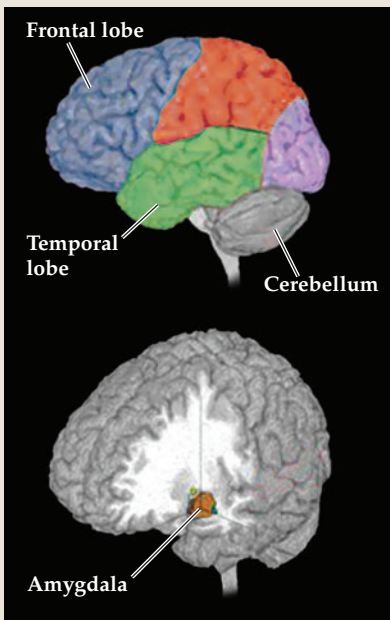
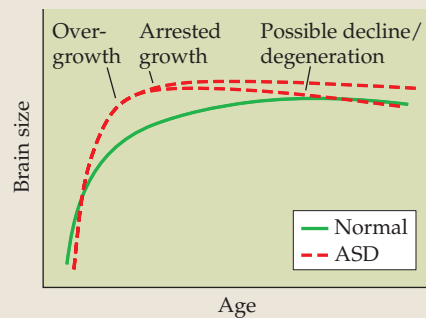


■ INTRODUCTORY BOX (continued)

(C)



Brain growth in autism. (C) Across developmental stages, there is a general pattern of brain enlargement followed by arrested growth. This pattern is found in portions of the frontal and temporal lobes, cerebellum, and amygdala, among others. ASD, autism spectrum disorder. (C after Courchesne et al. 2011.)

Autistic individuals tend to have relatively larger brain volumes, perhaps arising from overgrowth of connections early in development. These alterations in-

clude more white matter in the cerebrum and cerebellum and larger cerebral gray matter, particularly in the frontal lobes and other regions implicated in social processing, as outlined already. However, by late childhood these global structural differences tend to become normal (Figure C). Aberrant wiring patterns nonetheless persist in autistic adulthood, including more short- and medium-range connections within the hemispheres, but fewer interhemispheric connections.

Thus, behavioral impairments in autism are most likely a result of altered processing and/or connectivity among interacting brain regions that mediate social cognition, communication, and executive motor functions. Consistent with this idea, autistic individuals sometimes have extraordinary talent in restricted domains like mental calculation, historical facts, or art—a phenomenon sometimes referred to as **savant syndrome** (see Introductory Box in Chapter 15). At the same time, individuals with autism have more difficulty integrating parts into wholes and synthesizing information across domains (called *central coherence*)—skills that require the normal operation of interacting large-scale networks. Their enhanced reliance on local task features and attention to detail often leads to a bias toward *systemizing*, the tendency of autistic individuals to analyze problems and construct knowledge by applying rigid, often mechanical, rules.

Rehabilitative training in autism focuses on exploiting this penchant for rules, mechanics, and focal attention to facilitate social and emotional competence. For instance, psychologists train autistic children to discriminate emotions by morphing human facial expressions onto animated mechanical characters that move rigidly and express emotions according to a specific set of rules. Initial short-term results of such rehabilitation exercises are promising, but the extent to which the eye-tracking and fMRI activation patterns improve following training is not known. With increased activity of advocacy groups, enhanced public awareness, and high-profile personal triumphs like those of Temple Grandin,

research efforts are increasing to help understand this complex disorder.

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The Self

Distinguishing oneself from others is a necessary first step in establishing fluent social interactions. Understanding the nature of the self has long perplexed philosophers, psychologists, and laypeople alike. In his treatise on psychology

written at the end of the nineteenth century, William James described the self as follows:

Whatever I may be thinking of, I am always at the same time more or less aware of myself, of my personal existence. At the same time it is I who am aware; so that the total self of me, being as it were duplex, partly known and partly knower, partly object and partly subject, must have two aspects discriminated in it.

W. JAMES 1890, p. 176

Despite the conceptual difficulties in defining what constitutes the entity we all consider the **self**, a core cognitive ability described by James is the ability to consider one's own being as an object, and thus subject to objective consideration. This ability is called **self-reflexive thought**.

Non-human animals presumably possess a rudimentary ability to distinguish themselves from other animals because of its obvious biological value. However, more complex aspects of self-awareness that characterize humans provide the ability to think of oneself in abstract and even symbolic terms, including the creation of mental images to imagine alternative outcomes in complex social situations.

As described in Chapter 15, the capacity for self-awareness evolved in mammals and other animals in conjunction with related social, emotional, and cognitive skills. Animals with small brains and less complex nervous systems seem to operate in the world primarily by responding to external cues. But even rodents can navigate in their environment using either egocentric or allocentric frames of reference, indicating an ability to explore the world either in terms of their own place in it (egocentric, or first-person, view) or simply in terms of external reference points (allocentric, or third-person, view). Head direction cells in the hippocampus, thalamus, and retrosplenial cortex help rodents navigate in an egocentric framework, and shifting between these frames of reference involves transformations in the parietal cortex.

Some non-human animals can recognize themselves in a mirror. At first sight, great apes regard the individual reflected in the mirror as a conspecific and display interpersonal social signals. Over time, however, self-directed behaviors, such as self-grooming in response to the reflection become apparent. A hallmark of such self-recognition is the "mark test," in which an experimenter places a mark on the face or forehead of the animal that is viewable only in the mirror. The mark test is "passed" if the animal repeatedly palpates the mark while viewing itself in the mirror (relative to a comparable baseline period with no mirror present). In addition to great apes, elephants conduct self-examinations by using their trunks to touch a mark visible to them only in the mirror.

Despite these rudimentary abilities, self-recognition and self-reflexive behaviors are markedly more advanced in humans. The archaeological record suggests that the rapid development of culture with a focus on the importance of individuals (and thus the self) emerged in the evolution of humans approximately 50,000 years ago, as evidenced by ritualized burials and artifacts of self-ornamentation. The value of symbolic self-reflexive thought is not difficult to imagine. This ability enables an appraisal of one's personality traits, strengths, and weaknesses in comparison to others and to cultural norms. Such evaluation is essential to successful social behavior by generating self-esteem, regulating one's actions in social contexts, and abiding by social rules.

Whereas humans normally possess a sense of a unitary self across both time and space, the stable concept of the self breaks down in some clinical disorders. For example, **fugue states** are defined as transient states of confusion in which self-relevant knowledge is temporarily unavailable to consciousness,

and uncharacteristic and often self-destructive behaviors ensue. Fugue states can arise following some types of epileptic seizures, but how the sense of self is lost is unknown. In **dissociative identity disorder**, individuals have recurrent, multiple identities that emerge to control behavior at different points in time. This disorder typically originates following exposure to a highly traumatic event, and therapies are directed toward integrating the identities into a unified stream of consciousness. While we take a continuous sense of self in our personal lives for granted, these rare disorders highlight the profound social and behavioral impairments that can arise when discontinuities in self-awareness emerge.

Self-reflection

Only recently have the approaches of cognitive neuroscience been brought to bear on these philosophical and clinical concerns by identifying brain areas that mediate aspects of the self, including self-reflexive thoughts and self-directed feelings. Self-reflection requires an initial redirection of attentional focus from external sensory events to internal thoughts, memories, feelings, and visceral sensations. Two sets of brain regions have been broadly implicated in these functions—midline cortical regions involved in the **default mode** of brain processing, and limbic/paralimbic regions involved in **interoception**.

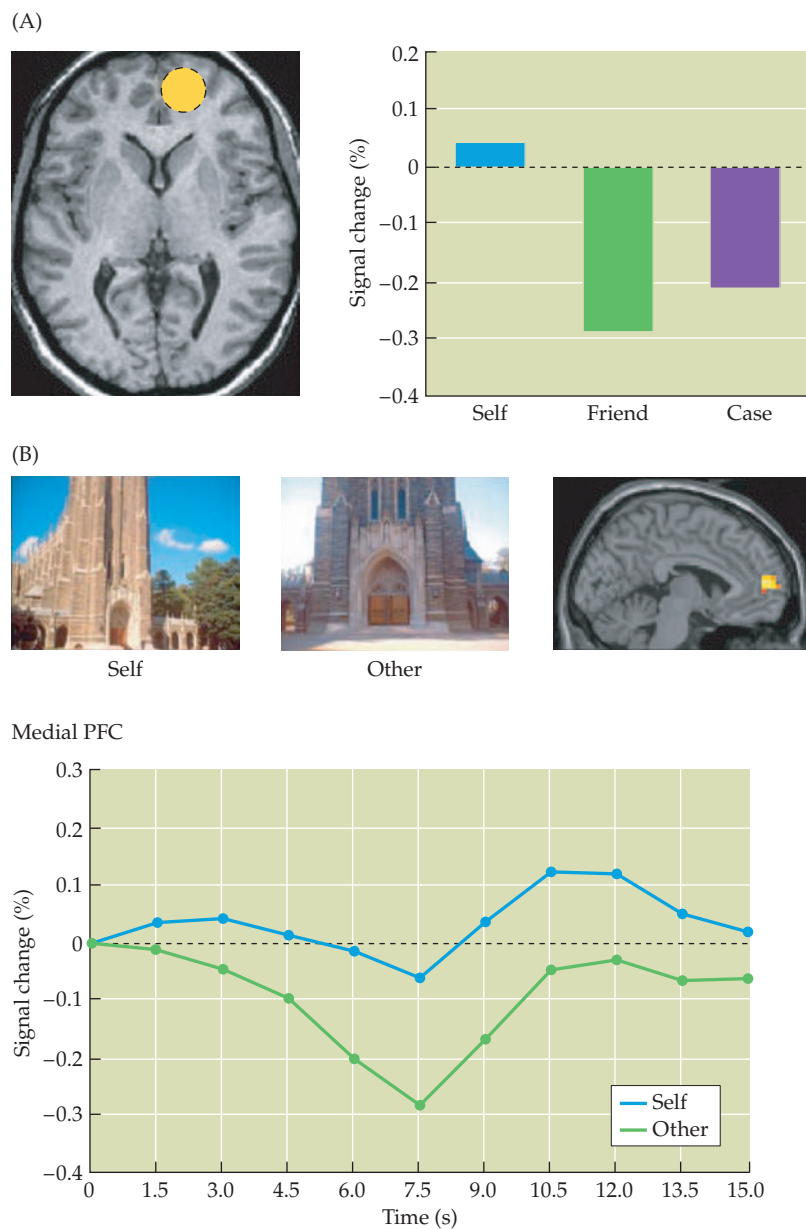
Recall from Chapter 7 that neuroimaging studies have identified brain areas whose activity *decreases* during tasks that require attention to external stimuli. This default-mode activity thus provides a basis for beginning to understand the brain regions that are more active during internal self-reflection and self-projection into another place or time unrelated to the current sensory environment. This spontaneous, coordinated activity occurs in the dorsal and ventromedial prefrontal cortex (PFC), posterior cingulate, and medial and lateral parietal cortex. Some researchers have speculated that this activity reflects an ongoing stream of consciousness. Indeed, some of these same brain regions are sensitive to variations in consciousness associated with different levels of self-awareness (e.g., stages of sleep, the effects of anesthesia, or recovery from vegetative states; see Chapter 7).

Building on these observations of resting-state activity, researchers have directed participants to explicitly engage in self-reflection during brain scanning. For instance, participants are asked to indicate how well adjectives referring to personal traits (e.g., *ambitious*) and sentences (e.g., “I tend to worry a lot”) describe themselves (self-endorsement tasks), or to compare their personality traits with those of famous people or individuals they know well (social comparison tasks). Activity in the anterior medial PFC and parietal regions is increased when identifying attributes of oneself relative to those of a stranger (**Figure 11.1A**). Moreover, TMS applied to the medial parietal cortex has been reported to temporarily block the retrieval of some self-relevant knowledge. The degree of anterior medial PFC activity in response to trait words during self-endorsement tasks also predicts their later recall. Because this finding does not generalize to nonsocial encoding tasks, such as those involving perceptual or semantic processing, a particular type of self-referential encoding process is implied.

These observations are consistent with studies of autobiographical memory retrieval, which implicate the same default-mode processing regions. For example, successful memory retrieval for spatial landmarks cued by photos taken by an individual elicits greater medial PFC activity than does successful retrieval cued by photos of the same landmark that were taken by others (**Figure 11.1B**). As described in Chapter 10, the medial PFC has been implicated more generally in mental processes needed to reflect on autobiographical memories, such as monitoring for their accuracy, and in generating the mental imagery required in working memory tasks that project actions of the self into the future.

Figure 11.1 Role of the medial PFC in self-referential processing

(A) Greater activity in the anterior medial PFC (yellow circle) is found when participants make trait judgments about themselves relative to trait judgments about a best friend or perceptual judgments about the appearance of the trait word (i.e., whether it is upper- or lowercase). (B) Activity in the same brain area during autobiographical memory retrieval. College students were instructed to take pictures of campus landmarks; they then viewed these photos, as well as pictures of the same landmarks taken by other people. Successful recollection of photos taken by the students themselves was associated with greater activity in the anterior medial PFC than was successful recollection of photos taken by others. In both (A) and (B), a self-referential effect is inferred from the lack of a deactivation pattern typically seen in midline cortical regions that constitute the “default mode” of brain processing. (A after Heatherton et al. 2006; B after Cabeza et al. 2004.)



While default-mode research has focused on judgments of personality traits or past experiences, other work has focused on the subjective feelings that accompany emotional or painful stimuli. These studies have implicated not only the brain regions involved in self-reflexive thought, but also brain regions implicated in interoception and empathy, such as the anterior cingulate and insula (see Chapter 10 and the discussion later in this chapter). Greater activity in the rostral anterior cingulate is found when participants are instructed to report their own arousal in response to emotionally aversive scenes than when they focus on the spatial layout of the scenes. Focusing on spatial layout, on the other hand, elicits greater activity in the posterior parietal cortex. Thus, the same emotional images can engage different brain regions depending on whether attention is on an internal evaluative response to the images or an analysis of their sensory features.

Anterior cingulate responses to emotional stimuli and emotional memories are further enhanced by individual differences in performance on the Levels of

Emotional Awareness Scale, which assesses how deeply and complexly emotions are experienced. Anterior cingulate activity increases with autonomic measures of arousal and the subjective experience of the unpleasantness of pain, and it is implicated in the regulation of pain modulation. This work further reinforces the idea that the anterior cingulate integrates attentional and emotional functions (see Chapter 10), but with the more specific goal of directing attention to one's own emotional responses in order to motivate plans of action.

The anterior insula signals awareness of bodily sensations, such as alterations in respiration and heart rate during arousing states. As reviewed in Chapter 10, the posterior and mid-insula are part of a visceral processing network that includes brainstem autonomic centers, the hypothalamus, the mediodorsal and ventromedial thalamus, and the anterior cingulate. Multiple afferent pathways converge on the anterior insula, particularly in the right hemisphere, which, in turn, projects to the orbitofrontal cortex. The cortical components of this hierarchy are hypothesized to represent body state in an integrated way. An awareness of body states signaled by these cortical regions presumably provides a basis for self-reflective feelings that involve affective and visceral components of self-awareness.

Embodiment

Embodiment refers to the sense of being localized within one's own body. The psychologist Ulrich Neisser has referred to this aspect of self-knowledge as the "ecological" self because the physical abilities of the body constrain how individuals interact with other agents and objects in the environment. The sense of embodiment gives rise to self-location (the feeling of being at a particular location and position in space) and egocentric frame of reference (navigating in the world with reference to one's own viewpoint and spatial location). The ability of humans to use symbolic analogues of themselves also permits mental imagery of the position of the body from a non-egocentric frame of reference (e.g., imaging the view of oneself from behind). In dreams and memories, experiences are sometimes transformed from a first-person to a third-person perspective, and some memories, such as the memory of giving a public address, tend to have a canonical third-person perspective (e.g., from the vantage point of the audience).

Although most individuals experience a spatial unity of self and body, in certain conditions individuals lose this routine sense. As described in Chapter 7, patients with right parietal damage may ignore or deny the existence of the left side of their body (neglect syndrome). Others experience sensations from an amputated body part (phantom limb sensations; see Chapter 4). Still other patients deny that their body is suffering from a particular ailment (agnosognosia) or may experience a feeling of being located outside their body (disembodiment). Out-of-body experiences can also be elicited by psychotropic drugs such as ketamine.

Two brain regions have been implicated in body representations and disembodiment phenomena. A region of extrastriate visual cortex, sometimes called the *extrastriate body area*, is engaged when individuals visually process human bodies or body parts, imagine changes in the position of a body part, or adopt a third-person perspective for visualizing their own body (**Figure 11.2A**). In addition, out-of-body experiences have been linked to the **temporoparietal junction**, a multisensory area at the border between the temporal and parietal lobes and surrounding the posterior aspect of the Sylvian fissure (**Figure 11.2B**).

The Swiss neurologist Olaf Blake examined these phenomena in epileptic patients undergoing neurosurgery, as well as in healthy adults during mental imagery tasks. One patient reported out-of-body experiences, illusory changes in arm and leg position, and whole-body displacements following stimulation of

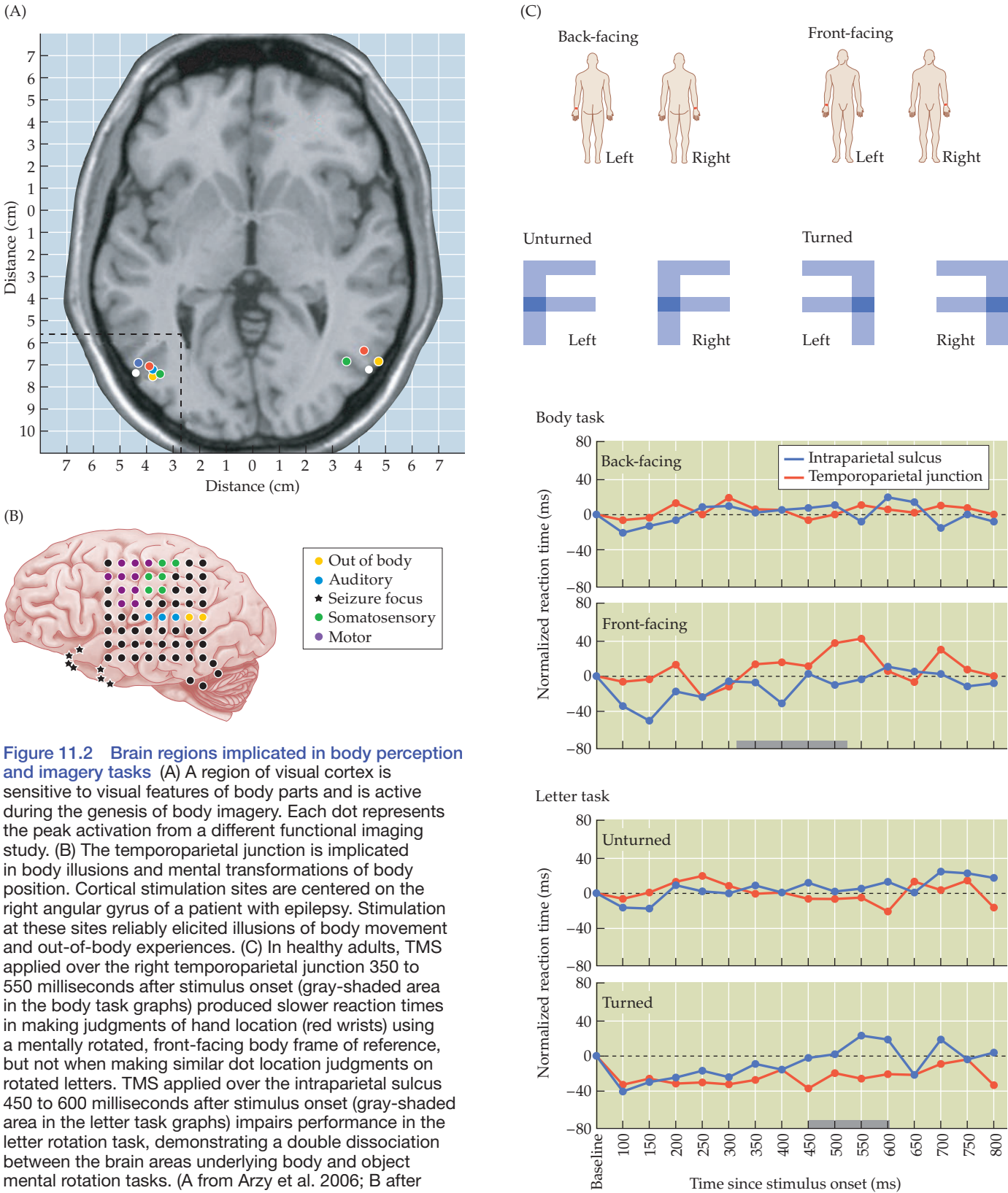


Figure 11.2 Brain regions implicated in body perception and imagery tasks (A) A region of visual cortex is sensitive to visual features of body parts and is active during the genesis of body imagery. Each dot represents the peak activation from a different functional imaging study. (B) The temporoparietal junction is implicated in body illusions and mental transformations of body position. Cortical stimulation sites are centered on the right angular gyrus of a patient with epilepsy. Stimulation at these sites reliably elicited illusions of body movement and out-of-body experiences. (C) In healthy adults, TMS applied over the right temporoparietal junction 350 to 550 milliseconds after stimulus onset (gray-shaded area in the body task graphs) produced slower reaction times in making judgments of hand location (red wrists) using a mentally rotated, front-facing body frame of reference, but not when making similar dot location judgments on rotated letters. TMS applied over the intraparietal sulcus 450 to 600 milliseconds after stimulus onset (gray-shaded area in the letter task graphs) impairs performance in the letter rotation task, demonstrating a double dissociation between the brain areas underlying body and object mental rotation tasks. (A from Arzy et al. 2006; B after Blanke et al. 2005.)

the right angular gyrus in the vicinity of the temporoparietal junction. Another patient was asked to mentally rotate her body to mimic the viewpoint of her seizure-induced out-of-body experience, and in this case increased activity was recorded near the seizure focus at the left temporoparietal junction. Similarly, healthy adults who imagine rotations of their body axis show enhanced ERP responses localized by source modeling to the temporoparietal junction bilaterally, but with a right-sided bias.

When TMS is applied to this region, judgments of body rotations are affected, but not judgments of mentally rotated objects (**Figure 11.2C**). Recall that areas near the temporoparietal junction in the right hemisphere have also been implicated in neglect syndrome (see Chapter 7). Given its multisensory input, this region may integrate visual attention with vestibular and somatosensory information to track body positions in space, establish an egocentric visual perspective, and help create a spatial unity of self and body.

In summary, focusing on oneself relies on processing in particular brain areas. The midline PFC, cingulate, and parietal regions contribute to aspects of self-reflexive thought; the insula and anterior cingulate contribute to the representation of central feelings, visceral sensations, and autonomic arousal; and the sense of embodiment relies on visual processing in the extrastriate visual processing areas and on multisensory integration in the temporoparietal junction. Other aspects of the self, including a first-person perspective during social interactions, a capacity for self-regulatory control, and the experience of ownership of intentional actions (agency), build on these basic processes that mediate focusing one's attention on the self and on a body representation of the self.

Perception of Social Cues Evident in the Face and Body

In primates, nonverbal cues in facial expressions and body language provide an abundance of information that influences interpersonal exchanges. Consider your reaction to greeting an acquaintance who fails to make eye contact, whose head and shoulders are turned down, and whose facial expression is unreactive during your conversation. Much information about the personality, mood, and intentionality of others can be inferred from such cues, even unconsciously. Comparisons of these cues with cultural schemas pertinent to social contexts and with prior encounters with the same individual allow you to infer the appropriateness of behavior, to detect changes in comportment, and thus to make appropriate responses. Decoding the nuances of these social signals requires the development of specialized perceptual skills, for an inability to extract such information can cause debilitating social deficits, as is evident in autism (see Introductory Box). The discussion that follows describes the analysis of facial and body movements; for a discussion of vocal affect, see Chapter 12.

Face perception

Human faces present particularly salient and complex social cues that we use to infer the mental states of others (a receptive function) and to influence someone else's thoughts and behavior (a communicative function). A prominent neuropsychological model of face perception (**Figure 11.3A**) includes a core system for the visual analysis of facial information that begins by parsing facial features in the occipital lobe. Following this initial stage, face processing is divided into two parallel but interacting processing streams. A ventral pathway—including portions of the fusiform gyrus and associated inferior temporal cortex—is specialized for the processing of invariant aspects of face perception in order to discriminate faces from other objects and to individuate particular people.