INTRODUCTION

A major goal of cognitive neuroscience is to identify the neural underpinnings of the processes by which individuals understand themselves and their relationships to others. This subfield, known as social neuroscience, builds on the developments in affective neuroscience described in Chapter 10—in particular, the evidence that emotions serve important social functions. Emotions evident in facial expressions, body language, and speech are a means by which we communicate our intentions to others, and by which we interpret their actions. Humans and other species that live in social groups have evolved mechanisms for establishing hierarchies among members, for building kinship and other social bonds, and for setting acceptable norms of behavior.

Dysfunctional social processing can have profound consequences, as exemplified by autism spectrum disorders (see Introductory Box) and antisocial personality disorders. In many animals the basis for social behaviors is determined genetically, with individual experience playing a relatively minor role. In humans, however, culture, customs, and social learning markedly influence behavior throughout the life span. Because social psychologists and neuroscientists have joined forces only recently, many issues and observations in this field are contentious, and the answers to many questions remain open. This chapter summarizes some of the areas at the forefront of this new subfield, including self-referential processing, perception of nonverbal social cues, social categorization, theory of mind, empathy, and social competition. Social communication by means of language is taken up specifically in Chapter 12, and social influences on decision making are discussed in Chapter 14.
INTRODUCTORY BOX AUTISM

The term autism spectrum disorder refers to any of a range of neurodevelopmental problems characterized by functional deficits in communication and social interactions, and by repetitive, stereotyped behaviors. Epidemiological research suggests that some form of autism affects up to one in every 100 children. The normal is highly variable, with approximately 98% heritable, with monozygotic twin studies indicating concordance rates from 50% to 65%.

Originally described by psychiatrist L. Kanner in 1943, autism (from the Greek word autos, meaning “self, same, spontaneous; directed from within”) is distinguished from other disorders by having social deficits as a core symptom. According to the American Psychiatric Association’s Diagnostic and Statistical Manual (DSM-IV-TR), the key criteria that define social deficits in autism include:

(A) impairment in using nonverbal behaviors in social interactions such as eye-to-eye gaze, facial expression, and body posture/gesture; (B) failure to develop peer relationships appropriate for the individual’s age level; (C) inability to spontaneously engage in or maintain social interests or achievements with other people; and (D) lack of social or emotional reciprocity. For these reasons, researchers have been greatly interested in autistic individuals to better understand how they perceive and interpret social elements that are crucial for others to understand.

When viewing faces, autistic individuals show reduced activation in the fusiform gyrus, inferior temporal gyrus, superior temporal sulcus, and amygdala. The activation decrements in the fusiform gyrus and amygdala correspond to a reduction in attentional allocation to the faces as measured by eye fixations (Figure B). Individuals with autism usually do not exhibit enhanced activity in these brain regions when the faces that they are viewing express emotions. Finally, unlike controls, autistic individuals do not exhibit activity increases in the superior temporal sulcus when gaze-directed biological motion sequences are viewed, as when viewing animated characters whose reaching motions seem to misdirect their intended targets.

Social impairments in autism extend beyond perceptual processes to include difficulties in interpreting meaning from interpersonal interactions. The inability to read the gaze of other individuals, which emerges early in development, contributes to later impairments in using gaze to understand other people’s intentions and desires and in developing vocabulary skills, which are socially learned by using gaze, head, and pointing gestures to associate objects in the environment.

Research efforts are increasing in part to help understand this complex disorder.

References

The Self

Distinguishing oneself from others is a necessary first step in establishing fluency in social interactions. Understanding the nature of the self is a long-standing concern of 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 duples, partly known and partly known, 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 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 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 shown to temporally block the retrieval of some self-relevant knowledge. The degree of anterior medial PFC activity in response to trait words during self-endowment 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 cues 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.
Emotional Awareness Scale, which assesses how deeply and completely 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 alternations in respiration and heart rate during arousal 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 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 parietal function, 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 Blanke 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
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 modelling 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 PPC, 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 unresponsive during your conversation. Much information about the personality, mood, and interpretability 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 neurophysiological 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 parts of the fusiform gyres 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
facial features, such as changes in emotional expression, mouth movements, and gaze shifts (see Figure 11.3A). The detection of these attributes of biological motion is relayed to the amygdala and other limbic forebrain structures for the analysis of emotion, to multisensory areas for the integration of mouth movements with speech, and to the parietal lobe for spatially directed attention to respond to head movements or gaze shifts. The two pathways must interact (e.g., detecting your sister's quirky smile can facilitate her identification), and later processing stations are assumed to feed back onto earlier ones to enhance attention to particular facial features as necessary (e.g., to focus attention on specific face parts in order to resolve ambiguous facial expressions).

Evidence for the partial independence of invariant and dynamic featural processing of faces comes from studies of prosopagnosic patients who have suffered damage to ventral regions of the temporal lobe (see Introductory Box in Chapter 3). These patients have difficulty recognizing individuals by their facial features, but they often identify emotional facial expressions correctly. In contrast, patients with damage to the amygdala or STS have difficulty evaluating emotional expression and/or eye gaze direction, but they can recognize and name individuals normally. Electrophysiological recordings from neurons in the temporal lobe of non-human primates confirm that different populations of cells are specialized for signaling facial identity versus facial expression (Figure 11.3B), in accord with neuroimaging observations in normal humans (Figure 11.3C).

Evidence for the integration of dynamic social information in faces has also come from electrophysiological studies of non-human primates. When monkeys watch images of conspecifics, neurons of the STS tend to increase their firing rate when there is a correspondence between the direction of head movement and the direction of eye gaze, suggesting a preference for a spatial alignment of these two signals (e.g., face forward with eye contact, or both face and eyes averted). In the human amygdala, activity in response to facial expressions also varies according to whether the direction of gaze is forward or averted (Figure 11.4). Responses in both of these regions are enhanced to stimuli that present dynamic shifts in facial configurations compared to static displays.

Decoding rapid changes in facial movements facilitates quick reactions during personal interactions and helps predict the impending actions of others. The ability to extract signals from the position of the eyes may have been helped by an evolutionary change in the color of the sclera, from the darker color in non-human primates to white in hominids. The whites of the eyes make it easier to discern the direction of gaze, and they are important for detecting a person's emotional state. For example, in response to the sympathetic nervous system activity elicited by fear, the palpebral fissure widens markedly, showing more scleral white, and the pupils dilate.

Figure 11.3 Pathways for face processing in the temporal lobe (A) Visual information flows along an inferior temporal—hippocampal route for facial identity, person recognition, and name retrieval. By contrast, a superior temporal—amygdala route processes dynamic feature encoding of facial information, including analysis of eye gaze and emotional expression. (B) Single neurons in the monkey temporal lobe responded to facial expression and identity. Macaque monkeys were shown three faces of conspecifics that expressed three different emotions. Recordings were obtained from 45 neurons that showed selective responses to faces relative to other objects. Whereas most emotion-selective neurons were located in the superior temporal sulcus, most identity-selective neurons were located in the inferior temporal cortex. (C) Similar dorsal/ventral dissociations in the temporal lobe are apparent in human subjects when participants are presented with faces that changed in either emotional expression or personal identity. pSTS, posterior superior temporal sulcus; ITG, inferior temporal gyrus; pSTG, posterior superior temporal sulcus. (A) after Haxby et al. 2000; B after Heiseim et al. 1989; C from LaBar et al. 2003.)

Figure 11.4 The importance of eye features in sociomotional communication. The amygdala responds with more intense fMRI activity to threatening faces when eye gaze is direct compared to when it is averted. Individuals tend to judge direct eye contact in the context of a negative social interaction as being more threatening. (After Adamer et al. 2003.)

particular people. Recall from Chapter 3 that a region in the fusiform gyrus called the fusiform face area is to some degree specialized for encoding such information about faces. Face representations of this ventral pathway are then linked with semantic and episodic knowledge about individuals (such as their names, personalities, and memories of shared experiences) through additional processing stages in the anterior temporal lobe, including the hippocampi and surrounding cortex. In this way, the ventral pathway forms the basis for person recognition.

Another pathway routed through more dorsal sectors of the temporal lobe, including the superior temporal sulcus (STS), is thought to process dynamic
Perception of biological motion

Nonverbal communication entails much more than analyzing faces; as already implied, body movements and gestures are equally important. In parallel with face processing, visual information about the position and status of other body parts is relayed from visual areas (including the specialized extrastriate body area) to similar person recognition and biological motion pathways in the temporal lobe.

Neuroimaging and intracranial recording studies of body part gestures and whole-body ambulation indicate that the posterior STS, particularly in the right hemisphere, discriminates biologically plausible from implausible motion (Figure 11.5). Responses of the STS are greater to human and robotic walking relative to either coherent mechanical motion, such as pendulum swings, or fragmented biological motion (moving but detached body parts). This brain area also responds to human walking even when body parts are partially occluded, which is important for tracking biological motion in natural circumstances.

The STS shows a preference for body actions that are meaningful and goal-directed. For instance, hand and arm gestures that complete intentional action sequences, such as grabbing a coffee cup and lifting it to the lips, are signaled more robustly than are meaningless or scrambled action sequences. In accord with this observation, sign language gestures that complete grammatically appropriate sentences engage this region more in studies of congenitally deaf individuals than do nonsense gestures.

Activity in the STS further indicates when body movements violate expectations set up by the social circumstance or conflict with other cues (Figure 11.6). For instance, when watching an animated figure direct eye movements in response to the appearance of a visual target, participants' activation in the STS are stronger when the figure's gaze fails to track the object than when it succeeds (Figure 11.6A). In most natural situations, a person's gaze tracks
objects that suddenly appear in the environment, so gaze tracking failures are considered a violation of expected behavior. In addition, the STS preferentially signals when animated characters display conflicting information between their arm gestures and facial affect during a social exchange compared to when these cues are congruent (Figure 11.6B). Such studies highlight the importance of prior knowledge about how people typically behave in social settings (generally, or individually) in gleanig insight into the meaning of their current actions.

Interpretation of body language is effective only insofar as it leads to appropriate planning of actions in social settings. The output of the STS is conveyed to frontalparietal cortices for intentional modulation and action planning, as well as to limbic brain structures for further interpretation of the emotional and motivational significance of the motion patterns.

Interpersonal attention and action direction

In social groups, changes in body posture, head orientation, direction of gaze, and facial expression are combined with vocalizations to communicate the attitudes of individuals toward one another and to signal the presence of significant stimuli in the environment. How these cues are used to interpersonally direct attention and initiate group actions has been investigated in studies of social referencing and joint attention.

Social referencing refers to the use of body gestures and facial and vocal expressions of others to determine how to deal with an ambiguous or novel situation. During development, social referencing is critical for learning how to appropriately behave in particular situations, given the lack of social knowledge and self-regulation abilities of young children. For instance, when confronted by a visual cliff apparatus that gives the illusion of a sudden drop in height, 10- to 12-month-old infants will cross the cliff only if guided by positive emotions and encouraging gestures expressed by the parent. In this case, the nonverbal signals communicate to the child whether approach or withdrawal behavior is appropriate in a given context. The emotions in this situation are used to direct the actions of the infant rather than to express the internal state of the parent. Social referencing occurs in a variety of interpersonal contexts to glean information from others to help select appropriate actions.

Joint attention refers to the allocation of processing resources toward an object cued by another individual. This ability emerges in infants around 1 year of age. Gaze direction, head orientation, and body and trunk position all indicate when an individual is focusing attention, making it easy for others to take advantage of this information, particularly to make inferences about features of the environment that otherwise would be ignored, or that are out of one’s own field of view. Nonhuman primates can also exploit joint attention through deception, presenting misleading displays to others and then directing their own actions elsewhere. In humans, this behavior is exemplified by pickpockets, magicians, and athletes, who fake an intended action to facilitate a different one.

Such abilities require knowledge about how others cue spatial locations in the environment. Electrophysiological studies of the monkey STS show that some neurons are tuned to multiple body features to signal the information conveyed by the orientation of a conspecific animal. For example, a neuron might fire in much the same way in response to downward deflection of the eyes or head, or a crouched body position of another monkey, all of which indicate the other animal’s attention to something on the ground.

A variant of the Posner attentional cueing task (see Chapter 6) has been used to investigate how gaze shifts can direct visual spatial attention in monkeys and humans. Recall that in this task a central cue is used to direct attention toward a peripheral location in space where an upcoming target may appear. For faces, the position of the eyes serves as a salient cue about where someone is focusing attention in space (even more so than head direction or body posture in some circumstances). To model such behaviors experimentally, subjects in a gaze-directed attentional cueing paradigm are shown a face and are required to respond to a subsequent target that appears either in a location cued by the gaze of the face (valid trials) or in the opposite hemifield (invalid trials) (Figure 11.7). The subject reaction time to detect or discriminate the target is then compared for validity cued and invalidly cued trials to quantify whether the gaze shift was attended by the participant (who is given no other explicit instruction about where to attend). Compared to the use of arrow cues in the standard Posner task, subjects are more willing to follow gaze even when its predictive value is low, suggesting more automaticity in following gaze than in using other symbols to guide attention.

Valid gaze cues improve target detection performance and lead to larger-amplitude early ERP components (P1 and N1) to those targets, implying...
attentional modulation of visual processing in extrastriate regions of cortex (see Chapter 6). Invalidly cued targets show slower reaction times and elicit a P300 component, suggesting a need to update information in working memory because the target appears in an unexpected location. Violations of expectancy based on gaze direction also modulate fMRI activity in the STS, further supporting the important role of this region in using biologically significant cues to guide attention in social settings.

In sum, nonverbal cues from the face and body provide a wealth of information that facilitates social interaction. Analysis of this information aids person recognition, provides insight into an individual’s emotional state, and guides interpersonal behavior through social referencing and joint attention. Several brain regions contribute to the perception of social cues, including face- and body-processing regions of the visual cortex, the amygdala, and the STS. Some of these areas, such as the amygdala and STS, are sensitive to multiple communicative signals. Stronger responses are elicited in the STS when perceived actions violate expectations, which helps to indicate when the behavior of others doesn’t align with their goals or when they are expressing mixed messages.

Social Categorization

The perception of people’s identifying features is also used to gauge the characteristics of individuals and place them into social groups. Resource models in social psychology argue that such processes are useful because they facilitate our ability to form impressions and make sense of those around us, especially given the large social network size of humans. For instance, if you are introduced to someone who claims to be a member of a particular political party or religious sect, this information can provide some clues as to the person’s core values. Categorizing individuals in this way involves both automatic and controlled processes and is influenced by cultural norms, knowledge of stereotypes, and personal attitudes.

From an evolutionary perspective, social categorization serves important survival functions in defending territories from invading groups, identifying and protecting kin, and selecting mates. In human cultures, however, it is also clear that prejudicial reactions based on stereotypes of individuals according to their gender, race, and other factors can and do lead to social injustice. As a result, there is much interest in using neuroscience approaches to inform theories and identify mechanisms of stereotyping and social categorization, and to determine the extent to which these phenomena can be voluntarily regulated and changed by social interactions with others.

Perception of social category information

Research using ERP has identified the earliest stages of neural processing that are influenced by social category information such as race. ERP studies have shown that the favored method because their temporal sensitivity permits an investigation of rapid, automatic influences of category information before participants can engage deliberate control processes to alter their responses (e.g., to appear more egalitarian). In a typical study, subjects view faces that vary in ethnicity (along with gender and other factors) and categorize those faces according to either racial or nonracial features. Effects attributed to racial categorization generally appear within 200 milliseconds of stimulus onset and are characterized by larger left frontal N1 and P2 amplitudes for racial out-group faces than for racial in-group faces (Figure 11.8). These early ERP components index attentional orienting responses (see Chapters 2 and 6) and may reflect greater vigilance to unfamiliar out-group members. Later in time the racial category effects reverse, such that enhanced frontocentral N2 responses are observed to in-group faces, perhaps indicating a shift toward greater individualization of the faces (see Figure 11.8). The impact of social category on early ERP amplitudes is greater when viewing racially ambiguous compared to ambiguous (biracial) faces, and when viewing faces relative to other body parts.

These ERP effects are present regardless of whether the task requires an overt racial categorization or not. Other studies have replicated these findings using tasks known to reduce stereotyping effects, such as detecting a particular visual feature in the stimulus (feature detection task) or judging whether the person depicted is likely to be introverted or to exhibit a particular food preference (individualization task). Such observations indicate that the early processing of social category information may be relatively obligatory, even when that information is not critical to the content of the social interaction.

Stereotypes and automatic racial biases

In addition to the analysis of perceptual features that indicate social categories, interpersonally exchanges can be affected by stereotypes, prejudicial emotional responses, and, ultimately, overt discrimination. In racially biased individuals, executive processing resources are often recruited in an effort to control the expression of automatic negative attitudes toward out-group members. Even in individuals with more egalitarian social views, automatic activation of familiar cultural stereotypes must be overcome to guide social behavior according to one's own attitudes. Building on a foundation of research on emotion processing, emotion regulation, and cognitive control (see Chapters 10 and 13), researchers have begun to identify brain regions whose activity relates to measures of racism and interracial interactions.
One such study reported a correlation in Caucasian participants between amygdala activity in response to unfamiliar African American faces and subtle eyeblink responses (see Figure 11.8). Because potentiated eyeblink responses are indicative of negative evaluations (see Box 10A), this study provided additional validation of the IAT as a measure of implicit racial attitudes. The results did not extend to explicit measures of racial bias as assessed by the Modern Racism Scale (see Box 11A), implying that the brain imaging findings may be more specifically associated with implicit racial biases. Subsequent research has also related stare responses and amygdala activation to implicit racial bias but has also shown that these effects are attenuated when the faces are familiar, when the faces have averted rather than direct gaze (which minimizes their threat value) see Figure 11.4, when the task emphasizes individualized rather than categorical processing of people, or when the faces are shown for prolonged durations (presumably reflecting engagement of control processes). Additional evidence suggests that face-processing regions of the fusiform gyrus show enhanced activity for faces of one's own race, perhaps because of greater individuation and/or familiarity with in-group members. Together, these findings highlight the plasticity, contextual modulation, and regional specificity of neurophysiological activity when members of stigmatized cultural groups are evaluated in various ways. Such work presents numerous ethical and experimental challenges, and the results must be interpreted cautiously. For instance, functional brain imaging is inherently correlational, and the causal role of brain activity in a given region for behavior as complex as social biases can only be suggestive. A brain scan cannot definitively indicate whether someone is racially biased, whether the activity patterns represent a source or a consequence of behavior, or whether the activity has been shaped by prior exposure to stereotyped messages or by personal experiences. Brain imaging provides only a snapshot of activity in an experimental setting during the performance of a particular cognitive task, and the results may not generalize to behavior during real-world social exchanges. Finally, such measures rarely distinguish between activation of semantic knowledge related to cultural stereotypes versus a personal, evaluative attitude toward members of a social category.

**Monitoring and controlling racial bias**

Additional work has focused on neural mechanisms engaged when group stereotypes induce response conflicts and motivate a need for voluntary control over biases that might be expressed. A two-stage model of cognitive control (see Chapter 13) supposes the following: (1) that anterior cingulate activity reflects continual monitoring of conflict during information processing; and (2) that prefrontal regions are subsequently recruited to implement regulatory responses once a need for conflict resolution has been detected. The two-stage model has been combined with knowledge about sources of ERP components to make predictions regarding when and how cognitive control is engaged in intergroup scenarios. For instance, a key ERP component is the error-related negativity (ERN), which is sensitive to information-processing conflicts that lead to response errors. The ERN has been localized to the anterior cingulate gyrus and offers a potential neural index of ongoing conflict monitoring that can be applied to studying personal interactions that lead to self-regulation failures (see Chapter 13 for other interpretations of the ERN).

As an example, the ERN has been used to investigate conflict monitoring of racial stereotypes on a weapons identification task. In this rapid classification task, Caucasian participants had to decide whether briefly presented pictures of objects on a computer screen were weapons or tools. Prior to each presentation, an African American or Caucasian face was flashed on the screen. Priming of objects by African American faces tended to facilitate detection of weapons and impair detection of tools, whereas priming by Caucasian faces had no differential effect. The ERN that was time-locked to the response showed not only sensitivity to performance (larger for errors than for correct object classifications) but also stereotype incongruity on error trials (larger for tools primed by African American faces than for the other face-object combinations; Figure 11.9).

The ERN stereotyping effects were larger in individuals who characterized themselves as being primarily internally motivated to regulate prejudiced reactions than in those who acknowledge avoidance of social disagreement as part of the motivation to regulate their reactions. If the two-stage model of cognitive control is correct, this finding suggests that internally motivated individuals exhibit greater online monitoring of stereotype conflict as a potentially biased response is generated. Because the behavioral and ERN results occur in individuals with low levels of racial bias, they implicate a Stroop-like response conflict due to automatic activation of learned cultural stereotypes in relation to aggression and hostility (see Chapters 7 and 13 for a discussion of the Stroop effect). Internally motivated, low-bias individuals have greater motivation to override these automatic stereotypes in order to behave in accordance with their egalitarian predispositions.

Prefrontal responses to out-group faces may also mediate the relationship between implicit racial attitudes and cognitive consequences following an intergroup encounter. In one study, researchers gave Caucasian participants the IAT test followed by a staged encounter with either an African American or a Caucasian experimenter, who asked them to comment on social topics of
racial profiling and the college fraternity system. A classic Stroop color-naming interference task (see Chapter 13) was then administered. In a separate session, the participants underwent fMRI scanning while being presented with either African American or Caucasian faces. Performance on the Stroop task was quantified as a function of implicit racial attitudes and the race of the experimenter in the social encounter, and compared with the fMRI activity to out-group faces.

As Figure 11.10 shows, individuals characterized by implicit racial bias based on IAT performance exhibited greater Stroop interference following the interpersonal encounter, but not following the encounter with an in-group member. Functional MRI analyses revealed a positive correlation between performance on the IAT task and activity in the anterior cingulate and dorsolateral prefrontal cortex (dPFC) to African American faces relative to Caucasian faces. The magnitude of dPFC activity also predicted the relationship between IAT and Stroop task performance. These results suggest that individuals with implicit racial biases exert greater effort in controlling reactions to out-group members in part by engaging prefrontal circuitry.

This initial body of research has laid the groundwork for discovering the relationships between social behavior and brain correlates of the psychological constructs underlying racial bias. To guard against the influence of cultural stereotypes, internally motivated, low-bias individuals experience greater demand on executive resources than do high-bias individuals. In contrast, high-bias individuals experience greater demand during inter racial encounters. Such endeavors inform debates about the role of neuroscience in contributing to an understanding of racial and other social prejudices.

Impression formation and trust

In addition to social category information, other personal attributes are readily judged from physical features and inferred from nonverbal behaviors to form general impressions of individuals. One such personality trait is trustworthiness. Many individuals end up in bankruptcy because they are susceptible to financial scams. People who find themselves in this predicament may be poor at evaluating the trustworthiness of those who are trying to get their money.

Neuroimaging studies have found that assessment of trustworthiness based on facial appearance alone is associated with activity in brain regions involved in other aspects of social cognition and emotional evaluation. In particular, enhanced activity is observed in the insula when participants are shown faces of individuals whom others have judged to have an untrustworthy appearance, and enhanced activity is observed in the medial PFC, orbitofrontal cortex, and claudate for faces deemed trustworthy. The amygdala responds to both highly trustworthy and highly untrustworthy faces; however, it is more sensitive to differences in untrustworthy faces (Figure 11.11A). These patterns are evident even when the faces are not explicitly appraised for trust, indicating automatic evaluative processes. Confirming the neuroimaging findings, autistic individuals
modeling one’s behavior after the behavior of others to transmit learning and establish cultural practices. In humans, social competence is further facilitated by inferring mental states in others, and attributing the actions of others to their beliefs, goals, desires, and feelings. This multifaceted capacity is called mentalizing or theory of mind.

Scholars debate about whether mentalizing occurs through simulation of the behaviors and internal states of others (e.g., mentally representing potential actions, feelings, or thoughts of others as if they were one’s own) or by the building of theories (scripts) of how others typically behave in particular contexts. The philosopher Daniel Dennett suggests that social interactions benefit when one adopts an intentional stance—that is, assuming that others are agents motivated to behave in a way that is consistent with their current mental state, which may differ from one’s own mental states and/or the reality of the situation. As detailed in the discussion that follows, coding and interpreting the actions and mental states of others are complex processes involving both dedicated neural systems and the co-opting of domain-general functions like working memory and symbolic representation.

Mirror neurons

To interpret behaviors meaningfully, it is useful to code actions performed by others in a way that is related to one’s own actions. In the 1990s, the discovery of mirror neurons in the premotor cortex of the macaque monkey brain sparked much interest and debate about possible neural mechanisms underlying action representation. These neurons in and around the inferior frontal gyrus (area F5) presumably homologous to the inferior frontal convexity in humans) increase their activity not only when a grasping action is selected and performed, but also when that action is passively viewed while it is being performed by another animal or a human experimenter (Figure 11.12).

Such mirror responses are more robust when participants are observing goal-directed biological actions compared to non-goal-directed biological actions (mirrors) or goal-directed mechanical actions (e.g., a hammer hitting a nail). The responses often track the general goal of the motor act (e.g., putting food into a bucket) rather than the specific features of the movement, such as the initial starting position or orientation of a hand executing the action. A smaller proportion of F5 neurons respond to both visual and auditory features of a unique goal-directed biological action (e.g., ringing a bell).
Figure 11.13 The monkey and human mirror systems. (A) Schematic of the key components in the macaque brain (shaded in yellow). The system includes the ventral premotor cortex (FS), ventral parietal region (IPG, AIP), and their interconnections (solid lines). Connections between the mirror system and some other brain areas are indicated by dashed lines. AIP, anterior intraparietal area; FS, dorsal premotor cortex; IAS, inferior limb of the arcuate sulcus; IPG, intraparietal sulcus; IF, inferior temporal lobe; IP, lateral intraparietal area; STS, superior temporal sulcus; vPM, ventral intraparietal area; vPF, ventral prefrontal cortex. (B) The putative human mirror system. Data are from an fMRI study that identified reliable activations across individual subjects for both action observation and action execution. vPM, dorsal prefrontal cortex; MTG, middle temporal gyrus; vPM, ventral premotor cortex. (A after Rizzolatti and Sinigaglia 2010; B from Keysers et al. 2010.)

Mirror neurons have also been found in a region of rostral inferior parietal cortex that projects to premotor area F5, implicating an interconnected frontal-parietal mirror system (Figure 11.13). Some neurons in this circuit also exhibit content specificity of the action sequences related to the end goal (e.g., selectively responding to grasping actions that lead to eating rather than grasping actions that simply move an object from one place to another). Neurons in the superior temporal sulcus (STS) relay peripersonal information about biological motor to the parietal component of this system but do not exhibit mirroring responses themselves. Because the observation of actions does not automatically elicit an analogous motor response, activity in this premotor circuit is inhibited to prevent obligatory copying behavior.

A number of investigators have used this neurophysiological evidence to speculate about the importance of these areas of the primate brain in generating an understanding of the intentions of others, language acquisition, and empathy (discussed below), as well as the functional deficits apparent in behavioral disorders such as autism (see the Introductory Box). Whether these implications will be validated remains to be seen, and caution is warranted. For one thing, adult monkeys do not learn much by direct imitation—a fact that undermines what would perhaps be the simplest interpretation of the role of mirror neurons. And in humans, where these speculations are most pertinent, the evidence for mirror neurons is suggestive but does not correspond directly to the anatomical or functional properties observed in monkeys. For instance, cortical activity detected with fMRI in response to similar paradigms in humans is more widely distributed throughout the motor system and STS; moreover, similar activity occurs when people mime. Unlike the monkey neurophysiological data, most of the human evidence has come from brain imaging studies. These studies do not have the spatial resolution to determine whether the executed and observed actions are being signaled by the same neurons (a key criterion for defining a mirror neuron) or by adjacent ones within the same general brain area.

Some researchers taking an embodied cognition perspective (see Chapter 9) have suggested that mirror neurons provide a means for understanding social actions through direct perceptual-motor links. Others believe such linkages are simply established by experience through general associative learning processes and do not represent a unique social cognitive function. Whatever the correct interpretation, these observations indicate that viewing actions pertinent to particular behavioral goals influences the activity of some frontoparietal neurons in the same way as performing those actions does.

Perspective taking and mental-state attribution

Although mirroring functions help establish shared representations used for understanding agent-directed actions, they do not readily distinguish the execution of one's own actions from the observation of similar actions executed by others. Moreover, actions do not map onto intentions in a one-to-one manner. Mirroring depends on another agent being present in the immediate environment and cannot account for other forms of mental simulation, such as self-projection into past or future circumstances. In short, differentiating one's actions from those of others and understanding the reasons behind others' actions clearly require cognitive abilities and mechanisms that go beyond mirroring.

Key among these is the ability to flexibly adopt the perspective of another individual (third-person perspective) and distinguish that viewpoint from one's own (first-person perspective). Because an egocentric view of the world may be part of a default mode of information processing, adopting other people's perspectives and inferring their beliefs, motives, or feelings requires a disengagement of self-directed thoughts, a redirection of attention to the mental and physical states of others, and a decoupling of knowledge of the actual unfolding of events from other people's perceptions of those events. Memory is also important in this process because prior knowledge about the personality traits and response patterns of others in similar contexts refines one's own interpretation of the current social context and the possible responses to it.

Neuroimaging studies have compared first- and third-person perspective taking across different cognitive, emotional, and motoric domains. For instance, participants might imagine themselves or someone else performing specific actions, responding to a painful stimulus, or reacting to an emotional scenario. Other studies of mental-state attributions have asked participants to consider the viewpoints of different characters in stories or cartoons, to guess what an opponent might do during an interactive game, or to judge whether historical figures had access to knowledge about specific artifacts. While many studies have used explicit instructions to adopt the perspective of another agent, in social situations often the intentions and mental states of others are inferred spontaneously.

In all these domains, taking the perspective of others and inferring their mental states elicits activity in a set of brain regions that includes the medial PPC (most consistently the paracingulate cortex), temporal polar cortex, right inferior parietal cortex, temporo-parietal junction, and superior temporal sulcus (Figure 11.14). Because of the complexity of the mentalizing construct, heterogeneity of the tasks involved, and variety of the control conditions employed, it is difficult to ascribe specific functions to these brain areas. Nonetheless, the temporo-parietal junction may be particularly concerned with transient inferences based on the current context, whereas the medial prefrontal cortex may be
Concerned with inferences based on more enduring traits or qualities. Although some view these regions as simply supporting domain-general cognitive operations needed to solve the mentalizing tasks (the functions needed to retrieve memories or semantic knowledge, reallocate attentional resources, manipulate internal representations, etc.), recent evidence indicates some specificity in the relevant brain activity for solving social problems. For instance, the medial PFC activation during mentalizing tasks is greater than during general reasoning tasks that do not involve social evaluations.

Theory of mind in children and apes

In the late 1970s, psychologists David Premack and Guy Woodruff raised the question of whether chimpanzees and other great apes have the capacity to represent and understand the mental states of conspecifics in the same general way that humans do. Observations of great apes in the wild indicate that they engage in deception to hoard food sources, for example, which requires at least some understanding of where conspecifics are orienting their attention and what they expect to happen in a given social context.

To ask whether chimpanzees have basic mentalizing abilities, experiments paired subordinate and dominant chimpanzees in a large chamber (Figure 11.15). The subordinate chimp was shown food items that the dominant chimp could either see or not see, or was shown that the location of a food item had not been switched out of view of the dominant chimp. In either case, the subordinate chimp showed a preference for moving toward food items about which the dominant chimp either had no knowledge or could be assumed to hold a false belief about its location. Such behavior clearly imparts an advantage to the subordinate chimp in the context of competition for food with a dominant conspecific, and could be interpreted as relying on some degree of third-person perspective taking.

However, the acid test of a theory of mind is the capacity to predict others' behavior according to false beliefs that they hold. Understanding the false beliefs of others requires making a distinction between knowledge about a true state of affairs and what another individual falsely believes to be true. False-belief experimental tasks come in two major flavors: location-change tasks and unexpected-contents tasks (see also Chapter 15). In location-change tasks, an object is placed in one location, and unbeknownst to a third party, the position of the object is switched to an alternate location. The participant then must indicate where the third party would look for the object (its true location or the location where the third party last viewed the object). In unexpected-contents tasks, an object is placed in a container, and unbeknownst to a third party, the object is replaced by another one. The participant must then indicate which object the third party thinks is in the container.

Humans develop false-belief attributions to characters in animated vignettes by about 4 years of age. However, because these tasks require complex narrative and action sequence comprehension, working memory, and inhibition of rapid responses, there is some debate about the specificity of the findings. Some investigators have proposed that children between 3 and 4 years old simply learn to select the correct responses in the task rather than depending on theory-of-mind abilities. Nonetheless, children of this age routinely use words like pretend, think, know, want, and like, implying some knowledge about mental states. In contrast, autistic children and autistic adults generally fail false-belief tests, although some investigators find the evidence to be equivocal because of the potentially confounding deficits in language abilities and executive function present in autism.

Given the controversy over whether children and chimpanzees possess theory-of-mind abilities, some investigators have turned to the distinction made in memory research between implicit and explicit processes (see Chapter 8). Most researchers believe that young children and great apes can implicitly (i.e., unconsciously) track another individual's mental state. However, they also admit that there is currently no convincing evidence that young children and apes can explicitly represent the mental contents of another individual, as in
the ability to have thoughts such as “I know my friend thinks that the food is in location A when I know it is really at B.” This ability to abstract the mental contents of agents in a social situation and represent them symbolically, also called *metarepresentation*, presumably requires further cognitive development and is unlikely in young children, let alone non-human primates.

**Empathy, sympathy, and prosocial behavior**

Understanding another individual's beliefs, goals, and intentions also extends to emotion. Although sometimes incorporated into the concept of theory of mind, understanding others' emotional states recruits brain regions that are not necessarily used for making inferences about other mental states. A better descriptor of understanding someone else's emotional state is **empathy**. Empathy is the capacity to comprehend and resonate with another's emotional experience, which leads to a sharing of that person's feelings. Once an empathic feeling arises, individuals must distinguish their own emotional responses from those of the other individual and regulate their responses accordingly. This ability requires knowing that the other person's feelings are the source of the shared emotional state.

Rather than exemplifying a specific emotion, empathy can be considered a process by which any emotion is shared according to the social context. For instance, having a conversation about a friend's nervousness before a job interview may lead to shared feelings of anxiety. When the conversation shifts to the outcome of the interview, feelings of disappointment may be shared upon hearing that the job was not obtained. Elliciting empathy is critical for effective storytelling and advertising.

Empathy differs from **sympathy** in that a sympathetic reaction does not entail a sharing of emotional experience. Rather, a person who is sympathetic may feel concerned or sorry for the plight of another person but does not feel the actual emotion felt by the other. In the job interview example, for instance, one may feel sympathetic toward a friend's situation without actually experiencing anxiety or disappointment of one's own.

Empathy has both automatic and controlled components and builds on basic social cognitive and emotion-processing mechanisms. Early in development, human infants will cry in reaction to another infant's cry and will mimic basic facial emotions expressed by a parent. At about 2 years of age, when self-versus-other distinctions and social emotions such as shame begin to emerge, children express sympathetic concern, such as gestures of consolation to family members in distress. Although initially such gestures are egocentric (e.g., offering a gift such as a doll to an adult whom the child likes), the offerings gradually become other-focused (e.g., offering a gift that the adult family member likes).

With increased cognitive and emotional capacities for perspective taking later in childhood, more complex forms of empathy are conveyed. Forms of empathy observed in apes presumably rely on more automatic aspects of emotion interpretation and somatic activation, which contribute to helping, affiliative, and cooperative behaviors.

Psychologist Jean Decety developed a model of empathy that encompasses several of the social and emotional processes, as well as the concept of representational, discussed earlier (Figure 11.16). According to the model, a full empathic response, which can be initiated either automatically or voluntarily, requires the coordinated operation of four component processes:

1. **Emotion sharing** between individuals is based on automatic perception-action coupling and shared somatic-emotional representations that rely on processing in the somatosensory cortex, insula, and anterior cingulate cortex.

   - **Emotion sharing**
   - Somatosensory cortex, insular system
   - Mental flexibility
   - Medial and dorsal PPC
   - Self-awareness
   - Inferior parietal cortex, PPC, and insula

   - **Mental flexibility**
   - Anterior cingulate cortex, lateral and ventromedial prefrontal cortex

   - **Emotion regulation**
   - Anterior cingulate cortex, lateral and ventromedial prefrontal cortex

   - **Self-awareness**
   - Inferior parietal cortex, PPC, and insula

2. **Self-awareness** and the distinction between self and other are also thought to entail processing in the parietal lobes, prefrontal cortex, and insula.

3. **Mental flexibility** to adopt the perspective of another individual recruits medial and dorsolateral prefrontal regions, among others.

4. **Emotion regulation** operates on the emotional and somatic states generated by engaging executive control mechanisms in the anterior cingulate and lateral and ventromedial prefrontal cortex.

Evidence to support the emotion-sharing component comes from studies that ask participants to observe another individual experience an emotion and to experience the same emotion themselves (or imagine their own emotional reaction to the same situation). The logic of these studies is similar to the mirroring tasks described earlier, but it concerns emotional states rather than motor actions. The brain regions involved in these tasks include the insula, anterior cingulate cortex, and secondary somatosensory cortices (Figure 11.17A), which are thought to represent a shared feeling state with another individual and promote a motivation to act. These areas are distinct from those that mediate the self-awareness (see Figure 11.1) and mental flexibility (Figure 11.17B; see also Figure 11.15) components of empathy, as well as the mirror neuron circuit for action understanding (see Figure 11.13). Brain regions that support emotion-regulating processes are discussed in Chapter 10.

Although it is generally assumed that empathy leads to helping others and altruistic behaviors, additional factors influence such prosocial behaviors. For instance, high levels of arousal associated with observing another's troubled emotional state can lead to personal distress, a lack of emotion regulation, and thus an inability to take action other than to alleviate one's own distress. Prosocial behaviors are more likely when an individual is in a positive mood; when the action required is not unpleasant or onerous, and when the person to be helped is not a direct competitor. Adults (but not young children) may also engage in helpful behaviors to repair sad moods because they understand the social rewards associated with the actions. Nonetheless, in some circumstances
empathy can lead to antisocial behavior, as when an accomplice is empathic toward the motives of a fellow criminal.

Social Competition

Competition among members of a species' social group establishes hierarchies that affect the distribution of wealth, resource allocation, mating opportunities, and division of labor. Leaders of the social group are responsible for defending against intruders and for establishing acceptable norms of behavior. Members who do not adhere to the rules face punishment or ostracism. Provided that governance and rank are not entirely inherited, group dynamics can influence the maintenance of the hierarchy, leading to social upheaval and a change in social structure. The biobehavioral processes that mediate social competition and its consequences for the individual are described here.

Of course, social competitive forces must be balanced by social cooperative and affiliative functions that promote social bonds among a particular group's members. Some evolutionary anthropologists believe that the drive for social cooperation was particularly influential in the evolution of advanced intellectual skills in humans. These topics are covered in Box 11B and Chapter 15.

Social rank and stress

For species that live in social groups, the relative dominance ordering (rank) of individuals has important implications for physical and mental health. In Westernized human societies, lower socioeconomic status is associated with increased risk of cardiovascular, respiratory, rheumatoid, and psychiatric diseases, as well as increased mortality rates (including infant mortality). Both physical and psychosocial stressors contribute to these effects (see Box 11B for a description of the stress system). The impact of rank remains significant even when other lifestyle factors, such as higher incidence of alcohol use or poor diet, are taken into consideration. Although socioeconomic status indicates rank at a macro level of social organization, the complex, nested structure of human cultures yields ranks at multiple social scales (e.g., within one's family, place of employment, or peer group).

Across species, the relationship between rank and stress further depends on the characteristics of the culture. For despotic social groups—in which resource access is skewed and dominance is attained through intimidation—stress is particularly high for subordinates. Stress, however, can shift among group members depending on how dominance is maintained. Dominant group members can experience high stress when their rank must be maintained by constant physical aggression (as in ring-tailed lemurs), or during times of major hierarchical reorganization when their rank is at risk of being lost. Thus, stress is associated with both lower rank and life "at the top" (Figure 11.19).

Subordinates have greater physiological indices of stress relative to dominant members when dominance is asserted through psychological intimidation (e.g., eye contact, vocalizations) or for social groups with stable, inherited social hierarchies, as in female rhesus macaques. Subordinates can reduce their stress if coping strategies are available. In non-human primates, these activities include forming social coalitions through grooming and roaming to avoid encounters
with dominant members. Rank-induced stress is evident across a variety of physiological measures, including hypertensive glucocorticoid secretion (see Figure 11.18), hypertension, impaired reproduction, immunosuppression, inhibition of neurogenesis, reduced synaptic plasticity and dendritic atrophy in brain regions such as the hippocampus. Given that the hippocampus provides negative feedback to the hypothalamic-pituitary-adrenal axis (see Box 108), the physical consequences are prolonged in situations of chronic stress.

**Power motivation and dominance contests**

To usurp status in a social hierarchy and ascend in rank, an individual must be both physically able to win dominance competitions and psychologically motivated to achieve power and status. In non-human animals, dominance contests are typically determined through physical battles between dominant and subordinate members. In humans, dominance contests can take the form of political debates, sports events, or battles of wits, intellect, or talent.

**Power motivation** in humans is defined as an enduring preference for having an impact on other people or the world at large. Individuals who express a need for power find this impact on others rewarding, and they are motivated to seek out opportunities to exert social influence. Power motivation can be implicitly measured through performance on a picture story exercise. In this exercise, participants are shown ambiguous pictures of people and are asked to write hypothetical narratives about them. The stories are then coded for the presence of power motivation themes, including descriptions of situations involving control or influence over others, fame or prestige, offers of unsolicited help or actions that evoke an emotional response in others. Individual differences in the degree to which these themes are present in the stories is used as a trait measure of implicit power motivation. Power can also be explicitly primed prior to the picture story exercise by having participants listen to powerful presidential speeches, movies, or stories of achievement.

Power motivation is associated with levels of the sympathetic catecholamines epinephrine and norepinephrine, which promote the release of testosterone in men (Figure 11.19). Testosterone, in turn, facilitates dopamine release in the nucleus accumbens, a key component of the brain's circuitry for reward learning (see Chapter 14). The neuroendocrine profile of power motivation in women is less clear but has been related to elevated levels of estradiol. Individuals who score high on measures of power motivation tend to engage in more risky behaviors, attain higher positions in corporate management, and be more sexually active. However, these individuals also tend to use alcohol more to enter into more complicated domestic relationships, including abusive ones.

Endocrine markers further indicate the outcome of a dominance contest. Victory is associated with a surge in testosterone in men and estradiol in women. In contrast, the stress hormone cortisol is elevated following defeat. These effects of winning and losing are even present in social observers who are not direct participants in the competition, as in the case of sports fans observing a team match, or voters participating in a political election.

**Summary**

1. Social interactions engage a distributed set of brain regions involved in self-evaluative processing, perception of biologically relevant cues such as body stance and biological motion, social categorization, and emotion interpretation.
2. Whether social interactions are an emergent property of the cognitive functions described in other chapters or a core set of specialized brain structures and processes has been widely debated. A reasonable view is that both domain-specific and domain-general factors contribute to social cognition.
3. The ability to think reflexively about the self and our sense of embodiment depends on processing in the temporoparietal junction, medial parietal, and prefrontal cortical regions, as well as specialized sectors of the visual association cortex.
4. The perception of socially relevant cues arising from the face and bodies of others depends on the fusiform gyrus, superior temporal sulcus, amygdala, and orbitofrontal cortex.
5. The categorization of individuals as members of social groups is rapid and automatic, and it depends in part on evaluative processes in the amygdala. Automatic influences of social stereotypes engage conflict-monitoring and self-regulation functions of the anterior cingulate gyrus and dorsolateral prefrontal cortex.
6. Theory-of-mind abilities, though present implicitly in great apes and young children, increase in complexity in late human development and depend on processing in the medial prefrontal cortex, temporal polar cortex, inferior parietal cortex, temporoparietal junction, and superior temporal sulcus, as well as areas that mediate symbolic representation more broadly.
7. Empathizing with the emotional state of others involves regions implicated in somatic and emotional state representation (including the insula), self-awareness, perspective taking, and emotion regulation.

8. Balancing the opposing forces of competition and cooperation is important for the stability and advancement of any social group. These forces affect the functioning of diverse physiological systems, including stress-related agents, hormonal markers of victory (testosterone) or defeat (cortisol), and agents related to social bonding (oxytocin/vasopressin).

9. Insights into the ways we perceive and make inferences from social cues have led to new treatments of autism spectrum disorders, as well as new developments in computer animation and human-machine interactions.

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**INTRODUCTION**

The human vocal tract includes the vocal apparatus from larynx to lips (Figure 12.1A). The air expired from the lungs streams through the opening between the vocal cords in the larynx (the glottis). As the airstream accelerates through this narrowing, the decreased pressure that results causes the cords to come together until the pressure buildup in the larynx forces them open again (the physical principle involved is what generates the lift given an airplane by the faster stream of air over the tip of the wings). It is called Bernoulli’s_

**Language**

**INTRODUCTION**

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