

Shared representations between self and other: a social cognitive neuroscience view

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The abilities to identify with others and to distinguish between self and other play a pivotal role in intersubjective transactions. Here, we marshal evidence from developmental science, social psychology and neuroscience (including clinical neuropsychology) that support the view of a common representation network (both at the computational and neural levels) between self and other. However, sharedness does not mean identity, otherwise representations of self and others would completely overlap, and lead to confusion. We argue that self-awareness and agency are integral components for navigating within these shared representations. We suggest that within this shared neural network the inferior parietal cortex and the prefrontal cortex in the right hemisphere play a special role in interpersonal awareness.

Humans, like most mammals, are highly social animals. Our survival relies on the existence of others and our ability to interact with others. Such social transactions involve both an ability to identify with others, and also an ability to distinguish ourselves from others. In this paper we argue that the self is a multi-dimensional construct (see [Box 1](#)) that relies on a distributed neural network that encompasses shared self–other representations. This network is predominantly right-hemisphere based and includes prefrontal, posterior temporal and inferior parietal areas. Rather than considering this network as a single module, we view it as a collection of interconnected regions that are essential for the subjective experience of a ‘self’.

Our view of the self relies heavily on the concept of shared representations between self and others, borrowed from developmental science and social psychology. Such a view has its roots in the phenomenological notion that the self cannot be grasped and conceptualized independently of a conceptualization of others. Accordingly, individuals internalize other people’s perspectives through interactions with others thereby promoting self-monitoring, self-regulation, and reflection on their own cognition [1]. This view is also compatible with the so-called ‘social embodiment’ hypothesis, which posits that states of the body, such as postures and facial expressions, arise during social interaction and play central roles in

social-information processing [2] and consistent with expanding literature in cognitive psychology suggesting that many cognitive functions reside in interactions between perception and action systems [3]. Similarly, recent evidence from neuroscience demonstrates that common coding between perception and action occurs at the level of single neurons in various parts of the monkey brain [4], and that, in humans, similar brain areas and computational processing are involved during mental representation of one’s own action and others’ actions, trait evaluations, and mental-state reasoning [5,6].

However, the self is not only social, but unique. As such, representations of self and other are overlapping but also distinct. We argue that the right inferior parietal cortex in conjunction with prefrontal cortex may be critical in distinguishing the self from the other. In addition, we review putative computational mechanisms by which self–other differentiation might be achieved.

Evidence from developmental science

The roots of the self begin early in infancy. Indeed, Gibson suggested that, from birth, infants coperceive themselves in acting and perceiving their environment. Neisser [7] has proposed this implicit self-knowledge may take 2 forms: an ecological self formed through interactions with physical objects and bodily perception, and an interpersonal self formed through infants’ interactions with others.

Infants’ representations of self and other actions are both overlapping and distinct. Infants readily distinguish their own actions from those of others early on [8]. However, infants also form shared representations of their own and others’ actions. Neonates imitate the actions of others in a flexible and goal-directed manner, suggesting that infants represent the other as ‘like me’ (e.g. as similar to self in some way [9]). Further evidence suggests that infants may productively use information from their own action capabilities to understand the actions of others [10]. In addition, infants also engage in affective sharing as demonstrated by the work of Trevarthen [11].

Over the first several years of life, children acquire knowledge of both objective and subjective aspects of self and others. By 18–24 months of age infants can recognize their own mirror image, a capacity that has been linked to the emergence of self-conscious emotions (e.g. embarrassment [12]). During the preschool years, children

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Box 1. What is the self?

For centuries, theorists have debated the best way to conceptualize, define and think about the concept of self. One approach is to view the self as consisting of several component parts, processes and structures [51,52]. Indeed, researchers across various domains have focused on describing or delineating different dimensions of the self. Table I provides a summary of the different dimensions of the self upon which researchers have focused, and their constituent aspects and characteristics.

For developmental scientists, a classic question is when and how the self develops. As such, they have focused on describing and explaining different levels of self. For example, Neisser [7] has argued that two early appearing perceptual forms of the self (ecological and interpersonal self) precede more conceptual forms of the self, based on mental representations. Similarly, other researchers have suggested that self-consciousness (the ability to focus attention on our selves) emerges by roughly 18 months of age as a result of the ability to create representations of representations [53]. The distinction raised by developmental scientists is an important one, as the vast majority of research on the self in adults focuses on this second level of awareness.

Some social and cognitive psychologists and scientists have focused on an individual's knowledge of the types of awareness that they possess. This knowledge translates into an awareness of the defining

features of one's individuality which includes an awareness of agency over one's actions and life events, an awareness of the distinctiveness of one's life experience, an awareness of personal continuity over time and an awareness of one's own self-reflective capabilities.

Other investigators have focused on the potential contents of self-awareness. Researchers have examined the characteristics or beliefs about the self, ranging from knowledge of physical features (such as weight, height, etc.) and action capabilities (e.g. tennis skill), to knowledge of psychological characteristics (e.g. honesty, kindness) through awareness or beliefs about social, relational or collective characteristics (e.g. profession, nationality, etc.). From our perspective, it is important to point out that the latter two dimensions are meaningful only when considering the self-in-context-of-the-other. For instance, awareness of individuality is possible only when comparing self to others, and knowledge of self-attributes is established, at least in part, via comparison with others.

In our view, one potential role that cognitive neuroscience can play in the study of the self is to help conceptually define the different dimensions, aspects and characteristics of the self and to help address the potential separability or relatedness of each component part of self-processing.

Table I. Conceptualizing the self

Dimension	Aspect	Characteristics
Levels of awareness	Aware	Appears early, primarily perceptual and embodied
	Self-aware	Appears later, based on mental representations
Type of awareness	Agency	Awareness of volition and ownership
	Distinctiveness	Awareness of uniqueness
	Personal continuity	Awareness of continuity through time
	Reflection	Awareness of awareness
Contents of awareness	Physical	Physical features
	Active	Action capabilities
	Psychological	Traits and values
	Social/relational/collective	Social roles and membership, reputation, relationship to others

simultaneously develop the capacity to represent their own and others' mental states [13]. This development entails the ability to recognize when self and other perspectives and experiences are shared and thus congruent, and under which circumstances they differ from one another. Interestingly, the development of mental-state understanding is functionally related to executive functions [14], suggesting that the prefrontal cortex is implicated in self/other cognitive representations. Indeed, neuroimaging data suggest that theory of mind tasks and executive function tasks share overlapping areas of activation in the medial prefrontal cortex (see Box 2). These findings suggest that self- and other-representations are closely interconnected beginning early in development, and that this interconnection might account for our capacity to identify with others.

Evidence from social psychology

Research from social psychology supports the nature of the self as both unique and shared. Individuals firmly believe that the self is unique in some sense, as is evident from self-serving biases, that is, the demonstrated tendency to view the self as better than average [15]. Indeed, supporting these positive self-illusions, adults sometimes perceive greater consistency in their own behavior than in

the behavior of other individuals [16]. In addition, individuals attribute their own and other's behavior to different sources. The classic actor/observer effects suggest that people perceive that their own behavior is determined by external sources whereas the locus of others' behavior is internal in nature [17]; but see [18] for an alternate explanation of this effect.

At the same time, however, the concept of self is closely intertwined with that of the other. Individuals regularly assert their own perspective in place of that of another person [19]. In addition, adults overestimate both the extent to which their isolated actions and appearance are noted by others, and the extent to which variability in these actions are detected by their social partners [20,21]. Social comparison theory suggests that people compare themselves with others to evaluate their abilities, opinions and characteristics [22]. Empirical evidence supports the speculation that information about another person's performance influences subjects' self evaluations [23]. Further support for shared mental representations of self and other comes from work suggesting that individuals readily confuse their own traits and attitudes with those of intimate or in-group others [24], leading some investigators to conclude that close relationships include viewing other in the self [6].

Box 2. The role of the prefrontal cortex in executive inhibition

Executive functions, and particularly inhibitory control, are crucial enabling factors for the development and the expression of Theory of Mind (ToM) – the ability to attribute mental states to self and others [43,54]. Converging evidence from neuropsychology [46] and neuroscience [55] points to the frontopolar cortex as being involved in inhibitory processing, and also in ToM [56]. Frontal damage can result in impaired perspective-taking ability [57] and a lack of cognitive flexibility [58]. Anderson *et al.* [59] reported the cases of two patients with early damage to the anterior prefrontal cortex (encompassing the frontopolar cortex) who, when tested on moral dilemmas exhibited an excessively egocentric perspective. In healthy subjects, we have demonstrated the specific activation of the frontopolar cortex when they are asked to adopt the subjective perspective of another individual (Figure 1), imagining her actions [38] or evaluating her knowledge [39], when contrasted with self-perspective in the same tasks.

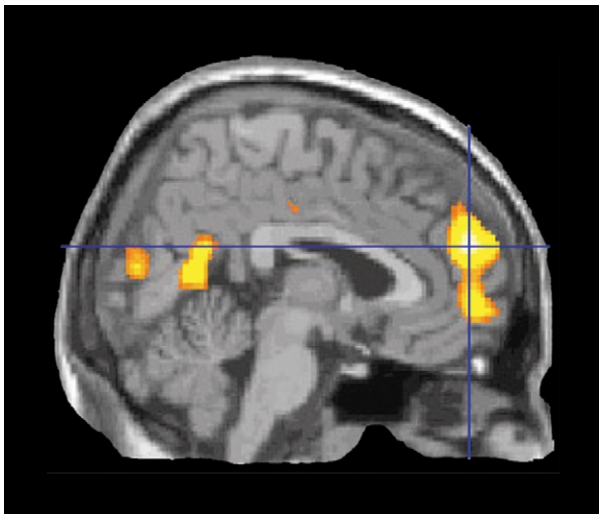


Figure 1. Frontopolar cortex activation in healthy subjects when asked to adopt the subjective perspective of someone else to answer health-related questions. (Adapted from [39].)

Finally, the extent to which individuals view self and others as similar or different is not only highly contextually dependent, but also task specific. When asked to make self/other trait comparisons, the extent to which individuals view the other as similar or dissimilar to the self depends on whether the self is the comparative target or referent. Comparing others to the self highlights differences between self and other, whereas comparing self to the other yields more similar self/other ratings [25].

Evidence from cognitive neuropsychology and neuroscience

Clinical cases support a privileged role of the right hemisphere in representing the self. Damage to the temporoparietal region may cause deficits in various aspects of self-processing, including face recognition [26]. Keenan *et al.* [27] demonstrated that patients undergoing a Wada test (i.e. behavioral testing after the injection of an anesthetic into the right or left internal carotid artery, which temporarily suspends the activity of one

hemisphere) were temporarily desensitized in the recognition of their own faces when the right hemisphere was anesthetized. Patients with right frontoparietal damage often suffer from asomatognosia: the failure to recognize part of one's body. For instance, Daprati *et al.* [28] reported a patient with a right thalamic-temporo-parietal lesion who consistently denied ownership of his contralesional hand when asked to identify the source of its movements. Interestingly, patients with asomatognosia often misidentify the affected limb as belonging to a loved one.

Right hemisphere damage can also be associated with impairments in autobiographical memory and self evaluation. Personal confabulation (akin to the creation of fictitious stories about the self) appears to be associated with damage to the right frontal lobe [29]. Severe deficits in personal autobiographical memory retrieval are also associated with damage to the right ventral prefrontal region [30]. Frontotemporal dementia (FTD) patients with severe hypofunction of the right frontal lobe show marked changes in personality traits and preferences since the onset of FTD, despite the sparing of dominant frontal functions [31].

Recent neuroimaging studies with healthy subjects provide converging evidence for right-hemisphere involvement in self–other processing. Selective activation of the right inferior frontal gyrus was reported when subjects viewed self faces [32]. Research on autobiographical memory and trait evaluations further support a right-hemisphere based network for representing the self. For instance, Fink *et al.* [33] reported activation of the right cingulate and prefrontal regions during presentation of personal autobiographical memories versus impersonal statements.

Thinking and perceiving others also involves right hemisphere resources (see Figure 1). Both neuroimaging studies [34], and patient studies [35] have shown that the right medial prefrontal cortex is involved in various forms of self and other mental state reasoning.

Distinguishing self from other

Both developmental science and social psychology suggest that we view the other like the self. This tendency can be considered a default mode of the human mind as illustrated by the egocentric bias in social psychology [6]. However, for successful social interactions, one also needs to have the capacity to distinguish self from other. Similar neural representations for self and other behavior raises the question of how we distinguish between actions produced by the self and those produced by others.

An influential cognitive-developmental model proposes that individuals represent their own and others' goal-directed actions via a single conceptual system. These intentional relation schemas have the capacity to coordinate first-person and third-person information. However, first person information is qualitatively different from third person information, allowing individuals to differentiate self from other. According to this model, development occurs as a result of the increasing integration of first- and third-person information, and the extent to which imagination (as opposed to perception) is involved in generating these cognitive representations [36].

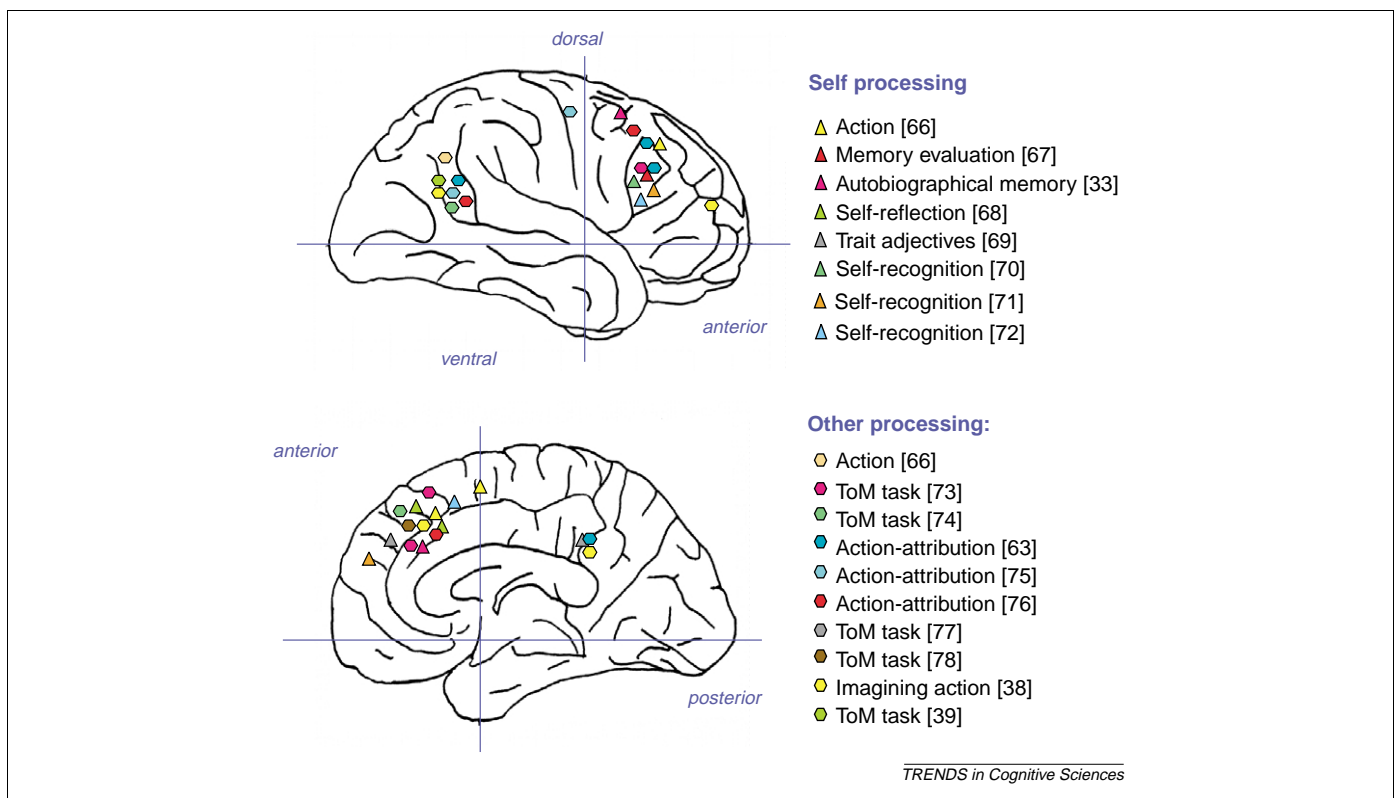


Figure 1. Overlapping clusters of activation in the prefrontal cortex and inferior parietal lobule of the right hemisphere found in various neuroimaging studies dealing with 'self-' and 'other' processing [33,38,39,63,66–78]. Top: lateral surface view of right hemisphere. Bottom: mid-sagittal view.

Others have proposed that we use a forward model (see Figure 2) to predict our actions as well as to predict the actions of others. According to this model, during self-produced actions a sensory prediction of the outcome of the action is produced along with the actual motor command. The results of the comparison (which occurs at a sub-personal level) between the sensory prediction and the sensory consequences of the act can then be utilized to determine the agent of the action.

At the neural level, recent research indicates that the insula and the right inferior parietal cortex may be crucial in distinguishing the self from the other. Activation of the right inferior parietal lobe correlates with the subjective sense of ownership in action execution [37]. Similarly, activation in the right inferior parietal lobe is found in reciprocal imitation (see Box 3). Mentally simulating the actions of another person results in activation in the right inferior parietal cortex [38]. When subjects are asked to

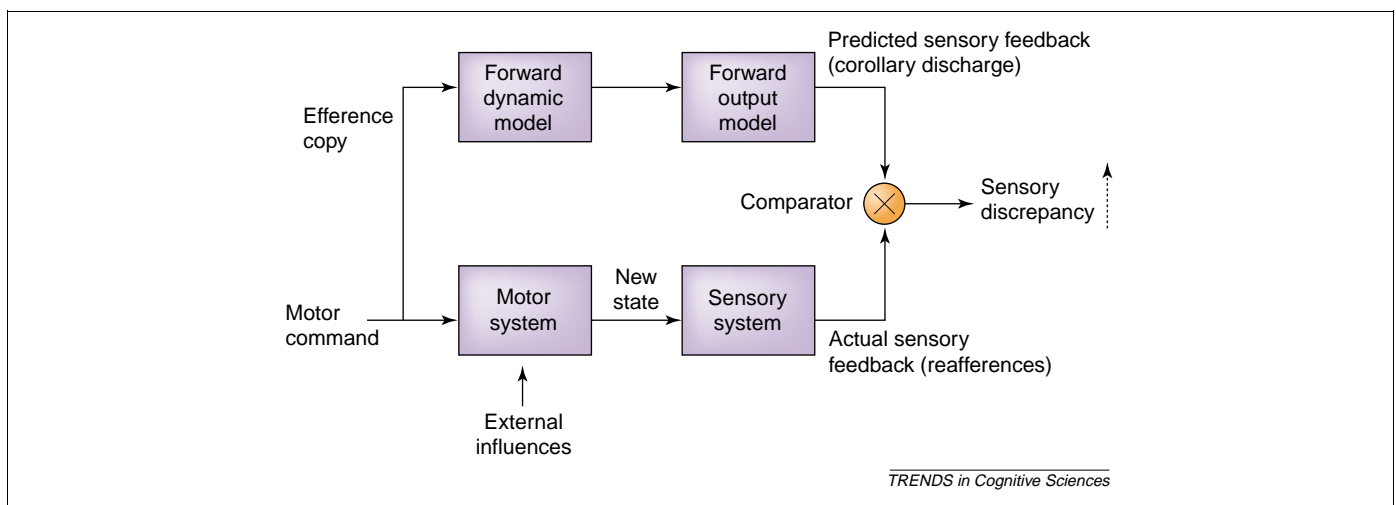


Figure 2. A forward dynamic model predicts the consequences of motor commands and these are compared with the desired state [79,80]. The forward output model makes a prediction of the sensory consequences of motor commands, which is compared with the actual consequences of movement (reafference). Discrepancies resulting from this comparison can be used to cancel reafferent inputs and to distinguish self-produced and externally produced signals. Blakemore and colleagues suggested that such a model can account not only for how we identify our own actions as self-produced, but also how we are aware of being the source of our own thoughts and beliefs [81]. In addition, Blakemore and Decety have discussed how this forward model could be used to predict what another person will do [82]. When we see someone else perform an action the forward model is reversed. We recruit the sensory consequences of the other person's action from our own model and then we use these to 'estimate' what our own intentions would have been for the same action. Subsequently, we attribute these intentions to the other.

Box 3. Reciprocal imitation

The investigation of the neural correlates of reciprocal imitation is extremely important because it provides an ecological paradigm (a situation close to everyday life) to address the issue of shared representations, as well as providing information regarding how the self/other distinction operates within these shared neural representations. Mutual imitation is acknowledged to play a central role in the development of intersubjectivity and shared motivational states [11,60,61]. Meltzoff and Gopnik proposed that mutual imitation games could be an especially meaningful avenue to early communication because both partners can recognize the common acts or 'self-other equivalences' that exist when the body movements of one person match the other [13]. Role-taking during early social interactions between infant and mother are frequent and considered a milestone in the linkage between their subjective experiences. Moreover, there is good evidence that reciprocal imitation plays a constitutive role in the early development of an implicit sense of self as a social agent [62].

Two PET studies explored the extent to which being imitated and imitating the other relies on similar or distinct underlying mechanisms. In one experiment, subjects were scanned while they imitated an experimenter performing constructions with small objects, and while the experimenter imitated them [63]. In both conditions, the subjects'

sense of ownership (the sense that it is I who am experiencing the movement or thought) as well as the visual and somatosensory inputs are similar or coincide. What differs between imitating and being imitated is the agent who initiated the action.

Several key regions were involved in the two conditions of reciprocal imitation compared with the control conditions (in which subjects acted differently from the experimenter), namely in the superior temporal sulcus, the inferior parietal lobule (see Figure 1a), and the medial prefrontal cortex. The left inferior parietal lobule was activated when subjects imitated the other, whereas the right homologous region was chiefly activated when being imitated by the other (Figure 1b). For both imitation conditions, haemodynamic increase was also detected in the posterior part of the superior temporal gyrus, in both hemispheres, a region known to be involved in the visual perception of socially relevant bodily movements. This part of the temporal cortex is an important component in a circuit involved in social cognition, which through direct and indirect connections receives input both from the ventral and the dorsal visual streams, the amygdala, the orbitofrontal cortex and the prefrontal cortices [64]. These results, especially the right inferior parietal activation, were reproduced in a follow up neuroimaging experiment [65]. In this latter study, all visual references to body parts were excluded.

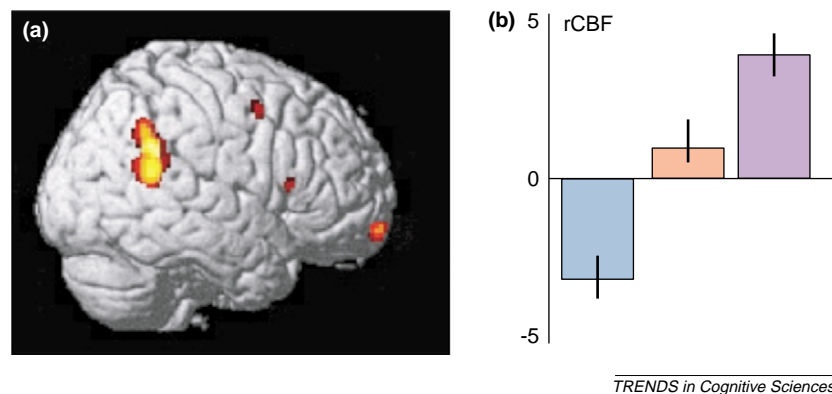


Figure 1. (a) Right inferior parietal lobule activation at the junction with the temporal cortex superimposed on an average MRI. (b) The relative hemodynamic variation (regional cerebral blood flow, rCBF) during self action, when subjects acted at will (blue) when they imitated the actions demonstrated by the experimenter (red) and when they saw their actions being imitated by the experimenter (purple). Note the dramatic increase in right inferior parietal lobe activation in this last condition. (Adapted from [63].)

adopt another person's perspective to evaluate their beliefs, the right IPL is also strongly involved [39]. Recently, it has been shown that direct cortical stimulation of this region in neurological patients induced an out-of-body experience (i.e. the experience of dissociation of self from the body) [40].

Importantly, Ramachandran and Rogers-Ramachandran [41] reported cases of patients with right parietal lesions in whom the denial of hemiplegia extended to the motor deficits of other patients. This suggests that availability of an efficient body schema is necessary not only for recognizing one's own actions, but also for understanding the actions of others.

Co-ordinating and contrasting self/other representations

Self-awareness of our own mental states (intentions, desires, beliefs, emotions) also enables us to read the mental states of others. Indeed, it has been argued that

self-awareness may have evolved for the specific purpose of allowing us to understand our own and others' behavior [42]. This necessitates a co-ordination of self and other mental representations that requires executive functions resources (a collection of processes responsible for higher-level action control such as inhibition, coordination, planning, attentional flexibility).

Developmental research has shown that inhibitory control is a crucial enabling factor for theory of mind (ToM) both in its development and expression [43]. Furthermore, there is a correlation between the development of response inhibition and maturation of the prefrontal cortex in children [44]. We argue that this executive inhibition component is required to suppress the prepotent self-perspective in favor of another perspective and thus allows cognitive flexibility. In support of this claim, a recent fMRI study has reported involvement of the right lateral prefrontal cortex when participants inhibited a prepotent response associated with belief-bias in a reasoning task [45].

Box 4. Questions for future research

- In which specific ways can neuroscience and clinical neuropsychology help tackle different levels of the self (see Box 1). Can cognitive neuroscience help to generate a more parsimonious description of the self? What are the limitations of these methodologies?
- What are the right versus left hemisphere responses to self/other processing in infants?
- What are the key regions within the right hemisphere, and can we elucidate a functional specialization of self/other processing in adults?
- What is the contribution of language and its development in the sense of self?

In various and complementary research fields the frontopolar region has been demonstrated to play a role in inhibitory function. Several studies have reported activation of this region when participants are overtly putting themselves in the shoes of others (see Box 2). In addition, neuropsychological investigations have shown that lesions of the anterior part of the frontal lobe can be associated with the emergence of an imitative behavior syndrome, in which individuals cannot refrain from imitating others actions [46,47].

Conclusion

Consistent with research and theoretical claims from developmental and social psychology, representations of aspects of the self both overlap with representations of other and are distinct from such representations. Common and distinct cognitive representations of self and other extend along many dimensions of self and other processing: from action recognition to mental state understanding. Indeed, such shared representations, including beliefs, unify the cognitive and motivational processes that constitute the contents of culture. These findings shed light on the nature of the self as both special and social, unique and shared.

We argue that the right hemisphere plays a predominant role in the way that the self is connected to the other. Interestingly, measurements of cerebral metabolism in children (aged between 18 days to 12 years) indicate a right hemispheric predominance, mainly due to neural activity in the posterior associative areas, suggesting that the right hemisphere's functions develop earlier than the left hemisphere [48]. This early activity of the right hemisphere may underlie infants' capacity to view the other as in some way analogous to the self [9,11,49], and as such pave the way for a host of right-hemisphere based intersubjective processes that rely on self/other identification [50]. Within this right-hemisphere based self/other network, we argue that the inferior parietal cortex plays a pivotal role in distinguishing self from other, and that prefrontal cortex is integral to coordinating and contrasting cognitive representations of self and other (see also Box 4 for future research questions).

Finally, it is interesting to note that our ability to represent our own thoughts and represent another's thoughts are intimately tied together and may have similar origins within the brain. The fact that there seems to be a partial overlap between self-processing and

processing of others fits well with the old adage of 'putting ourselves in another person's shoes'.

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