processing mode rather than an intrinsic property of the stimulus. It is likely that we adaptively switch processing modes flexibly and

without conscious awareness in accord with situational demands. For example, asking an individual to judge whether a target is an honest person will prompt internally-focused processing, whereas asking whether the same target is overweight will initiate externally-focused processing.

Existing neuroimaging data suggests that *medial* frontoparietal structures in the brain are engaged when an internal focus is adopted and *lateral* frontoparietal areas are involved in externally-focused processing. The studies reviewed above support the assertion that midline structures are important for internal focus as they have generally asked participants to adopt this perspective by making trait judgments of themselves. In contrast, tasks such as self-recognition generate lateral activations, but not medial activations, in the prefrontal and parietal cortices when individuals identify themselves in pictures (Uddin, Kaplan, Molnar-Szakacs, Zaidel, & Iacoboni, 2005). Similarly, investigations of agency (the sense of being responsible for one's own bodily movements) generally find that lateral parietal cortex (LPAC) is involved in detecting a mismatch between visual and proprioceptive information about one's own body (Farrer et al., 2003; Farrer & Frith, 2002; Leube, Knoblich, Erb, & Kircher, 2003; MacDonald & Paus, 2003; Shimada, Hiraki, & Oda, 2005).

This distinction suggests that in attempting to map the neural processes that underlie the self, future investigations should consider the extent to which tasks encourage a specific kind of focus to be adopted. This distinction also reminds us of the multifaceted nature of representations such as the self and that fact that there is probably no one specific "self" area of the brain. Rather, many component processes work together and under different circumstances to generate our sense of self.

Dual-Process Models and the Self

One can view much of the research on the self through the lens of dual-process models, which generally posit the existence of two processing modes that can be described as controlled and automatic. Controlled processes are intentional, operate sequentially, feel effortful, can be interrupted and are available to awareness (Wegner & Bargh, 1998). Automatic processes, on the other hand, lack at least one and preferably all of these qualities. Neurocognitive systems have been identified that roughly map on to these two modes of psychological processing (Lieberman, Gaunt, Gilbert, & Trope, 2002).

The X-system (named after the *x* in reflexive) is thought to be roughly equivalent to an automatic social cognition network in the brain. It includes VMPFC, amygdala, basal ganglia, lateral temporal cortex (LTC) and dorsal anterior cingulate cortex (dACC). The

X-system processes information in parallel, learns slowly, does not require cognitive resources, and operates quickly and without reflective awareness. It is responsible for the creation of our stream of consciousness and representing our statistical generalizations about the world.

Conversely, the C-system (after the *c* in reflective) is thought to roughly correspond to a controlled social cognition network in the brain and includes MPFC, lateral prefrontal cortex (LPFC), lateral parietal cortex (LPAC), medial parietal cortex (MPAC), medial temporal lobe (MTL), and rostral anterior cingulate cortex (*r*ACC). In contrast to the X-system, the C-system processes information serially, learns quickly, operates slowly and with conscious reflection, and requires cognitive resources. The C-system appears to be important for processing exceptions or symbolic problems that cannot easily be handled by the X-system.

In a recent investigation, Lieberman, Jarcho, and Satpute (2004) attempted to parse out how these dual processes may operate in the brain with respect to self-knowledge. Specifically, they hypothesized the existence of two systems, which they termed evidence-based and intuition-based self-knowledge. Evidence-based self-knowledge refers to the conscious, reflective processes that are enacted when an individual processes information in a low-experience domain. This kind of controlled processing is likely to engage C-system structures, as it will require conscious reflection and retrieval of episodic memories. In contrast, intuition-based self-knowledge is involved in accessing knowledge in high-experience domains. As such, it is a nonreflective, automatic way of knowing about the self that should therefore operate via X-system neurocognitive structures.

In this fMRI study, individuals who were either highly experienced soccer players or actors judged whether traits related to soccer or acting were self-descriptive. In line with their hypotheses, the authors found that processing information in one's high-experience domain (e.g., actors judging acting words) activated X-system structures. In contrast, processing information in one's low-experience domain (e.g., actors judging soccer words) selectively activated components of the C-system. Thus, it appears that as one gains experience within a domain, the neural structures that subserve its representation may move from brain regions that are associated with conscious control to those which are more automatic and affective. This change in neural circuitry makes intuitive sense because as one gains experience in a particular domain, processing information relevant to that domain is no longer an exception or special symbolic problem related to the self (province of the C-system) but has been incorporated into a generalized schema about the self (the domain of the X-system).

This research also highlights the notion that self-processes are diverse and contain both automatic and controlled components. In particular, there may be an important distinction between self-reflection and self-knowledge activation. In another recent study, Pfeifer, Lieberman, and Dapretto (under review) suggest that MPFC may be involved in self-reflection but not in accessing stored self-knowledge. The authors observed that during self-knowledge retrieval adults show less MPFC activation relative to children. This implies that MPFC is not a storage site for self-knowledge, as adults have presumably accumulated greater stores of knowledge about the self than children. Thus, MPFC may be important for the process of self-reflection rather than responsible for the actual representation of self-knowledge.

In ongoing research, we have been interested in the way in which X-system processing of schematic information may contribute to such information being more strongly encoded into memory. A schematic domain is one that is considered to be both highly descriptive and highly important to an individual's self-concept (Markus, 1977). Building upon the original work by Markus, we have found that even when biased responding and self-reference effects are controlled for, individuals who hold a self-schema in a particular domain remember schema-relevant information better than non-schematic material (Rameson & Lieberman, in prep). We think that this deeper encoding may result from X-system processing of schematic information, so that such material is encoded in a more affective and memorable manner.

In a recent fMRI pilot study, participants with varying levels of athletic schematicity viewed a series of neutral athletic and academic (control) pictures and judged whether each picture contained people or not. Thirty minutes later, participants were given a surprise memory test for the images that included an equal number of new athletic and academic pictures. Replicating earlier work in our lab, we found that higher levels of athletic schematicity were associated with greater activity in the amygdala and nucleus accumbens while judging whether athletic traits were self-descriptive or not. Moreover, activations in these regions during athletic trait judgments were also correlated with memory performance for athletic pictures. Thus, brain activity during trait judgment may be a sort of neural index of schematicity, which can be used to predict memory performance. This may suggest that amygdala and nucleus accumbens are critical mediators of the relationship between possession of a self-schema and enhanced recall for information within the schematic domain.

Past research has made it clear that emotional material is better remembered than non-emotional information at least partly through activation of X-system

structures like the amygdala (McGaugh, 2004), but our research extends these findings in suggesting that valence need not be a latent property of the stimulus. In this study, although the target stimuli were all pre-rated and selected to be neutral, a property of the individual (the self-schema) may have caused the “neutral” information to be processed affectively. In turn, this affective processing seems to be responsible for causing the information to be better remembered than information which was not related to one’s self-schema.

Dual Processing and Connectionism

After reviewing evidence that the self has both automatic and controlled components that are processed distinctly in the brain, it is not clear that all self-processes are equally amenable to being modeled using connectionism. Two questions in particular seem relevant. First, what kinds of processes are best modeled using connectionist theory? Second, to the extent that one wishes to construct a neuroanatomically plausible connectionist model, what neurocognitive systems might be the best candidates for performing connectionist processing?

Connectionist models are characterized by possessing subsymbolic, parallel processing architectures (Rumelhart & McClelland, 1986; Smolensky, 1988). By subsymbolic we mean that an individual node in the connectionist network should not represent a symbolic construct like “dog” or “sad.” Rather, representations in connectionist networks are achieved only by matching particular *patterns of activation* among the various nodes. By parallel processing, we mean simply that the operations of the network are carried out simultaneously rather than sequentially. This characterization, albeit brief and oversimplified, immediately suggests that connectionist networks may be more appropriate for modeling automatic, parallel processes rather than controlled, sequential processes (Rumelhart & McClelland, 1986).

As previously discussed, automatic processes are largely underwritten by the X-system, which performs subsymbolic, pattern-matching, parallel processing without conscious awareness (Lieberman et al., 2002). In contrast, hallmarks of the C-system are serial processing, use of symbolic logic, and the sense of agency that occurs with its instantiation. It is important to recognize that automatic processes are not just faster, more efficient versions of controlled processes. Although at times these processes look similar and produce similar outputs, their qualitative differences are evidenced by their differential engagement of the neurocognitive systems that underwrite their functions. For example, implicit pattern learning is associated with X-system inferior temporal cortex activation (Aizenstein et al., 2000). However, when individuals

are given explicit instructions to find patterns, PFC and hippocampus (C-system structures) are activated instead. Analogously, similarity-based pattern matching activates LTC but rule-based processing of similar problems results in prefrontal, anterior cingulate and hippocampus activations (Houde et al., 2000). Thus, even when both the X-and C-systems are capable of completing identical tasks, the mode of processing (pattern matching versus symbolic logic) remain fundamentally distinct.

Therefore, we submit that connectionist models may best describe processes that are automatic and processed in parallel. Furthermore, for connectionist models that strive to be biologically feasible, sensitivity to the processing constraints of the neurocognitive candidates involved in the model seems critical. Because the X-system shares many of the operating characteristics of connectionist models, namely parallel processing and subsymbolic pattern matching, we suggest that this neurocognitive system is an ideal candidate for connectionist models.

Note

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