

The X- and C-Systems

THE NEURAL BASIS OF AUTOMATIC AND CONTROLLED SOCIAL COGNITION

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The distinction between automatic and controlled processing is one of the most important theoretical distinctions made in social cognition. Our understanding of stereotyping (Banaji & Hardin, 1996; Devine, 1989; Macrae, Milne, & Bodenhausen, 1994), attitudes (Wilson, Lindsey, & Schooler, 2000), persuasion (Chaiken, Liberman, & Eagly, 1989; Petty & Cacioppo, 1986), person perception (Gilbert, 1989; Trope, 1986), self-regulation (Wegner, 1994), and mood effects (Bless & Schwarz, 1999; Forgas, 1995) has been transformed through the use of cognitive measures to assess automaticity and control. These measures have included reaction-time measures, manipulating interstimulus intervals, introducing cognitive load, subliminal priming versus drawing attention to the possible consequences of priming, sequential priming, memory clustering, and word-stem completion, among others (Bargh & Chartrand, 2000). But as with all measures, these have their limits. In this chapter, I hope to suggest that social-cognitive neuroscience (Ochsner & Lieberman, 2001) offers additional theoretical and methodological tools that can be marshaled in the effort to better understand the automatic and controlled bases of social cognition.

One of the most fundamental limitations of the dual-process literature (Chaiken & Trope, 1999) is that automaticity and control are defined as opposing anchors on a number of dimensions. Controlled processes are those that score high on dimensions of awareness, effort, intention, and inefficiency (Bargh, 1996). Automatic processes are those that score low on at least one and preferably most of these dimensions. Unfortunately, this

mostly paints a picture of what automaticity is not, rather than focusing on what automaticity is.

Whether automatic and controlled processes are endpoints on a continuum or qualitatively distinct processes is an empirical question. However, the traditional measures available to assess automaticity and control do not address the question, instead assuming a dimensional approach from the start. For instance, adding a secondary task (i.e., a cognitive-load manipulation) to be performed concurrently with the process of interest allows for the assessment of efficiency. Processes that are more affected by the secondary task are less efficient and therefore more controlled than processes that are less affected. This analysis provides only relative positioning on the dimension of efficiency but does not and cannot qualitatively identify or even posit boundaries between automaticity and control. However, one can imagine very different accounts of efficiency differences. On the one hand, some task that is performed with great efficiency may have become more automatic over time, moving from one end of the continuum toward the other, with the process's internal structure becoming solidified and more efficient. Alternatively, different processes may simultaneously support the task when the task is performed at different degrees of efficiency. Some processes may be specialized for performing new tasks, but never with great efficiency. Other processes may operate very efficiently but require a great deal of task experience until they develop to the point of being able to support task performance alone.

At root, this latter account allows for the possibility that qualitatively distinct processes could be at work without easily being identified as such with current measures (cf. Logan, 1988). Moreover, on many cognitive measures a person who is impulsive because of heightened automatic impulses would be indistinguishable from someone who is impulsive because of deficient control processes. In both cases, one would conclude that the individual's cognitive activity is more automatic than controlled, but the causes would be qualitatively different in the two cases, as would the treatments if the impairment was sufficiently severe.

If automatic and controlled components of social cognition can be studied separately from one another, it may help address numerous questions, such as: What is the representational structure of each type of process? Why do attempts at self-control often have paradoxical effects? Why do automatic processes appear to be both rigid (Kawakami et al., 2000) and flexible (Lowery, Hardin, & Sinclair, 2001; Mitchell, Nosek, & Banaji, 2003)? How can controlled processes interfere with automatic processes?

THE COGNITIVE NEUROSCIENCE REVOLUTION

The issue of whether the differences between automatic and controlled social cognition should be conceived quantitatively or qualitatively is no

different from many of the interpretive problems that have faced cognitive scientists for decades. Cognitive psychologists noted long ago that data from cognitive measures will always be consistent with multiple, and potentially infinite, theories or models (Anderson, 1978). Gilbert (1999) made the same assessment of dual-process models of social cognition and concluded that we may be limited to ruling out particular models without ever being able to determine the truth of the matter. Cognitive science's response to this limitation of cognitive measures provides hope. Starting in the 1980s, cognitive scientists began turning to brain data on a regular basis to contrast models of cognition and created the field of cognitive neuroscience in the process. In a long-standing debate over whether memory should be characterized as one or several systems, Schacter (1992) demonstrated with neuropsychological data, and later with neuroimaging data, that multiple memory systems exist. In another debate over whether visual imagery relies on the same or different processes as visual perception, Kosslyn (1994) used neuroimaging techniques to show that the same brain regions are involved in both and therefore that visual imagery recruits perceptual processes.

It is my hope that the study of automatic and controlled social cognition will similarly benefit from incorporating cognitive neuroscience approaches. To begin this process, my collaborators and I have developed a model of the neural bases of automatic and controlled social cognition (Lieberman, in press; Satpute & Lieberman, 2006). Our model starts from an assumption that automatic and controlled processes are qualitatively distinct, separately evolved, and functionally intertwined mechanisms. Importantly, this assumption is falsifiable and thus is a starting point rather than an ending point.

THE X- AND C-SYSTEMS

In characterizing what we believe to be the two neural systems responsible for automatic and controlled social cognition, we named one system the *X-system*, named for the *x* in reflexive, and the other the *C-system*, named for the *c* in reflective (Lieberman, Gaunt, Gilbert & Trope, 2002). Because the derivation of these two systems came from cognitive, phenomenological, and neural sources, there are many ways in which these systems are not simply automaticity and control with new names (for a review, see Lieberman et al., 2002). Nevertheless, it is fair to say that the X-system is largely responsible for social processes that would be designated as automatic and the C-system is largely responsible for social processes that would be designated as controlled. For the purposes of this chapter, I highlight the similarities more than the differences.

It is worth noting that the word "system" is being used in a loose rather than a strict sense here. That is to say, the X- and C-systems do not

differ as much, are not as discrete, and are not as independent as, for instance, the visual system and the digestive system. The X- and C-systems are not conceived as hermetically sealed Fodorian modules. Both the X- and C-systems function to process socioemotional information, and these two systems often work hand in hand to achieve socioemotional goals. However, each system has a collection of qualities that are relatively absent in the other system, and, for the most part, the subregions of each system often coactivate when one system's particular qualities are most adapted to current demands.

In this section, I review the brain regions nominated to each system and the original rationale for including them. On a personal note, I must admit that there was a certain degree of exploration in the conceptual development of these systems because cognitive neuroscience had not yet shown much of an interest in social cognition. I asked researchers where we might expect to find activations associated with schemas, implicit prejudice, self-focused attention, and intuitive processing and discovered that these were largely unexplored issues in brain research. As a result, I have assumed that the early proposals for the X- and C-systems would seem incomplete, inaccurate, and probably naive through the eyes of history. However, the distinction between automaticity and control is so crucial to social cognition that it seemed imperative to map out this distinction as well as possible and then update it as required by the data.

The X-System

The main criterion for a system to be nominated for inclusion in the X-system was that it be activated under conditions that promote automatic, implicit, or nonconscious processing of social information. These structures also tend to be phylogenetically older than structures in the C-system and are more conserved across species. According to these criteria, the X-system (see Figure 14.1) is composed of the amygdala, basal ganglia, lateral temporal cortex (LTC), ventromedial prefrontal cortex (VMPFC), and dorsal anterior cingulate cortex (dACC). The dACC is a recent addition to the X-system (Eisenberger & Lieberman, 2004) and is discussed in some detail later in the chapter, as it was originally included in the C-system, although always with certain caveats.

The amygdalae are almond-shaped subcortical structures located within the poles of each of the temporal lobes. There is ongoing debate about the amygdala's function; however, it does appear to be sensitive to novel and emotionally evocative stimuli (LeDoux, 1996; Wright et al., 2001). A recent meta-analysis suggests that it responds more to stimuli that are negatively rather than positively valenced (Wager, Phan, Liberzon, & Taylor, 2003). It is critical to fear conditioning in animals (Fanselow & LeDoux, 1999). Additionally, for individuals who have amygdala lesions, there can be major disturbances of automatic social cognition (Heberlein &

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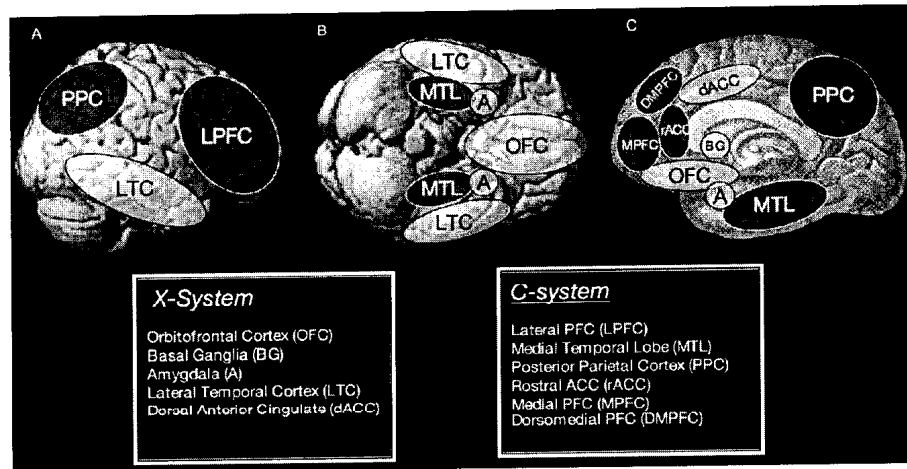


FIGURE 14.1. Neural correlates of the C-system and X-system displayed on a canonical brain rendering from (A) side, (B) bottom, and (C) medial views. Note: the hippocampus, nucleus accumbens, and amygdala are subcortical structures that are displayed here on the cortical surface for ease of presentation.

Adolphs, 2004). This region projects to various other regions that allow it to serve as something of an alarm, triggering top-down controlled processes in prefrontal cortex and autonomic nervous system responses that shift energy resources in the body to prepare for fight or flight. Most relevant to the X-system, however, are the numerous studies that have demonstrated that the amygdala responds to subliminal and unseen presentations of threatening images (Cunningham et al., 2004; Liddell et al., 2005; Morris, Öhman, & Dolan, 1999; Pasley, Mayes, & Schultz, 2004; Whalen et al., 1998).

The basal ganglia are curved horn-like subcortical structures that appear to be involved in the automatic components of affect, cognition, and behavior. The basal ganglia are best known for their central role in movement disorders such as Parkinson's disease and Huntington's disease; however, these disorders also lead to various social and affective deficits, including deficits in nonverbal communication (Lieberman, 2000a). In the past decade, a number of neuropsychological and neuroimaging studies have established that the caudate, a substructure within the basal ganglia, is involved in implicit learning of abstract sequential patterns that may subserve human intuition (Knowlton, Mangels, & Squire, 1996; Lieberman, Chang, Chiao, Bookheimer, & Knowlton, 2004). Finally, the ventral striatum, another subregion of the basal ganglia, has been linked to positive affective responses to stimuli ranging from drugs to money to pictures of romantic partners (Bartels & Zeki, 2000; Breiter et al., 1997; Zalla et al., 2000).

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VMPFC is the region of cortex at the intersection of the medial wall of prefrontal cortex and the orbital or bottom surface of prefrontal cortex. The damage to the famous patient Phineas Gage was primarily in VMPFC, and Gage's deficits in social cognition are well known (Damasio, 1994). It is only in the past decade, however, that data are beginning to demonstrate that the deficits associated with VMPFC damage are more automatic in nature. Damasio and colleagues (Bechara, Damasio, Tranel, & Damasio, 1997) have suggested that this region is involved in social intuition because it is critical to learning the long-term value of different alternatives in a gambling paradigm. For those who have VMPFC intact, accurate intuitions are formed about the different alternatives before explanations can be generated for the fact that some alternatives are better than others. Thus the learning appears to be implicit, as in the basal ganglia, at least for some period of time. Milne and Grafman (2001) have also observed that patients with VMPFC damage do not show evidence of implicit gender stereotyping on the Implicit Association Test (IAT; Greenwald, McGhee, & Schwartz, 1998). Most recently, Deppe et al. (2005) demonstrated that susceptibility to framing effects is positively related to activity in VMPFC. Framing effects have been considered a consequence of capitalizing on operational properties of intuitive over deductive reasoning (Kahneman, 2003), further supporting the role of VMPFC in conjunction with the basal ganglia in the formation of automatic intuitions. Finally, a recent ERP study (Carrette, Hinojosa, Mercado, & Tapia, 2005) localized early responses (~150 milliseconds) to subliminally presented threat stimuli to VMPFC meeting two criteria of the X-system in sensitivity of subliminal presentations and speed of response.

Unlike the other regions of the X-system, LTC, consisting of the lateral and inferior portions of the temporal lobes as well as the temporal poles, is primarily associated with semantic rather than affective processes. A degenerative brain disorder called semantic dementia (or the temporal variant of frontotemporal dementia) selectively affects LTC and produces major deficits in semantic knowledge while largely sparing memory for particular episodes (Garrard & Hodges, 2000; Mummery et al., 2000). A number of studies have now observed LTC activations associated with implicit semantic processing (Crinion, Lambon-Ralph, Warburton, Howard, & Wise, 2003; Mummery, Shallice, & Price, 1999; Rissman, Eliassen, & Blumstein, 2003; Rossell, Bullmore, Williams, & David, 2001) and have found that explicit or intentional semantic processes recruit lateral prefrontal cortex in addition to LTC (Lee, Robbins, Graham, & Owen, 2002; Xu et al., 2002). Additionally, the multistaged pathway from visual cortex to the temporal poles is massively parallel (Suzuki, Saleem, & Tanaka, 2000; Vogels, 1999), an architecture that appears to promote efficient but nonsymbolic processes (Smolensky, 1988). Lastly, the posterior superior temporal sulcus, a subregion of LTC, is critical to nonverbal decoding of facial expressions, a process that is probably automatic given how little effort or

intention is applied in determining the implication of most facial expressions (Ambady & Rosenthal, 1992).

The C-System

Nominating brain regions for the C-system required much less of an exploratory approach (guesswork) than the X-system because cognitive neuroscientists were already examining various networks relevant to controlled processing in their study of conflict detection, working memory, and episodic memory. From these lines of research, the C-system was posited to consist of anterior cingulate cortex (ACC), lateral prefrontal cortex (LPFC), posterior parietal cortex (PPC), and the hippocampus and surrounding medial temporal lobe region (MTL). In the current formulation, only the rostral anterior cingulate cortex (rACC) is included in the C-system, as is discussed in the next section. Medial prefrontal cortex (mPFC), particularly the medial portion of Brodmann's area 10, may be another good candidate region for the C-system, as it appears to be involved in self-focused attention (Gusnard, Akbudak, Shulman, & Raichle, 2001) and is a region that is disproportionately larger in humans than in other animals (Semendeferi, Schleicher, Zilles, Armstrong, & Van Hoesen, 2001).

LPFC is the heart of the C-system, as it is involved in numerous higher cognitive processes that are experienced as intentional and effortful, including working memory, implementation of top-down goals and plans, episodic retrieval, inhibition, and self-control (Cabeza & Nyberg, 2000). Though only rarely linked experimentally, working memory processes and controlled processes operate under similar constraints—functioning serially, rather than in parallel; operating on discrete symbolic representations and propositions; and limited by motivation, intention, and effort (Baddeley, 1986). Whereas X-system processes may be linked to our ongoing experience of the world, coloring in the semantic and affective aspects of the stream of consciousness, the C-system, and LPFC in particular, appears to be linked to our experience of responding to the world and our own impulses with our freely exerted “will” (Lau, Rogers, Ramnani, & Passingham, 2004).

Lateral posterior parietal cortex (LPPC) is thought to support many of the same functions attributed to LPFC, including working memory, controlled processing, and logic (Cabeza & Nyberg, 2000). A number of recent neuroimaging studies also suggest that medial PPC is involved in self-focused attention (Gusnard et al., 2001; Kelley, et al., 2002, Lieberman & Pfeifer, 2005), as well as in distinguishing one's own perspective from that of another (Ruby & Decety, 2001), both tasks that require effort and symbolic representations.

The hippocampus and surrounding mTL are included in the C-system because of their role in supporting episodic memory and the relation of episodic memory to controlled processing. One of the general functions of the

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frontal lobe and controlled processing is to exert control and override the X-system (and other habit-based processes such as motor functions) when the habits and impulses of the X-system are insufficient or contextually inappropriate (McClelland, McNaughton, & O'Reilly, 1995; Miller & Cohen, 2001; Sloman, 1996). Although the C-system is enormously flexible in its ability to create and implement new symbolic solutions in these situations, the C-system is also fragile because it processes information serially, which limits its speed and the number of problems that can be handled simultaneously. Additionally, there is growing evidence to suggest that controlled processes are analogous to muscles in that they can tire with continuous or intense use (Baumeister, Bratslavsky, Muraven, & Tice, 1998).

One way to greatly enhance the efficiency of the C-system would be to keep a repository of memories for the different times that the C-system was invoked to override the X-system. Such a repository would be called on when the same situation was encountered again, allowing the C-system to focus on implementing a plan rather than having to first deliberate to generate the plan anew. If a situation is encountered frequently enough, the X-system will change its habits to accommodate the situation; but the X-system is very slow to change, and thus these C-system memories would be very useful in the interim. Episodic memory can be characterized, in part, as a storehouse of memories for specific episodes when the C-system was engaged because things were running counter to expectations and one's habits were insufficient to guide behavior in a particular situation.

Since the 1970s, cognitive psychologists have known that "depth of processing" correlates with the strength of episodic memories; the more cognitive elaboration performed, the more likely the episodic memory will be successfully retrieved later (Craik & Tulving, 1975). The studies of patients like H.M., who are amnesic because of lesions to mTL, have suggested that mTL serves as the representational storehouse for episodic memories. Recent neuroimaging research has demonstrated that the success of episodic retrieval is predicted by the amount of activity in mTL, as well as LPFC (Brewer, Zhao, Desmond, Glover, & Gabrieli, 1998; Wagner et al., 1998). Moreover, the link between depth of processing and subsequent encoding has been tied to processing in the mTL and other regions of the C-system (Fujii et al., 2002). It appears, then, that the more work that is performed by the LPFC to override X-system habits, the better the long-term episodic memory is for that information.

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Dorsal and Rostral ACC

In previous discussions of the X- and C-systems, the anterior cingulate cortex (ACC) was included as a C-system structure, but always with caveats. The ACC functions, in part, as a conflict monitor detecting when expectations are violated or contextually inappropriate responses might be made (Botvinick, Braver, Barch, Carter, & Cohen, 2001). As such, the ACC is

something of an alarm system, triggering controlled processes, particularly in LPFC, to override contextually inappropriate responses. The prototypical example of ACC function is demonstrated in the Stroop task, when, for instance, one is required to say the ink color of a word (blue) although the word itself spells out another color ("R-E-D"). The ACC is thought to be critical in notifying LPFC that it needs to override the prepotent word-reading response. As the starting point in detecting the need for and triggering many controlled processes, it seemed appropriate to include the ACC in the C-system. However, part of the elegance of the connectionist models of ACC function is that the models explain how the ACC can detect conflict automatically, without having to posit an autonomous homunculus inside the ACC that guides the ACC through symbolic decision processes. One of the natural outputs of connectionist architectures is a tension parameter that reflects the total amount of tension in the system (Cohen, Dunbar, & McClelland, 1990; Hopfield, 1982).

More recently, Eisenberger and Lieberman (2004) have suggested that the dACC should be identified as an X-system structure, whereas the rACC should remain as part of the C-system. Eisenberger and Lieberman reviewed a number of cognition, affect, and pain studies and found that in each of these domains, dACC activations were associated with processes that could be characterized by nonsymbolic tension processes, whereas rACC activations were associated with processes for which a symbolic representation of what would or did constitute expectancy violations was explicitly held in mind. For instance, unexpected pain stimulation tends to activate dACC, whereas anticipation of pain activates rACC (Ploghaus, Becerra, Borras, & Borsook, 2003). Similarly, negative emotions, which are focused on a specific object or outcome, tend to activate rACC, whereas anxiety, which has been defined as similar to fear but without explicit focus on a specific object or outcome, tends to activate dACC. Additionally, Smith (1945) observed that in macaques, the entire ACC was morphologically analogous to human dACC. In other words, primates that lack the capacity for true symbolic processing (Thompson & Oden, 2000) have no rACC. More recent evidence points to "spindle cells" (Nimchinsky et al., 1999) that appear in rACC but not dACC and that are present in diminishing densities in the ACC of children and other primates paralleling the diminished symbolic capacities in these groups (Craig, 2004).

EVIDENCE FOR INDEPENDENCE OF THE SYSTEMS

The data used to nominate the brain regions to the X- and C-systems were largely obtained by considering the properties of each system separately. A number of more recent studies have specifically examined how neural activity in these systems changes as processing conditions are altered to favor automatic or controlled processing. By and large, these studies suggest that

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conditions favoring automatic processing tend to promote X-system activation with little C-system activation, whereas conditions favoring controlled processing tend to promote C-system activation with little X-system activation. It should be remembered that, whereas experimental tasks can be created that emphasize the processes of one system or the other, in everyday life, these two systems are often working together and simultaneously.

Category Learning

In one early study, Rauch et al. (1995) had participants perform a sequence learning task in which cues appeared in a nonrandom but nonobvious sequence of locations on the screen and participants produced location-specific responses as quickly as possible. Approximately half of the participants reported becoming aware of the pattern. Both aware and unaware participants showed evidence of sequence learning, as indicated by slowed reaction times when the learned sequence was interrupted and replaced by a random sequence; however, the brain activations were different for participants who were aware and those who were unaware. Participants who were unaware activated the basal ganglia in the X-system during task performance, whereas participants who were aware of the sequence did not activate the basal ganglia but instead activated the LPFC in the C-system.

In a similar study, Aizenstein et al. (2000) had participants perform a pattern learning task. In the first half of the study, participants were unaware that the dot arrays presented were all variations on a never-presented prototype (Posner & Keele, 1968). In this condition, implicit learning was associated with activation of the LTC in the X-system. Subsequently, participants were run through another block of trials, but this time they were informed that there was a pattern to be learned. Under these explicit learning conditions, the LTC activation disappeared and was replaced by C-system activations in LPFC, MTL, and PPC.

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Attitudinal Prejudice

A number of fMRI studies have looked at the neural underpinnings of race-related processes. The general finding across these studies is greater amygdala activity to African American (AA) faces than to Caucasian American (CA) faces (Hart et al., 2000; Cunningham et al., 2004; Lieberman, Hariri, Jarcho, Eisenberger, & Bookheimer, 2005; Phelps et al., 2000) which is consistent with the negative stereotype of African Americans and the amygdala's responsiveness to negative or threatening stimuli. Several findings suggest that the amygdala's response to AA faces reflects an automatic rather than a controlled process. First, Phelps et al. (2000) observed that the magnitude of the amygdala response to AA faces varied as a function of implicit, but not explicit, attitudes toward African Americans. Additionally, Cunningham et al. (2004) found that subliminal presentation of

AA faces produced greater amygdala activity than supraliminal presentation of AA faces. Finally, Lieberman et al. (2005) found that African American participants also showed greater amygdala activity in response to AA faces than to CA faces. This is consistent with the behavioral research showing that African Americans have negative implicit attitudes but positive explicit attitudes toward African Americans (Nosek, Banaji, & Greenwald, 2002).

Alternatively, when negative stereotypes and attitude objects were processed verbally, enhanced activity occurred in right LPFC, but no significant activity occurred in the amygdala. Cunningham et al. (2003) found that judging the attitudinal valence of infamous names such as Adolf Hitler produced right LPFC activity; however, judging whether these were the names of living or dead individuals did not produce this activity. That this effect emerged only when judging valence is important because it indicates that the LPFC activity was dependent on explicit consideration of one's attitudes toward the targets rather than a simple result of reading the names, which would produce implicit effects as well. In the Lieberman et al. (2005) study of race-related processing, a second condition required participants to categorize faces according to race using verbal labels. In this condition, there was activity in right LPFC, very close to the region found in the Cunningham et al. (2003) study during verbal categorization of AA faces compared with CA faces. Finally, in a neuroimaging study of automatic behavior (Lieberman, Eisenberger, & Crockett, 2006), the processing of words related to the negative stereotype of the elderly produced greater right LPFC activity in the same region seen in the previous studies when compared with the processing of words related to the relatively positive stereotype of intelligence.

Self-Knowledge

Another area in which a significant amount of social-cognitive neuroscience research has been conducted is the domain of self-knowledge (for reviews, see Lieberman & Eisenberger, 2004; Lieberman & Pfeifer, 2005). The most reliable findings are that self-judgments tend to be associated with MPFC and medial PPC. Given that these are the same regions that tend to be observed in studies of self-focused attention (Eisenberger, Lieberman, & Satpute, 2005; Gusnard et al., 2001), it is unclear whether these activations are associated with self-knowledge per se or with the retrieval of self-knowledge through self-focused processing.

Lieberman, Jarcho, and Satpute (2004) recently conducted an fMRI study in which self-knowledge judgments in high-experience and low-experience domains were compared. Our assumption was that actors would tend to be schematic for actor-relevant words and nonschematic for athlete-relevant words, whereas athletes would tend to show the opposite relationship (Markus, 1977). In other words, we expected each group to process high-experience words more automatically than low-experience

words, and indeed, reaction-time data bore out this assumption. Additionally, high-experience self-judgments activated VMPFC, basal ganglia, amygdala, and LTC in the X-system, along with PPC in the C-system. Alternatively, low-experience judgments produced only a C-system activation in LPFC.

Further inspection of the reaction-time data in this study indicated that approximately half of our participants did not show evidence of schematicity in their high-experience domain. Even though we selected people who clearly have much more experience in one domain than the other, some simply may not have had or used schemas in their high-experience domain. Consequently, all of the data were analyzed separately for schematics and nonschematics. When schematics made high-experience self-judgments, they produced increased activity in the VMPFC, basal ganglia, amygdala, LTC, and PPC and decreased activity in MTL and MPFC. Thus schematics tended to activate X-system structures and deactivate C-system structures when they made high-experience self-judgments. Nonschematics showed nearly the opposite pattern when they made high-experience self-judgments. Nonschematics produced increased activity in MTL, LPFC, MPFC, PPC, and LTC, along with no increases in X-system activity.

The results of this study provide strong evidence that automatic processes are not merely faster, quieter versions of controlled processes. If the representations used during automatic and controlled processes were the same, then one might expect controlled processing regions to show decreases for high-experience judgments without any concomitant increases elsewhere. In fact, some nonsocial forms of automaticity seem to follow this pattern (Jansma, Ramsey, Slagter, & Kahn, 2001). However, in our study, C-system decreases were matched by X-system increases, suggesting that two separate systems actively process social information under different conditions.

Personality

Extraversion has been frequently associated with positive affect and happiness, whereas neuroticism has been associated with negative affect and anxiety. There is also some evidence to suggest that extraverts and neurotics tend to differ with respect to automatic and controlled processing. Across several studies, extraverts were found to have greater working memory efficiency than introverts and thus were better able to handle multiple social-interaction goals simultaneously (Lieberman, 2000b; Lieberman & Rosenthal, 2001; Oya, Manalo, & Greenwood, 2004). Alternatively, trait anxiety, which is a construct similar to neuroticism, has been associated with greater automatic interference effects (Egloff & Hock, 2001) and diminished working-memory efficiency (Darke, 1988).

Eisenberger, Lieberman, and Satpute (2005) examined the neural reactivities associated with neuroticism and extraversion in an oddball task that combined conflict detection with exertion of control through response inhi-

bition. As described earlier, we believe dACC and rACC to be involved in nonsymbolic and symbolic conflict detection, respectively, whereas LPFC is involved in response inhibition. In this study, neuroticism was positively correlated with the dACC response to conflict detection and negatively correlated with the rACC response to conflict detection. In contrast, extraversion was negatively correlated with the dACC response to conflict detection but positively correlated with the rACC, LPFC, and PPC responses to conflict detection. These results approximately replicate those of Gray and Brayer (2002), who found similar personality correlations with the dACC and rACC. Together, these results suggest that extraverts tend to emphasize C-system processing, whereas neurotics tend to emphasize components of X-system processing, particularly those involved in automatic detection of threats and conflict.

EVIDENCE FOR C-SYSTEM REGULATION OF THE X-SYSTEM

The previous section reviewed research that suggests that during different kinds of social cognition, structures associated with the X- and C-systems tend to coactivate more with other structures from the same system than with structures from the other system. Additionally, these studies show that under processing conditions that favor automatic processing, X-system structures tend to be more active than C-system structures, whereas during conditions that favor controlled processing, C-system structures tend to be more active than X-system structures. These data suggest that qualitatively distinct systems support automatic and controlled social cognition. Although the conditions that are typically associated with eliciting automatic or controlled processing tend to vary in terms of awareness of stimuli and cognitive load, a central component of the X- and C-system's model is that the C-system has largely evolved to override the X-system when the habits and impulses of the X-system are contextually inappropriate. In this section, I review studies that demonstrate not only that the C-system is activated under different conditions than the X-system but also that the magnitude of C-system activity in these conditions is negatively correlated with X-system activity. In other words, these studies suggest that C-system activity can inhibit X-system activity.

Emotion Regulation

A number of recent studies have looked at intentional attempts at emotion regulation in neuroimaging paradigms (Beauregard, Levesque, & Bourgouin, 2001; Levesque et al., 2003; Ochsner et al., 2004; Schaefer et al., 2003; Small et al., 2001). In general, these studies show the same pattern of X- and C-system activity as reviewed earlier, with greater amygdala

activity during passive viewing of emotionally evocative images and greater LPFC activity during attempts at emotion regulation by way of reappraisal or suppression (Gross, 1998). One of these studies has looked at the relationship between X- and C-system regions during reappraisal attempts at emotion regulation. Ochsner, Bunge, Gross, & Gabrieli (2002) asked participants to passively view negatively valenced images in one condition and observed activation in the amygdala and VMPFC. However, in a second condition, participants were asked to reappraise each image by reinterpreting the photo "so that it no longer elicited a negative response" (p. 1225). In this condition, LPFC was active, but neither of the amygdala or VMPFC activations observed in the passive viewing condition were present.

In subsequent functional connectivity analyses, Ochsner et al. (2002) examined the between-subject differences in the C- and X-system activity during reappraisal. Ochsner et al. (2002) found that the greater the magnitude of the LPFC response was during reappraisal, the smaller the magnitude of the amygdala and VMPFC responses were during reappraisal. In other words, during reappraisal, some participants activated the LPFC a lot and others just a little. The more any participant activated LPFC, the greater the reduction in X-system activity. This analysis suggests that the C-system is not merely "speaking more loudly" than the X-system. Rather, it appears that under certain circumstances while the C-system is speaking up, it is also taking away the X-system's "microphone," so that its volume is diminished.

Affect Labeling

Another set of studies have examined the effects of affective labeling on the amygdala's response to negatively valenced images (Hariri, Bookheimer, & Mazziotta, 2000; Lange et al., 2003; Lieberman et al., in press; Taylor, Phan, Decker, & Liberzon, 2003). Philosophers have long suggested that thinking explicitly about one's affect can dampen the affect that is being reflected on (James, 1890/1950; Spinoza, 1675/1949). Although thinking about or labeling one's affect is not an emotion-regulation strategy per se, it may be a mechanism by which other emotion-regulation strategies have their effect. In other words, part of reappraisal's effectiveness may be due to the fact that it involves linguistic processing of affective stimuli and thus recruits the brain regions involved in affective labeling.

Similar to the studies of overt emotion regulation, these studies of linguistic regulation of emotion tend to find amygdala activity present during passive viewing of negatively valenced images, but this activity is absent or attenuated during explicit or linguistic processing of the images' affective content ("affect labeling"). During affect labeling, ~~the~~ amygdala activity is replaced by right LPFC activity. In two of these studies (Hariri et al., 2000, Lieberman et al., in press), functional connectivity between LPFC and the amygdala during affect labeling was assessed and found to be significantly

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negative; the greater the LPFC activity during labeling, the weaker the amygdala activity. These data suggest that merely activating this C-system region may be sufficient to down-regulate X-system activity, even in the absence of any explicit intention to self-regulate.

Attitudinal Prejudice

Some of the previously described studies of attitudes also examined functional connectivity. In each of the studies, during controlled processing of attitudinal objects, LPFC activity was negatively correlated with amygdala activity. Cunningham et al. (2004) found that in response to supraliminal but not subliminal presentations of AA faces, increases in dorsal LPFC predicted reductions in the magnitude of amygdala response. Lieberman et al. (2005) observed that right ventral LPFC activity while linguistically labeling the race of AA faces was negatively correlated with amygdala activity. Finally, in a study of automatic behavior (Lieberman, Eisenberger, & Crockett, 2006), right ventral LPFC activity during linguistic processing of stereotypes about elderly people was negatively correlated with amygdala activity. This pattern was not observed when participants processed words related to the intelligence stereotype, again suggesting that this effect may be specific to negatively valenced language.

It should also be noted that this study used the sentence-unscrambling task (Bargh, Chen, & Burrows, 1996) that requires linguistic processing of stereotypes without bringing the relevance of the stereotype to mind for participants. Thus there is no reason to assume participants were engaged in any kind of intentional emotion regulation.

Implicit Learning

Although research on the neural correlates of implicit learning has been decidedly nonsocial in nature, the implications for social psychology are substantial (Lewicki, 1986; Lieberman, 2000a). It is then of interest that a number of studies—neuroimaging studies in humans and lesion studies in rodents—have suggested that the basal ganglia and MTL function competitively (Poldrack & Packard, 2003). Packard, Hirsh, and White (1989) lesioned either the basal ganglia or the MTL in rodents and then had the rodents perform tasks that depend on one or the other of these brain regions. Not surprisingly, rats with basal ganglia lesions performed poorly on the basal-ganglia-specific task, and rats with MTL lesions performed poorly on the mTL-specific task. What is surprising is that the rats with basal ganglia lesions performed *better than normal* on the mTL specific task, and the rats with mTL lesions performed better than normal on the basal-ganglia-specific task. In other words, the presence of a normally functioning mTL tends to interfere with performance on tasks that strongly rely on the basal ganglia, and thus performance on these tasks are enhanced when the mTL is removed.

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Poldrack et al. (2001) found negative functional connectivity between the basal ganglia and mTL in humans during a category learning task that involves both explicit and implicit learning to some extent, such that the participants who activated mTL more during this task activated the basal ganglia less. Lieberman, Chang, Chiao, et al. (2004) extended this finding by using a paradigm in which trials promoting the use of implicit and explicitly learned cues were distinguishable and could be compared. On trials in which explicitly learned cues were likely to drive performance, greater MTL activity was associated with diminished basal ganglia activity. It should be noted that, on these trials, the implicitly learned cues were still relevant to accurate performance—more relevant in fact, than the explicitly learned cues—but with basal ganglia activity diminished under these conditions, behavioral performance suffered.

FUTURE DIRECTIONS: REFLECTIVE AND REFLEXIVE MODES OF SOCIAL COGNITION

It is a contrast between two modes of practice. One is the pushing, slam-bang, act-first and think-afterwards mode, to which events may yield as they give way to any strong force. The other mode is wary, observant . . . and inhibited . . . an ineffective Hamlet in performance.

—DEWEY, *Experience and Nature* (1925, p. 256)

The research reviewed in this chapter suggests that the X- and C-systems are differentially recruited during automatic and controlled processes of social cognition. The pattern of results seen across these studies indicates that, within the domain of social cognition, automatic processes are qualitatively distinct from controlled processes, as the activation patterns associated with automatic social cognition do not merely look like controlled processes with increased efficiency. If that were the case, one would expect to see efficiency associated primarily with decreased C-system activity. The fact that conditions that promote automaticity lead to increased activity in regions not associated with controlled processing indicates that distinct processes are being recruited. Additionally, evidence was presented to suggest that C-system activations can disrupt X-system activity. Thus the systems are independent in the sense that they rely on different neural structures, but they are not independent in the sense that there is no interaction between them. In most everyday experiences, it is likely that both systems are operating and contributing to ongoing thought and behavior, albeit in different ways.

Given that C-system activity can interfere with X-system activity under certain processing conditions, one might conclude that C-system activity leads to a self-sustaining *reflective mode* of social cognition and behavior in which the C-system has greater control over thought and behavior. One might also reasonably conclude that in situations that do not recruit signifi-

cant C-system activity, there may exist a *reflexive mode* of social cognition and behavior. What has not been examined in this chapter is the possibility that the reflexive mode is also self-sustaining, tending to inhibit C-system activity. There are indeed some tantalizing hints that this might be the case.

Noradrenaline serves as one of the major agents of physiological and neural arousal, helping to increase attention, vigilance, and autonomic readiness in response to potential threats (Berridge & Foote, 1991; Bouret, Duvel, Onat, & Sara, 2003). Over the past decade, numerous studies by Arnsten (1998) have demonstrated the deleterious consequences of noradrenaline and other catecholamines on the processing efficiency of LPFC. LPFC seems to follow an inverted-U processing efficiency curve with respect to noradrenaline such that increases from low to moderate levels enhance LPFC processing efficiency. This is thought to occur because the α_2 -receptor responds to noradrenaline in low concentrations and tends to facilitate neural efficiency. Once past a moderate level of noradrenaline, further increases tend to diminish LPFC processing efficiency. This is thought to occur because the α_1 -neuroadrenaline receptor is receptive only to high concentrations of noradrenaline and tends to inhibit or mute the function of LPFC.

Consistent with this account, Callicott et al. (1999) observed an inverted-U response in LPFC and PPC to increasing levels of stress during a working-memory task. Activity in these regions increased parametrically with task difficulty up to a point, but then became less active with higher levels of stress. Alternatively, the dACC in the X-system was one of the few regions found to increase activity linearly across all levels of task difficulty. Beversdorf, White, ~~Chey~~^{Chey}, Hughes, and Bornstein (2002) also found evidence that general cognitive flexibility, a hallmark of LPFC function, diminished with the administration of an adrenergic agonist and was enhanced with the administration of an adrenergic antagonist. Thus the C-system region seems to get "tired" or "frazzled" consistent with Baumeister's claims about the draining effects of self-regulation on further self-regulation attempts (Baumeister et al., 1998).

There is no evidence that X-system structures get frazzled from high arousal in the same way that LPFC does. To the contrary, amygdala activity enhances the noradrenaline production in the medulla (Dayas & Day, 2001) and locus coeruleus (Bouret et al., 2003), two major centers of noradrenaline production in the brain. Additionally, high levels of noradrenaline and stress are associated with enhanced amygdala function (McIntyre, Hatfield, & McGaugh, 2002; Shors & Mathew, 1998). Though the adrenergic effect of the amygdala on the prefrontal cortex is presumably mediated by the locus coeruleus, there is evidence that electric stimulation of the amygdala does result in noradrenaline increases in the neocortex (Kapp, Supple, & Whalen, 1994).

The tradeoff between the X- and C-system responses to arousal extends to the long-term consequences of chronic stress as well. There is

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ample evidence that chronic stress damages mTL neurons (McEwen, 1999), producing dendritic shortening (Conrad, Galea, Kuroda, & McEwen, 1996). However, recently it has also been discovered that chronic stress facilitates neuronal growth in the amygdala, producing dendritic lengthening (Vyas, Mitra, Shankaranarayana Rao, & Chattarji, 2002). These findings linking stress, arousal, and noradrenaline suggest that C-system structures function best at low to moderate levels of arousal, whereas the X-system may function better at higher levels of arousal, especially when we consider that at higher levels of arousal, C-system structures may be less able to regulate X-system activity. These findings are quite reminiscent of Zajonc's finding that arousal facilitates dominant responses but impairs nondominant responses (Bond & Titus, 1983; Yerkes & Dodson, 1908; Zajonc, 1965) and may explain why dominant responses are facilitated by stress. If response dominance is considered equivalent to habit strength, then it would be reasonable to say that X-system responses are more dominant than C-system responses.

Why would humans and other mammals have evolved these two modes controlled by arousal or stress level? If arousal is assumed, among other things, to index the intensity and immediacy of potential threats, then having these two modes triggered by arousal would be highly adaptive. When threats are not imminent, people are best served by gathering new information and flexibly considering options. However, our ability to think and learn flexibly comes at a cost: time and effort. When threats are imminent, especially the kind of threats that were relevant in our evolutionary past, taking the time to think through options might put one's life at risk. Thus, when threats are imminent and arousal is high, our brain takes the decision out of the hands of the C-system and leaves it to the X-system. If the X-system has strong contextually appropriate habits and impulses, then the individual will likely escape unharmed. If the situation is novel such that the individual lacks contextually appropriate habits and the threat is truly imminent, C-system processes may have proved too inefficient to be of service. Thus future work may examine the interaction of situational demands and arousal on the generation and maintenance of these two modes of social cognitive processing.

REFERENCES

- Aizenstein, H. J., MacDonald, A. W., Stenger, V. A., Nebes, R. D., Larson, J. K., Ursu, S., et al. (2000). Complementary category learning systems identified using event-related functional MRI. *Journal of Cognitive Neuroscience*, 12, 977-987.
- Ambady, N., & Rosenthal, R. (1992). Thin slices of expressive behavior as predictors of interpersonal consequences: A meta-analysis. *Psychological Bulletin*, 111, 256-274.
- Anderson, J. R. (1978). Arguments concerning representations for mental imagery. *Psychological Review*, 85, 249-277.

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- Arnsten, A. F. T. (1998). Catecholamine modulation of prefrontal cortical cognitive function. *Trends in Cognitive Sciences*, 2, 436–447.
- Baddeley, A. (1986). *Working memory*. Oxford, UK: Clarendon Press.
- Banaji, M. R., & Hardin, C. D. (1996). Automatic stereotyping. *Psychological Science*, 7, 136–141.
- Bargh, J. A. (1996). Principles of automaticity. In E. T. Higgins & A. W. Kruglanski (Eds.), *Social psychology: Handbook of basic principles* (pp. 169–183). New York: Guilford Press.
- Bargh, J. A., & Chartrand, T. L. (2000). The mind in the middle: A practical guide to priming and automaticity research. In H. T. Reis & C. M. Judd (Eds.), *Handbook of research methods in social and personality psychology* (pp. 253–285). New York: Cambridge University Press.
- Bargh, J. A., Chen, M., & Burrows, L. (1996). Automaticity of social behavior: Direct effects of trait construct and stereotype activation on action. *Journal of Personality and Social Psychology*, 71, 230–244.
- Bartels, A., & Zeki, S. (2000). The neural basis of romantic love. *NeuroReport*, 11, 3829–3834.
- Baumeister, R. F., Bratslavsky, E., Muraven, M., & Tice, D. M. (1998). Ego depletion: Is the self a limited resource? *Journal of Personality and Social Psychology*, 65, 317–338.
- Beauregard, M., Levesque, J., & Bourgouin, P. (2001). Neural correlates of conscious self-regulation of emotion. *Journal of Neuroscience*, 21, 6993–7000.
- Bechara, A., Damasio, H., Tranel, D., & Damasio, A. R. (1997). Deciding advantageously before knowing the advantageous strategy. *Science*, 275, 1293–1294.
- Berridge, C. W., & Foote, S. L. (1991). Effects of locus coeruleus activation on electroencephalographic activity in neocortex and hippocampus. *Journal of Neuroscience*, 11, 3135–3145.
- Beversdorf, D. Q., White, D. M., Chever, D. C., Hughes, J. D., & Bornstein, R. A. (2002). Central (?)adrenergic modulation of cognitive flexibility. *NeuroReport*, 13, 2505–2507.
- Bless, H., & Schwarz, N. (1999). Sufficient and necessary conditions in dual-process models: The case of mood and information processing. In S. Chaiken & Y. Trope (Eds.), *Dual-process theories in social psychology* (pp. 423–440). New York: Guilford Press.
- Bond, C. F., Jr., & Titus, L. T. (1983). Social facilitation: A meta-analysis of 241 studies. *Psychological Bulletin*, 94, 265–292.
- Botvinick, M. M., Braver, T. D., Barch, D. M., Carter, C. S., & Cohen, J. D. (2001). Conflict monitoring and cognitive control. *Psychological Review*, 108, 624–652.
- Bouret, S., Duvel, A., Onat, S., & Sara, S. J. (2003). Phasic activation of locus coeruleus neurons by the central nucleus of the amygdala. *Journal of Neuroscience*, 23, 3491–3497.
- Breiter, H. C., Gollub, R. L., Weisskoff, R. M., Kennedy, D. N., Makris, N., Berke, J. D., et al. (1997). Acute effects of cocaine on human brain activity and emotion. *Neuron*, 19, 591–611.
- Brewer, J. B., Zhao, Z., Desmond, J. E., Glover, G. H., & Gabrieli, J. D. E. (1998). Making memories: Brain activity that predicts how well visual experience will be remembered. *Science*, 281, 1185–1187.

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- Cabeza, R., & Nyberg, L. (2000). Imaging cognition: II. An empirical review of 275 PET and fMRI studies. *Journal of Cognitive Neuroscience*, *12*, 1–47.
- Callicott, J. H., Mattay, V. S., Bertolino, A., Finn, K., Coppola, R., Frank, J. A., et al. (1999). Physiological characteristics of capacity constraints in working memory as revealed by functional MRI. *Cerebral Cortex*, *9*, 20–26.
- Carrette, L., Hinojosa, J. A., Mercado, F., & Tapia, M. (2005). Cortical response to subjective unconscious danger. *NeuroImage*, *24*, 615–623.
- Chaiken, S., Liberman, A., & Eagly, A. H. (1989). Heuristic and systematic processing within and beyond the persuasion context. In J. S. Uleman & J. A. Bargh (Eds.), *Unintended thought* (pp. 212–252). New York: Guilford Press.
- Chaiken, S., & Trope, Y. (Eds.). (1999). *Dual-process theories in social psychology*. New York: Guilford Press.
- Cohen, J. D., Dunbar, K., & McClelland, J. L. (1990). On the control of automatic processes: A parallel distributed processing model of the Stroop effect. *Psychological Review*, *97*, 332–361.
- Conrad, C. D., Galea, L. A., Kuroda, Y., & McEwen, B. S. (1996). Chronic stress impairs rat spatial memory on the Y maze, and this effect is blocked by tianeptine pretreatment. *Behavioral Neuroscience*, *110*, 1321–1334.
- Craig, A. D. (2004). Human feelings: Why are some more aware than others. *Trends in Cognitive Sciences*, *8*, 239–241.
- Craik, F. I. M., & Tulving, E. (1975). Depth of processing and retention of words in episodic memory. *Journal of Experimental Psychology: General*, *104*, 268–294.
- Crinion, J. T., Lambon-Ralph, M. A., Warburton, E. A., Howard, D., & Wise, R. J. S. (2003). Temporal lobe regions engaged during normal speech comprehension. *Brain*, *126*, 1193–1201.
- Cunningham, W. A., Johnson, M. K., Raye, C. L., Gatenby, J., Gore, J. C., & Banaji, M. R. (2004). Separable neural components in the processing of black and white faces. *Psychological Science*, *15*, 806–813.
- Cunningham, W. A., Johnson, M. K., Gatenby, J. C., Gore, J. C., & Banaji, M. R. (2003). Neural components of social evaluation. *Journal of Personality and Social Psychology*, *85*, 639–649.
- Damasio, A. R. (1994). *Descartes' error: Emotion, reason, and the human brain*. New York: Putnam.
- Darke, S. (1988). Effects of anxiety on inferential reasoning task performance. *Journal of Personality and Social Psychology*, *55*, 499–505.
- Dayas, C. V., & Day, T. A. (2001). Opposing roles for medial and central amygdala in the initiation of noradrenergic cell responses to a psychological stressor. *European Journal of Neuroscience*, *15*, 1712–1718.
- Deppe, M., Schwindt, W., Kramer, J., Kugel, H., Plassmann, H., Kenning, P., et al. (2005). Evidence for a neural correlate of a framing effect: Bias-specific activity in the ventromedial prefrontal cortex during credibility judgments. *Brain Research Bulletin*, *67*, 413–421.
- Devine, P. G. (1989). Stereotypes and prejudice: Their automatic and controlled components. *Journal of Personality and Social Psychology*, *56*, 680–690.
- Dewey, J. (1925). *Experience and nature*. LaSalle, IL: Open Court Press.
- Egloff, B., & Hock, M. (2001). Interactive effects of state anxiety and trait anxiety on emotional Stroop interference. *Personality and Individual Differences*, *31*, 875–882.

- Eisenberger, N. I., & Lieberman, M. D. (2004). "Why it hurts to be left out": The neurocognitive overlap between physical and social pain. *Trends in Cognitive Sciences*, 8, 294–300.
- Eisenberger, N. I., Lieberman, M. D., & Satpute, A. B. (2005). Personality from a controlled processing perspective: An fMRI study of neuroticism, extraversion, and self-consciousness. *Cognitive, Affective, and Behavioral Neuroscience*, 5, 169–181.
- Fanselow, M. S., & LeDoux, J. E. (1999). Why we think plasticity underlying Pavlovian fear conditioning occurs in the basolateral amygdala. *Neuron*, 23, 229–232.
- Forgas, J. P. (1995). Mood and judgment: The affect infusion model (AIM). *Psychological Bulletin*, 117, 39–66.
- Fujii, T., Okuda, J., Tsukiura, T., Ohtake, H., Suzuki, M., Kawashima, R., et al. (2002). Encoding-related brain activity during deep processing of verbal materials: A PET study. *Neuroscience Research*, 44, 429–438.
- Garrard, P., & Hodges, J. R. (2000). Semantic dementia: Clinical, radiological and pathological perspectives. *Journal of Neurology*, 247, 409–422.
- Gilbert, D. T. (1989). Thinking lightly about others: Automatic components of the social inference process. In J. S. Uleman & J. A. Bargh (Eds.), *Unintended thought* (pp. 189–211). New York: Guilford Press.
- Gilbert, D. T. (1999). What the mind's not. In S. Chaiken & Y. Trope (Eds.), *Dual-process theories in social psychology* (pp. 3–11). New York: Guilford Press.
- Gray, J. R., & Braver, T. S. (2002). Personality predicts working-memory-related activation in the caudal anterior cingulate cortex. *Cognitive, Affective, and Behavioral Neuroscience*, 2, 64–75.
- Greenwald, A. G., McGhee, D. E., & Schwartz, J. L. K. (1998). Measuring individual differences in implicit cognition: The Implicit Association Test. *Journal of Personality and Social Psychology*, 74, 1464–1480.
- Gross, J. J. (1998). Antecedent- and response-focused emotion regulation: Divergent consequences for experience, expression, and physiology. *Journal of Personality and Social Psychology*, 74, 227–237.
- Gusnard, D. A., Akbudak, E., Shulman, G. L., & Raichle, M. E. (2001). Medial prefrontal cortex and self-referential mental activity: Relation of a default mode of brain function. *Proceedings of the National Academy of Sciences of the USA*, 98, 4259–4264.
- Hariri, A. R., Bookheimer, S. Y., & Mazziotta, J. C. (2000). Modulating emotional response: Effects of a neocortical network on the limbic system. *Neuroreport*, 11, 43–48.
- Hart, A. J., Whalen, P. J., Shin, L. M., McInerney, S. C., Fischer, H., & Rauch, S. L. (2000). Differential response in the human amygdala to racial outgroup vs ingroup face stimuli. *Brain Imaging*, 11, 2351–2355.
- Heberlein, A. S., & Adolphs, R. (2004). Impaired spontaneous anthropomorphizing despite intact perception and social knowledge. *Proceedings of the National Academy of Sciences of the USA*, 19, 7487–7491.
- Hopfield, J. J. (1982). Neural networks and physical systems with emergent collective computational abilities. *Proceedings of the National Academy of Sciences of the USA*, 79, 2554–2558.
- James, W. (1950). *Principles of psychology*. New York: Dover. (Original work published 1890)

- Jansma, J. M., Ramsey, N. F., Slagter, H. A., & Kahn, R. S. (2001). Functional anatomical correlates of controlled and automatic processing. *Journal of Cognitive Neuroscience*, *13*, 730–743.
- Kahneman, D. (2003). A perspective on judgment and choice: Mapping bounded rationality. *American Psychologist*, *58*, 697–720.
- Kapp, B. S., Supple, W. F., & Whalen, P. J. (1994). Effects of electrical stimulation of the amygdaloid central nucleus on neocortical arousal in the rabbit. *Behavioral Neuroscience*, *108*, 81–93.
- Kawakami, K., Dovidio, J. F., Moll, J., Hermsen, S., & Russin, A. (2000). Just say no (to stereotyping): Effects of training in the negation of stereotypic associations on stereotype activation. *Journal of Personality and Social Psychology*, *78*, 871–888.
- Kelley, W. M., Macrae, C. N., Wyland, C. L., Caglar, S., Inati, S., & Heatherton, T. F. (2002). Finding the self? An event-related fMRI study. *Journal of Cognitive Neuroscience*, *14*(5), 785–794.
- Knowlton, B. J., Mangels, J. A., & Squire, L. R. (1996). A neostriatal habit learning system in humans. *Science*, *273*.
- Kosslyn, S. M. (1994). *Image and brain: The resolution of the imagery debate*. Cambridge, MA: MIT Press.
- Lange, K., Williams, L. M., Young, A. W., Bullmore, E. T., Brammer, M. J., Williams, S. C. R., et al. (2003). Task instructions modulate neural response to fearful facial expressions. *Biological Psychiatry*, *53*, 226–232.
- Lau, H. C., Rogers, R. D., Ramnani, N., & Passingham, R. E. (2004). Willed action and attention to the selection of action. *NeuroImage*, *21*, 1407–1415.
- LeDoux, J. E. (1996). *The emotional brain: The mysterious underpinnings of emotional life*. New York: Simon & Schuster.
- Lee, A. C. H., Robbins, T. W., Graham, K. S., & Owen, A. M. (2002). “Pray or prey?” Dissociation of semantic memory retrieval from episodic memory processing using positron emission tomography and a novel homophone task. *NeuroImage*, *16*, 724–735.
- Levesque, J., Eugene, F., Joannette, Y., Paquette, V., Mensour, B., Deaudoin, G., et al. (2003). Neural circuitry underlying voluntary suppression of sadness. *Biological Psychiatry*, *53*, 502–510.
- Lewicki, P. (1986). *Nonconscious social information processing*. San Diego, CA: Academic Press.
- Liddell, B. J., Brown, K. J., Kemp, A. H., Barton, M. J., Das, P., Peduto, A., et al. (2005). A direct brainstem–amygdala–cortical “alarm” system for subliminal signals of fear. *NeuroImage*, *24*, 235–243.
- Lieberman, M. D. (in press). Social cognitive neuroscience: A review of core processes. *Annual Review of Psychology*.
- Lieberman, M. D., Eisenberger, N. I., Crockett, M. J., Tom, S., Pfeifer, J. H., & Way, B. M. (in press). Putting feelings into words: Affect labeling disrupts amygdala activity to affective stimuli. *Psychological Science*.
- Lieberman, M. D. (2000a). Intuition: A social cognitive neuroscience approach. *Psychological Bulletin*, *126*, 109–137.
- Lieberman, M. D. (2000b). Introversion and working memory: Central executive differences. *Personality and Individual Differences*, *28*, 479–486.
- Lieberman, M. D. (2003). Reflective and reflexive judgment processes: A social cognitive neuroscience approach. In J. P. Forgas, K. R. Williams, & W. von

- Hippel (Eds.), *Social judgments: Implicit and explicit processes* (pp. 44–67). New York: Cambridge University Press.
- Lieberman, M. D., Chang, G. Y., Chiao, J. Y., Bookheimer, S. Y., & Knowlton, B. J. (2004). An event-related fMRI study of artificial grammar learning in a balanced chunk strength design. *Journal of Cognitive Neuroscience*, *16*, 427–438.
- Lieberman, M. D., & Eisenberger, N. I. (2004). Conflict and habit: A social cognitive neuroscience approach to the self. In A. Tesser, J. V. Wood, & D. A. Stapel (Eds.), *On building, defending and regulating the self: A psychological perspective* (pp. 77–102). New York: Psychology Press.
- Lieberman, M. D., Eisenberger, N. I., & Crockett, M. (2006). *An fMRI study of automatic behavior: Comparing ideomotor and disruption accounts*. Manuscript submitted for publication.
- Lieberman, M. D., Gaunt, R., Gilbert, D. T., & Trope, Y. (2002). Reflection and reflexion: A social cognitive neuroscience approach to attributional inference. *Advances in Experimental Social Psychology*, *34*, 199–249.
- Lieberman, M. D., Hariri, A., Jarcho, J. J., Eisenberger, N. I., & Bookheimer, S. Y. (2005). An fMRI investigation of race-related amygdala activity in African-American and Caucasian-American individuals. *Nature Neuroscience*, *8*, 720–722.
- Lieberman, M. D., Jarcho, J. M., Berman, S., Naliboff, B., Suyenobu, B. Y., Mandelkern, M., & Mayer, E. (2004). The neural correlates of placebo effects: A disruption account. *NeuroImage*, *22*, 447–455.
- Lieberman, M. D., Jarcho, J. M., & Satpute, A. B. (2004). Evidence-based and intuition-based self-knowledge: An fMRI study. *Journal of Personality and Social Psychology*, *87*, 421–435.
- Lieberman, M. D., & Pfeifer, J. H. (2005). The self and social perception: Three kinds of questions in social cognitive neuroscience. In A. Easton & N. Emery (Eds.), *Cognitive neuroscience of emotional and social behavior* (pp. 195–235). Philadelphia: Psychology Press.
- Lieberman, M. D., & Rosenthal, R. (2001). Why introverts can't always tell who likes them: Multi-tasking and nonverbal decoding. *Journal of Personality and Social Psychology*, *80*, 294–310.
- Logan, G. D. (1988). Toward an instance theory of automatization. *Psychological Review*, *95*, 492–527.
- Lowery, B. S., Hardin, C. D., & Sinclair, S. (2001). Social influence on automatic racial prejudice. *Journal of Personality and Social Psychology*, *81*, 842–855.
- Macrae, C. N., Milne, A. B., & Bodenhausen, G. V. (1994). Stereotypes as energy-saving devices: A peek inside the cognitive toolbox. *Journal of Personality and Social Psychology*, *66*, 34–47.
- Markus, H. R. (1977). Self-schemata and processing information about the self. *Journal of Personality and Social Psychology*, *35*, 63–78.
- McClelland, J. L., McNaughton, B. L., & O'Reilly, R. C. (1995). Why there are complementary learning systems in the hippocampus and neocortex: Insights from the successes and failures of connectionist models of learning and memory. *Psychological Review*, *102*, 419–457.
- McEwen, B. S. (1999). Stress and hippocampal plasticity. *Annual Review of Neuroscience*, *22*, 105–122.
- McIntyre, C. K., Hatfield, T., & McGaugh, J. L. (2002). Amygdala norepinephrine

- levels after training predict inhibitory avoidance retention performance in rats. *European Journal of Neuroscience*, 16, 1223–1226.
- Miller, E. K., & Cohen, J. D. (2001). An integrative theory of prefrontal cortex function. *Annual Review of Neuroscience*, 24, 167–202.
- Milne, E., & Grafman, J. (2001). Ventromedial prefrontal cortex lesions in humans eliminate implicit gender stereotyping. *Journal of Neuroscience*, 21, RC150 151–156.
- Mitchell, J. P., Nosek, B. A., & Banaji, M. R. (2003). Contextual variations in implicit evaluation. *Journal of Experimental Psychology: General*, 132, 455–469.
- Morris, J. S., Ohman, A., & Dolan, R. J. (1999). A subcortical pathway to the right amygdala mediating “unseen” fear. *Proceedings of the National Academy of Sciences of the USA*, 96, 1680–1685.
- Mummery, C. J., Patterson, K., Price, C. J., Ashburner, J., Frackowiak, R. S. J., & Hodges, J. R. (2000). A voxel-based morphometry study of semantic dementia: Relationship between temporal lobe atrophy and semantic memory. *Annals of Neurology*, 47, 36–45.
- Mummery, C. J., Shallice, T., & Price, C. J. (1999). Dual-process model in semantic priming: A functional imaging perspective. *NeuroImage*, 9, 516–525.
- Nimchinsky, E. A., Gilissen, E., Allman, J. M., Perl, D. P., Erwin, J. M., & Hof, P. R. (1999). A neuronal morphological type unique to humans and great apes. *Proceedings of the National Academy of Sciences of the USA*, 96, 5268–5273.
- Nosek, B. A., Banaji, M. R., & Greenwald, A. G. (2002). Harvesting implicit group attitudes and beliefs from a demonstration web site. *Group Dynamics: Theory, Research, and Practice*, 6, 101–115.
- Ochsner, K. N., Bunge, S. A., Gross, J. J., & Gabrieli, J. D. (2002). Rethinking feelings: An fMRI study of the cognitive regulation of emotion. *Journal of Cognitive Neurosciences*, 14, 1215–1229.
- Ochsner, K. N., & Lieberman, M. D. (2001). The emergence of social cognitive neuroscience. *American Psychologist*, 56(9), 717–734.
- Ochsner, K. N., Ray, R. D., Cooper, J. C., Robertson, E. R., Chopra, S., Gabrieli, J. D. E., et al. (2004). For better or for worse: Neural systems supporting the cognitive down- and up-regulation of negative emotion. *NeuroImage*, 23, 483–499.
- Oya, T., Manalo, E., & Greenwood, J. (2004). The influence of personality and anxiety on the oral performance of Japanese speakers of English. *Applied Cognitive Psychology*, 18, 841–855.
- Packard, M. G., Hirsh, R., & White, N. M. (1989). Differential effects of fornix and caudate nucleus lesions on two radial maze tasks: Evidence for multiple memory systems. *Journal of Neuroscience*, 9, 1465–1472.
- Pasley, B. N., Mayes, L. C., & Schultz, R. T. (2004). Subcortical discrimination of unperceived objects during binocular rivalry. *Neuron*, 42, 163–172.
- Petty, R. E., & Cacioppo, J. T. (1986). The elaboration likelihood model of persuasion. *Advances in Experimental Social Psychology*, 19, 123–205.
- Phelps, E. A., O'Connor, K. J., Cunningham, W. A., Funayama, E. S., Gatenby, J. C., Gore, J. C., et al. (2000). Performance on indirect measures of race evaluation predicts amygdala activation. *Journal of Cognitive Neuroscience*, 12, 729–738.
- Ploghaus, A., Becerra, L., Borras, C., & Borsook, D. (2003). Neural circuitry

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- underlying pain modulation: Expectation, hypnosis, placebo. *Trends in Cognitive Sciences*, 7, 197–200.
- Poldrack, R. A., Clark, J., Par -Blagoev, E. J., Shohamy, D., Creso Moyano, J., Myers, C., et al. (2001). Interactive memory systems in the human brain. *Nature*, 414, 546–550.
- Poldrack, R. A., & Packard, M. G. (2003). Competition among multiple memory systems: Converging evidence from animal and human studies. *Neuropsychologia*, 41, 245–251.
- Posner, M. I., & Keele, S. W. (1968). On the genesis of abstract ideas. *Journal of Experimental Psychology*, 77, 353–363.
- Rauch, S. L., Savage, C. R., Brown, H. D., Curran, T., Alpert, N. M., Kendrick, A., et al. (1995). A PET investigation of implicit and explicit sequence learning. *Human Brain Mapping*, 3, 271–286.
- Rissman, J., Eliassen, J. C., & Blumstein, S. E. (2003). An event-related fMRI investigation of implicit semantic priming. *Journal of Cognitive Neuroscience*, 15, 1160–1175.
- Rossell, S. L., Bullmore, E. T., Williams, S. C. R., & David, A. S. (2001). Brain activation during automatic and controlled processing of semantic relations: A priming experiment using lexical decision. *Neuropsychologia*, 39, 1167–1176.
- Ruby, P., & Decety, J. (2001). Effect of subjective perspective taking during simulation of action: A PET investigation of agency. *Nature Neuroscience*, 4, 546–550.
- Satpute, A. B., & Lieberman, M. D. (2006). Integrating automatic and controlled processing into neurocognitive models of social cognition. *Brain Research*, 1079, 86–97.
- Schacter, D. L. (1992). Understanding implicit memory: A cognitive neuroscience approach. *American Psychologist*, 47, 559–569.
- Schaefer, A., Collette, F., Philippot, P., Van der Linden, M., Laureys, S., Delfiore, G., et al. (2003). Neural correlates of “hot” and “cold” emotional processing: A multilevel approach to the functional anatomy of emotion. *NeuroImage*, 18, 938–949.
- Semendeferi, K., Schleicher, A., Zilles, K., Armstrong, E., & Van Hoesen, G. W. (2001). Evolution of the hominoid prefrontal cortex: Imaging and quantitative analysis of area 10. *American Journal of Physical Anthropology*, 114, 224–241.
- Shors, T. J., & Mathew, P. R. (1998). NMDA receptor antagonism in the lateral/basolateral but not central nucleus of the amygdala prevents the induction of facilitated learning in response to stress. *Learning and Memory*, 5, 220–230.
- Slovan, S. A. (1996). The empirical case for two systems of reasoning. *Psychological Bulletin*, 119, 3–22.
- Small, D. M., Zatorre, R. J., Dagher, A., Evans, A. C., & Jones-Gotman, M. (2001). Changes in brain activity related to eating chocolate. From pleasure to aversion. *Brain*, 124, 1720–1733.
- Smith, W. (1945). The functional significance of the rostral cingular cortex as revealed by its responses to electrical excitation. *Journal of Neurophysiology*, 8, 241–255.
- Smolensky, P. (1988). On the proper treatment of connectionism. *Behavioral and Brain Sciences*, 11, 1–74.
- Spinoza, B. (1949). *Ethics*. New York: Hafner. (Original work published 1675)

- Suzuki, W., Saleem, K. S., & Tanaka, K. (2000). Divergent backward projections from the anterior part of the inferotemporal cortex (area TE) in the macaque. *Journal of Comparative Neurology*, *422*, 206–228.
- Taylor, S. F., Phan, K. L., Decker, L. R., & Liberzon, I. (2003). Subjective rating of emotionally salient stimuli modulates neural activity. *NeuroImage*, *18*, 650–659.
- Thompson, R. K. R., & Oden, D. L. (2000). Categorical perception and conceptual judgments by nonhuman primates: The paleological monkey and the analogical ape. *Cognitive Science*, *24*, 363–396.
- Trope, Y. (1986). Identification and inferential processes in dispositional attribution. *Psychological Review*, *93*, 239–257.
- Vogels, R. (1999). Categorization of complex visual images by rhesus monkeys: Part 2. Single-cell study. *European Journal of Neuroscience*, *11*, 1239–1255.
- Vyas, A., Mitra, R., Shankaranarayana Rao, B. S., & Chattarji, S. (2002). Chronic stress induces contrasting patterns of dendritic remodeling in hippocampal and amygdaloid neurons. *Journal of Neuroscience*, *22*, 6810–6818.
- Wager, T. D., Phan, K. L., Liberzon, I., & Taylor, S. F. (2003). Valence, gender, and lateralization of functional brain anatomy in emotion: A meta-analysis of findings from neuroimaging. *NeuroImage*, *19*, 513–531.
- Wagner, A. D., Schacter, D. L., Rotte, M., Koutstaal, W., Maril, A., Dale, A. M., et al. (1998). Building memories: Remembering and forgetting of verbal experiences as predicted by brain activity. *Science*, *281*, 1188–1191.
- Wegner, D. M. (1994). Ironic processes of mental control. *Psychological Review*, *101*, 34–52.
- Whalen, P. J., Rauch, S. L., Etcoff, N. L., McInerney, S. C., Lee, M. B., & Jenike, M. A. (1998). Masked presentations of emotional facial expressions modulate amygdala activity without explicit knowledge. *Journal of Neuroscience*, *18*, 411–418.
- Wilson, T. D., Lindsey, S., & Schooler, T. Y. (2000). A model of dual attitudes. *Psychological Review*, *107*, 101–126.
- Wright, C. I., Fischer, H., Whalen, P. J., McInerney, S. C., Shin, L. M., & Rauch, S. L. (2001). Differential prefrontal and amygdala habituation to repeatedly presented emotional stimuli. *Neuroreport*, *12*, 379–383.
- Xu, B., Grafman, J., Gaillard, W. D., Spanaki, M., Ishii, K., Balsamo, L., et al. (2002). Neuroimaging reveals automatic speech code during perception of written word meaning. *NeuroImage*, *17*, 859–870.
- Yerkes, R. M., & Dodson, J. D. (1908). The relation of strength of stimulus to rapidity of habit-formation. *Journal of Comparative Neurology and Psychology*, *18*, 459–482.
- Zajonc, R. B. (1965). Social facilitation. *Science*, *149*, 269–274.
- Zalla, T., Koechlin, E., Pietrini, P., Basso, G., Aquino, P., Sirigu, A., et al. (2000). Differential amygdala responses to winning and losing: A functional magnetic resonance imaging study in humans. *European Journal of Neuroscience*, *12*, 1764–1770.