Is Self Special? A Critical Review of Evidence From Experimental Psychology and Cognitive Neuroscience

Seth J. Gillihan and Martha J. Farah
University of Pennsylvania

Varied research findings have been taken to support the claim that humans' representation of the self is "special," that is, that it emerges from systems that are physically and functionally distinct from those used for more general purpose cognitive processing. The authors evaluate this claim by reviewing the relevant literatures and addressing the criteria for considering a system special, the various operationalizations of self, and how the studies' findings relate to the conclusions drawn. The authors conclude that many of the claims for the special status of self-related processing are premature given the evidence and that the various self-related research programs do not seem to be illuminating a unitary, common system, despite individuals' subjective experience of a unified self.

A basic goal of information-processing psychology is to characterize the computational architecture of the mind, that is, to delineate the components of the information-processing system and describe their functions. Within this common framework, theories differ according to how many distinct components are posited and how specialized their functions are. In the case of some kinds of human information processing, claims of extreme specialization have been made. Language, for example, is often said to be a product of systems that are physically and functionally distinct from those used for more general-purpose cognitive processing—in other words, language has been claimed to be special. Evidence for the claim that language is special includes its reliance on a network of perisylvian brain areas that are not needed for nonlinguistic sound recognition or vocalization and its species specificity. Face recognition is also considered special by many because it relies on parts of ventral visual cortex that are not needed for visual recognition of nonface objects and because face representation is more holistic than the representation of other objects.

In recent years another cognitive capacity has been accorded "special" status by some researchers, namely, the representation of the self. In the words of Kircher and colleagues (2000), "Processing of self-relevant information and self knowledge is regarded as distinct from processing 'objective' information" (p. 133). It is regarded by some as distinct even from the processing of infor-

mation about other people and their mental states, often termed *theory of mind;* as concluded by Vogeley and colleagues (2001), "Theory of mind and self involve at least in part separate neural mechanisms" (p. 180). Other researchers have proposed specific neural localizations of self-related processing in general, although their localizations have varied. For example, the left hemisphere has been hypothesized to be critical for recognition of our own face as well as "autobiographical knowledge, personal beliefs, currently active goal states and conceptions of self" (Turk et al., 2002, p. 842; see also Kircher et al., 2000). A similar role has also been claimed for the right hemisphere in the context of right prefrontal activation: "There is growing evidence that processing of self-related information (e.g., autobiographical memory, self-face identification, theory of mind) is related to activity in the right frontal cortex" (Platek, Myers, Critton, & Gallup, 2003, p. 147; see also Devinksy, 2000; Miller et al., 2001). It has also been noted that right lateral parietal cortex is implicated in the representation of the physical and mental self and hence plays a role in "self-representation in general" (Lou et al., 2004, p. 6831). Finally, medial prefrontal cortex in both hemispheres has been proposed as a site of the "self model . . . a theoretical construct comprising essential features such as feelings of continuity and unity, experience of agency, and body-centered perspective" (Fossati et al., 2003, p. 1943; see also Frith & Frith, 1999; Gusnard, Akbudak, Shulman, & Raichle, 2001; S. C. Johnson et al., 2002; Kelley et al., 2002; Wicker, Ruby, Royet, & Fonlupt, 2003).

A wide variety of research has been undertaken to test the claim that our representation of the self is special. The research encompasses behavioral studies with normal humans as well as with neurological and psychiatric patient populations and functional neuroimaging studies with normal humans and patients. The information-processing domains in which self processing has been examined are likewise varied, including vision, somathesis, semantic and episodic memory, and attention. The strength of support for a special "self" system comes partly from the wide array of methods used as well as the diversity of domains in which self-specific processing has been observed. Indeed, authors often cite converging evidence from different kinds of studies—for

Seth J. Gillihan and Martha J. Farah, Center for Cognitive Neuroscience, Department of Psychology, University of Pennsylvania.

Correspondence concerning this article should be addressed to Seth J. Gillihan, Center for Cognitive Neuroscience, Department of Psychology, University of Pennsylvania, 3720 Walnut Street, Philadelphia, PA 19104. E-mail: gillihan@psych.upenn.edu

example, explicitly relating first-person perspective in spatial navigation to first-person narrative comprehension (Vogeley & Fink, 2003), self-face recognition to self memory (e.g., Keenan, Freund, Hamilton, Ganis, & Pascual-Leone, 2000), or awareness of the boundaries of one's own body to awareness of relation of self to social environment (Devinsky, 2000). Wicker et al. (2003) attempted to localize brain areas recruited for self-related processing by integrating neuroimaging results from studies covering emotion, autobiographical memory, face recognition, and other processes related to the self.

Although others have presented reviews of studies that bear on the topic of self-related processing, to our knowledge none have yet addressed the specific issue of whether the self is special across a range of processing domains. Existing reviews have either addressed the question of whether the self is special in relation to a particular aspect of self-related processing (e.g., the self-reference effect in memory, described later) or summarized a broader range of findings about self-related processing without addressing the question of whether, or in what sense, it is special. Throughout this review we cite previous reviews that provide more thorough summaries of published research in various domains of self processing, and we focus our review on those studies that directly address the question of whether self-related processing is in some sense special.

We attempt to answer the question, Is self-related processing special? in the context of four related questions. The first concerns the meaning of *special*: By what criteria might we consider a system special, and which of these is relevant for each given study? The second concerns the meaning of *self*: Exactly what is meant by *self,* and how is self operationalized in each given study? The third concerns the relation between the findings and conclusions of each study: Relative to the senses of *special* and *self* being addressed in each study, how do the study's findings relate to the conclusions drawn? Finally, in the Discussion section we address the fourth question: To what degree are the many self-related research programs investigating a common system?

Criteria for Being "Special"

Systems are considered special on the basis of different criteria, which are often correlated. Four criteria are reviewed here. The most commonly cited criterion is anatomical. Engaging distinct brain areas, as demonstrated by functional neuroimaging studies, or requiring distinct brain areas, as demonstrated by lesion studies, is one sense in which a system can be said to be special. Two other types of criteria are functional. Functional uniqueness refers to the way in which information is processed within a system, rather than where it is processed. That face recognition is more holistic than other types of object recognition is a way that face recognition is functionally unique. Functional independence is a third criterion, which concerns the relations among systems. If one system's operation does not depend on another's, then they are functionally independent. The double dissociability of face and object recognition implies that the two systems are functionally independent. Finally, species specificity has been considered another way that a system—for example, language—can be special: Only humans use language.

The Many Meanings of *Self* and the Scope of This Review

Like many fundamental concepts in psychology, such as "consciousness," "attention," "perception," and "memory," the concept of "self" is difficult to define in an explicit and noncircular way. Nevertheless, most people's intuitions about what constitutes an example of self-related cognition, like most people's intuitions about what constitutes examples of these other fundamental concepts, are in agreement most of the time, and the absence of a precise definition is not necessarily an obstacle to progress. Indeed, one could argue that empirical research has clarified what we mean by these terms and that the complete definition of a concept such as "self" may emerge over time in the course of research rather than being a prerequisite for research.

A commonsensical approach to the meaning of *self* acknowledges both physical and psychological aspects. Studies of the physical self focus on either specific body parts—the face, arm, and hand—or the body as a whole and the spatial relations among its parts. For purposes of our review, the relevant studies are those that examine whether these aspects of the body are processed differently in the case of the individual's own body—for example, if one's own face is recognized in a different way from other familiar faces. Studies of the psychological self encompass knowledge of the self, including episodic memory knowledge (e.g., specific autobiographical events) and semantic memory knowledge (e.g., facts about oneself), as well as the first-person perspective of the self. Here we review studies that test whether self-knowledge and first-person perspective are functions of systems separate from knowledge of others and their perspectives. Finally, studies of agency combine elements of the physical and the psychological, in that agency concerns the role of the psychological self in causing the actions of the physical self. Cataloging the studies in this way highlights the diversity of ways in which the self has been conceptualized and operationalized. This diversity must be kept in mind as we attempt to relate the results of different studies to one another.

If there is any doubt that the concept of self is central to psychology, the results of a PsycINFO search should eliminate them. A May 2004 search of just the titles of journal articles yielded over 39,500 hits for the word *self,* corroborating the central importance of the concept to psychology and highlighting the necessity for explicit inclusion criteria for this review. It is not our intention to duplicate the reviews on self-related processing that exist already or to cover every topic that has been purported to involve "the self" (e.g., theory of mind, dissociative identity disorder, and a host of other topics). All of these research areas can indeed be conceived of as involving self-related processing, but we limit our inclusion of articles to those that bear directly on the idea of self as special. To identify these studies for the current review, we undertook keyword or title searches on PsycINFO using the terms for each topic as summarized in Table 1. We then screened the titles and abstracts of the resulting hits to determine whether candidate studies met our inclusion criteria, as outlined above. We also searched the reference sections of the articles that met our inclusion criteria and used cited reference searches to identify articles that cited particularly seminal works in a particular domain (e.g., Rogers, Kuiper, & Kirker, 1977, and the "self-reference effect") to further minimize our chances of having missed a relevant study. Finally, we asked four researchers from the field of

Table 1
Terms Used for Keyword and Title Searches on PsycINFO to Identify Studies for Inclusion

Topic	Keyword	BO	Keyword	BO	Keyword	BO	Keyword
Face recognition	Self	AND	Face	AND	Recognition	AND	Recognition
Body, posture, and movement recognition	Self	AND	Body OR movement OR posture	AND		AND	Recognition
Agency	Self	AND	Agency[a]	AND		AND	
Traits	Autobiographical OR self[a]	AND	Trait OR characteristic OR knowledge[a]	AND		AND	
Self-reference effect	Self	AND	Reference	AND		AND	Effect OR memory
Autobiographical memory	Autobiographical	AND	Memory	AND		AND	Self
First-person perspective	First	AND	Person	AND		AND	Perspective OR view OR awareness

Note. BO = Boolean operator.
[a] Denotes title search; all other terms represent keyword searches.

self-related processing to read a draft of our article, and each of these individuals made suggestions about studies to include, as did five anonymous reviewers. Table 2 provides a listing of the studies we review that fall under the various physical and psychological domains, organized by sense of special.

The Physical Self

As human beings, our awareness of our own bodies is perhaps the most fundamental aspect of self-awareness—the centering of our subjective experience in our physical bodies. In addition to recognition and awareness of having a body, we are able to recognize our own images, either in a mirror or in photographs. Awareness of one's own actions—the experience of agency—constitutes a third dimension of the physical self, and one that provides a bridge between the physical and psychological selves. Much work has been done in these areas; for the purposes of the present review we focus on studies that specifically address the question of whether self-related processing in the physical domain is special.

Face Recognition

We begin by reviewing the cognitive neuroscience of self-face recognition. One of the earliest contributions to research on the self was made by Gordon Gallup (1970, 1979), who attempted to operationalize self-awareness in animals and humans by studying the subjects' responses to the sight of their own face in a mirror. In a typical experiment, the subject's face is marked without the subject's awareness, and the subject then views him- or herself in a mirror. Self-awareness is indicated if the subject investigates the mark by touching his or her own face, as this behavior shows that the subject recognizes the correspondence between his or her own face and the face in the mirror. Chimpanzees and orangutans, and of course humans, pass this test of facial self-awareness, whereas other animals—including monkeys—do not (Gallup, 1970; Suarez & Gallup, 1981; for more detailed reviews of studies in this area, see Anderson, 1994; Anderson & Gallup, 1999; Gallup, 1991; Inoue-Nakamura, 2001). This finding has been expressed as the "demonstration of a self-concept in a subhuman form" (Gallup, 1970, p. 87). In humans this ability is developed in most children by the age of 18 to 24 months (Anderson, 1984; D. B. Johnson, 1983).

By what criteria do these results indicate special processing of self-related information? Although neither the anatomical specificity nor the functional uniqueness of self-awareness is addressed by these studies, the species specificity is: In contrast to other species, only chimps, orangutans, and humans seem to possess this ability. To what extent does the mirror test measure self-representation? Although an animal or a child must certainly be able to recognize that the mirror image corresponds to the self in order to pass this test, the test could be failed for a number of reasons other than the absence of a self-concept. For example, the test requires understanding the relation between real space and reflected space (Priel & de Schonen, 1986; see also Heyes, 1995; R. W. Mitchell, Parker, & Boccia, 1994). Even assuming for the moment that the species-specific cognition underlying mirror self-recognition is related to the self-concept rather than some more general intellectual capacity (and see Anderson & Gallup, 1999, for a response to various critiques), the data do not tell us whether

Table 2
Evidence Addressing Whether the Self Is Special, Organized by Domain and Sense of "Special"

Sense of *special*	Physical domains			Psychological domains		
	Face	Body	Agency	Traits	Memory	First-person perspective
Anatomical	Sperry et al. (1979); Preilowski (1979); Sugiura et al. (2000); Keenan et al. (1999, 2000, 2001, 2003); Kircher et al. (2000, 2001); Turk et al. (2002); Platek & Gallup (2002); Platek et al. (2004)	T. E. Feinberg (2001); Goldenberg (2003)	Farrer & Frith (2002); Ruby & Decety (2001); McGuire et al. (1996); Leube et al. (2003)	Craik et al. (1999); Kircher et al. (2001, 2002); Miller et al. (2001); S. C. Johnson et al. (2002); Kelley et al. (2002); Kjaer et al. (2002); Platek, Myers, et al. (2003); Fossati et al. (2003); Macrae et al. (2004)	Conway et al. (1999); Fink et al. (1996); Maguire & Mummery (1999)	Vogeley et al. (2001); Lane et al. (1997); Gusnard et al. (2001)
Functional uniqueness/ independence		Reed & Farah (1995)		Self-reference effect (various authors); Klein et al. (2002)		
Species specificity	Gallup (1970, 1979); Suarez & Gallup (1981)					

the self is represented separately from other persons. That is, passing the mirror test could reflect the operation of person representations that are used for representing both self and others. Therefore, we cannot conclude on the basis of the existing data that self-face recognition is special in the species-specific sense.

In addition to questions about species specificity, researchers have investigated questions about the neural localization of self-face recognition in humans. These studies address the hypothesis that the self is special in face recognition in the sense of anatomical specificity. The earliest of these studies used split-brain patients to address the issue of hemispheric specialization for self-face recognition. Sperry, Zaidel, and Zaidel (1979) tested subjects whose two cerebral hemispheres had been surgically disconnected in order to control medically intractable epilepsy. As a result of this surgery, any picture projected to one hemisphere (through brief lateralized presentation) can be processed only by that hemisphere. Sperry and colleagues found that self-recognition was possible in both hemispheres. However, in another split-brain study by Preilowski (1979), evidence was found for greater right hemisphere involvement in self-face recognition. A patient was presented images of self, other persons, and other stimuli to one hemisphere at a time while skin conductance was measured. The greatest responses were obtained when self-images were presented to the right hemisphere, suggesting the involvement of the right hemisphere in self-face recognition and specifically the activation of emotional centers in the right hemisphere.

A different split-brain patient was tested on the ability of each hemisphere to recognize his own face when morphed with the face of another (Turk et al., 2002). The researchers projected to one cerebral hemisphere at a time images of the patient's own face combined with the face of one of the authors, a familiar person to the patient, varying the degree to which his own face was morphed; the subject was to indicate whether the face was the subject's or the author's. By this measure, it was the left hemisphere of this split-brain patient rather than the right that preferentially recognized the subject's own face. This effect was replicated using three highly familiar others. Turk et al. (2002) concluded that the left hemisphere may in fact have a special role to play in the "self-memory system" (p. 842). Contrasting results were reported by Keenan, Wheeler, Platek, Lardi, and Lassonde (2003), who presented to a split-brain patient morphed images ranging from 100% the patient's face to 100% a famous person's face (Bill Clinton's); the subject's task was to indicate with either his left or his right hand whether the presented morph contained portions of his own face. As a control, the patient completed the same task but with his own image replaced by the image of another familiar person (a familiar experimenter's face) morphed with Bill Clinton's face. As predicted by right hemisphere superiority, the left hand responses were more accurate, and only in the self condition.

Hemispheric specialization for self-face recognition has also been studied in neurologically intact subjects. In the first of these studies, Keenan and colleagues (1999) presented subjects with upright and inverted pictures of their own face, a familiar other's face, and a stranger's face. The subjects' task was to indicate as quickly as possible which face it was by pressing one of three buttons with their right hand in one condition and left in another (resulting in six conditions—three types of faces times two hands). Results indicated a significant reaction time advantage for the self faces when subjects pressed the button with their left hand, which

is primarily controlled by the right hemisphere—that is, their reaction times for this condition were significantly faster than their reaction times in any of the other five conditions. In another study, subjects were shown morphed images of their own face and the face of a famous person (Keenan et al., 2000), similar to the design used in Keenan et al.'s (2003) patient study. Subjects were to indicate when the face looked more like themselves or more like the famous person, responding as before with either their left or their right hand and again with morphed images of a familiar person as a control. As predicted, left hand (right hemisphere controlled) responses were significantly more likely to identify the morphs as self than right-hand responses, whereas there was no significant difference between hands in the control condition. A final study that used the response-hand reaction time paradigm also reported a significant advantage for the left hand when subjects were reacting to pictures of their own faces versus the face of a famous person (Platek & Gallup, 2002).

In other studies, Keenan's group sought more direct evidence of hemispheric involvement in self-face recognition than is permitted by analyzing the effects of response hand. They used two methods of inactivating the cerebral hemispheres one at a time, using anesthesia (the "Wada test") with presurgery epilepsy patients and transcranial magnetic stimulation (TMS) with normal subjects (Keenan et al., 2001). Following inactivation of one hemisphere, patients were presented pictures of their own face morphed with that of a famous person's face. After recovery from anesthesia, they had to choose which of two faces they had been shown: either their own face or the face of the famous person, neither of which they actually had seen. Patients were much more likely to say they had seen the famous face if their right hemisphere had been anesthetized. Similar results were found for the normal subjects treated with TMS. Using motor-evoked potentials in response to TMS as an indication of brain activity, Keenan et al. found that the greatest brain activation of all experimental conditions was in the right hemisphere when subjects viewed their own faces. The results of these studies accord well with the previous two in supporting the existence of "hemispheric differences in the processing of self-related stimuli"—differences that they propose may be "a 'self-effect' rather than a 'self face-effect'" (Keenan et al., 1999, p. 1424).

Sugiura et al. (2000) used positron-emission tomography (PET) imaging to localize self-face recognition. A sequence of face pictures was shown, and subjects were instructed to judge the orientation of each picture (tilted to the left or right). In the self condition, pictures of the subject's own face were intermixed with pictures of strangers, whereas in the control condition the faces were all unfamiliar. In the "active" version of the task, subjects were instructed also to indicate when they saw their own picture, whereas in the "passive" version they were not given this instruction. Brain areas that were more active in the active condition relative to control included the left anterior insula, putamen, and pulvinar, as well as the right anterior cingulate and globus pallidus; areas more active in the passive condition relative to control included left fusiform gyrus and anterior cingulate plus right supramarginal gyrus, superior parietal lobule, and precuneus. Because neither task included a familiar face other than the subject's own face, we cannot know whether this activity reflected recognition of familiarity or selfhood per se.

Platek, Keenan, Gallup, and Mohamed (2004) used functional magnetic resonance imaging (fMRI) to localize brain activity in a face recognition task with the subject's own face intermixed with famous faces; subjects were instructed to think about the identity of the person pictured. The authors reported that self pictures evoked more right frontal activity in the middle, superior, and inferior frontal gyri.

Kircher and colleagues (2000) used morphed self–other images, similar to those of Keenan's earlier studies, with fMRI. Subjects viewed images of either their own face or the face of a familiar other, their partner, morphed with an unknown face, while attempting to classify the images as self, partner, or unknown. Increased activation for the self versus partner contrast was found in the right limbic system (insula, hippocampal formation, and lenticular/subthalamic nucleus) and in left prefrontal cortex (PFC; inferior and middle frontal gyri), along with additional activations in the right middle temporal gyrus and left cerebellum, parietal lobe, and lingual gyrus.

In sum, a number of studies have operationalized self-face processing in similar ways, with some using experimental paradigms that permit inferences about the self per se because of the familiar nonself-face control condition. Their methods for measuring brain activity were very different, with complementary strengths and weaknesses: For example, functional neuroimaging provides intrahemispheric localizing information but does not address the necessity of an area for a particular type of processing, whereas the Wada test and the split-brain preparation have the opposite pattern of strengths and weaknesses. The results of these different studies are inconsistent and cannot be reconciled simply in terms of the different strengths and weaknesses of the approaches: Two split-brain patients showed bilateral self-face recognition ability (Sperry et al., 1979) with greater right hemisphere involvement noted in two other cases (Keenan et al., 2003; Preilowski, 1979) and greater left hemisphere specialization reported in yet another (Turk et al., 2002). Keenan and collaborators inferred right hemisphere specialization for self-recognition in this task using normal subjects' response asymmetries, the Wada test, and TMS. The same group also reported right frontal activation in a slightly different task using fMRI (Platek et al., 2004), although a more similar task was reported to activate predominantly left frontal areas (Kircher et al., 2000). In short, a clear pattern of anatomical localization has yet to emerge for self-face recognition (see Table 3 and Figure 1). At the present time the most one can say with confidence is that both hemispheres probably participate to some degree but that right prefrontal areas may be particularly important.

Body Recognition

The physical self, of course, includes the entire body as well as the face, and one can inquire whether the internal representation of our own bodies or bodily actions is distinct from those of others—that is, whether self-body representation is special. There is relatively little evidence available on the processes by which people recognize their own body parts other than faces. Within experimental psychology, the most relevant studies have merely measured the accuracy with which people discriminate photographs or videos of their own hands or handwriting from others' and have found surprisingly low performance (e.g., Wolff, 1932). This does not so much answer the question of whether the bodily self is represented by a separate system from other bodies as whether the

Table 3
Brain Regions Associated With Various Operationalizations of Self

| Study by domain	Operationalization of self	Left hemisphere			Right hemisphere		
		PFC	Limbic	Other	PFC	Limbic	Other
Physical							
Face (Figure 1)							
Sperry et al. (1979)	Presentation of self-faces to either hemisphere following commissurotomy	Both hemispheres capable of self-face recognition					
Preilowski (1979)	Galvanic skin response to lateralized presentation of self-face and other images				Largest response to right hemisphere self-face presentation		
Sugiura et al. (2000)	Greater activation for active self vs. other identification			Anterior insula, putamen, pulvinar	Anterior cingulate gyrus		Globus pallidus
Sugiura et al. (2000)	Greater activation for passive self vs. other identification	Anterior cingulate gyrus		Fusiform gyrus			Supramarginal gyrus, superior parietal lobule, precuneus
Keenan et al. (1999)	Hand difference in reaction time for self-face recognition					Unspecified right hemisphere	
Keenan et al. (2000)	Hand difference in reaction time for self-face recognition					Unspecified right hemisphere	
Keenan et al. (2001)	Hemispheric difference in self-face recognition					Unspecified right hemisphere	
Platek & Gallup (2002)	Hand difference in reaction time for self-face recognition					Unspecified right hemisphere	
Turk et al. (2002)	Hemispheric difference in self-face recognition in split-brain patient		Unspecified left hemisphere				
Kircher et al. (2000, 2001)	Greater activation for self vs. partner face recognition	Inferior frontal gyrus		Inferior parietal, cerebellum, lingual gyrus, fusiform gyrus		Hippocampal formation	Insula; subthalamic nucleus, middle temporal gyrus
Keenan et al. (2003)	Discrimination of self and other faces following commissurotomy					Unspecified right hemisphere	
Platek et al. (2004)	Greater activation for self vs. famous face recognition				Inferior, middle, superior frontal gyri		
Body							
T. E. Feinberg (2001); T. E. Feinberg et al. (1990)	Asomatognosia: lack of recognition of one's own body part						Inferior parietal
Goldenberg (2003)	Autopagnosia: loss of knowledge of the spatial locations of, and relations among, body parts			Parietal			

(table continues)

Table 3 (continued)

Study by domain	Operationalization of self	Left hemisphere			Right hemisphere		
		PFC	Limbic	Other	PFC	Limbic	Other
Agency (Figure 2)							
Farrer & Frith (2002)	Greater activation for self-guided vs. other-guided cursor			Anterior insula			Anterior insula
Ruby & Decety (2001)	Greater activation for imagined self vs. other movement			Inferior parietal, posterior insula, postcentral gyrus, inferior occipital gyrus			Inferior occipital gyrus
Leube et al. (2003)	Greater activation for self vs. other movement and movement mismatch	Inferior frontal gyrus		Middle occipital	Inferior frontal gyrus		Inferior temporal, superior parietal, middle and inferior occipital
McGuire et al. (1996)	Greater activation for incongruent vs. congruent reading aloud conditions	Medial frontal pole		Superior temporal sulcus, insula/frontal operculum	Medial frontal pole		Superior/transverse temporal gyrus, superior temporal sulcus
Traits (Figure 3)							
Miller et al. (2001)	Change in self following degenerative disease						Fronto-temporal regions
Craik et al. (1999)	Greater activation for self vs. other trait adjectives	No significant differences between the self and other conditions					
Kircher et al. (2000)	Greater activation for self- vs. nonself-descriptive trait adjectives	Anterior cingulate, inferior frontal gyrus	Insula	Superior parietal, precuneus, postcentral gyrus, putamen, medial geniculate body; fusiform gyrus			Precuneus
Kircher et al. (2002)	Greater activation for incidental judgment of self- vs. nonself-descriptive trait adjectives	Inferior frontal gyrus		Superior temporal gyrus, lingual gyrus, superior parietal lobule			Inferior parietal lobe, middle temporal gyrus
Kelley et al. (2002)	Greater activation for self- vs. other-descriptive trait adjectives	Medial PFC		Posterior cingulate	Medial PFC		Posterior cingulate
S. C. Johnson et al. (2002)	Greater activation for self-reflection vs. semantic task	Medial PFC		Posterior cingulate	Medial PFC		Posterior cingulate
Kjaer et al. (2002)	Greater activation for reflection on self vs. other traits	Middle frontal gyrus		Precuneus, inferior parietal, supplementary motor area	Superior frontal gyrus		Precuneus, inferior parietal, supplementary motor area
Fossati et al. (2003)	Greater activation for self-description vs. semantic judgment	Medial PFC		Posterior cingulate	Medial PFC		
Platek, Myers, et al. (2003)	Hand differences in reaction time for words judged to be self-descriptive				Unspecified right hemisphere		

Table 3 (*continued*)

Study by domain	Operationalization of self	Left hemisphere			Right hemisphere		
		PFC	Limbic	Other	PFC	Limbic	Other
Traits (Figure 3) (*continued*)							
Macrae et al. (2004)	Greater activation for words judged to be self-descriptive	Medial PFC			Medial PFC		
Lou et al. (2004)	Greater activation for reflection on self *vs.* other traits						Inferior parietal
Memory (Figure 4)							
Hokkanen et al. (1995)	Retrograde autobiographical amnesia (but no evaluation of nonautobiographical memory)			Temporal lobe lesion			
Hodges & McCarthy (1993)	Impaired autobiographical memory with spared knowledge of famous people and public events following infarction			Paramedian thalamus			Paramedian thalamus
Conway et al. (1999)	Greater activation for autobiographical memory vs. memory control condition	Inferior, middle, and superior frontal gyri		Posterior and middle temporal gyri; occipital; posterior parietal; inferior temporal			
Maguire & Mummery (1999)	Greater activation for autobiographical vs. nonautobiographical memories	Medial PFC		Temporal pole; temporoparietal junction; hippocampus	Medial PFC		Temporoparietal junction
Fink et al. (1996)	Greater activation for autobiographical vs. nonautobiographical memories					Periamygdaloid	Superior and medial temporal gyri; anterior insula; posterior cingulate
First-person perspective (Figure 5)							
Gusnard et al. (2001)	Greater activation for internally vs. externally cued conditions	Dorsal medial PFC	Insula		Dorsal medial PFC		Cerebellum; insula
Lane et al. (1997)	Greater activation for focusing on emotional aspects vs. spatial properties of photos	Anterior cingulate	Insula		Anterior cingulate		Temporal pole
Vogeley et al. (2001)	Greater activation for theory-of-mind vs. self conditions	Anterior cingulate	Temporoparietal junction; precuneus		Anterior cingulate		Temporoparietal junction; superior parietal; precuneus; motor cortex

Note.   Where anatomical localizations are based on neuroimaging studies, only those areas more active in the self condition (vs. control condition) are listed. Areas of neural activity based on neuroimaging studies are depicted graphically in Figures 1–6; Figure 6 shows all areas of activation across domains. PFC = prefrontal cortex.
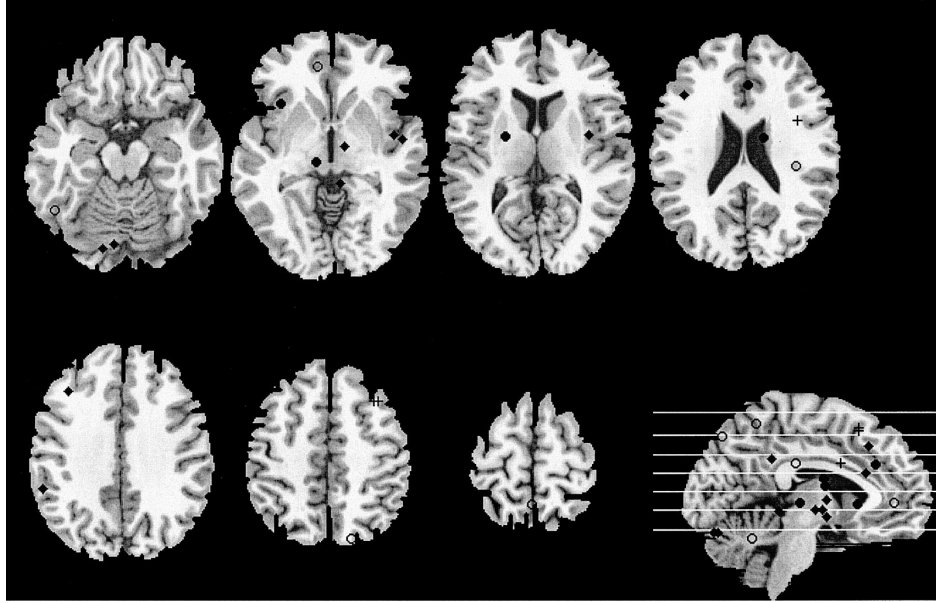
Figure 1. Brain regions reported to be more active when viewing one's own face versus a familiar other's face. Activation foci are shown in axial slices of the standard Montreal Neurological Institute brain (right is right), taken at the levels shown in the sagittal slice. The symbols represent the center of these activations according to the Talaraich coordinates provided by the authors and do not show the volume of activation. The sagittal view shows these symbols in "glass brain" view, such that all areas of activation are visible regardless of whether they fall on the midline. Symbols correspond with the following studies: ◆ = Kircher et al. (2001); + = Platek et al. (2004); ○ = Sugiura et al. (2000), passive condition; ● = Sugiura et al. (2000), active condition.

representations used to discriminate own and other bodies (be these representations separate or integral) are precise.

Within clinical neurology, there are many disorders of bodily sensation, action, and awareness (see Goldenberg, 2003, for a review), the most relevant being autotopagnosia and asomatognosia. Autotopagnosia refers to the loss of knowledge of the spatial locations of, and relations among, body parts. One might suspect, from the presence of the word root *auto,* that the disorder is limited to the patient's own body, and if this were true it would imply that the representation of the self's body is special in the senses of neuroanatomical specificity and functional independence. However, knowledge of the spatial layout of other people's bodies is equally impaired (Goldenberg, 2003). Patients with autotopagnosia cannot point to named body parts on command, either on themselves, the experimenter, a mannequin, or even a picture. Thus, autotopagnosia does not support the existence of a separate system for representing the physical self, distinct from others. On the contrary, it demonstrates the existence of a body-specific representation that is common to the self's body and other bodies.

In contrast, the disorder of asomatognosia involves a clear distinction between knowledge of self and others. Following brain damage that results in paralysis of an arm, these patients steadfastly maintain the belief that the paralyzed arm is not theirs. They often suggest that it belongs to a friend or family member, or to the clinician questioning them. For example, Todd Feinberg (2001) reported the following exchange with an asomatognosic patient, excerpted here to demonstrate the surprising tenacity of delusion:

Doctor: I want to ask you again now. What is this over here? Take a look at this over here. What is it?

Patient: Your fingers.
Doctor: My fingers?
Patient: Yes.
Doctor: Look at them again, take a good look now. OK . . . tell me what they are. . . .
Patient: The back of your hand. . . .
Doctor: Suppose I told you this was your hand.
Patient: I wouldn't believe you. . . .
Doctor: This is your hand.
Patient: No.
Doctor: Look, here's your right hand, and here's your left hand.
Patient: OK.
Doctor: Now, what's this [*holding out her left hand*]?
Patient: The back of your hand. (pp. 9–10)

Asomatognosia implies that awareness of one's own hand and arm is special in the sense of anatomical specificity: It depends on a brain area that can be selectively damaged—specifically, right supramarginal gyrus and adjacent white matter (T. E. Feinberg, Haber, & Leeds, 1990). Furthermore, it is specific to the self in that patients do not misattribute ownership of other people's limbs.

Another type of body-related information for which the self might potentially play a special role is information about bodily movement (see Jeannerod, 1997, for a thorough review of the cognitive neuroscience of action). Reed and Farah (1995) found an effect of people's own movements on their working memory for the position of other people's bodies but not for the position of other objects. The sense of "special" tested here concerns the functional independence of cognitive systems, specifically between the representation of body and nonbody position. In this

study, normal subjects performed a working memory task for body position, in which they viewed a model in one position, maintained their representation of that person's position over a brief delay, then viewed the model again, and judged whether the model had moved any part of her body. Subjects' ability to make this judgment depended on what they were doing with their own bodies at the time; when they were moving their own arms, they were more sensitive to changes in the model's arm position, and when they were moving their own legs they were more sensitive to changes in the model's leg position. This effect was body specific, in that subjects' movements had no spatially selective effect on judging the positions of abstract three-dimensional objects. It was also outside of attentional control, as it occurred even when subjects were instructed to attend to a different part than they were moving, satisfying one of Fodor's (1983) criteria for modularity, namely mandatory functioning. This pattern of results supports the existence of a special body-specific representation. As with autotopagnosia, however, it implies the very opposite of specialized self-representation, as the body-specific representation that is engaged during self movement appears to be engaged mandatorily when representing others' body positions.

Agency

The sense of agency represents a link between the psychological self and the physical self—specifically, the recognition of being the cause of an action (see Blakemore & Frith, 2003, for a review of agency and the self). It relies on both a recognition of one's body as one's own and of the actions as caused by oneself, or in the words of Jeannerod et al. (2003), "ownership" and "authorship." Alterations in sense of agency associated with an action can potentially reveal self-specific representations, either through experimental manipulations of the sense of agency or in pathological states that affect sense of agency.

Schizophrenia appears to involve alterations in the sense of self (a theory proposed by I. Feinberg in 1978; see also Daprati et al., 1997; Frith, 1992; Vogeley, Kurthen, Falkai, & Maier, 1999; for a comprehensive overview, see Kircher & David, 2003), including the overextension of agency to the actions of others (delusions of influence) and the attenuation of agency (thought insertion and delusions of alien control). Of direct relevance to the localization of agency, a PET study comparing schizophrenic patients while experiencing delusions of alien control and after resolution of this symptom found that the delusion of alien control was associated specifically with right parietal cortex hyperactivation (Spence et al., 1997).

A PET study of imagined movement provides another perspective on the neural substrates of agency. Ruby and Decety (2001) instructed subjects to imagine either themselves or the experimenter engaged in such actions as stapling a sheet of paper or peeling a banana. Imagined self-action, compared with experimenter action, activated the left inferior parietal lobule, posterior insula, and post-central gyrus, as well as bilateral inferior occipital gyrus; imagined experimenter action activated left posterior cingulate cortex and right precuneus, inferior parietal cortex, and frontopolar gyrus.

A more direct approach to mapping the anatomy of agency, taken by a number of recent studies, is to vary the congruence between subjects' intended and perceived actions (e.g., Farrer & Frith, 2002; Jeannerod et al., 2003). For example, Farrer and Frith

(2002) scanned the brains of subjects while they used a joystick to control the motion of a visually presented cursor, conferring a sense of agency, or used a disconnected joystick while watching the cursor move under the experimenter's control, a condition violating agency despite its similarity to the first in sensorimotor processing. Results were consistent with those of Ruby and Decety (2001), implicating bilateral insula activity in the experience of agency and bilateral parietal activity, including right inferior parietal cortex and left lateral premotor cortex, in the experience of external control. Leube, Knoblich, Erb, and Kircher (2003), using a similar experimental paradigm, reported right superior parietal cortex activity when subjects experienced a mismatch between their own action and the observed action of a hand, along with right inferior frontal activation; they also reported visual system activity, which they interpreted as being a result of visual differences in stimuli across conditions. Similar activations in the visual system (occipital cortex) were reported when subjects watched themselves perform an action with their hand versus watching a foreign hand perform the same action.

McGuire, Silbersweig, and Frith (1996) carried out the verbal analogue of this design, comparing reading aloud while hearing one's own natural voice and reading aloud while hearing either a transformed voice or the experimenter's voice. There was increased activity in lateral temporal cortex bilaterally, greater on the right, during the incongruent voice conditions (see Table 3 and Figure 2 for more details).

Taken together, these studies suggest that the experience of agency is special in the sense of anatomical specificity. For limb movements, the trend is for insular and right parietal cortices to be implicated in the sense of agency and violation of agency, respectively. For speech, lateral temporal cortex rather than parietal is implicated, with greater response on the right side.

In sum, the literature as a whole fails to support the idea of a special system of representation for the physical self, integrating facial appearance, the layout of the body's parts, body part ownership, position, and agency. Different aspects of the physical self appear to be represented in different ways, with some aspects clearly violating the hypothesis that the representation of self is special. For example, autotopagnosia implies that our knowledge of the spatial layout of our body parts is distinct from knowledge of the spatial layouts of other kinds of parts within complex wholes that are not bodies. However, the extension of the disorder to the localization of body parts on other people implies that the layout of our own body is represented in common with the layout of other people's bodies. Similarly, when we move and keep track of the position of a part of our body, we automatically engage body-specific representations, but these are also used to process the positions of other people's bodies. Evidence of specialization for self-face recognition, in the sense of anatomical specificity, is mixed, with a strong trend toward right prefrontal localization in the work of one lab. However, there are some aspects of the physical self that may be special. Asomatognosia implies the functional independence and anatomical specificity of body part (generally arm and hand) ownership, and a small number of imaging studies have repeatedly isolated a common set of areas involved in the experience of an action as caused or not caused by the self (see Table 3 and Figure 2). Thus, the senses of self constituted by body part ownership and action ownership, or agency, appear to be special.
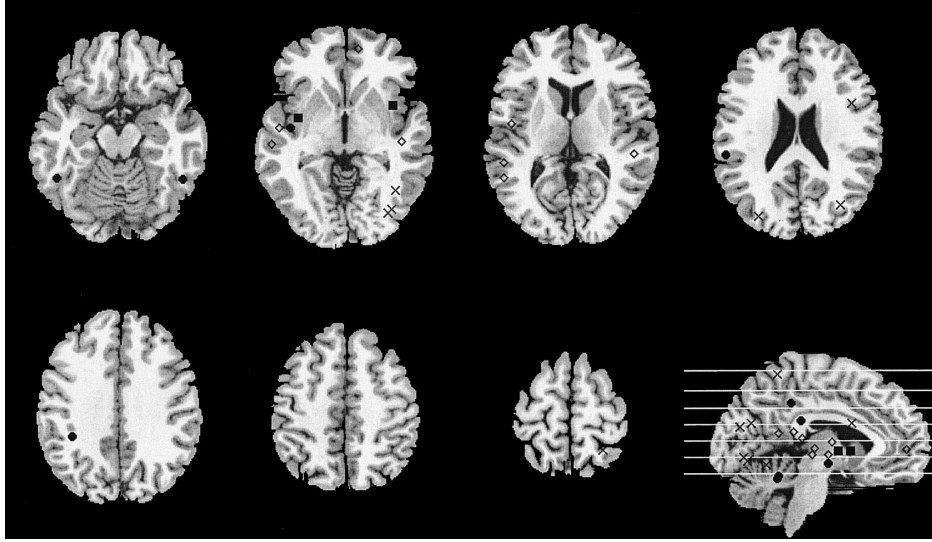
Figure 2. Brain regions reported to be more active when experiencing oneself versus someone else as being responsible for an action. Activation foci are shown in axial slices of the standard Montreal Neurological Institute brain (right is right), taken at the levels shown in the sagittal slice. The symbols represent the center of these activations according to the Talaraich coordinates provided by the authors and do not show the volume of activation. The sagittal view shows these symbols in "glass brain" view, such that all areas of activation are visible regardless of whether they fall on the midline. Symbols correspond with the following studies: ■ = Farrer and Frith (2002); ● = Ruby and Decety (2001); × = Leube et al. (2003); ◇ = McGuire et al. (1996).

Psychological Self

Perhaps not surprisingly, most research on the self in psychology concerns the psychological self: our personal traits, our autobiographical memories, and the subjective perspective from which we view the world. The literature on the psychological self can be classified into these three categories. As with our review of the literature on the physical self, we focus specifically on research relevant to the question of whether the self is special. More general reviews of related areas have addressed episodic memory and the frontal lobes (Wheeler, Stuss, & Tulving, 1997), self as an organization of knowledge (Greenwald, 1980), autobiographical memory (Conway & Rubin, 1993), and the development of autobiographical memory (Fitzgerald, 1986; Howe & Courage, 1997). Symons and Johnson (1997) provide a review of the literature on the self-reference effect in memory, which is discussed below in the context of several of the studies in this area. Klein, Loftus, and others have done significant work on the nature of trait self-knowledge (e.g., Klein, Babey, & Sherman, 1997; Klein, Loftus, & Plog, 1992; Klein, Loftus, & Sherman, 1993; Klein, Sherman, & Loftus, 1996), as well as work on the nature of trait other-knowledge (e.g., Klein & Loftus, 1990; Klein, Loftus, Trafton, & Fuhrman, 1992).

Traits

Traits, and knowledge of one's traits, have been studied in a number of ways, including behavioral observation of neurological patients, behavioral studies of normal subjects contrasting memory for self-related and self-irrelevant material, and imaging studies of normal subjects judging whether specific traits characterize them. Miller et al. (2001) focused on the neural basis of psychological traits in a study entitled "The Neuroanatomy of the Self." Review-

ing the charts of 72 patients with primarily left, right, or bilateral frontotemporal dementia, they sought to identify patients who had undergone "a shift from a previously well-defined self to a new well-defined self," where self was defined as "temporally stable, trans-situational consistencies in behavior, dress, or political or religious ideology" (Miller et al., 2001, p. 818). They found a relatively high incidence of change in normally stable traits such as political views and attitudes toward religion in patients with right hemisphere disease (though oddly enough not in bilateral patients who also have right hemisphere disease). They concluded that the right frontotemporal regions are crucial for the maintenance of enduring personality traits and attitudes, a claim that self is special in the sense of anatomical specificity. This research captures an interesting generalization about psychological traits and the brain. However, not all generalizations about personal traits pertain to the self—otherwise, all of personality psychology would qualify as the study of the self. Rather, traits figure in research on the self insofar as they are part of the individual's self-concept.

A recent case study with a neurological patient investigated trait self-knowledge. Klein, Rozendal, and Cosmides (2002) tested a patient who demonstrated severe amnesia for episodic autobiographical memory relative to controls and significant amnesia for semantic autobiographical memory. Relevant to the question of whether knowledge of one's own traits is part of a special self system, the authors noted that he had relatively better preserved knowledge of his own traits than of his daughter's traits. The correlation between the patient's and daughter's ratings of the patient's traits ($r = .64$) was almost identical to the correlation of ratings of control participants by the participants and their children ($r = .62$). However, the correlation between the patient's ratings of his daughter's traits and his daughter's own ratings was not significant ($r = .23$), whereas the parallel correlation between control

participants and their children was substantially greater ($r = .61$). What is unclear from this interesting case study is whether the discrepancy between the patient's knowledge of his own traits and his daughter's is more than could be expected by chance.

The memory literature in cognitive psychology and cognitive neuroscience contains many studies of the *self-reference effect* (SRE) that are directly related to the question of whether we represent knowledge of our own traits differently from knowledge of other people's. The SRE is the beneficial effect of encoding material with reference to oneself and is consistent with a functionally distinct memory system for self-knowledge. One of the first studies to report an SRE was by Rogers et al. (1977). They compared memory for adjectives in four experimental conditions, in which the subject was asked to judge (a) the size of the letters that made up the word, (b) whether the word rhymed with another word, (c) whether the word was a synonym for another word, or (d) whether the word described the subject. At the end of the encoding phase, subjects were given a blank piece of paper and asked to recall as many of the words as they could. The crucial comparison for Rogers et al. was between conditions (c) and (d) above, the semantic and self-reference conditions, respectively. They found that words rated with respect to the self were better recalled than words receiving more general semantic processing. They concluded that the self comprises "a superordinate schema" and that the superior recall of words in the self-reference condition "is due to the access of this schema" (p. 685). The SRE in memory has been replicated many times (see Symons & Johnson, 1997, for a full review). However, its interpretation has changed as further experiments have been done.

Subsequent studies in this area have found evidence for factors that influence memory for self-related information and questioned the need to hypothesize a unique self schema. Bower and Gilligan (1979) questioned whether the key distinction was between self and nonself schemata or between any well-known person and other semantic schemata. They found a memory-enhancing effect both for self-reference and for reference to one's mother. They concluded that "there is nothing special about the self-schema as a mnemonic peg; any well-differentiated person will do" (Bower & Gilligan, 1979, p. 429). Ferguson, Rule, and Carlson (1983) proposed that judging words for self-descriptiveness involves evaluative judgments and found evidence that simply making an evaluative judgment, even without reference to oneself (e.g., "Is this word a desirable characteristic?"), produced memory enhancement to the same extent as self-referent encoding. These results provided further evidence that the crucial factor in the SRE is depth of processing and not reference to the self per se.

Other factors contributing to the SRE were discovered by Klein and colleagues. They found that organization and elaboration are typically confounded with self versus other. For example, the task of organizing words into "like me" and "not like me" categories involves a more complex organization than simple semantic judgments, in which no categorization is required. Klein and Kihlstrom (1986) experimentally equated the amount of organization in semantic and self-referent encoding tasks and found that recall of semantically encoded and self-referentially encoded words was nearly numerically identical. Klein and Loftus (1988) demonstrated that elaborative processing is typically confounded with self versus nonself memory. Elaboration, by which is meant forming multiple associations between the target word and other material in memory, aids the encoding of memories by creating

multiple routes for retrieval as well as supporting inference-based reconstruction when retrieval fails.

The results of recent meta-analyses support the hypothesis that the SRE results from the effects of a number of highly confounded variables on memory. Symons and Johnson (1997) meta-analyzed the results from 42 studies of the SRE in memory and found that both organization and elaboration are responsible for the SRE, concluding, "It is premature to conclude that the self is a unique structure" (p. 392; for related views, see Greenwald & Banaji, 1989; Higgins & Bargh, 1987). In his meta-analysis of the SRE literature, U. Czienskowski (1997) suggested that mediators and moderators of the SRE include word type (particularly the concreteness of the words) and intimacy of the relationship with the "other" (see also W. Czienskowski & Giljohann, 2002; Lord, 1980).

Despite the existence of alternative explanations for the SRE in memory, self-reference paradigms have formed the basis for several studies of the brain bases of the self. Of course, the neuroscience approach could in principle distinguish among the alternative explanations if the self schema were anatomically distinct from other memory schemata. For all of the studies to be reviewed here, not only those based on the SRE, the sense in which the self is special concerns its anatomical locus relative to nonself processing.

Platek, Myers, et al. (2003) studied hemispheric specialization for self-trait knowledge. They asked subjects to indicate with either their left or right hands whether trait adjectives described the subject, someone the subject knew, or neither. They found a left hand advantage, implying right hemisphere superiority, for normal subjects, which was attenuated for those with higher levels of schizotypal personality (see I. Feinberg, 1978). A number of imaging studies have used similar tasks to address the hemispheric and intrahemispheric localization of trait self-knowledge.

Craik et al. (1999) reported a PET study of normal subjects making self-referent judgments about trait adjectives (self condition) and three other comparison judgments: whether the term describes a famous person (other condition), whether it is positive or negative (general condition), and how many syllables it has (syllable condition). This last task was used as a baseline that was subtracted from the self, other, and general conditions. Results from comparisons among these three semantic judgments yielded only one significant difference in relative regional cerebral blood flow: The self condition produced more activation of the right anterior cingulate area than did the general condition. The contrast of potentially greatest interest, namely, that between self and other judgments, was not significant. Indeed, the authors pointed out that "every significant activation in the *self-syllable* contrast was also found in either the *other-syllable* contrast or the *general-syllable* contrast, or both" (Craik et al., 1999, p. 30). In further analyses aimed at isolating self-related processing, they found activation of medial and right frontal areas when the self condition was compared with the combination of the other three conditions. However, the latter combination includes the syllable condition, and it is not clear what meaningful hypothesis is tested by a contrast with the three different nonself conditions together. Perhaps the most salient aspect of the results was, in the authors' words, the "striking . . . similarity among the *self, other,* and *general* conditions when compared with the *syllable* condition" (Craik et al., 1999, p. 31).

In a later study by Craik with different collaborators (Fossati et al., 2003), a self condition much like that of the previous study was

contrasted with a condition labeled *other* but in fact equivalent to the general condition in Craik et al. (1999), in that it required subjects to judge whether the trait words were positive or negative. The researchers systematically varied the emotional valence of the trait words and contrasted activation in what they termed the *self* and *other* conditions for positive and negative traits. They found self-related activity in dorsomedial PFC bilaterally as well as in left posterior cingulate, regardless of the emotional valence of the traits being judged.

Kircher and colleagues (2000) also imaged subjects making judgments about trait adjectives. However, rather than isolating self processing by contrasting self-reference judgment with other types of judgment, Kircher et al. (2000) contrasted two types of self-reference judgment: judgments of words that were self-descriptive and judgments of words that were not. They explained that this change was made in order to avoid "diluting" the self-judgment condition with the processing of nonself-descriptive adjectives. However, it is not clear whether this design would increase or decrease experimental power. On the assumption that the self-concept must be consulted in order to decide whether an adjective is or is not self-descriptive, Kircher et al.'s (2000) design involves contrasting two conditions that both evoke self processing. Indeed, by analogy with models of the lexical decision task in which the lexicon is searched exhaustively for nonwords to be correctly rejected (Forster, 1992), one might even hypothesize more self-related processing in the nonself-descriptive condition.

Nevertheless, Kircher et al. (2000) found activation differences between conditions. Several activations, mostly in the left hemisphere, were specific to the affirmative judgments (see Table 3 for specific areas of activation). The authors pointed out the similarity between this pattern of activation and one from a different task within the same study that involved making self–other face recognition judgments. As reviewed earlier, this study found more activation in the right limbic system and left PFC, among other areas, when subjects discriminated morphed versions of their own face from an unfamiliar face, relative to discriminating morphed versions of their partner's face and an unfamiliar face. Kircher et al. (2000) interpreted these results as evidence for a specific area that is involved in representing an internal self-concept that can be accessed both visually and verbally.

If judgments of self-descriptive and nonself-descriptive trait adjectives both engage the self-concept, as we have suggested they might, then what could account for the differences found in this study? There are two nonself-specific possibilities. First, the words in the two conditions were rated differently by subjects on both likeability and "meaningfulness" (see Jones, Sensenig, & Haley, 1974, for a similar association between self-relevance and positive words). Second, subjects were making different responses to the different blocks of words, affirmative to self-descriptive words and negative to nonself-descriptive words, and this might also account for activation differences.

In a later study by Macrae, Moran, Heatherton, Banfield, and Kelley (2004), subjects also were instructed to judge whether stimulus items were self-descriptive; greater activation was reported in left medial PFC for self-descriptive words. Likeability and meaningfulness of trait terms were not reported, but assuming they followed the usual trend, self-related traits would be higher on both measures. These differences could account for the reported activations.

In a second study by Kircher and colleagues (2002), the researchers introduced an *incidental* self-processing task. For this task, subjects were presented, as before, with words that were either self-descriptive or not, but the task was to judge whether the word was a physical or psychological trait. As before, the activation associated with the nonself-descriptive words was subtracted from the activation associated with the self-descriptive words. This comparison was taken to isolate incidental self processing, in that self-concept was not being accessed intentionally, and the resulting pattern of activation differed from the intentional self processing of the previous experiment. Specifically, the incidental processing of self-descriptive traits (vs. nonself-descriptive traits) showed activations in both the left and right hemispheres, including significantly more activation in the right middle temporal gyrus and inferior parietal lobe, and left inferior frontal gyrus and superior temporal gyrus (see Table 3 for more detail). The only areas of overlap between intentional and incidental self processing were two small regions of the left hemisphere, one in the fusiform gyrus and one in the superior parietal lobule. Although this experiment could potentially illuminate brain areas involved in incidental self processing, the confound between self-descriptiveness, likeability, and meaningfulness remains, along with the potential for the many other confounds noted in relation to the SRE. Therefore, we cannot conclude on the basis of these results that the activations for self-descriptive traits are due to self-specific processing.

S. C. Johnson et al. (2002) used fMRI to localize what they term the "self-reflection" involved in verifying statements such as "I catch on quickly" and "I get angry easily." This task was contrasted with the control task of verifying factual statements such as "You need water to live." Self task activity was significantly higher in medial PFC and posterior cingulate. These results are difficult to interpret owing to the nature of the control conditions; the control condition used by Johnson and colleagues differed in its social content, and the areas activated are associated with social–emotional cognition in tasks lacking self-related processing (Adolphs, 2001; Adolphs, Tranel, & Damasio, 2003), with the medial PFC in particular associated with knowledge about people (J. P. Mitchell, Heatherton, & Macrae, 2002). In order to conclude that self-reflection per se is responsible for the activation, it must be contrasted with a condition involving a specific other person.

Three recent studies have used an "other person" control condition. Kelley et al. (2002) used a trait-adjective judgment task in which they included three conditions: deciding whether the adjective described the subject (self condition) or President George W. Bush (other condition), or deciding whether the adjective was printed in capital or lowercase letters (case condition). If self-related processing evokes additional activation in the same regions as other-related processing, the authors would interpret this as evidence favoring the view that the SRE merely reflects the greater semantic organization and elaboration of the self schema relative to other schemata. In contrast, if distinct brain regions are activated during self processing, this would indicate that, in the authors' words, "the self-reference effect results from properties of a unique cognitive self" (Kelley et al., 2002, p. 786). The self and other conditions activated similar regions in the left frontal lobe (dorsal and inferior frontal cortex), compared with the case condition. However, regions of the medial PFC were activated in the self condition but not in the other condition. The authors concluded that "self-referential processing is functionally dissociable from

other forms of semantic processing within the human brain" (Kelley et al., 2002, p. 785).

Kjaer, Nowak, and Lou (2002) took a similar approach, asking subjects to reflect on their own personality and physical traits for short periods, as well as on the personality and physical traits of the Danish queen. They found increased neural activation in medial parietal cortex and in left orbitofrontal cortex when subjects reflected on their own personality traits, and in anterior cingulate cortex during reflection on their own physical traits, relative to the corresponding traits of the queen. Lou et al. (2004) carried out two more experiments with a similar task using only mental traits. In the first, they had subjects again recall their own traits, the Danish queen's traits, or their best friend's traits while undergoing fMRI. This time they found medial prefrontal activation common to both self and other conditions, with lateral regions in parietal and temporal cortex distinguishing self from other. A second experiment, using TMS to disrupt processing, found selective effects of parietal TMS for the self condition relative to the best friend condition.

In some of the foregoing studies, medial PFC was activated in association with self processing (see Table 3 and Figure 3). However, processing of the traits of others also activated this area, and even did so to the same extent in one study. It is therefore possible that medial PFC plays a role in person processing in general and is sometimes more strongly engaged by the self conditions of experiments for reasons similar to the causes of the SRE described earlier. Recall that the SRE in memory was originally obtained in experiments contrasting self- and other-related processing, but when differences between self and other in familiarity, differenti-

ation, elaboration, and so forth were controlled for, the effect vanished. Given the known association between the medial and orbital regions of the PFC and both person knowledge (J. P. Mitchell et al., 2002) and affective processing (Davidson & Irwin, 1999), it is possible that the activation of these areas is a function of amount and type of knowledge rather than self versus other knowledge per se. Although the experiments of Kelley et al. (2002) and Kjaer et al. (2002) included control conditions involving people, in both cases the control person was a public figure about whom the subjects would have had less knowledge, as well as less affective response. Of course, it may not be possible to equate the self and other conditions of any task for all of the potentially confounding factors. Nevertheless, it should be possible to more closely equate them—for example, by the use of a close other such as a spouse. The approach of parametrically varying familiarity and other attributes would also yield information concerning the role of these factors in self-related brain activity. The literature on the SRE in cognitive psychology demonstrates the feasibility and the importance of attaining experimental control over these factors.

Autobiographical Memory

Autobiographical memory is central to one's sense of self. Several self theorists have posited a central role for autobiographical memory (e.g., in Bruner's, 1994, "narrative self,"; in Greenwald's, 1980, conception of the "totalitarian ego,"; in McAdams's, 2001, work on life stories; for a review, see Wheeler et al., 1997). A number of studies in amnesic patients and normal individuals
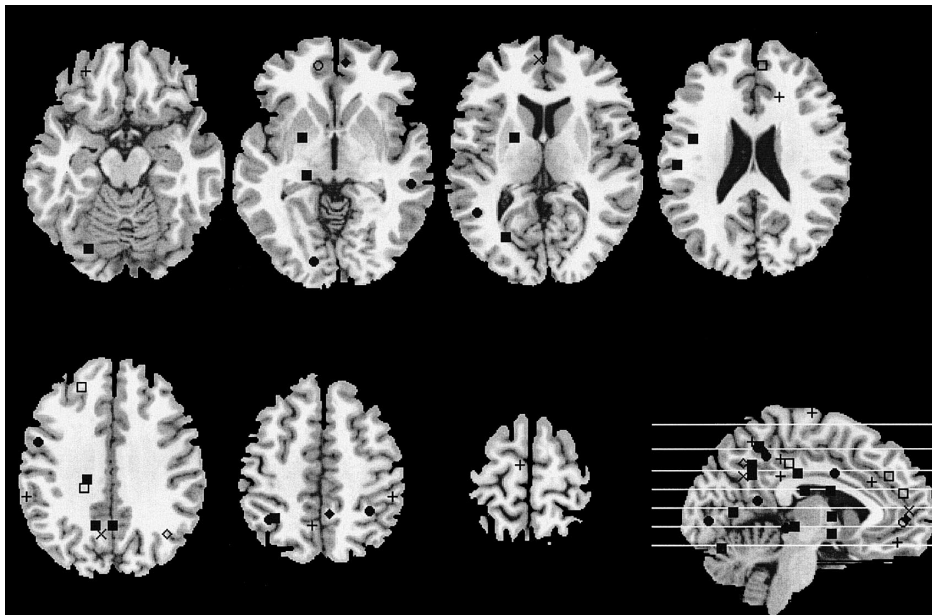
Figure 3. Brain regions reported to be more active when processing one's own traits. Activation foci are shown in axial slices of the standard Montreal Neurological Institute brain (right is right), taken at the levels shown in the sagittal slice. The symbols represent the center of these activations according to the Talaraich coordinates provided by the authors and do not show the volume of activation. The sagittal view shows these symbols in "glass brain" view, such that all areas of activation are visible regardless of whether they fall on the midline. Symbols correspond with the following studies: ■ = Kircher et al. (2000); ● = Kircher et al. (2002); ◆ = Kelley et al. (2002); ✕ = S. C. Johnson et al. (2002); + = Kjaer et al. (2002); □ = Fossati et al. (2003); ○ = Macrae et al. (2004); ◇ = Lou et al. (2004).

have explored the neural bases of autobiographical memory. For purposes of determining whether self memory, in the form of autobiographical memory, is special, there are two questions that can be posed to this literature: First, is autobiographical memory special in the sense of being functionally independent from equivalent forms of nonautobiographical memory, and second, is it special in the sense of relying on differently localized neural substrates?

De Renzi, Liotti, and Nichelli (1987) described a case of selective preservation of autobiographical memory. Their patient was left with a profound impairment of semantic memory after recovery from encephalitis, as well as severe anterograde amnesia and severe retrograde amnesia for world events. In contrast, her retrograde memory for personally experienced events was impressively good. She was able to recount events from high school, her marriage, honeymoon, summer holidays, and so on, with confidence and accuracy. The authors noted that on the few occasions when the patient was able to recall some fragmentary information about world events, it was in the context of her personal experience—for example, of the Chernobyl accident she remembered that something had exploded and polluted the atmosphere "because vegetables and houseplants I kept on the deck had suffered" (De Renzi et al., 1987, p. 587), but she did not report the location of the accident or the radioactive nature of the pollution.

This dissociation is consistent with the existence of a neuroanatomically distinct system for autobiographical memory that is functionally independent of memory for world events. However, it is unclear whether memory for world events is a type of episodic memory, comparable to the episodic memory for autobiographical events that is preserved in this patient, or a type of semantic memory, known to be impaired in this patient. In the latter case, the dissociation simply reflects the existence of dissociable systems for semantic and episodic memory, a long-established finding (Keane & Verfaellie, 2003). In addition, the generic alternative explanation for single dissociations in neuropsychology, that the preserved ability was simply an easier task than the impaired, cannot be ruled out. Perhaps the recall of world events is generally more taxing of memory than the recall of the types of personal events tested in this study. Individuals vary in their awareness of news outside their own circle of family and friends, and it is possible that this patient's premorbid knowledge of nonautobiographical information was particularly weak and hence more vulnerable to the effects of brain damage. The existence of patients with the opposite pattern of performance, namely, selective impairments of autobiographical memory with preserved nonautobiographical memory, could address the question more decisively.

Several studies of amnesic patients have documented impairments of autobiographical memory. In most cases, however, the status of nonautobiographical retrograde memory was not assessed (Hokkanen, Launes, Vataja, Valanne, & Iivanainen, 1995; Levine et al., 1998; Ogden, 1993; see also the group study of autobiographical memory by Della Sala, Laiacona, Spinnler, & Trivelli, 1993). It is therefore impossible to know whether the impairment was specific to autobiographical memory. Indeed, one might even wonder whether, in principle, episodic memory and autobiographical memory could ever be dissociated, given that episodic memory is defined as the ability "to recollect past episodes from a specific place and time" (Levine et al., 1998, p. 1953), which seems to require autobiographical awareness.

This question highlights the two distinct ways in which autobiographical memory is related to the concept of self. First, the content of the memory pertains to the self—for example, information about one's family, friends, and home. Second, the perspective of the memory is "through the eyes of" the self. In this regard, autobiographical memory can be considered equivalent to episodic memory, in that the remembered information is embedded in at least some aspects of the spatiotemporal context in which it was originally experienced. Memory that is about the self but not recollected with a self perspective can be considered semantic autobiographical memory. Such memories could be based on what other people have told us about ourselves. Indeed, patients with retrograde episodic memory impairment may regain knowledge of their lives if taught by others, but in this case they report no sense of personal recognition (Levine et al., 1998; Ogden, 1993; Tulving, Schacter, McLachlan, & Moscovitch, 1988). However, if we include a self perspective as part of the definition of autobiographical memory, then none of the cases cited so far shows a dissociation between memory for self-related information from a self perspective and memory for nonself-related information from a self perspective. This would require assessing retrograde episodic (self perspective) memory for nonself-related information.

Such a comparison was carried out in one case of autobiographical memory impairment, by Hodges and McCarthy (1993). Their patient was a 67-year-old war veteran with retrograde amnesia and the severe and persistent delusion that he was currently on leave from the Navy during World War II. The patient's retrograde memory was tested for events in his own life as well as two types of nonself-related information, famous people and world events. His knowledge of famous people was impressively preserved. However, his knowledge of world events was severely impaired, ruling out a truly specific impairment for autobiographical memory.

In sum, memory abilities can dissociate in many different ways following brain damage. The question of relevance to self-specific processing is whether autobiographical memory, defined as memory about the events of one's life recalled from the perspective of the self, can dissociate selectively from other components of memory. There is little evidence for this in the literature. Although one case of selectively preserved autobiographical memory has been reported, it is difficult to know whether the impaired memory for nonautobiographical events was comparably episodic or whether it was part of the patient's more pervasive semantic memory impairment. Reports of impaired autobiographical memory have either not included information about nonautobiographical memory or reported that it is impaired. As a whole, there is insufficient evidence from the neuropsychological literature on amnesic patients to support the existence of a neuroanatomically distinct system for autobiographical memory.

More recently there have been attempts to study the patterns of neural activation associated with autobiographical memory. Fink et al. (1996) scanned subjects while they listened to a narrative describing a memory of their own (autobiographical) and a narrative describing another person's memory (nonautobiographical). The autobiographical condition evoked greater activation in the right temporal lobe, anterior insula, and other right hemisphere areas (see Table 3 and Figure 4 for more detailed localization information). As the authors pointed out, their two conditions differed in several ways aside from the presence versus absence of autobiographical memory per se. Some of these differences nev-
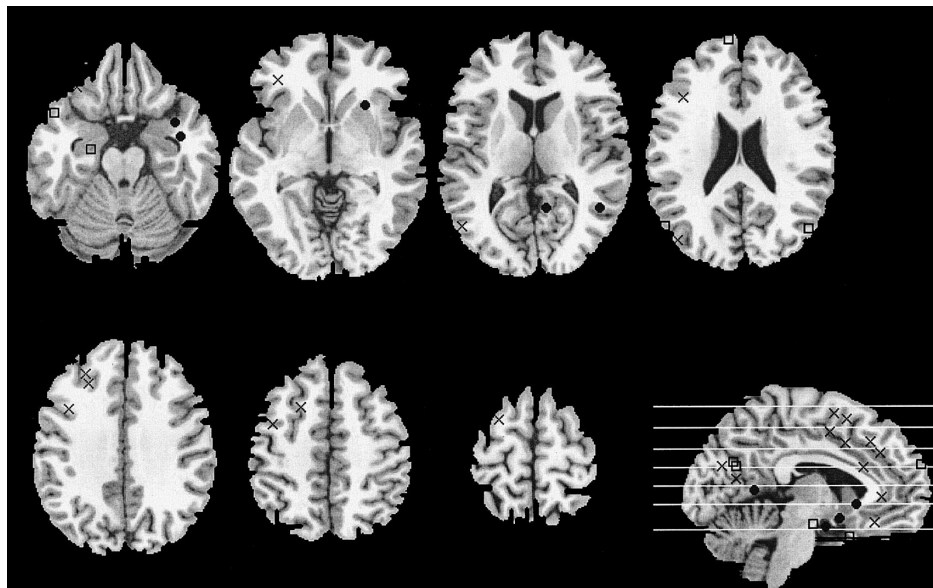
Figure 4. Brain regions reported to be more active during autobiographical memory retrieval. Activation foci are shown in axial slices of the standard Montreal Neurological Institute brain (right is right), taken at the levels shown in the sagittal slice. The symbols represent the center of these activations according to the Talaraich coordinates provided by the authors and do not show the volume of activation. The sagittal view shows these symbols in "glass brain" view, such that all areas of activation are visible regardless of whether they fall on the midline. Symbols correspond with the following studies: × = Conway et al. (1999); ● = Fink et al. (1996); □ = Maguire and Mummery (1999).

ertheless pertain to self-specific processing, for example, the difference in personal relevance between the two types of memory and the difference in perspective between imagining oneself or another person in the narrative. Unfortunately, the conditions also differ in ways that are not at all related to the self: The autobiographical narratives were generated by the subject, whereas the nonautobiographical narratives were not (see Slamecka & Graf, 1978, for generation effects in memory), and the autobiographical narratives had last been encountered weeks before the scan, whereas the nonautobiographical narratives had been presented to them just one hour before the scan. Additionally, the hemispheric encoding/retrieval asymmetry model (Tulving, Kapur, Craik, Moscovitch, & Houle, 1994) suggests that the right hemisphere is preferentially involved in episodic memory retrieval, and many studies have supported this claim (see Nyberg, Cabeza, & Tulving, 1996, for a review). Therefore the greater activation in right hemisphere regions could be a function of the episodic retrieval in the autobiographical condition, rather than a result of self-related processing per se.

Conway et al. (1999) compared the PET activations associated with retrieving autobiographical memories and a simple paired-associates memory control task. Prior to the scan, subjects chose autobiographical memories to recall in response to specific cue words. When the cue word was presented during the scan, subjects were to recall the memory and respond with a word that would later help them report the details of the memory to the experimenters. As a control task, subjects were taught word pairs such as *flower–clock* before the scan, and when cued with one word during the scan, they were to respond with the associated word. The comparison between the two tasks revealed greater activation of large areas of the left hemisphere during autobiographical recall,

including inferior, middle, and superior frontal gyri; posterior to middle temporal gyrus; anterior occipital lobe; and posterior parietal lobe (for more details, see Table 3 and Figure 4). As before, however, the memory control task differed from the autobiographical recall task in a number of ways, including the absence of any meaningful narrative linking the associated words, and the activation differences therefore do not necessarily result from the difference in autobiographical content per se.

Maguire and Mummery (1999) avoided many of the difficulties of the previous studies by designing true-or-false memory questions tailored to each individual subject and systematically varying the personal relevance and temporal specificity of these questions. For example, "You were Mike's best man at his wedding" (personally relevant, specific time), "Ray is the youngest of your brothers" (personally relevant, no specific time), "Zola Budd tripped with Mary Decker" (not personally relevant, specific time), and "Presenter Chris Evans has red hair" (not personally relevant, no specific time). We do not know how the memories used in the different conditions varied from one another in terms of familiarity, affective content, and so forth. However, at the very least the questions allowed the researchers to compare self-related and nonself-related memories in the context of generally similar tasks and materials. The relevant contrast showed activation of medial prefrontal, temporal, and parietal cortex bilaterally, as well as left hippocampus and temporal pole.

In sum, imaging studies of autobiographical memory have been limited by confounds between the autobiographical content of memory and other aspects of memory, and the brain regions implicated have varied. Even the best matched experimental design (that of Maguire & Mummery, 1999) did not control or measure potential confounds. Nevertheless, that study did opera-

tionalize self- and nonself-related processing in similar ways using real-world memory, and its findings therefore offer a useful and interesting starting point for future investigations.

First-Person Perspective

First-person perspective has been defined in a number of ways. Within philosophy it has been related to subjectivity and the qualitative aspects of conscious awareness. For example, in Nagel's (1974) classic essay "What Is It Like to Be a Bat?" the title is a question about the bat's first-person perspective in the sense of subjective experience. In psychology and cognitive neuroscience research, in contrast, first-person perspective concerns the differential availability to the self, as opposed to others, of particular types of objectively describable information. This meaning often involves perceptual information. For example, in a recent review of the subject, Vogeley and Fink (2003) defined first-person perspective as the "centeredness of one's own multimodal experiential space upon one's own body, thus operating in an egocentric reference frame" (p. 38).

There is a sense in which early visual areas of the brain, and even the retina, comprise a specialized system for instantiating the self's visual representation of the world, but clearly there are other ways of construing the objective sense of first-person perspective. A number of studies concern a more narrative sense of first-person perspective—that is, people's perspectives are defined in terms of the facts, beliefs, and motives that are uniquely available to them. Three such studies have looked for evidence for special processing related to the first-person perspective.

In Vogeley et al.'s (2001) study, subjects read scenarios told in either the first person or the third person. In the theory of mind (TOM) condition, the story concerned someone else, and afterward the subject answered questions about the person's actions, beliefs, and perceptions. In the self condition, subjects read similar stories and were then asked questions about their own actions, beliefs, and perceptions within the story. For example, the subject read a story about leaving his or her umbrella at home, and later in the day it starts to rain; the subject then answered the question "What do you think?" A baseline condition with no person's psychological perspective (self or other) was included in the design, and baseline activations were subtracted from the self and TOM condition activations. Not surprisingly, the self and TOM tasks involved some common areas of activation, in the right PFC. In addition, the self condition activated certain distinct areas, namely, the right temporoparietal junction and bilateral anterior cingulate cortex. The authors concluded that "this study provides experimental evidence for an at least in part independent cerebral implementation of self perspective in the context of theory of mind" (Vogeley et al., 2001, p. 180).

The design of this study is, in principle, well suited for isolating the self perspective, as it contrasts thinking about one's own thoughts and experiences with thinking about those of another person in the context of an otherwise similar task. However, the findings must be interpreted with extreme caution because of the authors' use of a fixed-effects model for their statistical analyses, particularly given the small number of subjects (8) and stories per condition (eight). Fixed-effects models tend to overestimate the reliability of findings obtained from groups of subjects and do not address the question of whether the experiment, if done again with different stimulus items and different subjects, would replicate

(Aguirre, 2003; see also Hildebrand, 1986). Therefore, we cannot know whether specific subjects' responses to the task, or incidental features of a few of the stories in the TOM and self conditions, are responsible for the reported differences.

Emotional response is another aspect of first-person perspective that has been studied using functional neuroimaging. Lane, Fink, Chau, and Dolan (1997) had subjects view emotional pictures and focus attention on either the spatial aspects of the pictures or their own emotional responses to the pictures. When attention was focused on the subjects' own emotional responses as compared with the pictures' spatial properties, there was significantly more activation evoked in the anterior cingulate cortex, in addition to other areas. Gusnard et al. (2001) operationalized the concept of first-person perspective in a similar way, comparing the internally cued condition, in which subjects judged whether each image in a series gave them a pleasant, neutral, or unpleasant feeling, and the externally cued condition, in which they judged whether the image depicted a scene that was indoors or out-of-doors. These authors found increased medial prefrontal activity (dorsal to midsections) associated with the internally cued condition, in addition to greater activity in the frontal operculum/left insula (see Table 3 and Figure 5 for a comparison of neural localizations across these first-person perspective studies). A difficulty in interpreting these data comes from the ways in which the conditions designed to include first-person perspective differed from the nonself-processing comparison conditions. In both the Lane et al. and the Gusnard et al. studies, the self-processing task had an affective component whereas the comparison task did not, and this alone might be expected to recruit medial prefrontal brain regions (Bush, Luu, & Posner, 2000; Drevets & Raichle, 1998). In fact, affective evaluation has been found to activate these areas outside of tasks that call for first-person perspective (Zysset, Huber, Ferstl, & von Cramon, 2002).

In sum, the psychological self has been operationalized in a number of different ways that seem, intuitively, related to one another. Our self-concept, in the sense of traits that we believe characterize us and facts that we believe are true of us, is related to our autobiographical memory in that we achieve most of our self-knowledge through personal experience, and our autobiographical memory may also be filtered through our self-concept. First-person perspective operates at different levels of the perceptual–mnemonic continuum from visual–spatial perspective to narrative perspective and is the defining feature of episodic autobiographical memory. Do any of these different ways of operationalizing the psychological self provide evidence that the self is special? Do they identify a common system underlying trait knowledge, autobiographical memory, and first-person perspective?

The enhanced memory for self-related trait concepts has been viewed by some as evidence that self-related processing is functionally distinct from other kinds of processing, but as we saw in earlier discussions of the SRE, self-related and other-related traits differ in many ways, including familiarity, elaboration, organization, intimacy, and affective content, and the interpretation of such enhancement is therefore difficult. A neurological dissociation between knowledge of own traits and others', or between autobiographical and nonautobiographical memory, would indicate a functionally and anatomically distinct system for self-related memory, but relatively few cases have been reported and none has provided the necessary evidence of preserved memory for others
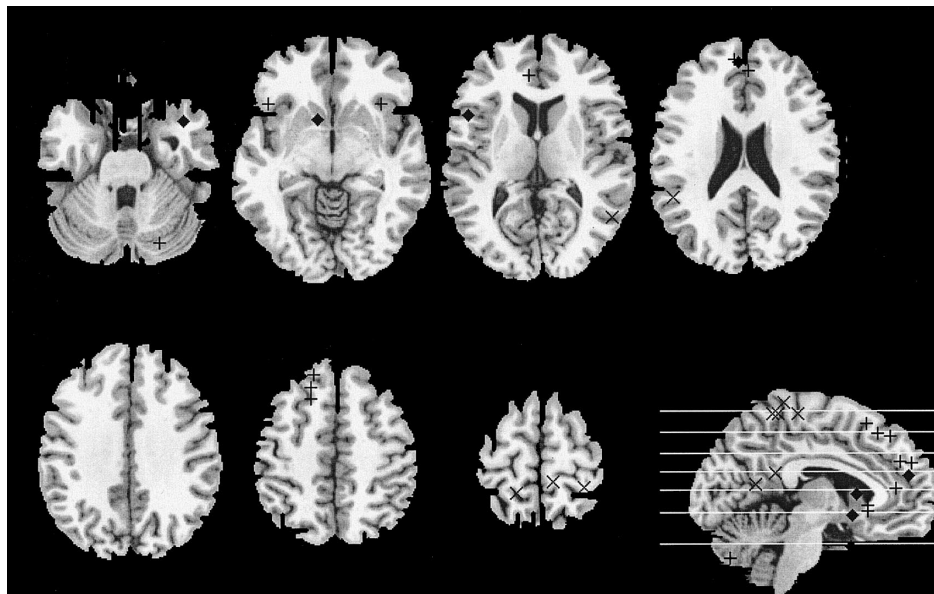
Figure 5. Brain regions reported to be more active while experiencing the first-person perspective. Activation foci are shown in axial slices of the standard Montreal Neurological Institute brain (right is right), taken at the levels shown in the sagittal slice. The symbols represent the center of these activations according to the Talaraich coordinates provided by the authors and do not show the volume of activation. The sagittal view shows these symbols in "glass brain" view, such that all areas of activation are visible regardless of whether they fall on the midline. Symbols correspond with the following studies: + = Gusnard et al. (2001); × = Vogeley et al. (2001); ◆ = Lane et al. (1997).

(if the impairment is reported to be selective for the self) or for self (if the impairment is reported to be selective for others). Only a few studies have contrasted anatomical substrates of first-person perspective with other types of processing, and these either have lacked the kind of minimally different control condition needed to isolate self-related processing per se or have not demonstrated statistical significance by conventional standards. In sum, there are currently few appropriate data for testing the hypothesis that the psychological self is special, and claims to that effect are therefore premature.

Discussion

In this article we set out to address several questions about the nature of self-related processing. The first question is whether self-related processing is "special," analogous to the way in which language and face processing have been said to be special. The second question is whether the many different facets of self-related processing are the function of a unitary system. The bulk of the research reviewed here was intended to answer the first question. According to the results of that research, the short answer is "yes and no." More specifically, for some aspects of the physical self the answer is "yes," but for most aspects of the self, both physical and psychological, there is no good evidence that the self is special, and in some cases there is evidence that it is not.

There are two, possibly related aspects of the physical self that seem to be special. Asomatognosia demonstrates both the functional independence and the neural localization of limb ownership; our sense of a limb as being our own is distinct from our sense that other people's limbs belong to them. Studies of the experience of

agency in limb movements indicate a similar functional independence and neural localization. In contrast, other aspects of the physical self have not yielded evidence of consistent localization or dissociation from corresponding nonself processing. Studies of self-face recognition have yielded inconsistent localizations. It is possible that further research will reveal a special system for self-face recognition, but at present the evidence appears mixed. Studies of the representation of body layout and posture, far from being indecisive, indicate that we use the same representations for our own and others' bodies, thus indicating that these aspects of the physical self are not special.

For most aspects of psychological self, interpretation of the evidence is difficult because of the many ways in which self and other processing differ in the studies, aside from involving the self. As we saw in the SRE literature, early studies that did not control for these confounds concluded prematurely that the self was a functionally unique cognitive structure. Subsequent work with more careful controls failed to support that conclusion. More recent neuroimaging research has yet to include the needed controls to equate self and nonself conditions in familiarity, affective associations, and other respects. The different ways in which the self–nonself distinction is confounded with other distinctions across studies are likely to account for the different patterns of activation in different studies of the psychological self, even when the same aspect of the self is under study, as shown in Figures 3–5. Even the frequent finding of medial prefrontal activation in these studies is difficult to interpret. Given the well-established role of this area in affective and person-related processing in general, the results are consistent with the hypothesis that self-related process-

ing is a function of the same neural systems involved in person-related processing, with the self simply being the person we know best and care most about.

Problematic or missing control conditions are not unique to neuroimaging studies of the psychological self. Patient-based studies of memory have often failed to assess abilities that are critical for contrasting self-related memory with nonself-related memory. Most reported cases of impaired autobiographical memory have not addressed the status of nonautobiographical retrograde memory, making it impossible to conclude that the autobiographical memory system is functionally or anatomically independent from nonautobiographical memory. In sum, the available data neither prove nor disprove the hypothesis that the psychological self is special.

The hypothesis of a special self system has intuitive plausibility, and this may have kept researchers from perceiving the need for more careful experimental controls. It may also account for the generally uncritical acceptance of published interpretations of results. Indeed, even when results are interpreted with caution by the authors of a study, that caution may be neglected by later authors citing the results. For example, although Craik et al. (1999) stated that "every significant activation in the [self condition] was also found in either the [other person condition] or the [general semantic] condition, or both" (p. 30), many authors cite this study as evidence for specialized self processing (e.g., Conway et al., 1999; Fossati et al., 2003; Keenan et al., 2000; Kelley et al., 2002; Platek et al., 2004). Despite Vogeley et al.'s (2001) caution that their fixed-effects analysis precludes generalizing the results to other subjects or materials, their results are also frequently cited in support of a special self system (e.g., Keenan et al., 2003; Kjaer et al., 2002; Northoff & Bermpohl, 2004; Platek, Critton, Myers, & Gallup, 2003; Platek et al., 2004).

We now turn to the second question: 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)? Figure 6 is a compilation of the activation maxima observed across imaging experiments concerning all of the aspects of the self reviewed here. Had the points clustered in certain regions or along certain networks, the hypothesis of a unitary self system would have been supported. However, 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.

Future studies in this area can yield more decisive results by carefully constructing the control conditions, as was done in later studies of the SRE. In neuroimaging studies of the self, this means that researchers should equate or independently manipulate the conditions on potentially confounding variables such as familiarity, response given, judgment or evaluation required, and categorization. Similarly, patient case studies need to assess patient performance on all of the subcomponents of the "self" task except for the crucial self element—such as assessing nonautobiographical memory in amnesic patients. Explicitly identifying the aspect of the self under study and the sense in which it is hypothesized to be special may also help to reconcile and unify emerging models of the self.

The compelling intuition that the self is a distinct and unitary entity may have more to do with the subjective nature of conscious awareness, in the sense of first-person perspective addressed by Nagel (1974), than with the information-processing activities of the brain that are the subject matter of the research reviewed here. Some authors have suggested that we must simply consider more complex interactions among brain systems to understand the emergence of the phenomenology of selfhood from the physical activity
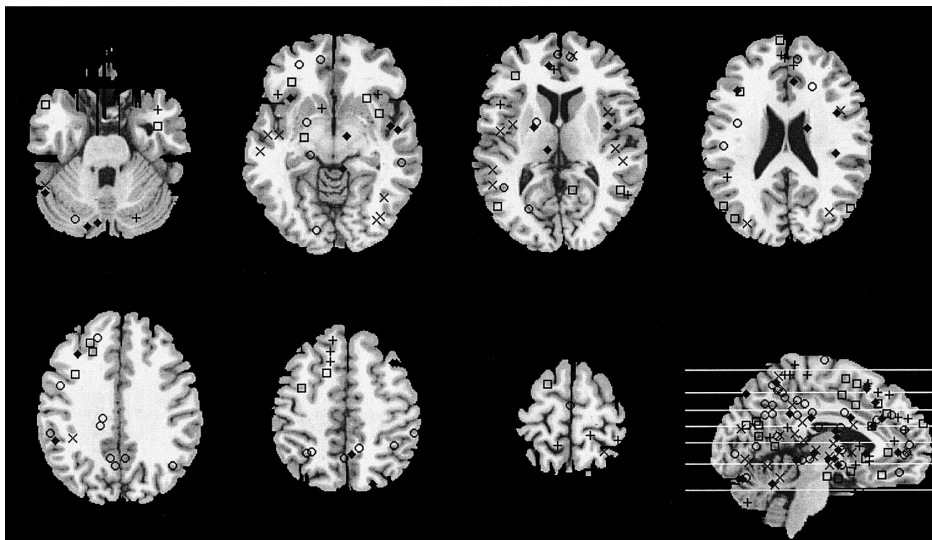
Figure 6. Brain regions reported to be more active during self-related processing across multiple domains, collapsed across studies within domain (e.g., traits). Activation foci are shown in axial slices of the standard Montreal Neurological Institute brain (right is right), taken at the levels shown in the sagittal slice. The symbols represent the center of these activations according to the Talaraich coordinates provided by the authors and do not show the volume of activation. The sagittal view shows these symbols in "glass brain" view, such that all areas of activation are visible regardless of whether they fall on the midline. Symbols correspond as follows: ◆ = face; × = agency; ○ = traits; □ = memory; + = first-person perspective.

of the brain (e.g., Decety & Sommerville, 2003; Kircher & Leube, 2003; Metzinger, 2003). However, it is also possible that the relation between brain systems and self-awareness is simply not understandable in the terms in which our minds evolved to think. Pinker (1997) has proposed that the human mind represents the world syntactically, by parts and their relations, whereas the perennial mysteries of philosophy involve holistic concepts that cannot be reduced. In his words, "The I is not a combination of body parts or brain states or bits of information, but a unity of selfness over time, a single locus that is nowhere in particular" (Pinker, 1997, p. 564). Our vivid awareness of a self, like awareness more generally, may not be explicable in terms of the mechanistic workings of the brain.

However, even if our subjective sense of self cannot be understood within the framework of empirical science, all of the aspects of the self reviewed here are represented in our brains and play important roles in human information processing, from guiding bodily movement to providing an organizing schema for memory. The self thus remains a central topic for psychology and cognitive neuroscience. As the philosopher Patricia Churchland (2002) has pointed out, "Questions about self-representation are steadily shifting into the province of the brain and cognitive sciences" (p. 309; see also Gallagher, 2000). We agree insofar as self-representation is interpreted in information-processing terms and not phenomenological terms. Although our review suggests that the brain and cognitive sciences have yet to overcome certain methodological difficulties in studying the self, we are optimistic that they soon will.

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