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What Is Self-Specific? Theoretical Investigation and Critical Review of Neuroimaging Results

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The authors propose a paradigm shift in the investigation of the self. Synthesizing neuroimaging results from studies investigating the self, the authors first demonstrate that self-relatedness evaluation involves a wide cerebral network, labeled E-network, comprising the medial prefrontal cortex, precuneus, temporoparietal junction, and temporal poles. They further show that this E-network is also recruited during resting state, others' mind reading, memory recall, and reasoning. According to these data, (a) the profile of activation of the E-network demonstrates no preference for the self, and (b) the authors suggest that activity in this network can be explained by the involvement of cognitive processes common to all the tasks recruiting it: inferential processing and memory recall. On this basis, they conclude that standard ways to tackle the self by considering self-evaluation do not target the self in its specificity. Instead, they argue that self-specificity characterizes the subjective perspective, which is not intrinsically self-evaluative but rather relates any represented object to the representing subject. They further propose that such self-specific subject–object relation is anchored to the sensorimotor integration of efference with reafference (i.e., the motor command of the subject's action and its sensory consequence in the external world).

Keywords: first-person perspective, sensorimotor integration, efference, shared representations, reasoning, social cognition

The concept of self is widely debated in various disciplines, such as philosophy, psychology, psychiatry, sociology, anthropology and cognitive sciences. Across these disciplines, conceptions of self are so far from reaching consensual definition that any investigation always runs the risk of ignoring dimensions of the self that turn out to be central in other frameworks. Consequently,

> Defining the concept of self and understanding the cortical underpinnings of such a concept is a challenge for scientists. Although the psychological and neuroscientific literatures include countless articles, chapters and books that touch upon such ideas as "self-awareness," "self-consciousness," and "self-efficacy," there is no coherent body of knowledge that comprises a cognitive neuroscience of self. Indeed, the relevant evidence comes from sources that have only minimal cross-talk with one another. (Keenan, Wheeler, Gallup, & Pascual-Leone, 2000, p. 338)

In this article, we intend to maximize the integration between the theoretical investigation of what is self-specific and the empirical investigation of which physiological mechanisms may underlie such self-specificity. As becomes clear as we proceed, this interdisciplinary integration is meant to be bidirectional: not only may theoretical analyses ground reappraisal of empirical data but, conversely, empirical evidence may allow conceptual progress.

Context of Our Investigation: Nonreductionist Naturalism

The present investigation follows a naturalistic perspective (S. Gallagher, 2005; Thompson, 2007) that implies that the self can be investigated (a) with first-person methodologies (introspective and phenomenological investigations) and (b) with third-person methodologies (psychological and neuroscientific investigations). Since we take these methodologies to be complementary, our approach is naturalistic but not reductionist. Moreover, the nonreductionist naturalistic approach we advocate here does not lead to any ontological dualism since we assume this approach at the epistemological level.

Note that since it is nonreductionist, our approach is not targeted by classical skeptic arguments against reductionism, according to which it would be impossible to reduce mental subjective phenomena to physical objective processes (Jackson, 1982; Nagel, 1974). Moreover, the present work will not address the "hard problem" (Chalmers, 1995) of bridging the "explanatory gap" (Levine, 1983, p. 354) between an investigation of physical processes correlated with consciousness on the one hand and the understanding of why such physical processes elicit consciousness on the other. Our investigation does not intend to reevaluate the conditions for the possibility of naturalization. Acknowledging that this important

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issue remains to be solved, we nonetheless assume that a naturalistic perspective can be relevantly implemented and tested (S. Gallagher & Sørensen, 2006; Zahavi, in press). Consequently, we exclusively consider the notion of self from a perspective that is naturalistic from the outset. This framework allows us to investigate positions that are dominant in contemporary research by considering in detail a focused question that has remained unquestioned from within the naturalistic perspective itself: Can a naturalistic notion of self be investigated in its specificity? We address this issue according to the following plan.

State of the Art: The Self in Cognitive Neurosciences

Despite ongoing controversies about the definition of self and despite philosophical arguments against the very possibility of reducing the self to neurophysiological processes, more and more research in cognitive sciences studies the self empirically, using neuroimaging techniques. This approach thus deserves close scrutiny. Recently, a review of such investigations concluded that "the absence of a precise definition [of self] is not necessarily an obstacle to progress" (Gillihan & Farah, 2005, p. 77), thereby potentially implying that neuroscientific results could provide some post hoc determination of what the self is. Strictly speaking, such a position would be methodologically flawed since it would allow running experiments without any precise characterization of their object of investigation. Nonetheless, this position might be motivated by a pragmatic stance and raises the following question: Do the numerous results obtained in this domain provide any reliable post hoc characterization of the self? We address this question by considering the results of the mainstream approach in cognitive neuroscience.[1]

The Cerebral Correlates of the Self as Classically Investigated in Cognitive Neuroscience Show No Preference for the Self

The Cerebral Correlates of the Self as Classically Investigated in Cognitive Neuroscience: The E-Network

Cognitive neuroscience mostly investigates the self by contrasting self-related with non-self-related stimuli or tasks. With such a paradigm, studies using positron emission tomography (PET) and functional magnetic resonance imaging (fMRI) techniques have aimed at revealing the cerebral correlates of, for example, recognizing one's own face (Kircher et al., 2000, 2001; Platek, Thomson, & Gallup, 2004), detecting one's own first name (Perrin et al., 2005; Sugiura et al., 2006), attributing an action to oneself (Farrer et al., 2003), recalling personally relevant information (Maguire & Mummery, 1999; Vinogradov et al., 2006), or assessing one's own personality, physical appearance, attitudes, or feelings (Craik, Moroz, & Moscovitch, 1999; D'Argembeau et al., 2007; Fossati et al., 2003; Gusnard, Akbudak, Shulman, & Raichle, 2001; Gutchess, Kensinger, & Schacter, 2007; Johnson et al., 2002; Kelley et al., 2002; Kircher et al., 2000, 2002; Kjaer, Nowak, & Lou, 2002; Lou et al., 2004; Ochsner et al., 2005; Schmitz, Kawahara-Baccus, & Johnson, 2004). These various studies are considered to tackle a common and unique object of investigation: the self. However, as this list illustrates, theses studies in fact

[1] Cognitive neuroscience of the self aims at localizing cerebral areas or networks whose activity varies according to the self-relatedness dimension. Note that the localist assumption of such an approach can be criticized in itself, to favor a functionalist approach: What is done, that is, which cognitive processes are executed, would be more informative, computationally speaking, than where it is done in the brain. However, it is fair to say that in contemporary research, most localist conclusions are exploited in functional terms and as emphasized by Golland et al. (2007, p. 766): "Besides providing important information regarding the location of different functional areas, the search for cortical subdivisions has been motivated by the notion that understanding cortical neuroanatomical organization provides important insights into the functional specialization of the brain."

involve a large variety of cognitive tasks and stimuli. Therefore, it comes as no surprise that brain regions reported to be activated when subjects are involved in such self-related tasks are as many as the following list: medial prefrontal cortex, precuneus/posterior cingulate gyrus, temporal pole, temporoparietal junction, insula, postcentral gyrus, superior parietal cortex, precentral gyrus, lateral prefrontal cortex, hippocampus, parahippocampal gyrus, fusiform gyrus, and occipital cortex (see Table 1).

Considering such scattering, Gillihan and Farah (2005) concluded that no decisive results could be found in the literature that would allow the determination of neurophysiological correlates of the self:

> Is there evidence that the self is a unitary system, encompassing the different aspects of self that researchers have investigated (e.g., self-face recognition, self-trait knowledge)? . . . neither the imaging nor the patient data implicate common brain areas across different aspects of the self. This is not surprising because there is generally little clustering even within specific aspects of the self. In the absence of evidence that each of the individual aspects of the self is special, the question of the organization of specialized self processing is, for now at least, moot. (Gillihan & Farah, 2005, p. 94)

This unsatisfactory conclusion leaves open many unresolved black holes and calls for further investigations and/or conclusions.

In an attempt to provide more constructive conclusions, we considered data with another angle of clearance. Gillihan and Farah (2005) inspected a set of neuroimaging studies one by one and demonstrated theoretical or methodological limits for each of them considered in isolation from each other. Here, we instead explore whether the integration of many results could highlight (otherwise hidden) regularities among such studies, beyond their respective particularities and limits, thereby providing the ground for an encompassing interpretation. Among all the brain regions that have been reported in many studies investigating the self, one can see in Table 1 that at least four regions of the long list mentioned above are in fact repeatedly activated in self versus nonself contrasts, that is, medial prefrontal cortex, precuneus/posterior cingulate gyrus, temporoparietal junction, and temporal pole (this set of regions is called the *E-network* throughout the article to simplify the reading; the reasons for using this name are explained below). Two of these regions, the medial prefrontal cortex and the precuneus/posterior cingulate gyrus, were frequently pointed out in neuroimaging studies of the self, but the temporoparietal junction and the temporal pole are also recurrently activated in self-related tasks, even though they are less often considered as such (see Table 1 and Figure 1, white points; coordinates of these brain activations are reported in Table 2). In fact, most synthetic articles focused only on some of these scattered self-reactive brain regions (e.g., Northoff & Bermpohl, 2004, and Northoff et al., 2006, focused on cortical midline structures, and Gusnard, 2005, concentrated her article on prefrontal and parietal brain areas).

By contrast, our meta-analysis underlines the consistent implication of the regions of the E-network across self studies and leads us to conclude that they are the main brain regions involved in the cognitive process(es) common to all the tasks used in these studies. However, are these results enough to say that this cerebral network (these cognitive processes) is (are) specifically devoted to the self?

The Cerebral Correlates of Others' Mind Reading

According to our review of the literature, the regions of the E-network are repeatedly reported in self versus other contrasts. This is not enough to consider this network a self-network, however, since it is not self-dedicated, that is, it does not demonstrate any self-preference. Indeed, a close look at the literature reveals a striking resemblance between the cerebral correlates of the self and the cerebral correlates of others' mind reading at the brain regional level. The brain regions commonly reported to be active during others' mind representation comprise the medial prefrontal cortex, the precuneus/posterior cingulate gyrus, the temporoparietal junction, and the temporal poles, that is, the E-network (e.g., Brunet, Sarfati, Hardy-Bayle, & Decety, 2000; Calarge, Andreasen, & O'Leary, 2003; Castelli, Happe, Frith, & Frith, 2000; Fletcher et al., 1995; H. L. Gallagher et al., 2000; Goel, Grafman, Sadato, & Hallett, 1995; Mitchell, Banaji, & Macrae, 2005b; Mitchell, Macrae, & Banaji, 2006; see Table 1 and Figure 1, blue points; coordinates of these brain activations are reported in Table 3). Importantly, studies that directly investigated brain activations common to the representation of self and others' mind also reported regions of this network (Fossati et al., 2003; Lawrence et al., 2006; Ochsner et al., 2004, 2005; Sugiura et al., 2006; see Table 1). As a consequence, it is not surprising that some authors could not find any significant difference in the cerebral correlates of self and others' mind representation (Craik et al., 1999; Ochsner et al., 2005; see Table 1).

Overlapping brain activity for self- and others' representations has been demonstrated and stressed by several authors especially in sensorimotor domains (e.g., perception: Keysers et al., 2004; action: Grèzes & Decety, 2001; emotion: Ruby & Decety, 2004; Wicker, Keysers, et al., 2003). However, this overlap was less often pointed out in conceptual tasks involving mind reading. Until now, mainly medial prefrontal cortex and the precuneus were reported to participate both in self and others' mind representation (Amodio & Frith, 2006; Beer & Ochsner, 2006; Calder et al., 2002; Uddin, Iacoboni, Lange, & Keenan, 2007; Wicker, Ruby, Royet, & Fonlupt, 2003). Our review of neuroimaging literature demonstrates that self and others' mind representation also share cerebral activations in the temporoparietal junction and in the temporal pole, in both hemispheres (see Table 1 and Figure 1).

This result is quite a highlight. Indeed, it was often argued that the temporoparietal junction participates in self–others distinction (e.g., Blakemore & Frith, 2003; Blanke & Arzy, 2005; Chaminade & Decety, 2002; Decety, Chaminade, Grezes, & Meltzoff, 2002; Iacoboni et al., 2001; Ruby & Decety, 2001, 2003, 2004; Schilbach et al., 2006; Sirigu, Daprati, Pradat-Diehl, Franck, & Jeannerod, 1999; Vogeley et al., 2001, 2004), that is, to a *who* system enabling the disambiguation of representations shared both by self and by others (Farrer et al., 2003; Farrer & Frith, 2002; Georgieff & Jeannerod, 1998). Like Calder et al.'s (2002), our meta-analysis demonstrates, with a wider sample of data, that this region in fact participates in a cognitive process shared by self and others. In other words, we demonstrate that the main brain regions recruited for others' mind representation are also and precisely the main brain regions reported in self studies and that this overlap extends beyond the brain areas usually pointed out, that is, it comprises the

(*text continues on page 258*)

Table 1
Results of Most Major Studies That Investigated the Self With Neuroimaging Techniques

Study	Contrast reported	P.M.	P.	A.T.	T.P.J.	I.	Post	S.P.	Pre	L.P.	H.	PH.	F.G.	O.
							SELF							
Kircher et al. (2000)	**Self–Unknown face recognition**	M	M	R	L	R				L	R		L	
	Fitting judgment of personality trait (Self descriptive–Nonself descriptive)		M			L	L	L					L	
	Common to Self face recognition and Self personality trait assessment		M			R							L	R
Platek et al. (2004)	**Self–Famous face recognition**									R				
Perrin et al. (2005)	**Brain area varying with the amplitude of P300 to one's own first name**	M	M		R									
Sugiura et al. (2006)	**Familiar (names of relatives)–Unfamiliar name recognition**		M	LR	LR									
	Familiar (names of relatives)–Famous name recognition		M		LR									
Vinogradov et al. (2006)	**Memory for words (Self-generated–Presented by the experimenter)**	M												
Farrer et al. (2003)	**Self–Other action attribution**					R								
Gusnard et al. (2001)	**Self feeling–In/out judgment [IAPS pictures]**	M				LR								
	Self feeling judgment seeing IAPS pictures–Fixation cross	M												
Kjaer et al. (2002)	**Self–Other reflection about physical appearance**	M								L				
	Self–Other reflection about personality	M	M		LR									
Kircher et al. (2002)	**Overlap between Incidental and Intentional Self personality trait processing**							L					L	
Johnson et al. (2002)	**Reflection on Self trait–General knowledge condition**	M	M	LR						LR				
Lou et al. (2004)	**Self–Queen fitting judgment of personality trait**				R									
	Self fitting judgment of personality trait–Lexical task	M	M	L	LR									LR
Fossati et al. (2003)	**Self–Other fitting judgment of emotional personality traits**	M	M											
Kelley et al. (2002)	**Self–Other fitting judgment of personality traits**	M	M											
Schmitz et al. (2004)	**Self–Other fitting judgment of personality traits**	M										R		
Ruby et al. (2007)	**Correlation between self social behavior awareness and brain metabolism at rest**			L										
D'Argembeau et al. (2007)	**Self–Other personality assessment irrespective of the perspective taken**	M	M											
Gutchess et al. (2007)	**(Self–Other fitting judgment of personality traits) common to young and elderly**	M			L									
Craik et al. (1999)	**Self–Other fitting judgment of personality traits**						No significant increase							
Ochsner et al. (2005)	**Self–Close Other fitting judgment of personality traits**						No significant increase							
	1PP on Self–1PP on Friend personality [personality traits]	M												
	1PP on Self–1PP on Other personality [personality traits]	M			R									
	1PP–3PP (friend) on Self personality assessment [written words]		M											
	1PP–3PP (other) on Self personality assessment [written words]		M			L		L						
Seger et al. (2004)	*1PP–3PP in food preference assessment [written names]*						LR							
Farrer & Frith (2002)	*I (1PP)–He (3PP) caused the movement of the dot [moving dot during action]*					LR								

(*table continues*)

Table 1 (*continued*)

Study	Contrast reported	P.M.	P.	A.T.	T.P.J.	I.	Post	S.P.	Pre	L.P.	H.	PH.	F.G.	O.
Vogeley et al. (2001)	*Main effect of 1PP [written stories]*	M	M		R				R	R				
	1PP–3PP [written stories]		M		LR		?		R					
	Interaction 1PP and 3PP = (1PP when also 3PP) − (1PP without 3PP)									R				
Vogeley et al. (2004)	*1PP–3PP in visual field assessment [pictures]*	M	M	L	L	R	R							
Ruby & Decety (2001)	*1PP–3PP in action imagination [pictures of objects and spoken sentences]*				L	L	L							LR
Ruby & Decety (2003)	*1PP–3PP in conceptual knowledge assessment [written sentences]*		M		R		LR							R
Ruby & Decety (2004)	*1PP–3PP in socioemotional reaction assessment [written sentences]*						R							
Ochsner et al. (2004)	*1PP–3PP in emotion assessment [IAPS pictures]*	M		M										
	OTHER													
Gusnard et al. (2001)	In/out judgment seeing IAPS pictures–Fixation cross	M												
Farrer et al. (2003)	Other–Self action attribution	M			LR					R				
Fletcher et al. (1995)	TOM–Physical task [written stories]	M	M		R									
Goel et al. (1995)	TOM–Visual task [pictures of objects]	M	M	L	L									
	TOM–Memory retrieval	M			L									
	TOM–Simple inference	M		L	L									
Brunet et al. (2000)	TOM–Physical causality with character [drawings]	M		LR	LR				L	LR				L
H. L. Gallagher et al. (2000)	TOM–Non-TOM stories	M		LR	LR									
	TOM–Non-TOM drawings	M	M		R					R			R	
	TOM–Non-TOM stories and drawings	M	M	L	LR					R				
Castelli et al. (2000)	TOM movement–Random movement [simple shapes]	M		LR	LR									LR
Calarge et al. (2003)	Create a TOM story–Read a non-TOM story	M	M	L	L					L				
Lou et al. (2004)	Queen fitting judgment of personality trait–Lexical task	M	M	LR	L									LR
	Queen–Self fitting judgment of personality trait			L										
Sugiura et al. (2006)	Famous–Unfamiliar name recognition			LR	L									
Gutchess et al. (2007)	(Other–Self fitting judgment of personality traits) common to young and elderly			L										R
Craik et al. (1999)	Other–Self fitting judgment of personality traits						No significant increase							
Mitchell et al. (2005b)	Emotional mental state attribution–Physical judgment [pictures of faces]	M	M	R	LR	L	LR			L				LR
Mitchell et al. (2006)	3PP when the target person is (Self-similar–Self-dissimilar) [sentences]	M								R				LR
	3PP when the target person is (Self-dissimilar–Self-similar) [sentences]	M												
Ochsner et al. (2005)	1PP on Friend–1PP on Self personality [personality traits]	M	M			R		LR	LR	LR				
	1PP on Other–1PP on Self personality [personality traits]			R								L		
	3PP (Friend)–1PP on Self personality assessment [written words]	M	M			R						L		L
	3PP (Other)–1PP on Self personality assessment [written words]			LR										
Seger et al. (2004)	3PP–1PP in food preference assessment [written names]	M	M							L				
Farrer & Frith (2002)	He (3PP)–I (1PP) caused the movement of the dot [moving dot during action]		M		LR					L				

(*table continues*)

Table 1 (*continued*)

Study	Contrast reported	P.M.	P.	A.T.	T.P.J.	I.	Post	S.P.	Pre	L.P.	H.	PH.	F.G.	O.
Vogeley et al. (2001)	Main effect of 3PP [written stories]	M		L					L	L				
Vogeley et al. (2004)	3PP–1PP in visual field assessment [pictures]	M	M		L					LR				L
Ruby & Decety (2001)	3PP–1PP in action imagination [pictures of objects and spoken sentences]	M	M		R									R
Ruby & Decety (2003)	3PP–1PP in conceptual knowledge assessment [written sentences]	M		LR	LR					L				
Ruby & Decety (2004)	3PP–1PP in socioemotional reaction assessment [written sentences]	M	M	L	LR									
D'Argembeau et al. (2007)	3PP–1PP in personality assessment irrespective of the target person	M	M	L	L					L				L
Ochsner et al. (2004)	3PP–1PP in emotion assessment [IAPS pictures]									L				LR
COMMON TO SELF AND OTHER														
Fossati et al. (2003)	(Self condition–Lexical task) and (Other condition–Lexical task)	M	M											
Sugiura et al. (2006)	(Self condition–Unfamiliar condition) and (Famous condition–Unfamiliar condition)			LR	L									
Lawrence et al. (2006)	Brain activation correlated with self overlap in the trait task	M	M		L									
Wicker, Ruby, et al. (2003)	Meta-analysis showing overlap of activations issued from self and TOM studies	M												
Ochsner et al. (2005)	(Self condition–Lexical task) and (Other condition–Lexical task)	M												
Ochsner et al. (2004)	(Self–in/out judgment) and (Other–in/out judgment) [IAPS pictures]	M	M		LR					L				
RESTING STATE														
Gusnard & Raichle (2001)	Active regions during the Resting state	M	M	LR	LR									
Wicker, Ruby, et al. (2003)	Internally vs. Externally guided task	M												
D'argembeau et al. (2005)	Brain activation common to (Self–Other) and (Resting state–Society)	M												
INDUCTIVE AND DEDUCTIVE REASONING														
Goel et al. (1995)	Simple inference–Visual task		M											
	TOM–Memory retrieval	M			L									
	TOM–Simple inference	M		L	L									
Goel et al. (1997)	Deduction–Sentence comprehension									L				L
	Induction–Sentence comprehension	M		L						L				L
	Induction–Deduction	M												
Goel & Dolan (2000)	Difficult inductive reasoning									R				
Christoff et al. (2001)	(Two-relational–One-relational) reasoning	M							L	LR				
Fangmeier et al. (2006)	Integration phase of Deductive reasoning	M												
Geake & Hansen (2005)	Fluid analogies	M	M		LR					LR				LR
Mitchell et al. (2005a)	(Mental state–Body part) attribution	M	M		R									L
Zysset et al. (2002)	Evaluative judgment–Semantic memory tasks	M	M		L					L				
	Evaluative judgment–Episodic memory tasks	M								L				
Fonlupt (2003)	(Judgment–Neglect) of causality [movies of balls rolling]	M												

(*table continues*)

Table 1 (*continued*)

Study	Contrast reported	P.M.	P.	A.T.	T.P.J.	I.	Post	S.P.	Pre	L.P.	H.	PH.	F.G.	O.
	MEMORY RECALL													
Cavanna & Trimble (2006)	Episodic memory retrieval (review)		M											
Wagner et al. (2005)	Episodic memory retrieval (review)		M		LR									
Lundstrom et al. (2005)	Correct source memory retrieval–New item		M	R	L					L				L
	Incorrect source memory retrieval–New item	M								L				L
Graham et al. (2003)	Autobiographical–Semantic recall	M	M	LR	LR									
	Semantic–Autobiographical recall			L	L					LR				
Dolan et al. (2000)	Emotional–Neutral memory conditions [IAPS pictures]			LR										
	Picture Recognition related activation [IAPS pictures]	M			R									
Maguire & Mummery (1999)	All memory task(+/− personally relevant and +/− precise in time)–Lexical task	M	M	L	LR						L	L		
	Memory related activations (no difference according to the different tasks)		M	L								L		
	Personally relevant memories irrespective of temporal context				LR									
	Personally relevant time-specific memories	M		L							L			
Fink et al. (1996)	Autobiographical episodic memory retrieval–Rest	M	M	LR										
	Autobiographical–Nonautobiographical episodic memory retrieval		M	R	R	R					R	R		
Piefke et al. (2003)	Autobiographical memory–Baseline	M	M	LR	L			L		L	L	L	LR	LR
Goel et al. (1995)	Memory retrieval–Visual task		M											
Zysset et al. (2002)	Episodic–Semantic memory tasks	M	M											

Note. To guide interpretation of the results of the review, the table also reports non-self-related conditions of activation of the brain areas in which main self-related activations were reported. Note that for this review, we chose to use large brain regions as units. This choice was guided by a failure to find in the literature any unanimous subdivisions of the main regions of interest (medial prefrontal, precuneus, temporoparietal junction, and temporal pole) according to a pertinent functional criterion (see Northoff et al., 2006, for the medial prefrontal cortex; this review revealed that activations for self vs. nonself contrast were found all along the medial prefrontal and parietal cortex). Results of neuroimaging studies (positron emission tomography and functional magnetic resonance imaging) that investigated cerebral correlates of self and other processing, resting state, reasoning, and memory recall are presented in the different sections of the table. References to publications are specified in the first column. The second column indicates the contrast reported: Between square brackets are the types of stimuli used in the study. Also in the second column, we stress two types of approach in experiments that investigated the self: In bold typeface are mentioned the reported contrasts of studies that manipulated stimuli (my face/your face, my name/your name, my personality/your personality) with a constant type of processing (recognition, reflection, assessment). In italic typeface are mentioned the reported contrasts of studies that manipulated process (first- and third-person perspectives) with constant stimuli (pictures of object, written sentences describing social situations, IAPS pictures). TOM = theory of mind; IAPS = International Affective Picture System; 1PP = first-person perspective; 3 PP = third-person perspective; Self overlap = the percentage of self traits that were attributed to the other in Lawrence et al. (2006); ? = a cerebral coordinate close to postcentral gyrus in Vogeley et al. (2001) but out of the brain limits; P.M. = medial frontal cortex from X = 0 to the superior frontal sulcus (BA 6, 8, 9, 10, 11, 24, 32); P. = precuneus/posterior cingulate cortex (BA 23, 31, 7); A.T. = anterior temporal cortex (BA 38 and anterior part of BA 20, 21, and 22); T.P.J. = temporoparieto-occipital junction (BA 39 and posterior part of BA 40, 37, and 22); I. = insula; Post = postcentral gyrus; S.P. = superior parietal cortex; Pre = precentral gyrus; L.P. = lateral prefrontal cortex; H. = hippocampus; PH. = parahippocampal gyrus; F.G. = fusiform gyrus; O. = occipital cortex; M = activation located in the medial regions; L = activation located in the left hemisphere; R = activation located in the right hemisphere.

medial prefrontal cortex, the precuneus/posterior cingulate, the temporoparietal junction, and the temporal pole.

Interpretation of the Overlap Between the Cerebral Correlates of Self and Others' Mind Representations

Even though one cannot necessarily expect a neuronal system that would be activated for the self only, the authors of the aforementioned self studies certainly hypothesized that a given cerebral substrate should be systematically more activated for the self than for nonself. Our review demonstrates that the cerebral network they identified does not exhibit such a functional profile. Rather, regions of the E-network are sometimes more activated for the self than for others and sometimes more activated for others than for the self. A comprehensive explanation of the conditions of activation of this network is thus needed to progress in our understanding of the self as it is approached in cognitive neuroscience. Below, we propose a candidate for such an explanation.

A Nonspecific Cognitive Ability: Inferential Processing and Memory Recall

We identified that the E-network is activated for the self and also for others' mind reading (see Table 1). This suggests that these various tasks require general cognitive process(es) that is

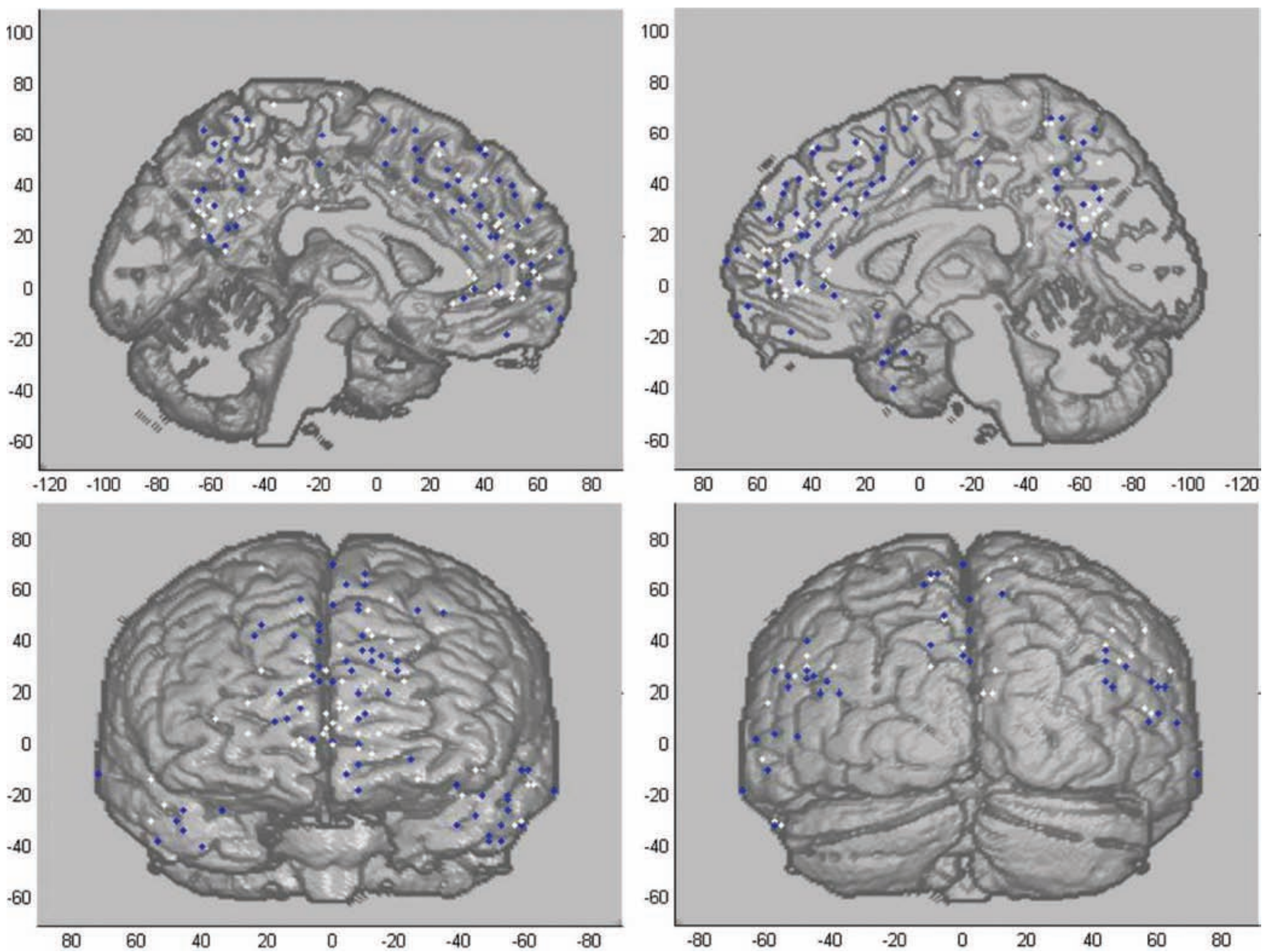

Figure 1. Figure showing the peaks of activation reported in neuroimaging studies (positron emission tomography and functional magnetic resonance imaging) for self versus other (in white) and other versus self (in blue) contrasts in the four brain regions repeatedly reported across studies on the self and that we label the E-network (medial prefrontal cortex, precuneus/posterior cingulate, temporal poles, and temporoparietal junction). Brain activations (listed in Tables 2 and 3) are reported on the Montréal Neurological Institute (MNI) brain template available in SPM99 software (http://www.fil.ion.ucl.ac.uk/spm/; given the limited spatial incertitude due to the space of reference, no coordinate transformation were applied from Talairach and Tournoux coordinates to MNI coordinates, to minimize data manipulation and source of errors). Peaks of activation are shown with a depth tolerance of 20 mm on views of the medial part of the brain (top panels) and with a depth tolerance of 30 mm on the front and the back views (bottom panels).

(are) neither domain specific (i.e., the E-network is involved for tasks in the sensory, motor, or mental domains) nor subject specific (i.e., the E-network is involved for tasks targeting the self and tasks targeting others' mind representation). Which cognitive process(es) may be then subserved by this network?

The cognitive processes that would be the smallest common denominator to all the tasks recruiting the E-network need to be identified to explain the activity in this network. We propose that such cognitive processes may be inferential processing using information recalled from memory (see Figures 2c–2d). We label the combination of these two cognitive processes *evaluation,* hence the label *E-network* (E for evaluation).

The term *evaluative* refers to a set of mental operations, such as deduction, induction, and recall of memories, that allow the subject to draw conclusions on the basis of a series of premises and rules. The premises can be perceived or recalled from memory, and the conclusion is drawn applying rules either known or hypothesized by induction.

Induction applies when the question is ambiguous and cannot be disambiguated only on the basis of the information directly provided by the stimulus. Reaching a conclusion (i.e., disambiguating the question, given the stimulus presented) requires in this case that a rule be hypothesized on the basis of the perceptual context and representations recalled from memory. This

(*text continues on page 264*)

Table 2
Coordinates of Brain Activations Reported in Table 1 and Shown in White in Figure 1

	Self versus other/control contrasts				
Study	Space of reference	*x*	*y*	*z*	Brain region
D'Argembeau et al. (2007)	m	−10	46	22	Medial frontal
		10	44	24	Medial frontal
		−8	50	−2	Medial frontal
		12	44	0	Medial frontal
		0	35	0	Medial frontal
		−4	−52	44	Precuneus/PC
Ruby et al. (2007)	m	40	12	−20	Anterior temporal
		−58	−10	−30	Anterior temporal
		56	18	−14	Anterior temporal
Gutchess et al. (2007)	m	−8	60	4	Medial frontal
		−8	46	−2	Medial frontal
		−6	28	−6	Medial frontal
		−22	50	24	Medial frontal
		−70	−40	22	TPJ
		−60	−44	16	TPJ
		−48	−44	8	TPJ
Kircher et al. (2000)	t	3	36	4	Medial frontal
		6	42	−2	Medial frontal
		0	6	37	Medial frontal
		−26	31	37	Medial frontal
		−23	−67	9	Precuneus/PC
		−12	−22	31	Precuneus/PC
		6	−64	20	Precuneus/PC
		9	−61	26	Precuneus/PC
		−3	−47	31	Precuneus/PC
		−6	−44	37	Precuneus/PC
		0	−67	37	Precuneus/PC
		9	−64	20	Precuneus/PC
		49	−3	−7	Anterior temporal
		−49	−42	31	TPJ
Perrin et al. (2005)	t	8	64	12	Medial frontal
		−6	−66	48	Precuneus/PC
		64	−58	28	TPJ
Sugiura et al. (2006)	m	−6	−68	24	Precuneus/PC
		8	−60	26	Precuneus/PC
		−10	−66	30	Precuneus/PC
		10	−64	28	Precuneus/PC
		−56	−4	−32	Anterior temporal
		56	2	−30	Anterior temporal
		−56	−50	30	TPJ
		−40	−80	30	TPJ
		−48	−70	34	TPJ
		48	−72	32	TPJ
Vinogradov et al. (2006)	t	−4	56	14	Medial frontal
		2	40	28	Medial frontal
		−2	58	14	Medial frontal
		−4	32	20	Medial frontal
Gusnard et al. (2001)	t	−9	39	42	Medial frontal
		−3	53	24	Medial frontal
		−11	23	52	Medial frontal
		−11	30	44	Medial frontal
		7	45	25	Medial frontal
		−5	3	48	Medial frontal
Kjaer et al. (2002)	t	2	42	12	Medial frontal
		−22	22	−16	Medial frontal
		14	22	34	Medial frontal
		−14	60	4	Medial frontal
		22	28	28	Medial frontal

(*table continues*)

Table 2 (*continued*)

Study	Space of reference	Self versus other/control contrasts			
		x	*y*	*z*	Brain region
		−26	46	−14	Medial frontal
		0	−14	76	Medial frontal
		0	−56	56	Precuneus/PC
		56	−36	44	TPJ
Johnson et al. (2002)	m	0	54	8	Medial frontal
		−2	−62	32	Precuneus/PC
		52	−6	−24	Anterior temporal
		−62	−14	−16	Anterior temporal
Lou et al. (2004)	t	−8	40	54	Medial frontal
		4	−50	30	Precuneus/PC
		44	−58	38	TPJ
		−48	−66	30	TPJ
		52	−70	34	TPJ
		−44	30	−10	Anterior temporal
Fossati et al. (2003)	t	10	49	16	Medial frontal
		−16	40	27	Medial frontal
		−14	−27	37	Precuneus/PC
Kelley et al. (2002)	t	10	52	2	Medial frontal
		12	−48	50	Precuneus/PC
Schmitz et al. (2004)	t	26	52	16	Medial frontal
		−28	46	16	Medial frontal
Ochsner et al. (2005)	m	26	42	4	Medial frontal
		36	42	10	Medial frontal
		−18	22	56	Medial frontal
		−12	40	42	Medial frontal
		8	32	32	Medial frontal
		16	−56	14	Precuneus/PC
		18	−22	50	Precuneus/PC
		16	−34	50	Precuneus/PC
		46	−54	44	TPJ
Vogeley et al. (2001)	t	6	54	−4	Medial frontal
		22	2	68	Medial frontal
		−12	50	−4	Medial frontal
		−10	−48	64	Precuneus/PC
		8	−46	64	Precuneus/PC
		16	−38	72	Precuneus/PC
		−10	−46	64	Precuneus/PC
		58	−56	12	TPJ
		56	−58	14	TPJ
		−46	−44	22	TPJ
Vogeley et al. (2004)	t	−2	58	6	Medial frontal
		2	34	6	Medial frontal
		−18	36	40	Medial frontal
		0	−22	40	Precuneus/PC
		−6	−54	28	Precuneus/PC
		22	−40	16	Precuneus/PC
		−60	−8	−16	Anterior temporal
		−52	−60	26	TPJ
Ochsner et al. (2004)	m	−2	58	38	Medial frontal
		−2	50	16	Medial frontal
		−62	−34	−6	Anterior temporal

Note. m = Montréal Neurological Institute space of reference; t = Talairach and Tournoux space of reference; TPJ = temporoparietal junction; PC = posterior cingulate cortex.

Table 3
Coordinates of Brain Activations Reported in Table 1 and Shown in Blue in Figure 1

		Other versus self/control contrasts			
Study	Space of reference	*x*	*y*	*z*	Brain region
D'Argembeau et al. (2007)	m	−10	14	62	Medial frontal
		−10	−64	38	Precuneus/PC
		−52	−2	−32	Anterior temporal
		−54	−54	26	TPJ
Gutchess et al. (2007)	m	−68	−8	−18	Anterior temporal
Sugiura et al. (2006)	m	−62	−46	32	TPJ
		46	16	−40	Anterior temporal
		−44	16	−40	Anterior temporal
Kelley et al. (2002)	t	0	14	42	Medial frontal
Vogeley et al. (2001)	t	6	56	2	Medial frontal
		6	56	26	Medial frontal
		4	28	30	Medial frontal
		22	46	46	Medial frontal
		−58	10	−10	Anterior temporal
Vogeley et al. (2004)	t	2	−60	56	Precuneus/PC
		−30	0	52	Medial frontal
		−42	−32	40	TPJ
Gusnard et al. (2001)	t	−3	3	48	Medial frontal
Farrer et al. (2003)	t	0	14	54	Medial frontal
		12	30	42	Medial frontal
Fletcher et al. (1995)	t	−12	36	36	Medial frontal
		0	38	24	Medial frontal
		6	−56	16	Precuneus/PC
Goel et al. (1995)	t	−12	38	32	Medial frontal
		4	52	24	Medial frontal
		−20	34	32	Medial frontal
		−6	46	28	Medial frontal
		2	−62	20	Precuneus/PC
		−42	−62	24	TPJ
		−46	2	−20	Anterior temporal
		−44	−64	20	TPJ
		−48	−16	−16	Anterior temporal
		−44	14	−16	Anterior temporal
Brunet et al. (2000)	t	4	56	44	Medial frontal
		16	44	20	Medial frontal
		8	32	−4	Medial frontal
		14	−20	60	Medial frontal
		−8	36	0	Medial frontal
		54	−10	−38	Anterior temporal
		52	−46	0	TPJ
		−38	8	−16	Anterior temporal
		−64	−42	2	TPJ
H. L. Gallagher et al. (2000)	t	−8	50	10	Medial frontal
		4	26	46	Medial frontal
		−10	48	12	Medial frontal
		12	−52	58	Precuneus/PC
		2	−50	44	Precuneus/PC
		−48	14	−36	Anterior temporal
		54	12	−44	Anterior temporal
		−46	−56	26	TPJ
		66	−52	8	TPJ
		58	−44	24	TPJ
		−48	16	−38	Anterior temporal
		−54	−66	22	TPJ
		60	−46	22	TPJ

(*table continues*)

Table 3 (*continued*)

Study	Other versus self/control contrasts				
	Space of reference	*x*	*y*	*z*	Brain region
Castelli et al. (2000)	t	−4	60	32	Medial frontal
		−58	−48	4	TPJ
		60	−56	12	TPJ
		−38	−4	−32	Anterior temporal
		34	6	−26	Anterior temporal
Calarge et al. (2003)	t	0	45	1	Medial frontal
		5	33	15	Medial frontal
		−20	10	50	Medial frontal
		−15	31	34	Medial frontal
		−17	42	20	Medial frontal
		−8	−55	23	Precuneus/PC
		−44	0	−28	Anterior temporal
		−48	−64	25	TPJ
Lou et al. (2004)	t	−8	38	54	Medial frontal
		−4	−52	24	Precuneus/PC
		−54	−2	−22	Anterior temporal
		46	12	−26	Anterior temporal
		−48	−66	28	TPJ
		−50	2	−20	Anterior temporal
Mitchell et al. (2005b)	m	−9	51	36	Medial frontal
		0	−21	48	Precuneus/PC
		45	−6	−15	Anterior temporal
		−51	−48	3	TPJ
		57	−51	9	TPJ
Mitchell et al. (2006)	m	18	57	9	Medial frontal
		−9	45	42	Medial frontal
Ochsner et al. (2005)	m	−12	26	40	Medial frontal
		−8	20	36	Medial frontal
		18	24	28	Medial frontal
		−10	2	66	Medial frontal
		−4	6	62	Medial frontal
		−6	16	50	Medial frontal
		−20	32	28	Medial frontal
		22	18	40	Medial frontal
		−12	−64	62	Precuneus/PC
		−10	−48	66	Precuneus/PC
		20	16	−12	Medial frontal
		−8	−52	66	Precuneus/PC
		48	14	−30	Anterior temporal
		40	10	−40	Anterior temporal
		46	−16	−22	Anterior temporal
		−54	0	−26	Anterior temporal
		−54	−10	−20	Anterior temporal
		46	0	−34	Anterior temporal
		46	−16	−18	Anterior temporal
Seger et al. (2004)	t	−26	20	52	Medial frontal
		−34	20	51	Medial frontal
		16	−61	18	Precuneus/PC
		−12	−50	45	Precuneus/PC
Farrer & Frith (2002)	t	−6	−58	50	Precuneus/PC
		2	−50	44	Precuneus/PC
		44	−58	32	TPJ
		−48	−52	40	TPJ
Ruby & Decety (2001)	m	14	72	10	Medial frontal
		−12	−50	38	Precuneus/PC
		0	−66	34	Precuneus/PC
		−66	−32	26	TPJ
		44	−64	24	TPJ
		50	−58	30	TPJ

(*table continues*)

Table 3 (*continued*)

Study	Space of reference	Other versus self/control contrasts *x*	*y*	*z*	Brain region
Ruby & Decety (2003)	m	−24	50	−6	Medial frontal
		0	20	70	Medial frontal
		10	24	56	Medial frontal
		−8	40	52	Medial frontal
		24	48	42	Medial frontal
		−4	68	−12	Medial frontal
		−52	−4	−38	Anterior temporal
		−60	−34	−10	Anterior temporal
		−54	−14	−10	Anterior temporal
		72	−18	−12	Anterior temporal
		44	−70	36	TPJ
		−38	−62	20	TPJ
Ruby & Decety (2004)	m	−8	48	−18	Medial frontal
		−8	64	−8	Medial frontal
		10	68	14	Medial frontal
		4	50	40	Medial frontal
		−8	44	20	Medial frontal
		2	−60	32	Precuneus/PC
		−58	−58	28	TPJ
		62	−64	22	TPJ
		46	−56	22	TPJ
		−58	−4	−32	Anterior temporal

Note. m = Montréal Neurological Institute space of reference; t = Talairach and Tournoux space of reference; TPJ = temporoparietal junction; PC = posterior cingulate cortex.

last operation typically refers to induction, which is a form of hypothesis generation and selection where one must search a large database and determine which items of information are relevant and how they are to be mapped onto the present situation (Carbonell, Michalski, & Mitchell, 1983; Russell, 1986).

It is important to note that inferential processes can be made explicitly but most of the time are made implicitly: Inferences are not only explicit relations between sentences or thoughts but are also cognitive processes involving interpretations that people automatically entertain when going beyond what the premises present intrinsically. This point was well expressed by Goel and Dolan (2000, p. 110), who said that "induction is an ubiquitous, often effortless, process involved in many cognitive tasks, from perception, categorization, to explicit reasoning in problem-solving and decision-making."

The rationale for our proposal that evaluation (inferential processes and memory recall) is the common cognitive process recruiting the E-network comes from our synthetic analysis of the classical paradigms used to investigate the self–others in cognitive neuroscience. As described below, although these studies involved diverse cognitive domains and tasks, they all involved common cognitive processes by using protocols that always involve a certain degree of uncertainty, that is, they ask a question for which there is no true verifiable answer, that is, the answer depends on numerous factors that are not necessarily known and need in this case to be evaluated. Subjects are indeed questioned about ambiguous stimuli (morphed faces, movements of gloved hands, etc.) or asked to make predictions, such as the prediction of their own behavior or that of another person. This point may be enlightened by the following descriptions of the cognitive operations involved in the tasks recruiting the E-network.

Others' mind reading. When the attribution of mental states to others or the prediction of others' behavior is questioned, the mental operations involved can be described as follows:

—Perception and integration of the stimulus (e.g., a picture showing a man pouring some water from his glass),

—Consideration of the question asked (e.g., did the man pour some water intentionally?),

—Consideration of contextual cues (e.g., Case 1: the man is looking at his wristwatch, or Case 2: the man is in front of a dry flower),

—Recalling of similar/associated/related situations (e.g., Case 1: I happened to spill some water onto the floor accidentally while looking at my watch; asking someone holding a glass the time, expecting that he will spill some water onto the floor, is a well-known joke; Case 2: when a flower is dry, I water it; I have often seen people water dry plants),

—Comparison and/or association of the recalled episodes/information, which leads to

—A generalization or the formulation of probabilistic rule (e.g., Case 1: when a man is pouring some water onto the floor while looking at his wristwatch, it is usually unintentional; Case 2: when a man pours some water onto a dry flower, it is usually intentional), and

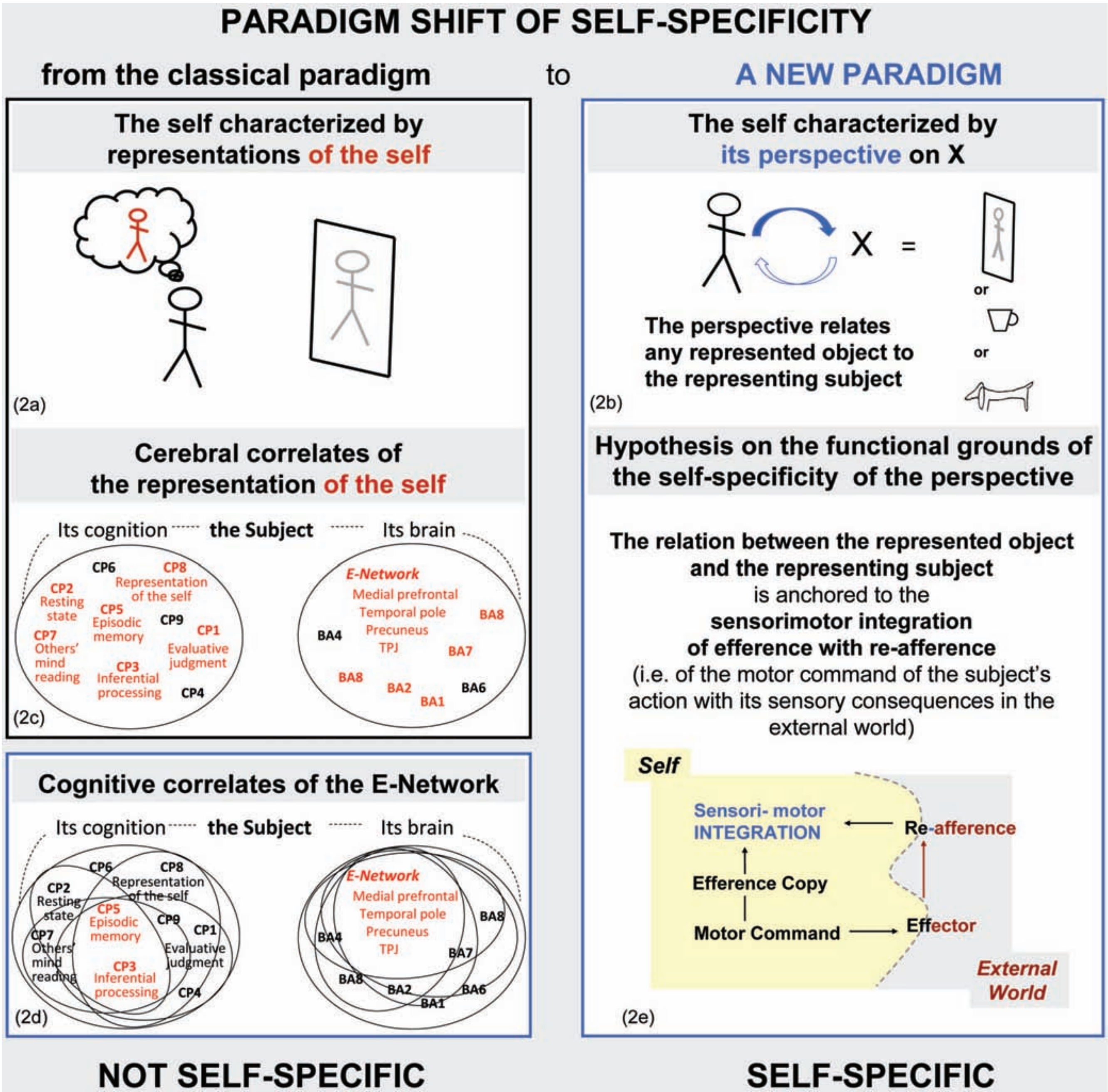

Figure 2. Paradigm shift of self-specificity from the classical paradigm to a new paradigm. (2c) Representation of the self recruits a cerebral network comprising the E-network as well as many other tasks, states, or cognitive processing, such as CP1, CP2, CP3, CP5, and CP7. (2d) All the tasks, states, or cognitive processing, CP1, CP2, CP7, CP8, involve Inferential processing (CP3) based on information issued from memory (CP5) and from the context.

—Application of this newly formulated rule to the presented stimulus allowing for a conclusion (e.g., Case 1: the man poured some water unintentionally, or Case 2: intentionally).

Personality traits attribution. When the attribution of personality traits is questioned, the cognitive operations can be described as follows:

—Consideration of the question asked (e.g., does the personality trait apply to you?),

—Perception and integration of the stimulus (e.g., shyness),

—Recall of relevant situations (e.g., I blushed the last time John said something embarrassing to me, even though I usually do not blush easily),

—Comparison or association of these recalled events with each other, which leads to a

—Generalization or the formulation of probabilistic rule (e.g., most of the time I am confident and do not blush in embarrassing situations), and

—Application of the rule, which allows a conclusion to be drawn (e.g., I am not shy).

Physical traits attribution. When the attribution of physical traits to oneself or others is questioned, the cognitive operations may be the following:

—Perception and integration of the stimulus (e.g., a face),

—Consideration of the question asked (e.g., is it your face?),

—Recall of related stimuli from past events (e.g., my face in the mirror this morning, my face with short hair, my face with attached hair, my face when I was 13, etc.),

—Attempt at integration of these facial traits to form a mean/probable representation of "my" face,

—Comparison of the latter with the stimulus, and

—Automatic use of an implicit rule (e.g., resemblance is usually a good predictor of identity) allowing the subject to draw the conclusion (e.g., this is my face).

It appears from the cognitive decomposition of these different tasks that they may all involve the same cognitive operations of inferential processing using information recalled from memory. The extent to which each operation is involved may vary, however, according to the task, the stimuli, and the subjects. Indeed, according to the person asked, his or her habits, personality, present mood, past, and familiarity with the particular stimuli used, one or the other of these cognitive operations may be shortened or skipped (e.g., generalization may be skipped, e.g., if the subject concludes on the basis of only one recalled event).

Importantly, this analysis of the tasks recruiting the E-network makes it clear that evaluation is a cognitive process that is involved irrespective of the subject targeted in the task. Evaluation may be needed to answer a question about oneself as well as a question about one's mother or cat. Such a cognitive process is thus neither domain specific nor subject specific and is in fact required any time two stimuli are compared explicitly or implicitly in any cognitive domain. What would modulate the recruitment of evaluation would not be the stimulus evaluated but the level of uncertainty and ambiguity of the question, given the amount of information available from the stimulus.

Our proposition that self-relatedness evaluation and others' mind representation both rely on inferential processes using information from both the present context and memory recall is fully coherent with the psychological description of social cognition proposed by Beer and Ochsner (2006), who suggested that

> [several] cues may be categorized or labeled in order to extract psychological meaning (i.e., a smile vs. a frown). Once this initial assessment is formed, more information about the cues may be extracted from information gathered in the context or stored information derived from previous experience with the context and/or person involved. (Beer & Ochsner, 2006, p. 99)

The explanatory framework we propose here implies that evaluation is involved in numerous tasks targeting the self and also that evaluation is not preferentially involved in self-relatedness evaluation. This coheres with Amodio and Frith's (2006) claim that "observations from self-knowledge studies raise the possibility that activations elicited during the judgment of self-attributes . . . might actually represent a more general process of thinking about 'social' attributes, regardless of whether they pertain to the self" (p. 273). Following this same line of thought, we go one step further and argue that the processes at stake in self-relatedness evaluation are general enough to be recruited for self-related (e.g., self-attribution, self-recognition, self-directed thought, self-mind-reading), others-related (e.g., others attribution, others recognition, others' mind-reading) or objects-related (e.g., inductive reasoning about objects) cognitive tasks.

Simulation?

Simulation theories have been predominantly put forward to account for the overlap of self and other representations (e.g., Gallese & Goldman, 1998; Goldman, 1989; Gordon, 1986; for a critical discussion, see S. Gallagher, 2001). This hypothesis proposes that when seeing or interacting with an individual A, (a) one simulates the action, sensation or feeling that oneself would experience in the situation faced by A and (b) one uses the results of this simulation to attribute mental states to A or predict A's futures actions. This theory can then explain what are called mirror activations (activations elicited both when I feel/do something and when I see another individual feeling/doing the same thing; for a critical discussion, see S. Gallagher, 2007; Jacob, 2007; Legrand, 2007a), that is, it accounts for the data suggesting that one activates the motor cortex when seeing another person acting (e.g., Grèzes & Decety, 2001), the somatosensory cortex when seeing someone being touched (Keysers et al., 2004), the amygdala when representing someone facing a threatening situation (Ruby & Decety, 2004), or the insula when seeing a facial expression of disgust (Wicker, Keysers, et al., 2003).

However, while it may be compatible with sensory, motor, or emotional activations, that is, with domain-specific mirror activations, the simulation hypothesis does not seem sufficient to account for the brain activations associated with mind reading, for the following three main reasons.

1. Similar brain activations are obtained for self and others' mind representations whatever the content represented, that is, actions, sensations, feelings, or thoughts, while mirror activations are domain specific.

2. These activations are in the E-network. We want to stress here, first, that these activations are outside any cortex designated for sensorimotor functions and, second, that as far as we know, no results in the literature allow the conclusion that the E-network is primarily and preferentially associated with self-representation. All together, these points make it difficult to explain the activity in the

E-network for others' mind reading by a simulation of the self.

3. The E-network is recruited by many cognitive tasks/states (memory recall, resting state, and inductive and deductive reasoning; see Table 1) that do not necessarily involve representing any subjects (neither self nor others). For example, this is the case for inductive reasoning about objects (e.g., Fangmeier, Knauff, Ruff, & Sloutsky, 2006; Goel & Dolan, 2000). Again, these data could hardly be interpreted by appealing to the simulation hypothesis.

Looking at the results obtained by Mitchell et al. (2006), however, one may disagree and argue in favor of the simulation hypothesis even at the conceptual level of mind/thought representation. Indeed, this team showed that the more another person is similar to oneself, the more representing his or her mind recruits an area of the medial prefrontal cortex previously found to be activated by self-reflection. However, to support a simulationist interpretation of these data, it is not enough to demonstrate that the brain area in the medial prefrontal, which they found to be activated in reading the mind of a similar other, is also involved when the subject entertains self-referential thoughts; it must also be demonstrated that this area is dedicated to representing the mind of the self in the first place and is reactivated in a simulated way in others-related tasks. To our knowledge, no empirical data are available in the literature to support this point. In other words, both the simulation of the self-mind and the involvement of a non-self-specific cognitive process (common to representing the mind of both self and others) can account for these data. In addition, it is important to note that a simulationist interpretation of the data obtained by Mitchell et al. (2006) leaves unexplained why representing the mind of a person dissimilar to oneself also induces an activation in the medial prefrontal cortex close to the one found for representing the mind of a similar person (see below for an alternative interpretation).

Differentiating several forms or levels of simulation would not be sufficient to avoid the aforementioned problems. For example, Keysers and Gazzola (2007) speculated that mirror activations would provide low-level prereflective representations, activated during the mere observation of others, and a second type of simulation would be used when reflecting and reporting others' states. The latter would not be domain specific and would be correlated to activation of the ventral medial prefrontal cortex. However, this double-simulation hypothesis can again be questioned on the two following points.

1. At the neuroscientific level, it proposes to relate reflective simulation only to the activation of the ventral medial prefrontal cortex, thereby leaving unexplained the conditions of activation of the other cerebral areas of the E-network repeatedly activated in the self studies.

2. Again, at the theoretical level, what does justify a simulationist interpretation of the data? What does allow waving the self flag over the ventral medial prefrontal cortex, regardless of the activation of this area in other-related tasks? If the prior identification of a given brain area as self-reactive is not revised in light of further investigations suggesting activation of these same regions in others-related tasks, one then needs to invoke the involvement of self-simulation to save this interpretation from blatant incoherence. An alternative, more economical interpretation remains closer to the data and simply attests (quite tautologically) that brain areas activated both for self and others cannot be adequately interpreted as showing any self-preference, as defended above.

Putting Our Proposal to the Test of Empirical Results

We now need to address the following questions: Is our proposition neurophysiologically plausible? What are the cerebral correlates of inferential processing and memory recall? Do they superimpose on the E-network?

The Cerebral Correlates of Inferential Processing and Memory Recall

Several studies have shown that inferential processing in general and inductive and deductive reasoning in particular involve one of the areas of the E-network, that is, the medial prefrontal cortex (cf. Table 1). Note that mental calculation, which mainly involves intraparietal sulcus (see Hubbard, Piazza, Pinel, & Dehaene, 2005, for a review), is not considered an inferential process.

More in detail, Zysset, Huber, Ferstl, and von Cramon (2002) investigated evaluative judgments using preference assessments with fMRI (e.g., "I like George W. Bush": yes/no). In comparison with episodic memory recall, they showed that this evaluative task induced more BOLD (blood oxygen level dependent) signal only in the medial prefrontal cortex and in the lateral prefrontal cortex. Moreover, studies that specifically investigated reasoning also reported medial prefrontal cortex activations. An fMRI study investigated reasoning using problems adapted from the Raven's Progressive Matrices (Raven, 1938): Participants had to identify the rule governing the sequence of three figures on the basis of two examples. This study demonstrated an increased activity in both medial prefrontal cortex and lateral prefrontal cortex associated with the increase in reasoning complexity (Christoff et al., 2001). Importantly, Goel, Grafman, Tajik, Gana, and Danto (1997) demonstrated that inductive reasoning recruits the dorsomedial prefrontal cortex, whatever the content of the premises, that is, objects or subjects. A recent fMRI experiment (Fangmeier et al., 2006) further showed that the medial prefrontal cortex is activated precisely during the so-called premise integration phase of the deductive reasoning process. This activation happens when the second premise (information) is presented. At this point, the two premises are integrated into one unified representation, and a putative conclusion is drawn. It is noteworthy that this study used not human-related stimuli but arrays of single letters as premises. In the same line, Fonlupt (2003) demonstrated that the medial prefrontal cortex was involved at a very simple level of logical reasoning. In this study, subjects were presented movies of two rolling balls. Results show that blood flow increased in the medial prefrontal cortex when the subject had to answer whether one ball caused the movement of the other as opposed to whether a ball changed color. Interestingly, the involvement of the prefrontal medial cortex in the pervasive cognitive component of evaluation fits well with its activation during creative reasoning, as reported by Geake and Hansen (2005). These authors explored the ability to make fluid and creative analogical relationships between distantly related concepts or pieces of information, using the fluid-analogy-making task (subjects chose their own best completions from four plausible response choices to 55 fluid letter string analogies across a range of analogical depths). While doing this task, which typically requires creating new representations, subjects activated a large brain network comprising the medial prefrontal, precuneus, and temporoparietal junction (i.e., three of the four areas comprised in the E-network).

Finally, what is critical to note when reconsidering the functional role of medial prefrontal cortex during self-relatedness evaluation and theory of mind (ToM) is the result of the meta-analysis by Wicker, Ruby, et al. (2003). These authors highlighted that foci of activation for self-referential information processing, ToM, and reasoning are all close and mixed up in the medial prefrontal cortex (see also Table 1). All together, these results support our proposition that the medial prefrontal cortex is not preferentially dedicated to self-related inference but rather subserves more general inferential processing, such as comparison, synthesis, and induction.

In addition to the medial prefrontal cortex, tasks involving self-relatedness evaluation and others' mind representation activate the medial parietal cortex, temporoparietal junction, and temporal poles (see Table 1 and Figure 1). These three regions have been repeatedly reported to be involved in memory recall, be it semantic or episodic (Cavanna & Trimble, 2006; Dolan, Lane, Chua, & Fletcher, 2000; Graham, Lee, Brett, & Patterson, 2003; Lundstrom, Ingvar, & Petersson, 2005; Maguire & Mummery, 1999; Piefke, Weiss, Zilles, Markowitsch, & Fink, 2003; Wagner, Shannon, Kahn, & Buckner, 2005; see Table 1).

As highlighted in Table 1, when a task involving episodic memory is subtracted from a task involving evaluative preference (Zysset et al., 2002), only the medial prefrontal cortex is differentially activated. This suggests a cerebral functional segregation between an inferential prefrontal cortex and memory-related parietal and temporal regions. In light of these data, our proposition is that posterior activations of the E-network (see Figure 1) are associated with memory recall providing information for inferential processing. This proposition coheres (a) with numerous interpretations of the activation of temporal poles (e.g., Brunet et al., 2000; H. L. Gallagher & Frith, 2003; Olson, Plotzker, & Ezzyat, 2007) and precuneus (e.g., H. L. Gallagher et al., 2000) as memory-related in mind reading tasks; (b) with the recent study by Mitchell (2008), who detected an increased BOLD signal in the right temporoparietal junction (RTPJ) both for mental state attribution and for nonsocial attentional tasks; (c) with the recent results of Addis, Wong, and Schacter (2007), who reported common activations in all regions of the E-network for the elaboration (imagination and/or recall) of both past and future events; (d) with the review of Buckner and Carroll (2006), which highlighted that envisioning the future, remembering the past, ToM, and navigation all involve the E-network; and (e) with the proposition by Bar (2007) explaining the default mode of the brain (i.e., activity in the E-network) by a continuously busy brain generating predictions that approximate the relevant future:

> This proposal posits that rudimentary information is extracted rapidly from the input to derive analogies linking that input with representation in memory. The linked stored representations then activate the associations that are relevant in the specific context, which provides focused predictions. (Bar, 2007, p. 280)

Coherent with our proposition, this last view would apply to the cases of the resting state and of ToM, that is, generating predictions that approximate the relevant future and/or other's behavior/thoughts.

To sum up, our review of neuroimaging data allows us to propose that the E-network activated both in self- and other-related tasks (medial prefrontal cortex, precuneus/posterior cingulate gyrus, the temporoparietal junction, and temporal pole; see Figure 1) in fact subserves nonspecific cognitive processing required for general evaluative abilities such as comparison, synthesis, or creative reasoning. Activation of the medial prefrontal cortex would be related to the mobilization of inferential processes, such as deductive and inductive reasoning, and activations of medial parietal cortex, the temporoparietal junction, and the temporal pole would be associated with memory recall providing premises for these inferences.

The strong advantage of this framework is that it proposes an economical way to explain why the cerebral network illustrated in Figure 1 is shared by as many cognitive tasks as self-relatedness evaluation, others' mind reading, memory recall, inductive and deductive reasoning, and resting state (see Table 1). Note that the framework is fully compatible with recent psychological and neurophysiological descriptions of self-related and social cognition (e.g., Amodio & Frith, 2006; Beer & Ochsner, 2006; Buckner & Carroll, 2006; Keysers & Gazzola, 2007; Klein, Rozendal, & Cosmides, 2002; Uddin et al., 2007). Our proposition thus enables us to merge many results coming from different domains of research in a comprehensive framework of interpretation.

Reinterpretation of Previous Results: Toward a Comprehensive Framework

The proposed framework enables us to account for many unexplained variations in neuroimaging results between studies and teams working in social cognitive neuroscience. Indeed, it may explain why the E-network (see Figure 1) is more activated for self-related tasks in some studies, while being more activated for others-related tasks in other studies (see Table 1). Evaluation involves complex cognitive processes, and it seems quite likely that a large variability is introduced by the uncontrollably changeable strategy used by the subject to achieve the required task, that is, the variable balance between inferential processing and memory recall. Interestingly, Beer and Ochsner (2006) had this intuition and stated in their recent article that

> arguments for modules specific to self-processing have not been robustly borne out in the research literature. Although neural differences have been found for self-processing, *they appear to reflect the application of different strategies* [italics added] (e.g., drawing on abstract rather than episodic information) for perceiving one's self versus another. (Beer & Ochsner, 2006, p. 102)

More specifically, we propose here that according to the specific task required, the context, and/or the groups of subjects involved, the condition "self" can be associated with either more or less inferential processing and memory recall than the condition "others." In other words, we propose that *the intensity of activity in the different regions of the E-network would be modulated by the varying need in inferences on the one hand, and in memory recall on the other hand, rather than by the person targeted in the task, that is, self versus other.* We next put this proposition to the test of experimental results.

Studies investigating self-relatedness evaluation. The study by Johnson et al. (2002) can be interestingly interpreted within the proposed framework. In their experiment, subjects were required to make a self-evaluation in the domains of mood, social interactions, and cognitive and physical abilities (e.g., "I forget important things," "I'm a good friend," "I have a quick temper"). These conditions were contrasted with conditions in which the subject was asked to make truthfulness judgments about factual knowledge such as "Ten seconds is more than a minute" and "You need water to live." This study thus contrasted questions that have no absolute answers with questions that have known absolute answers. In this case, overactivation of the medial prefrontal, posterior cingulate, and bilateral temporal pole for the self condition can then be well explained by a more important need in inferential processing and episodic memory recall in the self condition, in comparison with the factual knowledge condition.

In another study contrasting recognition of personally familiar names with famous names (Sugiura et al., 2006), one may explain the increased activity in the memory-related regions (both temporal poles, both temporoparietal junctions, and precuneus) for self-related others versus famous others by the fact that the self-related names are related to many autobiographical memories (triggering these, then, whether consciously or unconsciously), whereas famous names may be associated with less episodic or semantic events.

Studies investigating others' mind representation. By contrast with the studies presented in the previous section, the paradigm used in some other types of studies turns out to induce an increased need in inferences and memory recall for the other condition. For example, it is certainly the case for the standard ToM paradigm used in neuroimaging studies, which contrasts (a) other's mind reading or intention/action prediction with (b) simple physical logic (e.g., Brunet et al., 2000; see also Beer & Ochsner, 2006; H. L. Gallagher & Frith, 2003). One can see in Table 1 and Figure 1 that temporal poles are more often activated in this kind of task (ToM) than in tasks requiring self-relatedness evaluation. This may seem surprising, given the well-known role of temporal poles in storing personal semantic and episodic memories (Fink et al., 1996; Graham et al., 2003; Maguire & Mummery, 1999; Piefke et al., 2003). However, this result may be explained by an increased need of autobiographical recall for another versus self, to create a general representation of the other's personality and then of his or her putative actions and thoughts. Indeed, autobiographical memory appears as a privileged database for finding precise examples of encounters with others (i.e., episode witnessing the way a known person behaves in a social context), and this kind of example may be especially needed to draw a general representation of the personality of someone one knows less than oneself or to predict his or her behavior. This account would also well explain increased left temporal pole activity for others' versus self personality assessment in the study of Lou et al. (2004).

Interestingly, Mitchell et al. (2006) demonstrated that a functional dissociation could be made within the prefrontal cortex: Representing minds of similar others would be associated with ventromedial prefrontal cortex activation, while representing minds of dissimilar others would be associated with dorsomedial prefrontal cortex activation. According to the framework proposed in the present article, Mitchell et al.'s results may be interpreted as revealing two different kinds of reasoning strategies (subserved by segregated areas in the medial prefrontal cortex) for reading minds of similar and dissimilar others. One may speculate that the reasoning strategy may be influenced by the amount of information available to formulate a hypothesis (more associative information can be used for a similar than for a dissimilar other). The reasoning strategy may also have been influenced by an emotional factor in Mitchell et al.'s study, that is, one cannot exclude that reading minds may be associated with a stronger affective/emotional component for a similar than for a dissimilar other. This interpretation fits with previous results showing rather dorsal medial prefrontal cortex activation for neutral mind reading (Ruby & Decety, 2003) and ventral medial prefrontal cortex activation for mind reading in an emotional context (Ruby & Decety, 2004).

Studies investigating resting state. Interestingly, our framework can also explain why the E-network is active by default during the so-called resting state (Gusnard et al., 2001; Gusnard & Raichle, 2001). The fact that these regions are involved in both resting and self-relatedness evaluation has often led authors to propose that resting is self-related (Beer, 2007; D'Argembeau et al., 2005; Wicker, Ruby, et al., 2003). However, no rationale justifies interpreting the data this way, rather than by the involvement of a more general cognitive operation in both self-related tasks and resting states. In fact, the resting state remains poorly described in cognitive terms. All we know is that the resting subject is deprived of explicit focused external stimulation and has no cognitive constraints. He or she is thus free to think about whatever he or she wants. It can be about oneself, others, objects, about any present percept, recalled event, or prospective thoughts (e.g., "Which kind of food should I cook tonight? Perhaps I could spend my holidays in Russia? I shouldn't have told the truth to Raymond yesterday. Why is this experimenter so slow, I'm late already"; it can also be nonverbal thoughts, such as the imagery of the manipulation of a Chinese puzzle, of an engine, etc.). The only component that seems to be always present during resting states is associative ideas and manipulation of diverse types of representations (Bar, 2007). In fact, the resting state seems mostly to involve spontaneous processing of available information, including information resurging from memory.

The interpretation we propose here coheres with studies demonstrating that the resting states share common cognitive mechanisms with purposeful, task-related thought processes. In agreement with our meta-analysis, an overlap has indeed been demonstrated in the pattern of activation of various cognitive tasks and rest, with a number of higher cortical regions commonly activated (see Christoff, Ream, & Gabrieli, 2004). More precisely, Christoff et al. (2004) reported an fMRI study in which rest was compared with a simple left–right response task of minimal cognitive demands. In this study, the resting condition was associated with greater activation in temporopolar cortex, parahippocampus, rostrolateral prefrontal cortex, and parietal and visual cortical areas. In particular, the authors pointed out that activation of temporal lobe structures was particularly extensive and robust, suggesting that long-term memory processes may play a major role in spontaneous thoughts during resting.

Moreover, our framework allows us to propose a constructive interpretation of a critical functional profile of the default mode of the brain, that is, the decrease of activation of the E-network during processing of external stimulation (Goldberg, Harel, & Malach, 2006; Golland et al., 2007; Gusnard & Raichle, 2001; Wicker, Ruby, et al., 2003). Goldberg et al. (2006) showed an activation of the medial prefrontal cortex during introspection, in contrast to sensory categorization. The authors concluded from their contrastive fMRI results that introspection is not involved in sensory categorization. However, even if this point is correct, it cannot rigorously be concluded from these data since the experiment did not control for the confounding factor of the degree of evaluation involved in each condition. Indeed, in this particular experiment, the introspective task required the subjects to evaluate their emotional response, while the task of sensory categorization involved the selection of an absolutely correct answer. An alternative proposal coherent with these data and the present framework is that the so-called default mode of the brain, activated during introspection, does not specifically reflect self-directed processes since the modulation of activity in the cerebral areas of this network can be explained by the degree of involvement of inferences and memory recall.

To sum up, this set of arguments converges to suggest that the cognitive counterpart of the so-called default mode of the brain comprises inferential processing of information issuing from the context and from memory recall.

Conclusion of the Synthetic Analysis of the Neuroscientific Results on the Self

All together, neuroimaging results show that common brain areas of the E-network are recruited for self-relatedness evaluation, representation of others' minds, memory recall, inductive and deductive reasoning, and the cognitive processes going on during the resting state. The standard petitio principii is to take for granted that the medial prefrontal cortex is involved in self-processing and to conclude from this that any cognitive task eliciting activation in this brain area should be self-related too (see, e.g., Beer, 2007). For example, Gusnard (2005, p. 689) emphasized that self- and non-self-related tasks activate common brain areas and asked, "How might one reconcile this? . . . clues may arise from consideration of functionality that has been associated with having a self or self-awareness." She thus suggested that the common ground explaining the shared brain activation mentioned would be a self-related functionality. As well, Goldberg et al. (2006, p. 329) mentioned that the link between self-related and others-related brain activations "is intriguing, since it may offer a role for self-representations in social cognition." In reply to such interpretations,[2] one may ask, Why not interpret the same results (shared brain activations) as conversely offering a role for social cognition in self-representation? Either way, such interpretations are methodologically flawed in that they assume and generalize what still remains to be demonstrated: the main and primary cognitive operation subserved by this brain region. No serious rationale in fact justifies assigning, for example, the midline cortical structure preferentially to self-related processing rather than to any other processing also recruiting this region. Therefore, we propose another explanatory framework.

The alternative interpretation we propose remains closer to empirical data: From the observation that diverse tasks (self-relatedness evaluation, others' mind reading, resting state, memory recall, and inductive and deductive reasoning) all activate overlapping brain areas belonging to the E-network, we argue that these tasks must share common cognitive processes, without prejudging what these common processes might be (self-related or not). In fact, given the diversity of the tasks and stimuli involved in the aforementioned studies (see Table 1), we ought to conclude that these common processes must be general. Specifically, we propose here that what may explain the involvement of the medial prefrontal cortex in all these tasks is a general inferential ability enabling comparison, synthesis, or creative combinations (see Figures 2c and 2d). Evaluated information would originate both from the context and from memory, thanks to the activity of parietal and temporal areas. Such cognitive processing seems to be the smallest common denominator to all these tasks, and as such, it appears a justified candidate to explain the activity of the E-network.

To summarize, in the first part of this article, we have demonstrated that

1. Not only the medial prefrontal cortex but also precuneus/posterior cingulate, temporoparietal junction, and temporal pole were repeatedly reported to be activated in neuroimaging studies of the self;

2. The usually reported overlap between cerebral correlates of self and others' mind representations have been underestimated and involve all the regions mentioned in 1;

3. There is no ground for arguing that this network would be preferentially activated for the self or would be common to only self and other mind representation. Indeed, it is also recruited for memory recall, reasoning, and resting state;

4. The activity in the E-network can be explained by the involvement of inferential processes using information issued from memory recall and from the context; and

5. Self as classically investigated in cognitive neuroscience involves processes of inferences that are not self-specific.

At this point, the intermediary conclusion is that standard neuroimaging studies of the self tackle processes that happen to be involved in self-related tasks in that they are required for reflective processing allowing the self-attribution of mental and physical features. Thus, these studies inform us about the cerebral correlates of self-evaluation. However, according to the reinterpretation of the literature we have just proposed, neuroimaging techniques themselves make it clear that the evaluative processes enabling identification, attribution, and reflection upon a subject are not different for self and others.

[2] See also our discussion of simulationist interpretations of representation shared by oneself and others, above.

Note that even if, at this point, the question of what makes a self a self is left unresolved, this intermediary conclusion can be constructive if it is exploited to reorient studies of the self beyond the investigations that are mistakenly focused on non-self-specific processes (and that currently abound in the literature). For such reorientation to be possible at all, though, one needs to go further in the investigation and consider *what (if anything) is self-specific*.

New Perspective: Paradigm Shift

No Self?

Recent neuroscientific data have been exploited to defend a form of skeptical conception of the self, that is, the no-self position, according to which externally oriented perception would occur without a self and, in particular, without perceiver. This view has been recently defended on the basis of empirical data suggesting that rest, introspection, or self-relatedness evaluation on the one hand and externally oriented tasks on the other hand would elicit segregated brain activations. On the basis of such results, Goldberg et al. (2006) concluded that "self-representations are not a necessary element in the emergence of sensory perception" (p. 337). These results are important in that they "clearly argue against the inclusion of self-related representations in the list of ingredients necessary for the emergence of subjective awareness" (Goldberg et al., 2006, p. 337). We agree with this interpretation, but it is important to emphasize that the self is not lost for all that: There remains a world-directed subject of the "intense sensory perceptual states" described by these authors (Goldberg et al., 2006, p. 329). Concluding from these data that there were no self would be justified only if the brain network active during resting state were devoted to the self. However, our review of the neuroimaging literature demonstrates that this is not the case. According to the framework of interpretation we proposed above, there would be two segregated cerebral networks for introspection and externally oriented tasks because these tasks rely on different cognitive processing involving segregated brain areas, that is, inferential processing using information recalled from memory (with attenuated sensory processing) for the former and sensory processing (with attenuated inferential processing using information recalled from memory) for the latter. In other words, according to this reinterpretation, the contrast introspection versus categorization does not isolate a self component (that would only be present during introspection). Rather, the observing self is present both during introspection and during categorization. Therefore, the results reported by Goldberg et al. do not mean that mere perception lacks any self.

Nonetheless, a skeptic may insist on exploiting neuroscientific data to support the view according to which there would be no self. From our review, we conclude that cerebral correlates of self-relatedness evaluation are not specific to the self but rather correlate with the nonspecific process of evaluation. However, it is important to stress that none of these data and interpretations suffices to draw a further conclusion, which would be skeptical in the following way: If self-evaluative processes do not activate self-specific cerebral correlates, it might seem that the self, whatever it might be, is not in the brain. Pursuing this line of thought one step further on reductionist grounds, one may then exploit such a view to eliminate the notion of self altogether (on different grounds, but coherent with the framework and conclusion defended by Metzinger, 2003). However, such a skeptical conclusion is certainly not justified by the empirical evidence we have presented above (see also below for another take on this issue). Indeed, the only point that our review supports is that evaluation in self-evaluation is not self-specific. Eliminating the self on this basis would be warranted only if the self could be adequately reduced to self-evaluation, which needs to be argued for on independent grounds. By contrast, considering that (a) we intuitively have a sense of self that needs to be accounted for and (b) evaluative processes involved in self-identification and self-attribution are not self-specific, one is led to conclude that such processes of self-evaluation cannot be all there is to selfhood. Again, we thus need to address more carefully the following question: What is self-specific?

The Need for a Criterion to Define the Self

As discussed at length above, the investigation of the self in cognitive neurosciences has failed to identify a correlate specifically devoted to self-related tasks. In addition, the theoretical characterization of the self notoriously lacks consensus. The strongest theoretical contrast exists between positions that propose an elimination of the notion of self (Metzinger, 2003) and positions that rather propose an extension of the list of different forms of self. For example, following Strawson (2000), one can easily list up to 25 forms of self, depending on the background one refers to:

> There are many different notions of the self. Among those I have recently come across are the cognitive self, the conceptual self, the contextualized self, the core self, the dialogic self, the ecological self, the embodied self, the emergent self, the empirical self, the existential self, the extended self, the fictional self, the full-grown self, the interpersonal self, the material self, the narrative self, the philosophical self, the physical self, the private self, the representational self, the rock bottom essential self, the semiotic self, the social self, the transparent self, and the verbal self. (Strawson, 2000, p. 39)

It is important to note that the very possibility of eliminating the self or of listing its different forms exhaustively implies answering the following questions: What is it that has to be eliminated, or what is common to all phenomena referred to as self, over and above their differences? In either case, one needs a criterion that allows the determination of what a self is, in turn justifying its elimination or the categorization of different phenomena as a form of self (Legrand, 2004). As recently stated by Northoff et al. (2006, pp. 440–441),

> distinct concepts of self differ in the class of stimuli and their specific material or content reflecting what is called different domains . . . . what remains unclear, however, is what unites these distinct concepts of self allowing us to speak of a self in all cases.

Northoff further assumed that self-referential processing "is common to the distinct concepts of self in the different domains" (Northoff et al., 2006, p. 441). Here, we question such a standard assumption: Referential processing involves the evaluative processes described above (e.g., one refers to "this face" as one's own by evaluating the resemblance of this face to one's representation of one's face), and coherent with the cerebral data presented above, such a process is devoted not only to the self but also to tasks targeting other subjects. Another criterion for the self has then to be determined.

What Is Self-Specific?

In an attempt to overcome some of the difficulties linked to the ill-defined notion of self, we propose to continue our investigation by considering the most basic conception of self: The least one can say about the self is that it has to be distinct from nonself. Note that this remains the case even if nonself properties may be ordered gradually, from more to less resemblance to properties of the self. Moreover, as becomes clear below, this basic self–nonself divide does not rule out the possibility that the self is constituted by its relation with nonself.

From this starting point, we reconsider standard conceptions of the self in the light of the operational notion of *self-specificity*. We define the notion of self-specificity according to the two criteria of *exclusivity* and *noncontingency*. We argue that a given self S is constituted by a self-specific component C only if C characterizes S exclusively (i.e., C does not characterize non-S) and noncontingently (i.e., changing or losing C would amount to changing or losing the distinction between S and non-S). Non-self-specific components would characterize S nonexclusively (i.e., they also apply to non-S) and contingently (i.e., losing such characteristics does not amount to losing the distinction between S and non-S). The self can be characterized both by self-specific and non-self-specific components, but only the former are constitutive in the sense that, for any self-specific component C, the presence or absence of C determines the self–nonself divide.

In the following, we propose to use this operational notion of self-specificity to evaluate different standard conceptions of self and guide new elaborations. We begin our investigations with the following consideration: Standard self-related tasks involve the ability to (a) interrelate by means of evaluation (b) the representation of oneself with (c) the perception of a given stimulus. For example, in face recognition tasks, the subject needs to (a) recognize the similarity or dissimilarity between (b) his or her (explicit or implicit) representation of his or her own face and (c) his or her perception of the picture of the face. Above, we provided empirical arguments suggesting that (a) evaluation is not self-specific. In the following, we consider whether (b) the representation of oneself and/or (c) the perception of a given stimulus are self-specific.

Self-Related Contents?

In cognitive neuroscience, philosophy, developmental psychology, and psychiatry, the self has mostly been characterized by a particular content of information as opposed to another content of information (my face vs. another person's face, my first name vs. another person's first name, my personality vs. another person's personality, etc.; see Figure 2a). The relevance of such a conception of the self-as-content is evident: It is surely crucial to be able to differentiate self-related contents from others-related contents, and sensitivity to the contents of one's self-representation is an important predictor of behavior. However, does such self-relatedness necessarily imply that these contents are self-specific? Our answer is no, for reasons we now explain.

Self-related contents are not self-specific. The conception of the self-as-content is partial, for the following reasons.

First, studies investigating the self frequently use stimuli involving general contents that can be attributed either to the self or to others. For example, this is the case of personality traits or actions: Both oneself and others can be shy, and both oneself and others can lift the index finger on request. Since they are at least potentially owned both by oneself and by others, none of these contents can be considered intrinsically self-specific: They do not meet the criterion of exclusivity (a constitutive characteristic of the self should apply to the self and not to nonself).

Second, another set of stimuli involves contents that are only contingently related to oneself, for example, one's facial features. Even if these features were unique to the self, they would not allow the specification of the self as such, since the same self–nonself distinction can be made even if these contents change: One obviously does not cease to be oneself by merely changing one's facial features. In other words, such contents fail to meet the criterion of noncontingency (any change or loss of a constitutive characteristic of the self should entail a change or loss of the self—nonself distinction).

A subset of such contents is interesting to consider more closely here since they give us the most intuitive and robust sense of self: the feeling of one's body. The latter is exclusive to the self at least in the sense that we do not feel others' bodies in the same way we feel ours. Since we can never directly experience the somatosensory state of others, any somatosensory signal indicates the boundaries between me and the rest of the world, and crossing this line is potentially dangerous for me. Processing exclusive somatosensory contents (e.g., interoception and proprioception) would be crucial to account for our intuitive sense of being ourselves located where the body is felt and represented. This idea fits well with the fact that bodily consciousness is intertwined with self-consciousness in many ways (Bermudez, 1998; S. Gallagher, 2005; Legrand, 2006, 2007c; Thompson, 2005, 2007). However, we also want to point out that these special contents are not sufficient to ensure self-specificity: Even if somatosensory contents are exclusively related to the self, they nonetheless characterize the self only contingently. Indeed, the distinction between a given self and nonself does not collapse as soon as these exclusively self-related contents change, are lost, or are misattributed. For example, the self–nonself distinction remains relevant for deafferented patients even if they have lost the proprioceptive sense of their body (Legrand, 2007c). Likewise, the self–nonself distinction remains relevant for schizophrenic patients even if they misattribute their intentional actions to others (Legrand, 2007a).

As already stated above, we do not mean to deny that erroneous representations of self-related contents have consequences that are important for the self or that these representations and experiences of contents as self-related are indeed important dimensions of the self. Nonetheless, as relevant for selfhood as they may be, these contents are not self-specific because, strictly speaking, they characterize the self only contingently. Therefore, self-related information can be used but cannot suffice to differentiate others from oneself. Given that self is most often confused with self-related contents, the scope and limitations of the conception of the self-as-content are worth detailing.

Self-related contents are functionally determined. As we have just seen, contents are only contingently related to the self. Nonetheless, they obviously end up being self-related, as opposed to others-related. However, it is crucial to understand that this self-relatedness is not intrinsic to any content. As stated by Northoff et al. (2006, p. 449), "the exact mechanisms by which a purely sensory stimulus is transformed into a self-referential remain unclear," and underlining that such mechanisms might involve activation of the cortical midline structures is inadequate to provide any full explanation. Here, we rather propose a functional consideration of this difficulty.

To begin with, it must be underlined that the source of a signal, for example, in-skin or on-skin sensory receptors, cannot in itself provide any specific signature of the self since the same receptor can provide information originating not only from the self but also from the external world. This is the case even for proprioceptive information. In more detail, Eilan, Marcel, and Bermudez (1995, p. 13) differentiated three types of proprioceptive systems: Some process information about one's body only (e.g., homeostatic processes), others process information about the body relative to the external environment (e.g., the vestibular system), and still others process information that can be either about the world or about one's body (e.g., touch). The authors concluded, "it is neither true that internal proprioceptive systems can provide information only about the body, nor is it true that information about the body comes only via the internal proprioceptive systems" (Eilan et al., 1995, p. 14). In other words, it is not enough to have proprioceptive information to determine whether a given content is self-related or not.

More generally, neither proprioceptive information nor any other purely sensory content (as described by Northoff in the aforementioned quote; Northoff et al., 2006, p. 441) is self-specific in itself. By analogy, it is not the source itself of a neuronal activation that can determine its afferent or efferent nature: There is no such thing as intrinsically afferent or intrinsically efferent signals since the trains of afferent and efferent neuronal action potential are identical at the biological level. The difference between afferent and efferent signals is therefore only functional. In other words, a signal is afferent rather than efferent because of the way it is processed, not because it is architecturally linked to a sensory receptor, that is, not because some kind of mechanism is able to compute the fact that this signal has been generated by the activation of a sensory receptor. Rather, being generated by the activation of a sensory receptor normally implies being processed in a way that makes a signal afferent: It is the processing, not the source, that specifies a signal as afferent rather than efferent.

Likewise, at another descriptive level, there is no particular information that is intrinsically labeled self, even when it happens to be architecturally linked to the self, that is, even if the source happens to be one's body: A perceptual content is not intrinsically but functionally self-related. To put it differently, when a given content is related to the self, it is so because it is processed as such, not because it is an intrinsically self-related feature.

This characterization of the functional determination of the self-relatedness of contents has an important implication: It implies that *self-related contents as such cannot constitute the self since they presuppose a self-specific process determining a functional distinction between self and nonself*, thereby allowing the secondary differentiation between self-related and non-self-related contents.

Importantly, these considerations imply that an integration of several or all self-related contents cannot account for self-specificity in any satisfying manner since, again, such integration presupposes a functional process allowing the differentiation between self-related and non-self-related contents. Even a list of numerous personality traits describing a personality as a whole cannot constitute a self-specific combination. Indeed, such personality can be lost, that is, dramatically modified, in pathological cases such as frontotemporal dementia or Alzheimer disease (Ruby et al., 2007, in press), while the patient remains a subject and can still differentiate himself or herself from another person.

Likewise, the integration of proprioception with other sensory information is often considered as "the modality of the self 'par excellence" (Rochat & Striano, 2000, pp. 516–517). To explain in greater detail, the signature of the self would be the redundancy of different sets of sensory information that would not need to be self-specific in themselves but whose integration would be specific to one's own body (Rochat & Striano, 2000). For example, visual information about one's body part would be systematically correlated with proprioceptive information about this same body part. This correlation of different sets of sensory information with proprioception would provide a reliable signature of the self.

This position is certainly interesting. However, how can self-specificity be constituted by the integration of contents that are not themselves self-specific? In fact, it is crucial to understand that the very possibility of such integration presupposes determined self-specificity to tease apart self-related from non-self-related contents. Therefore, even the whole list of self-related contents would fail to constitute self-specificity. The problem remains of determining how such a list would be related to oneself as such (for more detailed argumentation of a similar point from a different perspective, see Legrand, 2006; Shoemaker, 1968).

Intermediary conclusion. To conclude the current point, we argue that the equation of self with self-content is importantly mistaken in that it focuses exclusively on non-self-specific representations of self-related contents and the consequences of such representations (behavioral and/or neuronal correlations). It thereby leaves unexplored what makes a particular content self-related in the first place.

It thus appears that contrasting different contents with neuroimaging techniques cannot reveal any self-specific results both for theoretical reasons (the contrast self-related vis-à-vis others-related contents does not isolate any self-specific cognitive component) and for methodological reasons. Indeed, neuroimaging techniques are not so much tuned to detect neurophysiological correlates of contents,[3] as to distinguish cognitive processes. For example, the scanner will show the same image of V4 if I see a yellow or a red dot and the same temporohippocampal pattern whatever the precise episode I recall from memory (e.g., my grandmother cooking, my cat purring on the bed, or the day I drove my first car). By contrast, it will show different images for different cognitive processes (e.g., color perception, motion detection, episodic memory recall, executive processing, spatial orientation, etc.). On this basis, we argue that neuroimaging studies that investigated self-related and non-self-related contents revealed similar cerebral correlates for both these contents (see Figure 1) because in these studies brains were scanned while the subject was involved in the same type of cognitive processing for each content

[3] Recent advances such as fMRI adaptation seem promising regarding this objective.

(e.g., perception, identification, or evaluation of self- and others-related contents). Thereby, they produced helpful results concerning neuronal activations involved during self-related cognition, but they failed to answer a question that remains crucial for any investigation of the self: What (if anything) is self-specific?

Subjective Perspective?

The perspective of the self. Neither evaluation nor self-related contents meet the criteria for self-specificity. At this point, one may be tempted again to draw a skeptical conclusion and doubt that there is anything self-specific and/or that the self is a valid notion. However, at the experiential level, there is no doubt that the self is specific, at least in the sense that we can hardly help distinguishing between the self and everything else (accurately or not, we keep doing it). An explanation of this phenomenon is still pending.

To make any progress, one needs to emphasize that both evaluation and self-related contents presuppose more basic processes. To recall the example given above, in, for example, face recognition tasks, the subject needs to (a) recognize the similarity or dissimilarity between (b) his or her (explicit or implicit) representation of his or her own face and (c) his or her perception of the picture of the face. Above, we argued that neither evaluation (a above) nor the ability to entertain a mental representation of oneself (b above) is self-specific. However, perception of a given stimulus (c above) is in fact particularly relevant here. Indeed, even if such basic processes as the perception of a given stimulus do not involve any representation of the self per se, they are nonetheless related to the self by being grounded in the perspective of the perceiv*ing* subject (Legrand, 2007b; Thompson, 2007; Zahavi, 2005).

The perspective of the subject is best characterized by differentiating between what is perceived (determining the contents) on the one hand and on the other hand who perceives it, how it is perceived, and from where it is perceived (determining the perspective). Following this distinction, there is more to perception than the perceived contents. In particular, the objects of perception can be processed through different modalities and may be misrepresented, while the perceiving self remains present throughout.

In this view, a perspective grounds every perception and representation held by any given subject. Consider, for example, the simple experience of biting a lemon. The features of this experience are threefold: It is characterized by a specific content (e.g., lemon as opposed to chocolate), a specific mode of presentation (e.g., tasting rather than seeing a lemon), and a specific perspective (e.g., my experience of tasting a lemon). The last is what makes the perception/representation of the lemon my own perception/representation. In other words, it is what makes the lemon perceived by me, from my own perspective.

Our question thus becomes whether my perception of the lemon juice is specific to me even if it does not involve any representation of myself as such. More generally, we now need to consider whether the perspective meets the two criteria for self-specificity: exclusivity (a self-specific characteristic of the self should apply to the self and not to the nonself) and noncontingency (changing or losing a self-specific characteristic of the self should amount to changing or losing the self–nonself distinction).

The subjective perspective is self-specific. Crucially for the point at stake here, the perspective meets both criteria for self-specificity: exclusivity and noncontingency.

First, a given perspective is exclusive to a given self: It applies to the self and not to nonself, thereby determining a self–nonself distinction. Others do entertain a perspective, their own, which differs systematically from one's own. Two people can perceive the bitter taste of lemon juice, but neither respective perception can be reduced to the other, most notably because one person perceives this taste from his or her own perspective, while the other person perceives this taste from another perspective, which differs systematically from that of the first person.[4]

Second, a given perspective characterizes a given self noncontingently: Any change of perspective changes the self–nonself distinction. There is no way for a given self to entertain representations that would not be grounded in a given perspective or that would be grounded in another person's perspective. Surely, a given subject can adopt a so-called third-person perspective, thereby considering the perspective of another subject, for example, trying to evaluate what can and cannot be seen from there in contrast to here. However, this subject necessarily does so from his or her own perspective. There is no way to adopt a perspective entirely detached from one's own.[5] "We cannot truly imagine the world as viewed from nowhere, pace Nagel" (Metzinger, 2003, p. 567; see Nagel, 1986). Surely, one can take a detached perspective on oneself, but one would do so from a specific perspective, which would remain one's own, even if it is potentially modified or attenuated.

Given that it meets both the criteria of exclusivity and noncontingency, we can conclude that the perspective is self-specific. It is a property that a self cannot lack, and it cannot be replaced by some non-self-related property: My perceptions, representations, and experiences are anchored in my perspective, and by virtue of this, they are mine rather than someone else's or nobody's. In this view, being a self not only corresponds to taking oneself as an object of perception/representation/experience, thereby entertaining self-related contents (see Figure 2a), but also and fundamentally corresponds to experiencing the world from one's specific perspective (see Figure 2b).

Historical Hint

The characterization of the self as a subject holding a self-specific perspective is not only coherent with the current framework but also has philosophical roots independent of the proposed criteria for self-specificity. Indeed, despite the lack of consensual conception of the self throughout the history of philosophy, one can note the recurrence of the distinction between the self-as-object (object of representation/perception/experience) and the self-as-subject (subject of representation/perception/experience). Let us mention very briefly only a few such influential positions.

[4] Note that we argue here that different selves hold different perspectives that are irreducible to each other. This view should not be confused with an epistemological approach that would argue that subjective perspectives are irreducible to any objective viewpoint (Jackson, 1982; Nagel, 1974).

[5] Note that this might also explain why the so-called first- and third-person perspectives would activate shared representations (e.g., Anquetil & Jeannerod, 2007; Ruby & Decety, 2004; and Table 1).

In a radical doubt, Descartes (1641/1996) intended to abstract his thinking from the objects of his thoughts. The outcome is *cogito,* that is, the very subject of thinking. The Cartesian "I think therefore I am" first of all means that no matter what I think, no matter the status I attribute to the objects of my thoughts (illusory or veridical), there remains an indubitable fact: I am, there is a subject of thinking. Kant (1781) placed the subject rather than objects at the center of the epistemic system. On the one hand, he insisted that the self is an object among others that turns out to be myself. Experiencing such self-as-object presents the same conditions, and thus the same limitations, as any experience of non-self-objects. Yet Kantian transcendental idealism argues that there is more to the self than such self-as-object. The subject is also at the very foundation of knowledge, the knower who is never known as such, which structures a priori any experience. James (1890) described different self-possessions (material, social, and spiritual), which all contingently and dynamically constitute one's personal identity, but he also insisted that all such self-possessions presuppose a self of all other selves, that is, the subject owning such self-possessions. Husserl (1900–1901/1973) and Sartre (1936/1957) argued that the ego we would experience, for example, through introspection must be distinguished from the self who is the very subject of such introspection and of any experience. Appearance of the self-as-object is an "aberrant type of appearance," as it does not give us the self as its acts and perceives but only as it is acted on and perceived (Sartre, 1943/1956, pp. 357–358). Wittgenstein (1958/1996) offered a clear distinction between the I-as-object and the I-as-subject. For example, when I look at my image reflected in a mirror, the perceived me corresponds to the I-as-object, while the perceiving I corresponds to the I-as-subject.

Most of these positions forcefully disagree with each other about the very definition of the self. Yet they nonetheless all converge on the idea that, whatever the self might be, it is not reducible to the object of one's representations. In contrast, more recent positions in philosophy of mind and cognitive sciences might be tempted to propose a more restricted notion of self, abusively reducing it to the object of self-representations and thereby ignoring the very subject of such representations. We argue here that this latter position is not only incomplete but also misleading in that it leaves out what is self-specific: the perspective held by a given subject.

Paradigm Shift

We propose here a paradigm shift (see Figure 2) where the question "What is self-specific?" is not answered by determining which contents of representations are evaluated as self-related. Rather, we argue that what matters for self-specificity is not representing oneself per se but primarily being a self, and we propose that being a self at this level involves a self-specific perspective. Obviously, not all representations are about oneself, that is, not all representations have the self as their object, but all representations specify the self as the subject entertaining these representations.

Importantly, the characterization of self-specificity in terms of perspective does not face the problem mentioned above about self-related contents, namely, a perspective does not presuppose the constitution of the self before it entertains its perspective. Rather, the constitution of the perceiving self and its perspective are concomitant to the perceptual act (for discussion of this point, see Metzinger, 2003; Zahavi, 2005). In this view, the perspective is fundamentally a self-specifying process in the sense that it constitutes the self–nonself distinction. The self is differentiated from nonself in a systematic manner, thanks to the fact that a perspective relates self and nonself in a nonsymmetrical manner: The self is representing, and the nonself is represented.

An important implication of the current proposal is that the determination of self-specificity is no longer concerned with whether the distinction between self-related and others-related contents is made accurately or not. Being a self is not only being a particular physical or mental object, characterized by particular physical or mental contents, identified or misidentified as belonging to the self. Rather, and fundamentally, the self is also characterized by the perspective it specifically holds, which is necessary for the very possibility of distinguishing, accurately or not, between self-related and others-related contents. Conversely, the evaluation of the self-relatedness of contents is not necessary to hold a perspective that is self-specific. In other words, the distinction between self- and others-related contents is secondary to the distinction between self and nonself per se, and the latter distinction is determined by the perspective held by the self. In light of these considerations, studies of the self should avoid reducing their scope to the investigation of self-directed but non-self-specific representations and should rather encompass studies of the non-self-directed but self-specific perspective.

New Methodologies: Naturalistic Investigation of Self-Specific Perspective

In the context of the present investigation, we now need to consider how the self-specific perspective has been and can be accounted for in cognitive neuroscience. This point is crucial for any investigation of the self in naturalistic terms. Indeed, even if one agrees that a subjective perspective cannot be accounted for reductively from an objective viewpoint, an objective investigation of the self's perspective is yet worth pursuing. This is what Nagel (1974) argued for when defining his objective phenomenology. Without advocating the latter in particular, we agree that

> Setting aside temporarily the relation between the mind and the brain, we can pursue a more objective understanding of the mental in its own right . . . . *structural features of perception* [italics added] might be more accessible to objective description, even though something would be left out. (Nagel, 1974, p. 449)

In what follows, we propose first to describe the structural features of perspective, which will then allow further investigations at the neurophysiological level.

Methodological Considerations

An important methodological worry for the investigation of the physiological mechanisms of self-specific processes is that the latter have been described as the subjective perspective anchoring any perception/representation/experience of any particular subject. The obvious problem is that, defined as such, self-specific processes are not tractable in terms of brain correlates. Indeed, to pin down cerebral correlates of any process, one needs to contrast a condition where the given process is present with a condition where this same process is absent, all other (relevant) factors being kept constant. Strictly speaking, this is impossible to achieve when investigating subjective perspective, as it is not possible to contrast, ceteris paribus, a condition where the subjective perspective is present with a condition where it would be altogether absent. Indeed, by definition, and as recalled above, any act, any move, or any thought is anchored to the perspective of the subject.

Again, however, this difficulty should not block the investigation of the neurophysiological mechanisms underlying self-specific processes. Rather, this particularity imposes another methodological strategy.

In particular, we propose that the cognitive neuroscience of the self would benefit from the following four-step methodology: (a) a description of the self that is conceptually and phenomenologically relevant and that allows for (b) an operationalization of this description in functional terms, in turn allowing for (c) the identification of the types of neurophysiological processes involved in Step b and then (d) the design of neuroimaging studies allowing the correlation between cerebral activations and Step c.

By proposing these methodological steps, we intend to consider how such an approach might provide some understanding of self-specific processes rather than considering whether the cognitive neurosciences of the self are altogether doomed to failure for theoretical or methodological reasons. Our view is not that what it is like to be oneself can be reduced to the functioning of cognitive processes implemented at the neuronal level, nor is it that the investigation of what it is like to be oneself can be reduced to the investigation of such processes. Rather, on the basis of the naturalistic approach we advocate, we nonetheless favor a nonreductionist consideration of the self where theoretical and experimental investigations can enrich and constrain each other (Legrand & Grammont, 2005). The point of the proposed methodology is that it is inadequate to investigate the self without conceptual clarification and without considering closely the experiential level of description (Step a, above), just as it is illusory to think that we could naturalize the self by linking directly a purely experiential description of the self (Step a, above) to a purely neuronal description of its underlying mechanisms (Step d, above).

Let us detail how this methodology applies here. Above, we determined that a self-specific feature of the self is to anchor a perspective. At this step, a characterization of the functional feature of the first-person perspective is required.

Self-Specific Perspective on the World

A perspective involves a process relating any perceived object to the perceiving subject (see Figure 2b). If such a description captures what is central to the notion of perspective, then the latter refers to the fact that any perception/representation/experience is determined both by the external world (the perceived object) and by states of the perceiving subject.

Importantly, the perceived object is perceived from the perspective of the perceiving subject even if and when the latter is not represented as such. In this view, the self's perspective is non-self-representational and should thus be differentiated both from explicit and implicit self-referential processes. Indeed, it is important to understand that both explicit and implicit self-referential tasks share the consideration of the self as an (explicit or implicit) object of experience/representation. By contrast, the self's perspective is characterized by processes that do not require any representation of the self as such, that is, it involves object representations that are subject-related (related to the subject's perspective).

This characterization of the first-person perspective challenges several other views. First, unlike classical views of the self, it avoids the problematic conception of perspective as characterizing the self's internal realm and of the observing self as any inner entity, as some kind of hidden ghost in the machine (Ryle, 1949). Secondly, our view goes beyond standard externalist positions that exclude notions of introspection and the self's perspective altogether by reducing them to representations of the external world (e.g., Tye, 1995, 2003; for a discussion, see Legrand, 2005; for a balanced view, see Jacob, 2001). Rather, we privilege a view of perspective as relating a perceiving subject and a perceived object. In other words, holding a perspective does not require any introspection or any representation of self-related contents. Rather, a perspective is defined simultaneously in relation to a self holding it and in relation to the external environment.

Implementing the Functional Characteristic of Perspective in Sensorimotor Processing

As just recalled, a perspective is defined as relating a perceiving subject and a perceived object. Our proposition is that this relation is made by the intertwining of the subject's actions and their perceptual consequences in the world (see Figure 2e). Such intertwining of perception and action is fully compatible with motor theories of perception according to which perception is not to be conceived as pure passive reception. Rather, perception is intrinsically active, that is, is constrained by action (for an early view, see Gibson, 1979; for more recently articulated proposals, see, e.g., Hurley, 1998; Noë, 2004). We apply this idea to the notion of perspective and propose that the specificity of the perspective at the neurophysiological level is to be anchored to the loop relating the subject's action to his or her perception of the external world (i.e., an object). In this view, as defended in detail by Hurley (1997, 1998),

> Having a perspective means in part that what you experience and perceive depends systematically on what you do, as well as vice versa. Moreover, it involves keeping track, even if not in conceptual terms, of the ways in which what you experience and perceive depends on what you do. (Hurley, 1998, p. 140)

This view also coheres with the notion of bodiliness introduced by O'Regan and Noë (2001) that intends to capture the fact that one's bodily movements affect only one's perception of what is in one's perspective and do not affect what is out of one's perspective (for a discussion, see Thompson, 2005, 2007).

More in detail, the proposal here is that there is an interesting functional equivalence between, on the one hand, the fact that the self is specifically characterized by the perspective that anchors it in the world and, on the other hand, the fact that perception is characterized by its anchoring to the action of the perceiving subject (see Figures 2b and 2e). We thus propose the following hypothesis: The self-specific perspective is paradigmatically constituted by the sensorimotor loop specifically characterizing a given perceiving agent. On this basis, we would like to stress that, at the most basic level, such a sensorimotor loop is implemented by the integration of efferent and reafferent information. We now elaborate on this point.

Reafference

Reafference corresponds to afferent signals issuing from the perceiving subject's own action. Reafferent information is thus specifically and intrinsically related to one's own action. Crucially, there is no way to define what a reafference is without mentioning the fact that it is related to the perceiving subject's own action. In other words, there is no such thing as a non-self-related reafference. By definition, a reafference is a perception related to one's own action. For example, when I bite a lemon, afferent information (muscular contractions, somatosensory feeling of the lemon in my mouth, etc.) is not a mere exafference but a reafference, that is, it is linked to my biting action. What is critical here is that a given perceptual content will be specifically processed according to the fact that it is a reafference, that is, according to the fact that it is related to oneself as a perceiving agent/active perceiver. Our proposal is that relating an efference with its reafference[6] is a process enabling the perceptual act to be characterized not only by a given content (the acidity of the lemon) but also by a self-specific perspective (I am the one experiencing the acidity of the lemon juice). Indeed, only one's action, not another agent's action, has specific perceptual consequences. Processing the latter as such leads the subject to perceive the world from his or her own agentive perspective. In these general cases, one's perception of the external world is self-specific. In some particular cases, in addition, what is perceived is oneself. Here again, these situations are characterized by a self-specific sensorimotor coherence. For example, when one visually observes one's body, not when one visually observes another body, there is a specific match between the content of one's perception and the content of one's action. This self-specific coherence is not merely multisensory but sensorimotor since it implies some coherence between what one does and what one perceives.[7]

Our point here is thus to exploit the well-known notion of reafference in the context of the debates about selfhood. Our proposal is that, being related to one's own action, perceptual information is related to oneself, hence perceived from one's own perspective. In other words, our hypothesis is that the self-specific perspective would be basically sensorimotor and would rely on the matching of one's perceptual and one's motor processes (i.e., matching the perceptual consequences of one's action with its motor command; see Figure 2e).

Internal Models

Relating self and action has become widespread in cognitive sciences (for a recent overview, see, e.g., the series of articles in the special issue of *Consciousness and Cognition* [Knoblich, Elsner, Aschersleben, & Metzinger, 2003]). A dominant view in this approach is advocated by Frith (e.g., Frith, Blakemore, & Wolpert, 2000), whose model is based on the conception of a mechanism of sensorimotor integration called *action monitoring,* first developed by von Holst (1954). Schematically, the latter consists in a comparator between a copy of the motor command (information on the action executed) and the sensorial reafferences (information on the perceptual modifications due to the action). Frith's model is a sophistication of the action monitoring model, which crucially includes intention and an internal model allowing the prediction of the perceptual consequences of the action (Blakemore, Frith, & Wolpert, 1999; Wolpert, Ghahramani, & Jordan, 1995). A comparator between intended, predicted, and real reafferences is thus added to von Holst's comparator between efference and afference.

A comparison between efference copy and reafference also plays a crucial role in our model since we intend to ground (self-specific) perspective in a mechanism relating each efference to its reafference (see Figure 2e). However, beyond the use of the same notions, Frith's hypothesis contrasts sharply with the position we present here (see also Legrand, 2006). What is important in Frith's model is that, thanks to the aforementioned comparator and internal model, the organism can register the difference between world-related (exafference) and action-related (reafference) perceptual information. The latter is considered relevant for self-related cognition in that it would allow differentiation between self's and others' actions, that is, the ability to self-attribute observed actions. In other words, Frith's model remains restricted to the conception of the self as self-attributed contents, which, as demonstrated above, are not self-specific.

By contrast, what is important in our model is that, thanks to a basic comparator like the one described by von Holst (1954), efferences would be systematically related to their reafferent consequences. The crucial point for us here is not that this process would or could result in some self-attribution of relevant contents. Rather, through such a mechanism, the organism would be able to register the fact that it has executed a given movement and to use this information to process ensuing perceptual modifications. The outcome is straightforwardly the anchoring of efference to reafference, that is, the efference relatedness of afference, which corresponds to the self-specific process we have described above.

To state it differently, we propose that the tracking of afferences as reafferences leads to the anchoring of the perception to action, that is, the anchoring of one's perception of the world to one's agentive perspective. This process is more basic than Frith's model because it requires only tracking of the afferent consequences of efferences, whether or not there is a matching of the respective informational contents. A subject attributing (correctly or not) an observed action to another subject may do so on the basis of a mismatch between what he or she does and the content of what he or she perceives. Nonetheless, it is obvious that even in such a case, the subject perceives the observed action from his or her self-specific perspective. Our hypothesis is that this self-relatedness of world perception may be due to the constant tracking of one's perception as anchored to one's action (reafference), which remains operational independently of the outcome of the comparison between efference and afference (match or mismatch).

[6] Note that proprioception may play a crucial role here, as it is recurrent reafferent information. However, this role is not linked to proprioception per se but to its integration with the efference.

[7] Note that this position is coherent with the results obtained by Rochat and Striano (2000), even though their interpretation mentioned only multisensory integration (Legrand, 2007b).

Intermediary Conclusion

Our considerations allow us to differentiate self-representational processes and self-represented contents on the one hand and non-self-representational processes on the other hand. We have determined that the self-representational processes of evaluation of self-related contents are not self-specific. Rather, we propose that

1. Self-specificity characterizes non-self-representational processes determining the subject's perspective;

2. The perspective relates any represented object to the representing subject; and

3. At a basic physiological level, such a link is grounded in sensorimotor integrative processes relating efferent information to its reafference and allowing any represented object to be related to the representing subject.[8]

We now consider how neuroimaging techniques can add any new relevant information to this investigation of self-specificity. Note that, since our framework proposes a functional determination of self-specific processes (and not self-related contents), neuroimagery can be expected to be a technique relevant to showing its cerebral correlates.

Neuroimaging the Self's Perspective

The first thing to note is that, given that the subject's perspective characterizes all of his or her representation, no sharp-contrast first perspective on versus first perspective off can be used. What is called third-person perspective in the neuroimaging literature is never completely segregated from the first-person perspective. It would thus be better considered as a modulation of the first-person perspective and would in fact involve an attenuation of the first-person perspective rather than its suppression. One may indeed speculate that, to represent another's perspective, one needs to attenuate one's own.

Second, given that we anchor self-specificity to processes of integration of efferent and reafferent information, we can hypothesize that the relevant neurophysiological mechanisms involve sensory- and/or motor-related cortices.

The results of the few studies that investigated first- and third-person perspectives with neuroimaging techniques (Farrer & Frith, 2002; Ochsner et al., 2004, 2005; Ruby & Decety, 2001, 2003, 2004; Seger, Stone, & Keenan, 2004; Vogeley et al., 2001) are presented in Table 1. The critical distinction between these studies and the aforementioned neuroimaging studies of the self is that they always used the same stimuli (same content) in both the self and others conditions. The difference between conditions thus relied only on the perspective taken by the subject to answer the question (e.g., "What can you see?" vs. "What can he see?", "How would you react?" vs. "How would she react?").

Importantly, these studies used evaluative tasks, that is, tasks requiring evaluation ("How would you react?" vs. "How would she react?", "Would you like this food?" vs. "Would your friend like this food?", etc.). In this context, given what we argued above, it is not surprising to see (in Table 1) that first- versus third-person perspective and third- versus first-person perspective highlight some brain regions of the E-network (see Figure 1). According to our framework, this may be due to the fact that the respective need in inferential processing and memory recall for first- and third-person perspective may vary according to paradigms and studies.

What is particularly interesting to note in relation to the aforementioned prediction is that these studies quasi-systematically reported modulation of somatosensory-related cortices' activity according to the perspective taken by the subject. Indeed, contrary to the results obtained in the self-evaluation studies (which contrasted self- vs. others-related contents), regions out of the non-specific E-network were repeatedly activated. Notably, the postcentral gyrus and the insula were reported several times in self versus others contrasts, but not in others versus self contrasts (see Table 1). In nearly all studies contrasting first- and third-person perspective, greater activity in somatosensory-related cortices (postcentral gyrus or insula) was reported for the first-person perspective, whatever the context (motor, visual, conceptual, or emotional), whatever the target person whose perspective the subject was to take (avatar, layperson, a friend, the subject's mother, etc.), and whatever the predictions of the authors. Interestingly, Schilbach et al. (2006) investigated social cognition with fMRI, using a paradigm that could be likened to a first- versus third-perspective manipulation (self condition: a virtual character looks at me; other condition: a virtual character looks at someone else) and they also reported an increased activity in the insula for self versus other conditions.

These results are interesting to consider in our quest for self-specificity, for the following reasons.

1. Some somatosensory-related cortices' activations for self's versus others' perspective were found outside any sensorimotor context (stimuli presenting conceptual facts in Ruby & Decety, 2003, 2004; stories in Vogeley et al., 2001). Hence, in these studies, the postcentral activity cannot be accounted for by any kind of somatosensory imagery triggered by action- or senses-related stimuli and remains to be explained.

2. The increased activity in somatosensory-related cortices for the first-person perspective coheres with the predictions made on the basis of the theoretical framework we propose here. Indeed, according to our proposal, crucial self-specific processes rely on the integration of efferent and reafferent information, that is, on sensorimotor integration.

[8] Although it falls beyond the scope of the present investigation to address this issue in more detail, it is interesting to note that our proposal coheres with the idea that schizophrenia would be notably characterized by perturbed sensorimotor integration on the one hand and, on the other hand,

> a disturbance in which the sense of the self no longer saturates the experience. For instance, the sense of *myness* of experience may become subtly affected . . . . [A patient] summarized his affliction in one exclamation: "my first personal life is lost and is replaced by a third-person perspective" (He was not at all philosophically read). (Parnas & Handest, 2003, p. 125)

Note again that the somatosensory-related cortices are not activated for the first-person perspective in contrast to a condition where the first-person perspective would not be involved at all. Rather, the somatosensory-related cortices are more activated when the first-person perspective is involved in contrast to a condition where it is attenuated (more or less strongly) to allow mental and/or spatial modulations during third-person perspective taking.

At this point, we wish to remain cautious in our interpretation of the somatosensory cortex activation for the first-person perspective. Further experiments are required to confirm these data, and to identify more specifically the cerebral correlates of self-specific processes determining the first-person perspective. Such studies would have to rely on neuroimagery and also on other relevant techniques to consider activations of single neurons and their networks. Studies in neuropsychology and psychiatry would also allow the consideration of the consequences of brain lesions and psychopathologies on the self-specific processes at stake here. In particular, our framework opens the empirically tractable hypothesis according to which a manipulation of sensorimotor processes disrupting the integration of efference with its specific reafference would lead to a modulation of the self-specific perspective. In particular, neuroscientific investigations of the self should pursue the study of the specific contribution of sensorimotor integrative processes to perspective taking. Even though such sensorimotor integrative processes have been investigated for their own sake, as well as for their implication in the evaluation of self-related contents, their role in constituting selfhood through the constitution of a self-specific perspective at a basic level remains to be further explored.

Conclusion

Gillihan and Farah (2005) asked, "Is self special?" This question was raised because the self is special intuitively and phenomenologically. In this article, we propose a framework that intends both to account for such experiential evidence and to open new possibilities for investigating the self in its specificity within the framework of cognitive neurosciences. We do not claim that all there is to the self can be subsumed under a single process but propose that both basic and complex forms of self have to rely at least partly on self-specific processes that we intend to determine theoretically and investigate empirically.

The unitary framework we propose

1. Makes it possible to demonstrate that standard conceptions of self involve self-representational processes of evaluation of self-related contents that are not self-specific;

2. Proposes a coherent and encompassing explanation of the activity of the E-network in various tasks/states and explains apparently inconsistent data yielded by different studies of the self in neuroimagery. Beyond the complexity of the issues involved, we indeed propose the following tentative hypothesis: All the tasks recruiting the E-network rely on the common cognitive processes of inferential processing and memory recall;

3. Argues that self-specificity characterizes non-self-representational processes determining the perspective that relates any represented object to the representing subject; and

4. Operationalizes the notion of first-person perspective in functional terms at the sensorimotor level, thereby allowing for further investigations of self-specific processes at the neurophysiological level.

We believe that this characterization of self-specificity allows for important progress in both theoretical and empirical investigations of the self. Indeed, facing the impasse of the equation of self with the evaluation of self-related contents, we nonetheless avoid its elimination and rather conceive the self as characterized by dynamic self-specific processes. Moreover, such characterization of the self in terms of functional processes is simultaneously phenomenologically sound and relevant for neuroimaging investigations, thereby offering a way out of the current failure of such studies to determine the self and its cerebral correlates.

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