Evidence-Based and Intuition-Based Self-Knowledge: An fMRI Study

Matthew D. Lieberman, Johanna M. Jarcho, and Ajay B. Satpute
University of California, Los Angeles

Behavioral and neuropsychological studies have suggested multiple self-knowledge systems may exist (i.e., evidence-based and intuition-based self-knowledge); however, little is known about the nature of intuition-based self-knowledge. In a functional magnetic resonance imaging study, the neural correlates of intuition-based and evidence-based self-knowledge were investigated. Participants with high and low experience in different domains (soccer and acting) made self-descriptiveness judgments about words from each domain while being scanned. High-experience domain judgments produced activation in a network of neural structures called the *X-system*, involved in automatic social cognition, whereas low-experience domain judgments produced activations in a network called the *C-system*, involved in effortful social cognition and propositional thought. The affective and slow-changing nature of intuition-based self-knowledge is discussed.

A world without memory is a world of the present. The past exists only in books, in documents. In order to know himself, each person carries his own Book of Life, which is filled with the history of his life . . . . Without his Book of Life, a person is a snapshot, a two-dimensional image, a ghost.
—Alan Lightman, *Einstein's Dreams* (1993, p. 82)

This vignette from Lightman's (1993) delightful collection of alternate realities describes a world in which "people have no memories" (p. 82). The story resonates with the common belief that the memories we can retrieve about ourselves, the entries in our internal "Book of Life," are essential to self-knowledge, and without these memories we would be little more than ghosts of our former selves. We imagine ourselves incapable of knowing who we are once we are cut off from the rich expanse of autobiographical detail each of us possesses. Researchers have addressed this view empirically, asking to what extent autobiographical memory is critical to the upkeep of one's self-knowledge. Though some

research points to autobiographical memory being accessed when constructing or retrieving self-knowledge (Fink et al., 1996; Kelley et al., 2002), a number of studies have suggested that a good deal of self-knowledge is represented independently of autobiographical memories (Klein & Loftus, 1993). These latter studies have examined a variety of conditions under which the telltale markers of autobiographical memory use are absent during normal performance on tests of self-knowledge. This research suggests that self-knowledge based on autobiographical memory cannot be the whole story of self-knowledge, implicating at least one self-knowledge system that does not recruit autobiographical evidence. Nevertheless, little is known about the characteristics of this other system apart from its independence from autobiographical memory.

We conducted a functional magnetic resonance imaging (fMRI) study in which we attempted to identify the neural correlates of multiple distinct self-knowledge systems. Finding the neural correlates of the second self-knowledge system would allow researchers to develop new hypotheses based on what is already known about the functional properties of those brain regions. We generated neural hypotheses based on results of previous social cognitive neuroscience research on automatic and controlled social cognition (Adolphs, 1999; Klein & Kihlstrom, 1998; Ochsner & Lieberman, 2001). We begin with a description of two plausible self-knowledge systems and discuss the neurocognitive structures that might support their processes.

Evidence-Based Self-Knowledge and the C-System

It is an extraordinary achievement that humans are capable of answering an endless assortment of questions about themselves. Whereas other animals have traits, abilities, and preferences, only humans demonstrate knowledge of and beliefs about their attributes. No matter how sweet and cuddly a cat might be, there is

no evidence to suggest that any feline is aware of or has thoughts about its own sweetness and cuddliness ("If I turn on my charm, maybe I'll get more of the leftovers than Rover"). Part of the mystery of self-knowledge can be unraveled by understanding how this knowledge is constructed and represented. One way that people generate self-knowledge is by reflecting on their past behavior and then using memories as evidence in the self-inference process (Bem, 1972). For instance, if Robert is asked if he is a good golfer, he can think back over his poor performance the two times he has played golf and surmise that he is not a good golfer. Because this kind of self-knowledge results from an evidentiary process of retrieving and evaluating autobiographical information, we refer to it here as *evidence-based* self-knowledge. This designation refers to the phenomenological experience associated with generating this type of self-knowledge and is not meant to indicate accuracy.

To the extent that Robert retrieves and evaluates autobiographical evidence to assess his golfing prowess, episodic memory processes should be involved in retrieving autobiographical details. Moreover, working memory processes should be involved in keeping these details in mind while evaluating their implications. We assume that evidence-based self-knowledge can be derived from small amounts of evidence and updated on the basis of any new information. Thus, Robert does not need to go golfing dozens of times to assess his golfing proficiency; rather, Robert can construct a coherent self-knowledge representation in this domain after playing just twice. Robert might even have a belief about his golfing ability before he ever plays, relying on imagined behavior as evidence.

In previous work, Lieberman, Gaunt, Gilbert, and Trope (2002) described a neurocognitive system called the *C-system* (for the *C* in *reflective*) that is involved in effortful and intentional social cognition. This system relies on symbolic representations, which are organized into propositions and processed serially in working memory and episodic memory. Functionally, the C-system is called on to respond flexibly when habits and instinct are ill equipped to handle the demands of a situation. For instance, in the Stroop task, individuals are required to name the color of the ink in which a word is written; however, the word itself is sometimes the name of another color. When the word *R-E-D* is written in blue ink, there is an automatic impulse to read the word and respond "red"; however, this impulse is contextually inappropriate given the goal of indicating the ink color. Working memory processes are critical for holding current goals in mind and, in this case, using the goal representation to intentionally override the impulse to read the word (Miller & Cohen, 2001).

Episodic memory also plays an important part in the process of overriding contextually inappropriate impulses. Imagine that Erin has a designated parking slot that she finds occupied one morning and thus is forced to park elsewhere. Later on, the conditioned process of leaving work and heading toward the parking garage will likely activate the impulse to walk toward her usual parking spot (James, 1890/1950). Erin will rely on her episodic memory of where she parked that particular morning to avoid going to her typical spot. In this way, episodic memory serves as a reminder of how to handle unusual circumstances.

Thus, episodic memory is often used to retrieve information that has become contextually significant ("I remember that my car is in a different place today, so I won't go to the usual spot"), and

working memory is often used to hold contextually significant information in mind ("Say the ink color, not the word"). That working memory and episodic memory work together is evidenced by depth of processing research suggesting that greater working memory processing at encoding is an important determinant of retrieval success later on (Brewer, Zhao, Desmond, Glover, & Gabrieli, 1998; Craik & Tulving, 1975; Wagner et al., 1998).

Among the brain structures included in the C-system are lateral prefrontal cortex, posterior parietal cortex, and hippocampus along with surrounding medial temporal lobe structures (see Figure 1; Lieberman, Chang, Chiao, Bookheimer, & Knowlton, 2004; Lieberman et al., 2002; Lieberman & Pfeifer, in press). To some extent, each of these structures has been identified with both working memory and episodic memory processes (Cabeza & Nyberg, 2000; Ranganath & D'Esposito, 2001). These structures have also been associated with the controlled processing components of various aspects of social cognition, including dispositional and causal inference (Satpute et al, 2004), explicit categorization (Lieberman, Chang, et al., 2004; Smith, Patalano, & Jonides, 1998), deductive reasoning (Kroger et al., 2002), self-regulation of prejudice and pain (Lieberman, Hariri, Jarcho, Eisenberger, & Bookheimer, 2004; Lieberman, Jarcho, et al., 2004), and intentional reappraisal of affective stimuli (Beauregard, Levesque, & Bourgouin, 2001; Ochsner, Bunge, Gross, & Gabrieli, 2002). Despite the diversity of these processes, their common neural bases suggest that the C-system may perform similar computations in the service of many kinds of controlled social cognition.

In the current investigation, we extend the scope of the C-system by hypothesizing that evidence-based self-knowledge will also depend on the C-system. We are not hypothesizing that evidence-based self-knowledge will rely exclusively on the C-system; rather, it is merely a starting point. We are using the C-system as a guide in the generation of predictions in order to avoid a wholesale fishing expedition in this relatively uncharted territory of research. Clearly, it is a rough guide that will undoubtedly require refinement in light of future results.

Intuition-Based Self-Knowledge and the X-System

Anecdotally, people seem to rely on evidence-based self-knowledge much of the time. Ask anyone how they know they possess Attribute X, and they can rattle off a list of times they engaged in behaviors indicative of that attribute; however, the generation of reasons after the fact is no guarantee that those reasons guided the initial judgment (Nisbett & Wilson, 1977; Wilson & Schooler, 1991). In the case of Tiger Woods, for example, it would be surprising if he retrieved memories of specific golf-playing episodes in evaluating his golfing abilities. There is a growing body of research suggesting the existence of implicit, tacit, or automatic self-processes that operate without effort, intention, or awareness (Bargh, 1982; Greenwald & Banaji, 1995; Hetts, Sakuma, & Pelham, 1999; Koole, Dijksterhuis, & van Knippenberg, 2001; Lieberman, Ochsner, Gilbert, & Schacter, 2001; Markus, 1977; Pelham, Mirenberg, & Jones, 2002; Spalding & Hardin, 1999) that could lead to self-judgments based on accumulated experience without the explicit retrieval and evaluation of autobiographical evidence. Neuroimaging studies have indicated that C-system structures are activated when people are making self-knowledge judgments (Fink et al., 1996; Kelley et al., 2002).
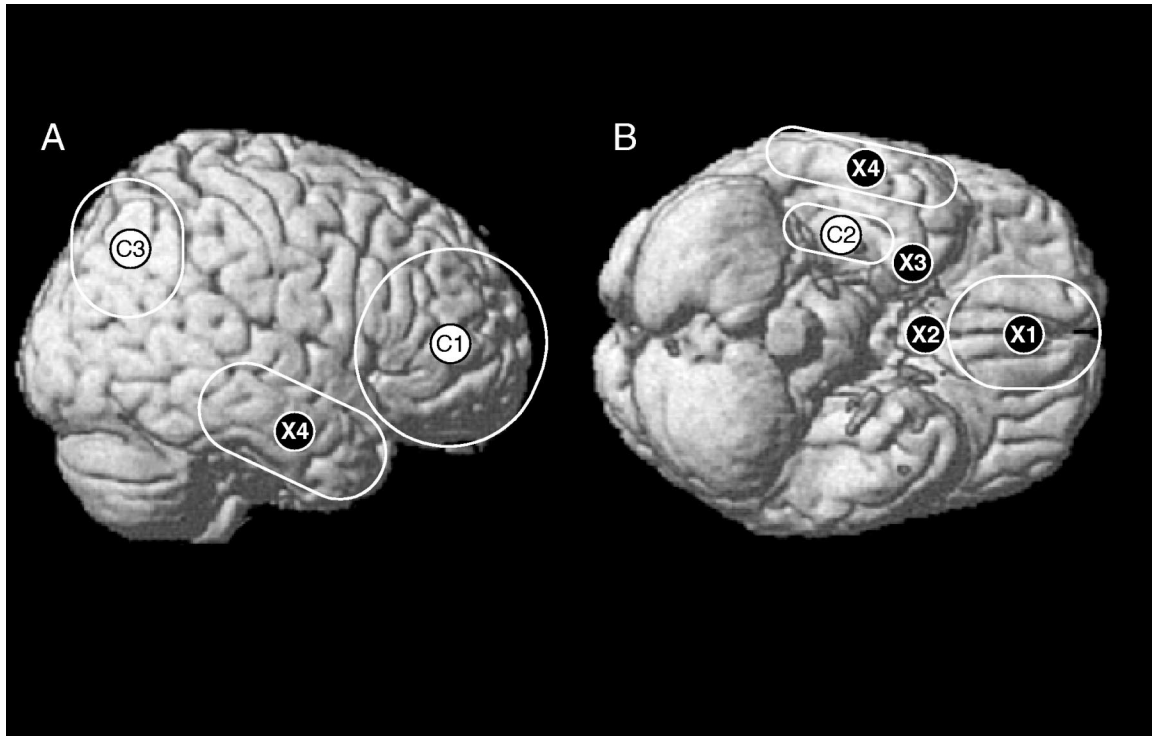
Figure 1. Neural correlates of the C-system (for the *C* in *reflective*; involved in effortful and intentional social cognition) and X-system (for the *X* in *reflexive*; automatically constructs some of the social and affective aspects of the stream of consciousness) displayed on a canonical brain rendering from side (A) and bottom (B) views. C-system regions displayed are lateral prefrontal cortex (C1), hippocampus and medial temporal lobe (C2), and posterior parietal cortex (C3). X-system regions displayed are ventromedial prefrontal cortex (X1), nucleus accumbens (X2), amygdala (X3), and lateral temporal cortex (X4). The hippocampus, nucleus accumbens, and amygdala are subcortical structures that are displayed here on the cortical surface for ease of presentation. Similarly, some structures are only displayed in one hemisphere even though all structures exist in both hemispheres.

However, Klein and his colleagues (e.g., Klein & Loftus, 1993) have found that under a variety of processing conditions, the C-system may be relatively uninvolved in self-knowledge judgments.

Klein and Loftus (1993) examined whether markers characteristic of episodic memory use were present when making self-knowledge judgments. They argued that if autobiographical details are accessed during self-knowledge judgments, such judgments should be made more quickly to the extent that the relevant autobiographical details have recently been activated and rendered more accessible. In one series of studies, Klein and his colleagues (Klein, Loftus, Trafton, & Fuhrman, 1992) found that under most conditions, participants were no faster to make self-knowledge judgments after the activation of relevant autobiographical memories than when no autobiographical memories had been activated. Only when participants made self-judgments in domains in which they had comparatively little experience was evidence found for episodic retrieval processes. These findings suggest that evidence-based self-knowledge cannot account for all self-knowledge judgments and may be limited to low-experience domains. However, it is difficult to use cognitive methods alone to establish the independence of two types of representations or processes (Neely, 1989; Roediger, Rajaram, & Srinivas, 1990).

Klein and colleagues used three neuropsychological case studies as another means of demonstrating the existence of self-knowledge representations that do not depend on episodic memory. Patient W.J. suffered a traumatic head injury that temporarily rendered her incapable of retrieving memories of events that had occurred in the previous 12 months. Despite this impairment in episodic memory, W.J. was able to produce personality ratings for herself that were highly correlated with the ratings she produced after she regained access to her episodic memories (Klein, Loftus, & Kihlstrom, 1996; see also Tulving, 1993). Although it is possible that she was retrieving episodic memories from earlier time periods to make the judgments, the same explanation cannot be given for patient D.B., who was permanently amnesic and could not recall any episodic memories from his entire life. Similar to patient W.J., patient D.B. made personality ratings of himself that were as highly correlated with his daughter's ratings of him as ratings made by healthy age-matched father–daughter controls (Klein, Rozendal, & Cosmides, 2002). Additionally, autistic patient R.J. had both episodic and semantic memory deficits, yet his self-knowledge had remained intact (Klein, Chan, & Loftus, 1999; Klein, Cosmides, Costabile, & Mei, 2002). Klein and colleagues concluded that at least some forms of self-knowledge do not depend on the retrieval and evaluation of autobiographical details from episodic memory.

These findings, however, are more suggestive than conclusive, because these single-subject case studies lacked clearly specified neuroanatomical bases for the deficits they displayed.

If evidence-based self-knowledge does not explain all self-knowledge judgments, how are other self-knowledge judgments made? To date, the enigmatic second self-knowledge system has largely been defined negatively, by comparison with the evidence-based self-knowledge system. The primary identifying attribute of this second system, for instance, is that it is not linked to episodic memory. An additional attribute suggested by Klein et al.'s (1992) work is that the second system may guide self-judgments to the extent that an individual has extensive domain-specific experience. Thus, evidence-based self-knowledge may dominate in domains for which there has been relatively little experience, because more integrated self-knowledge representations have not yet reached maturity.

One method for determining the attributes of a second self-knowledge system involves finding its neural correlates and then using what is known about the computational properties of those brain structures to generate a model of that self-knowledge system. In addition to the C-system, Lieberman and colleagues (Lieberman, 2003; Lieberman et al., 2002) have previously described a neurocognitive system called the *X-system* (for the *X* in *reflexive*) that automatically constructs some of the social and affective aspects of the stream of consciousness and produces some of the habitual responses and impulses that guide much of people's daily activity.[1] Though there is no empirical evidence linking the X-system to self-knowledge processing, we believe it may be a good place to start the search for a second self-knowledge system.

The X-system includes ventromedial prefrontal cortex, basal ganglia, amygdala, and lateral temporal cortex (see Figure 1; Lieberman, 2003; Lieberman & Pfeifer, in press; Lieberman, Schreiber, & Ochsner, 2003). The ventromedial prefrontal cortex and basal ganglia are capable of learning abstract relationships between features of the environment and the affective significance of these features without conscious awareness or intention (Bechara, Damasio, Tranel, & Damasio, 1997; Knowlton, Mangels, & Squire, 1996; Lieberman, Chang, et al., 2004). Once learned, these structures can apply this abstract knowledge to new situations without effort, intention, or episodic retrieval of the specific experiences that contributed to the abstract knowledge. These structures have each been characterized as the neural basis of social intuition (Damasio, 1994; Lieberman, 2000; Milne & Grafman, 2001), and thus we refer here to self-knowledge that might arise from these structures as *intuition-based* self-knowledge. As with our C-system hypothesis, we take the X-system as a starting point and do not presume that intuition-based self-knowledge is exclusively dependent on these structures.

Another reason for linking intuition-based self-knowledge to the X-system is the speed at which new representations form in the basal ganglia and ventromedial prefrontal cortex. As described previously, Klein's work suggests that intuition-based self-knowledge representations develop slowly with extended experience in a domain. Similarly, X-system representations, in contrast to C-system representations, develop and change slowly with increased experience. For instance, in Damasio and colleagues' well-known gambling task that relies on ventromedial prefrontal cortex, participants form intuitions about the overall value of different decks of cards that they are drawing from (Bechara et al.,

1997). Though intuitions eventually guide the choices of healthy participants, these intuitions take many trials before they gain behavioral control. Similarly, in implicit learning paradigms, it sometimes takes thousands of trials before the impact of intuitive processing is seen (Lewicki, Czyzewska, & Hoffman, 1987).

If intuition-based self-knowledge relies on X-system processes and thus forms very slowly, this provides a mechanism for experimentally disentangling evidence-based and intuition-based self-knowledge. Klein et al.'s (1992) finding that episodic memory involvement is restricted to self-knowledge judgments in a low-experience domain is consistent with the idea that intuition-based self-knowledge might not yet have been strong enough to guide these judgments, necessitating the use of evidence-based self-knowledge. Thus, having individuals make self-judgments in domains for which they have a high or low degree of experience should differentially activate the neural systems supporting intuition-based and evidence-based self-knowledge, respectively.

Though the amygdala and lateral temporal cortex have been classified as X-system structures, it is more difficult to theorize about their potential roles in intuition-based and evidence-based self-knowledge. The amygdala is involved in multiple forms of automatic social cognition, including the registration of subliminal fear stimulus presentations, and often develops new representations slowly according to classical conditioning procedures (Adolphs, Tranel, & Damasio, 1998; Hariri, Bookheimer, & Mazziotta, 2000; Hart et al., 2000; Morris, Ohman, & Dolan, 1999; Pasley, Mayes, & Schultz, 2004; Phelps et al., 2000; Whalen et al., 1998). On the other hand, the amygdala can in some cases engage in single-trial learning consistent with the rapid updating of evidence-based self-knowledge and is not exclusively associated with automatic affective processes (Morris et al., 1999). Thus, although we do predict amygdala involvement in intuition-based self-knowledge, this prediction is more tentative than the others for this study.

Lateral temporal cortex, extending into the anterior temporal pole, has been associated with semantic knowledge (Garrard & Hodges, 2000; Mummery et al., 2000) and the slow formation of representations (McClelland, McNaughton, & O'Reilly, 1995). However, there is evidence suggesting that lateral temporal cortex partakes in both controlled–explicit and automatic–implicit semantic processes. When semantic memory is used explicitly, lateral prefrontal cortex and lateral temporal cortex are typically coactivated (Lee, Robbins, Graham, & Owen, 2002; Xu et al., 2002), whereas implicit semantic memory appears to activate lateral temporal cortex without lateral prefrontal cortex (Crinion, Lambon-Ralph, Warburton, Howard, & Wise, 2003; Mummery, Shallice, & Price, 1999; Rissman, Eliassen, & Blumstein, 2003; Rossell, Bullmore, Williams, & David, 2001). This suggests that although controlled prefrontal processes can access or work with

---

[1] These structures are considered together because they serve related functions and are capable of automatic processing relevant to social cognition. We do not think that these regions necessarily operate together in unison (Lieberman & Eisenberger, 2004). Nor do we think that the X-system competes with the C-system to control behavior, though under certain processing conditions, particular structures of the X- and C-systems can interfere with one another (Hariri et al., 2000; Lieberman, Jarcho, et al., 2004).

the representations stored in lateral temporal cortex, in the absence of top-down control, lateral temporal cortex may automatically color the semantic aspects of cognition and the stream of consciousness. When lateral prefrontal activation is absent, it is reasonable to tentatively conclude that lateral temporal cortex activity represents relatively automatic processing. In the context of intuition-based self-knowledge, the implication of lateral temporal cortex activations may therefore differ based on the additional presence or absence of lateral prefrontal activity.

Overview of the Study

We conducted an fMRI study in which participants made self-judgments in high-experience and low-experience domains in order to dissociate the two forms of self-knowledge (Klein et al., 1992). We hypothesized that making self-judgments in the high-experience domain would isolate the neural correlates of intuition-based self-knowledge, whereas making self-judgments in the low-experience domain would isolate the neural correlates of evidence-based self-knowledge. Each participant was either a soccer player or an improvisational actor, and all participants judged the self-descriptiveness of words related to soccer and improvisational acting. We included both groups so that our results would be generalizable beyond either group's idiosyncratic characteristics. We hypothesized that self-judgments in a high-experience domain would differentially activate X-system structures and that self-judgments in a low-experience domain would differentially activate C-system structures.

Method

Participants

Eleven college-level or higher soccer players (hereafter referred to as *athletes*; 11 male, mean age = 21.7 years) and 11 improvisational actors (hereafter referred to as *actors*; 8 male, mean age = 30.0 years), all right-handed, received $30 for participating in this study. Written consent in accordance with the University of California, Los Angeles (UCLA) Institutional Review Board's approved procedures was obtained from each participant.

Experimental Paradigm

On arrival at the UCLA Brain Mapping Center, participants were informed that they were participating in a study exploring the neural correlates of self-knowledge. Participants were told that during the experiment they would be asked to indicate whether or not various words described them. After giving consent, participants were then fitted with fiber-optic goggles with a computerized input source, given a two-button response box in their right hand, and placed in a GE 3.0 Tesla scanner (Advance NMRI Systems, Inc., Wilmington, MA). fMRI scanning sessions consisted of two functional scans separated by 1 min of rest. Each functional scan was composed of three experimental blocks of trials. At the start of each block, 15 s of blank screen was followed by a 3-s screen-centered fixation mark signaling the start of experimental trials. Twenty-seven words were presented for 3 s each, one at a time, during which time participants indicated if the word described them ("Me"), by pressing the left button with their index finger, or did not describe them ("Not Me"), by pressing the right button with their middle finger. Participants were asked to respond as quickly and accurately as possible. To remind participants of their task, the words *Me* and *Not Me* remained in the bottom left and right corners of the screen, respectively, for the duration of each trial block. The actor and athlete blocks each consisted of 20 trials of either actor or athlete words randomly interspersed with 7 neutral word trials. Neutral blocks were composed of 27 neutral word trials. Each of the three block types (actor, athlete, neutral) was presented in both functional scans; thus, each trait word was presented twice, once per scan. The order of the blocks was counterbalanced across functional runs and across participants.

Materials

The actor and athlete words (see Appendix) were selected according to ratings produced by nine raters in a pilot testing session prior to the beginning of our study. Each of a pool of words was rated for how well it described improvisational actors on Likert scales whose endpoints were 0 (*does not describe an improvisational actor*) and 7 (*very much describes an improvisational actor*) and how well it described soccer players on Likert scales whose endpoints were labeled 0 (*does not describe a soccer player*) and 7 (*very much describes a soccer player*). Selected acting words were rated as highly descriptive of improvisational actors (M = 6.19, SD = 0.58) but not descriptive of soccer players (M = 1.83, SD = 1.37), whereas selected athletic words were rated as highly descriptive of soccer players (M = 6.05, SD = 0.49) but not descriptive of improvisational actors (M = 1.75, SD = 0.75).

Image Acquisition

Images were acquired using a GE 3.0 Tesla scanner with an upgrade for echo-planar imaging (EPI). For each participant, a high-resolution structural T2-weighted EPI volume (spin echo; repetition time = 4,000 ms; echo time = 54 ms; 26 axial slices; 3.125-mm in-plane resolution; 4-mm thick, skip 1 mm) was acquired coplanar with the functional scans. Two functional EPI scans (echo-planar T2*-weighted gradient echo; TR = 3,000 ms; TE = 25 ms; flip angle = 90°; 19 axial slices; 3.125-mm in-plane resolution; 4-mm thick, skip 1 mm) were acquired, each for a duration of 5 min and 6 s. Each functional scan was composed of 102 brain volume images, with 1 image acquired every 3 s. The first 5 images were taken during a scanner equilibration period and thus were not analyzed. The remaining 97 images corresponded to a fixation cue (1 image), three rest periods (5 images each), and three task blocks (27 images each).

Data Analysis

The imaging data were analyzed using statistical parametric mapping (SPM99; Friston et al., 1995). Images for each participant were first realigned to each other to correct for head motion, then normalized into a standard stereotactic space as defined by the Montreal Neurological Institute and smoothed with an 8-mm Gaussian kernel, full width at half maximum, to increase signal-to-noise ratio. The correction for multiple comparisons was carried out using an uncorrected *p* value of .005 in conjunction with a cluster size threshold of 10—corresponding to a per-voxel false positive probability of less than .000001 (Forman et al., 1995; see also Eisenberger, Lieberman, & Williams, 2003; Poldrack et al., 1999; Wagner, Pare-Blagoev, Clark, & Poldrack, 2001). Planned comparisons were computed as linear contrasts for individual participants. The resulting contrast images were then used in random effects analyses at the group level.

Results

Behavioral Results

The computer did not collect responses from the button box used in the scanner for one of the athletes; consequently, behavioral data are only reported for 21 of the 22 participants. Actors responded more quickly to acting words than to athletic words

(1,168 ms vs. 1,308 ms), $t(10) = 2.11$, $p < .05$, whereas athletes responded more quickly to athletic words than to acting words (1,163 ms vs. 1,360 ms), $t(9) = 3.86$, $p < .005$. There were no significant differences between athletes and actors in terms of how quickly they responded to words from their high-experience domain versus their low-experience domain. Similarly, actors characterized more acting words as self-descriptive than athletic words (88% vs. 69%), $t(10) = 3.80$, $p < .005$, whereas athletes characterized more athletic words as self-descriptive than acting words (89% vs. 60%), $t(8) = 4.37$, $p < .005$. There were no significant between-groups differences in the likelihood of characterizing high- and low-experience domain words as self-descriptive.

Because the differences in judging the self-descriptiveness of words from high-experience and low-experience domains were approximately the same for athletes and actors, and because there was no intrinsic interest in either group per se, we collapsed across the two groups to make one composite group. For each participant we computed an index of schematicity, reflecting the strength of their schema in the high-experience domain relative to the low-experience domain, by subtracting participants' average reaction time to high-experience domain words from their average reaction time to low-experience domain words. Higher difference scores on this measure indicate the presence of a more developed and efficient schema in the high-experience, as compared with the low-experience, domain (Collins & Loftus, 1975; Markus, 1977). We separated our participants into two groups using a median split applied to their schematicity scores. Whereas the schematic group (9 men, 1 woman) produced a significant speed advantage for high-experience as compared with low-experience domain judgments ($M = 328$ ms), $t(9) = 8.42$, $p < .001$, the nonschematic group (9 men, 2 women) did not produce a significant speed advantage for the high-experience as compared with the low-experience domain judgments ($M = 22$ ms), $t(10) = 0.69$, ns.

The absence of a speed advantage in the nonschematic group does not differentiate individuals who are not efficient in the high-experience domain from individuals who happen to be highly efficient in both the high- and low-experience domains. Inspecting the overall pattern of means (see Figure 2), however, it is clear that the nonschematic group was slower than the schematic group in their high-experience domain rather than being faster in their low-experience domain. Schematic high-experience domain judgments were significantly faster than those of nonschematics ($M_{schematic} = 1,040$ ms vs. $M_{nonschematic} = 1,279$ ms), $t(18) = 2.62$, $p < .02$; however, schematic low-experience domain judgments were not significantly different in speed from those of nonschematics ($M_{schematic} = 1,368$ ms vs. $M_{nonschematic} = 1,300$ ms), $t(18) = 0.90$, ns, nor were the neutral trait word judgments different in speed across the two groups ($M_{schematic} = 1,387$ ms vs. $M_{nonschematic} = 1,376$ ms), $t(18) = 0.13$, ns.

These results suggest that even though we selected participants we hoped would be schematic in one of the domains, a good portion of those participants did not present an efficiency marker of strong schematicity. There was also a marginally significant effect of being schematic on how many more words from the high-experience domain were affirmed than words from the low-experience domain, such that there was a bigger difference for schematic than nonschematic participants (31% vs. 17%), $t(18) = 1.84$, $p < .10$.
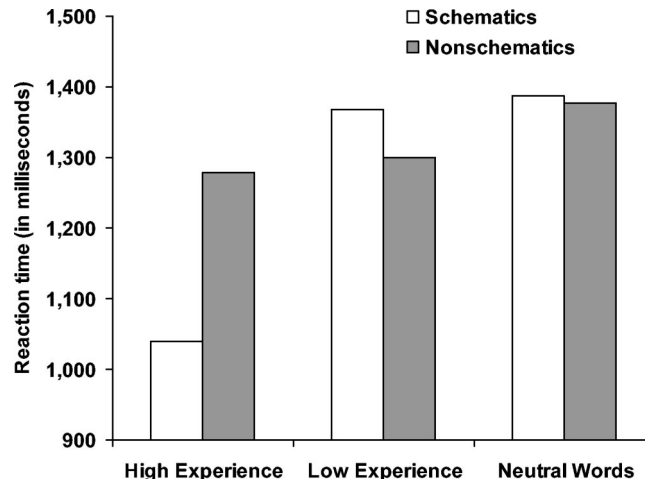

Figure 2. Reaction times in milliseconds for schematics and nonschematics making self-judgments in the high-experience and low-experience domains and with neutral trait words.

fMRI Results

All participants. We hypothesized that intuition-based self-knowledge would be recruited when making high-experience domain self-judgments and that this would be associated with X-system activations. Regions that were more active while making high-experience domain judgments than low-experience domain judgments included left ventromedial prefrontal cortex, left nucleus accumbens in the basal ganglia, left amygdala, right lateral temporal cortex, and right posterior parietal cortex (see Table 1). Thus, all X-system regions were more active in this statistical comparison. Additionally, only one C-system region was significantly active. The only region more active during low-experience domain judgments than high-experience domain judgments was right lateral prefrontal cortex, consistent with C-system activations hypothesized for evidence-based self-knowledge.

For each participant, making judgments in their low-experience domain should be roughly equivalent to making self-knowledge judgments for the neutral block of words.[2] Consequently, we compared the high-experience domain judgments to the neutral word judgments and found a similar pattern of activations. The ventromedial prefrontal cortex and amygdala activations, along with the right lateral prefrontal cortex deactivation from the previous analysis, were present in identical regions in the current analysis. The nucleus accumbens and right lateral temporal cortex were not significantly active in this analysis. There were additional activations in posterior cingulate (Talairach coordinates: $x = -4$, $y = -55$, $z = 23$; $p < .005$) and left lateral temporal cortex ($x = 61$, $y = -8$, $z = 2$; $p < .005$) and a relative deactivation in right dorsolateral prefrontal cortex ($x = 40$, $y = 29$, $z = 34$; $p < .005$).

One possible confound in these data is the frequency with which participants indicated that the trait words were self-descriptive for

---

[2] The neutral block, in retrospect, was not an ideal control, because the neutral words spanned numerous domains and therefore may have required greater cognitive set shifting from one trial to the next. Low-experience domain judgments, consequently, serve as our main control comparison to high-experience domain judgments.

Table 1
Brain Regions More Active When Judging the Self-Descriptiveness of High-Experience Domain Words Than Low-Experience Domain Words (All Participants)

			Talairach coordinate				
Region	Brodmann's area	L/R	x	y	z	Voxels	Z score
High experience > low experience							
vmPFC	11	L	−4	58	−12	35	3.71
Nucleus accumbens		L	−4	6	−2	55	3.56
Amygdala		L	−22	−2	−22	176	3.86
Lateral temporal	22	R	64	−8	4	39	3.70
Inferior parietal	40	R	58	−34	50	97	3.61
Low experience > high experience							
dlPFC	8	R	28	0	40	84	3.26

Note. L = left; R = right; vmPFC = ventromedial prefrontal cortex; dlPFC = dorsolateral prefrontal cortex.

their high- and low-experience domains. Participants indicated that 88% of high-experience domain words were self-descriptive compared with 65% of low-experience domain words. Consequently, our results could reflect, to some degree, the mental processes involved in giving an affirmative compared with a negative response. Because we used a block design, we could not separately analyze the trials that were responded to as self-descriptive or not in a post hoc fashion (see Wagner et al., 1998). To partially remedy this limitation of our experimental design, we computed the high-experience versus low-experience contrast analysis again, this time covarying out individual differences in the tendency to respond to high-experience words as self-descriptive more often than low-experience words. For each participant, we calculated the percent of high- and low-experience words that were affirmed as self-descriptive and subtracted the low-experience percent from the high-experience percent. The resulting number was used as the covariate in our follow-up analysis. With this covariate removed, each of the activations from Table 1 was still significant. There was also an additional activation in a region overlapping posterior cingulate and precuneus ($x = 6$, $y = −48$, $z = 32$; $p < .005$).

Schematics. The behavioral data suggested that our participant recruitment had yielded a mix of participants who were schematic or nonschematic for their high-experience domain. Consequently, the previously reported fMRI results may reflect a mix of evidence-based and intuition-based self-knowledge as the two groups of participants were mixed together. The fMRI contrast between high-experience and low-experience domain judgments was computed again for just the 10 schematic participants in order to better isolate intuition-based self-knowledge.

As predicted, schematics produced greater activations in high-experience domain judgments than low-experience domain judgments in ventromedial prefrontal cortex, nucleus accumbens, amygdala, and lateral temporal cortex, each in the left hemisphere (see Table 2, top half, and Figure 3). These activations were nearly identical to those identified in the initial contrast that included all participants. A region overlapping posterior cingulate cortex and precuneus in posterior parietal cortex was also activated. The right hippocampus was relatively deactivated for this contrast. Thus, X-system regions were activated in schematic participants when

making judgments in a high-experience domain, whereas only one C-system region was activated along with another being relatively deactivated.[3]

Nonschematics. Given that the nonschematics did not exhibit a reaction time advantage for high-experience domain judgments over low-experience domain judgments, these participants may not have developed intuition-based self-knowledge in their high-experience domain, or at least may not have been utilizing it while responding during the experiment. Thus, these participants were expected to rely more on evidence-based self-knowledge processes in the C-system when making high-experience domain judgments. Nonschematics should have more episodic memories in their high-experience domain than their low-experience domain; however, the reaction time data suggest that more efficient intuition-based self-knowledge representations were not available or were not used by these participants. As anticipated, nonschematic participants had greater activation in a wide assortment of C-system structures, including right hippocampus, bilateral precuneus activation in posterior parietal cortex, and bilateral lateral prefrontal cortex when making high-experience domain judgments (see Table 2, bottom half, and Figure 3). Lateral temporal cortex was also activated bilaterally. Finally, left ventromedial prefrontal cortex was the only region of the brain that was relatively deactivated for nonschematics during high-experience domain judgments. Thus, C-system regions were activated in nonschematic participants when they were making judgments in a high-experience domain, whereas only one X-system region was activated along with another being relatively deactivated.

We should note that any conclusions that can be drawn from the nonschematics' data must be considered tentative. This is because we have minimal insight into why these individuals should be nonschematic. Each nonschematic participant had a good deal of experience in their high-experience domain and thus probably should have efficient schemas in that domain. It is possible that

---

[3] The relatively small sample size for the subgroups could result in Type II errors such that other real effects might have been overlooked because of insufficient power.

Table 2
Separate Activations for Schematics and Nonschematics

Region	Brodmann's area	L/R	Talairach coordinate			Voxels	Z score
			x	y	z		
Schematics only							
High experience > low experience							
vmPFC	11	L	−6	54	−10	55	3.07
Nucleus accumbens		L	−2	8	−4	30	2.65
Amygdala		L	−22	0	−14	41	3.40
Lateral temporal	21	L	−54	−14	−2	62	3.03
Post. cing./precuneus	7/31	L	−8	−46	30	29	3.04
Low experience > high experience							
Hippocampus		R	24	−26	−14	186	3.18
dmPFC	8	R	14	30	48	126	3.02
Nonschematics only							
High experience > low experience							
Hippocampal gyrus	30	R	18	−46	−2	42	3.81
dlPFC	44	R	56	8	18	37	3.94
dlPFC	44	L	−54	6	14	38	3.84
dlPFC	9	L	−38	30	30	43	3.41
dlPFC	8	R	22	36	42	72	3.29
dmPFC	9	R	12	52	32	68	3.89
dmPFC	6	L	−10	−6	54	32	3.69
Post. cing.	23	R	2	−18	32	59	3.16
Precuneus	7	L	−16	−52	44	190	4.21
Precuneus	7	R	8	−58	34	20	3.76
Inferior parietal	40	R	52	−38	48	126	4.12
Lateral temporal	38	R	46	4	−12	50	3.63
Lateral temporal	21	R	58	−10	−16	70	3.19
Lateral temporal	39	L	−40	−64	18	83	3.16
Low experience > high experience							
vmPFC	11	L	−20	52	−10	16	3.16
vmPFC	11	L	−22	30	−16	70	3.22

Note. L = left; R = right; Post. cing. = posterior cingulate cortex; dmPFC = dorsomedial prefrontal cortex; dlPFC = dorsolateral prefrontal cortex; vmPFC = ventromedial prefrontal cortex.

these individuals are different, either cognitively or neurally, such that schemas form less readily for these individuals. Moreover, although we have assumed that these individuals have more episodic memories available in their high-experience domain, this is an untested assumption.

Schematics versus nonschematics. In a final set of analyses, we directly compared schematic and nonschematic groups. When making high-experience domain judgments, as compared with low-experience domain judgments, schematics produced greater activation than nonschematics in ventromedial prefrontal cortex ($x = 0, y = 42, z = −14$; $p < .005$). Nonschematics, alternatively, produced greater activations than schematics in the hippocampus ($x = 20, y = −48, z = −2$; $p < .005$) and dorsolateral prefrontal cortex ($x = 26, y = 26, z = 44$; $p < .005$). When making low-experience domain judgments, as compared with high-experience domain judgments, schematics produced greater activation than nonschematics in right hippocampus ($x = 26, y = −26, z = −14$; $p < .005$), right dorsolateral prefrontal cortex ($x = 26, y = 26, z = 44$; $p < .005$), and right anterior cingulate cortex ($x = 14, y = 32, z = 48$; $p < .005$). Nonschematics, alternatively, produced greater activations than schematics in ventromedial prefrontal cortex ($x = 0, y = 48, z = −14$; $p < .005$). Finally, analysis

of variance indicated that a participant group (schematic vs. nonschematic) by brain region (ventromedial prefrontal vs. hippocampus) interaction was significant, $F(1, 38) = 18.11, p < .001$ (see Figure 4). In other words, the processing conditions produced a double dissociation between the contributions of these two neurocognitive systems in self-knowledge judgments.

General Discussion

We began with a question: Can a person know themselves in the absence of memory for their past behavior, and if so, how? Our fMRI study suggests that people can indeed know themselves without retrieving pages from their internal "Book of Life," their autobiographical memory. The results also provide insight into how such judgments might be made. Across different analyses, we found that when participants judged the self-descriptiveness of trait words, different neural structures were recruited depending on how much experience the participants had in the relevant activity domain. Our first pass estimate of experience was participants' self-reported classification of being an active soccer player or improvisational actor. When participants made judgments in their high-experience domain, they differentially activated X-system
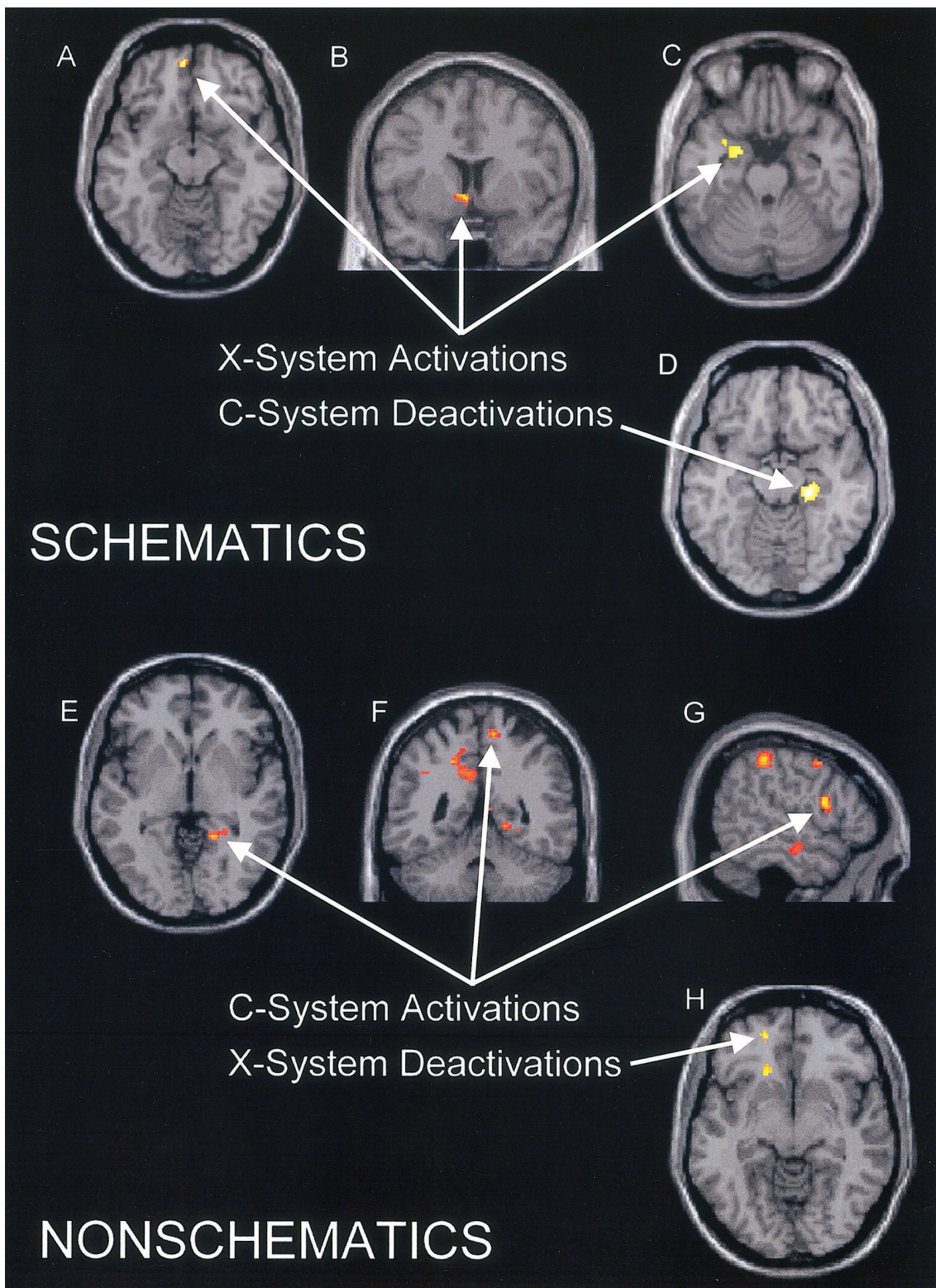
Figure 3. X-system activations in schematics for high-experience domain self-judgments in (A) ventromedial prefrontal cortex, (B) nucleus accumbens, and (C) amygdala, with a C-system deactivation in (D) hippocampus. C-system activations in nonschematics for high-experience domain self-judgments in (E) hippocampus, (F) posterior parietal cortex, and (G) lateral prefrontal cortex and posterior parietal cortex, with an X-system deactivation in (H) ventromedial prefrontal cortex.
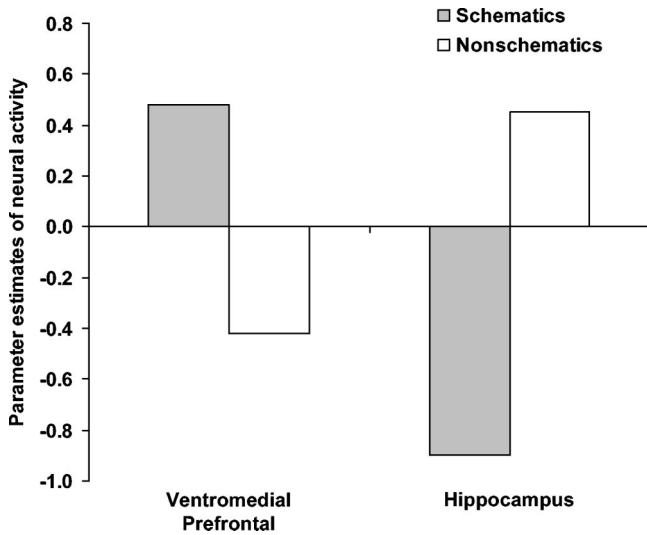
Figure 4. Relative activation in ventromedial prefrontal cortex and hippocampus for schematics and nonschematics when they were making self-judgments in high-experience versus low-experience domains.

structures (ventromedial prefrontal cortex, nucleus accumbens, amygdala, and lateral temporal cortex), which are not typically involved in episodic recall and explicit evaluation. When participants made judgments in their low-experience domain, a C-system region in lateral prefrontal cortex was the only area differentially activated. These results suggest that when making judgments in high-experience domains, people rely to a greater degree on intuition-based self-knowledge. Moreover, this form of self-knowledge does not appear to depend on episodic memory structures like the hippocampus and surrounding medial temporal lobe as much as evidence-based self-knowledge does.

For further analyses, we divided our participants into two groups on the basis of a reaction time index of schematicity. One group, though originally designated as having high experience in one of the domains, did not show reaction time evidence of schema-related processing efficiency (Markus, 1977), suggesting that they did not have or did not use well-developed intuition-based self-knowledge representations and thus relied on evidence-based self-knowledge. These nonschematic participants did show evidence of recruiting C-system structures, thought to subserve evidence-based self-knowledge, and in fact produced a relative decrease in activity in ventromedial prefrontal cortex. Alternatively, those participants who both identified themselves as highly experienced in one domain and showed greater cognitive efficiency in their reaction times for that domain relied more on the X-system when making high-experience domain judgments and produced a relative decrease in activity in the hippocampus. Across schematics and nonschematics, there was a double dissociation between the response of ventromedial prefrontal cortex in the X-system and the hippocampus in the C-system (see Figure 4). Precuneus and lateral temporal cortex were activated for both schematics and nonschematics, and thus it is unclear whether either of these regions contributes to intuition-based self-knowledge specifically or is more generally involved in self-knowledge processes.

Relation to Other Processing Dichotomies

To put our results in the context of the broader cognitive neuroscience literature, we review three other processing dichotomies that have been studied with both cognitive and neuroimaging methodologies (implicit–explicit; automaticity–control; semantic–episodic). For each, we consider how our results fit within that processing dichotomy.

Implicit–explicit memory. At first blush, our paradigm might seem to be examining implicit versus explicit self-knowledge, which would suggest obvious comparisons to implicit and explicit memory (Schacter, 1992). Though our intuition–evidence dichotomy is hardly orthogonal to the implicit–explicit dichotomy, it is not clear that the results of our study should be interpreted directly within that framework. Our dependent variable was an explicit measure of self-knowledge, even when this measure was used to assess intuition-based self-knowledge. We think our dichotomy reflects differences in the extent to which evidentiary representations are being accessed when making self-knowledge judgments. An implicit–explicit interpretation would suggest that the same representations are being accessed but in a more efficient way that does not require that those representations enter conscious awareness.

In neuroimaging studies of implicit memory, a common finding is decreased activation in the regions involved in explicit or unprimed use of a memory representation relative to the activation found during explicit recall (Schacter & Badgaiyan, 2001; Wagner, Koutstaal, Maril, Schacter, & Buckner, 2000). Changes are typically found in left inferior prefrontal areas supporting conceptual processing and extrastriate visual cortex supporting perceptual processing. The pattern of activations in our study is not consistent with a strict implicit–explicit memory interpretation, because we found increased activity in multiple X-system regions when intuition-based self-knowledge was probed.

If implicit learning is considered to be a form of implicit memory (Squire, 1987), then our results are partially interpretable within the implicit–explicit dichotomy. *Implicit learning* refers to the unintentional learning of the probabilistic relationships between various cues or stimuli (Bechara et al., 1997; Knowlton & Squire, 1996). Increased nucleus accumbens activity and ventromedial prefrontal activity during intuition-based self-knowledge judgments are consistent with an implicit learning interpretation.

Automaticity–control. Neuroimaging studies of expertise development are typically conceptualized as changes in the need for explicit control over performance in some task domain. By definition, as the task becomes less controlled, it is assumed to become more automatic (Schneider & Shiffrin, 1977). The most common finding is that some region of lateral prefrontal cortex will be more active during early task learning and significantly less active later when greater automaticity or expertise has developed. This has been found with motor (Jueptner et al., 1997; Muller, Kleinhans, Pierce, Kemmotsu, & Courchesne, 2002; Shadmehr & Holcomb, 1997; van Mier, Tempel, Perlmutter, Raichle, & Petersen, 1998), visual (Grosbras et al., 2001), and cognitive tasks (Jansma, Ramsey, Slagter, & Kahn, 2001; Petersen, van Mier, Fiez, & Raichle, 1998). Though some studies have not found these decreases in prefrontal cortex replaced by increases elsewhere (Jansma et al., 2001), most have found expertise-related increases in sensory or motor areas that vary greatly with task domain. Thus it seems that

control may be a relatively unified common resource depending on lateral prefrontal cortex, whereas the neural correlates of automaticity and expertise are task specific.

In our study, we observed lateral prefrontal activations when participants made low-experience domain self-judgments consistent with a need to exert greater control in these judgments. The greater activation of ventromedial prefrontal cortex, nucleus accumbens, and amygdala found for high-experience domain judgments does not replicate the previous activations from automaticity and expertise studies; however, previous studies most often focused on motor and visual sequence learning, which might not be the ideal comparison. Work with the Iowa gambling task (Damasio, 1994) and with the Implicit Association Test (Milne & Grafman, 2001) has suggested that ventromedial prefrontal cortex may be involved in automatic affective evaluations. Thus the automaticity–control dichotomy can account for at least a portion of our results.

Episodic–semantic memory. A final dichotomy relevant to the current data is semantic versus episodic memory. The recall of particular events that forms the basis of episodic memory should support evidence-based self-knowledge. When nonschematics made high-experience judgments, the pattern of neural activity overlapped substantially with regions seen in episodic retrieval tasks, including left inferior prefrontal cortex, precuneus, and hippocampus (Cabeza & Nyberg, 2000; Schacter & Badgaiyan, 2001). Similarly, semantic memory might be able to support some intuition-based self-knowledge given that semantic knowledge often consists of facts disconnected from proof or rationale ("the fork goes on the left"). When schematics made high-experience judgments, lateral temporal cortex, which is most closely associated with semantic memory, was active (Garrard & Hodges, 2000).

Apart from the constraints placed on an episodic–semantic model of self-knowledge from previous behavioral and neuropsychological research (Klein, Cosmides, et al., 2002), there are other limitations of this model for interpreting the current results. First, lateral temporal cortex and precuneus were relatively active for both schematics and nonschematics when making high-experience self-knowledge judgments, suggesting that the episodic–semantic dissociation does not cleanly map onto evidence-based and intuition-based self-knowledge. Second, the double dissociation in hippocampus and ventromedial prefrontal cortex that does distinguish evidence-based from intuition-based self-knowledge only partially maps onto the episodic–semantic dichotomy. Ventromedial prefrontal cortex has not been closely associated with either episodic or semantic memory but seems to play a key role in distinguishing self-knowledge types in our study.

What Is Intuition-Based Self-Knowledge?

The foregoing discussion of processing dichotomies provides a reasonably complete account of evidence-based self-knowledge in terms of controlled process assessments of explicit–episodic memories. But what can be said of intuition-based self-knowledge? For each of the dichotomies, intuition-based self-knowledge was not well accounted for. It may be automatic, but it does not fit well with the known neural correlates of automaticity, and although there may be implicit–semantic memory processes involved, the primary activations for intuition-based self-knowledge are outside the bounds of activations typically associated with implicit–semantic memory.

Without even considering the particular contributions made by the neural structures identified in our study, the mere presence of a double dissociation between ventromedial prefrontal cortex and the hippocampus indicates that intuition-based self-knowledge is not just a faster, quieter version of evidence-based self-knowledge. From reaction time data alone, it would seem possible that the same representations are used in both kinds of self-knowledge but are simply used more efficiently in intuition-based self-knowledge. Our fMRI results rule out this possibility, instead demonstrating the existence of two distinct systems, each recruiting brain regions not significantly activated or significantly deactivated by the other.

Given that the neural basis of intuition-based self-knowledge includes ventromedial prefrontal cortex, nucleus accumbens, and amygdala, we can draw several more specific inferences about the nature of this self-knowledge system on the basis of what is known about the functions of these structures. Though some of the following conclusions have a stronger foundation than others, and the science of functional neuroanatomy is constantly evolving, the differential involvement of these brain regions suggests that intuition-based self-knowledge is (a) affective, (b) slow to form, (c) slow to change, (d) relatively insensitive to one's thoughts about oneself and behavior, and (e) relatively insensitive to explicit feedback from others.

Ventromedial prefrontal cortex, nucleus accumbens, and the amygdala have each been linked to affective or motivational processing (Damasio, 1994; Wager, Phan, Liberzon, & Taylor, 2003). In contrast, the brain regions differentially associated with evidence-based self-knowledge have not been found to play any direct role in affect or motivation (Wager et al., 2003). In addition, the one X-system structure that is not typically associated with affective processing, lateral temporal cortex, was not differentially active in schematics. Campbell (1990) suggested that schema development is associated with self-esteem, but this is the first study to provide a mechanism by which this relationship might form. As self-knowledge develops, it not only becomes more efficient but also seems to move its base of operations to neural mechanisms that are more affective at their core. Exactly how affective processing can contribute to self-knowledge is still a mystery that awaits further investigation.

Apart from the affective nature of the regions involved in intuition-based self-knowledge, an additional computational feature of this self-knowledge is that it is probably slow to form new representations and slow to change existing representations. This inference was already suggested by the work of Klein et al. (1992); however, now we can give an account of why this is true. Most of the X-system develops its representations slowly, because the X-system represents statistical generalizations about the world (Damasio, 1994; Lieberman, 2000; Lieberman et al., 2002; McClelland et al., 1995). As with any statistical generalization, sample size is critical to the robustness of the inference, with each new piece of data adding only incrementally to the overall inference. C-system representations, in contrast, can be entirely changed in light of a single piece of new information. Together, these systems represent long-term generalizations about the world as well as important changes to this information or context-specific modifications in these generalizations. Computational modeling has suggested that evolution had little choice but to assign these tasks to

different neural systems, because any attempt to combine these tasks into a single system will produce a catastrophic loss of existing information when attempts are made to integrate new information (McClelland et al., 1995).

The speed with which X- and C-system representations are changed suggests that evidence-based self-knowledge might, ironically, be more easily changed than intuition-based self-knowledge. The irony is that with evidence-based self-knowledge, individuals can actually report why they have the self-beliefs they do, and this would seem to be associated with stronger, less changeable beliefs, but the differential flexibility of the neural structures supporting intuition-based and evidence-based self-knowledge may prove otherwise.

Finally, intuition-based self-knowledge may not be very sensitive to one's own thoughts about one's behavior or to explicit feedback from others. Though intuition-based self-knowledge may require some minimal attention to stimuli and behavior in the development of representations (Curran & Keele, 1993; cf. Seger, 2003), there is some evidence to suggest that the content of thought while attending (e.g., one's mental narration of events) may not affect the representations (Graf & Mandler, 1984). On the other hand, C-system representations depend substantially on the goals, motivation, and explicit content of thought. For the same reason, feedback communicated by others may have a greater impact on evidence-based, as compared with intuition-based, self-knowledge. In a sense, intuition-based self-knowledge may stay closer to the statistical implications of one's actual behavior, because it might be insensitive to potentially biased thoughts about that behavior provided by self and others. This is perhaps the most speculative of the conclusions that could be drawn from the current data and what is known about these brain regions, but it does suggest future avenues of research that could potentially disentangle social from nonsocial influences on self-concept formation.

Limitations

Before concluding, we address two aspects of our experimental design that could limit the study's inferential power. First, our trait words ranged from neutral to positive, with no clear negative trait words in any trial blocks. There are at least three ways that our results could be reinterpreted as reflecting affect-driven rather than schema-driven processes. The simplest possibility is that the presentation of positively valenced words promoted activity in affect regions such as ventromedial prefrontal cortex, nucleus accumbens, and amygdala. The fact that there were positive words in both the high- and low-experience domain and that the words that constituted high- and low-experience domain trait words varied by participants rules out this simple account.

Second, one could argue that affect regions in the brain were particularly active in response to positive words from the high-experience, and therefore more self-relevant, domain. Presumably, words from the high-experience domain are more salient for participants than words from the low-experience domain, and thus the presentation of high-experience domain words may have greater affective consequences. It is unlikely, however, that all words from a high-experience domain uniformly produced positive affect. For instance, a soccer player who is strong and aggressive but has also been criticized frequently for not being fast enough would not be expected to have a positive affective response to the presentation

of the word *fast*. Being reminded of the ways in which one deviates from the norms of a schema with which one identifies should produce negative rather than positive affect (Straumann & Higgins, 1987). This suggests the third, and most plausible, alternative: The affect regions might be disproportionately activated by positively valenced high-experience domain words that are judged as self-descriptive. In this account, intuition-based self-knowledge processes are presumably processing the trait processes; however, the activations in the affect regions may be a consequence of, rather than a causal contributor to, the self-descriptiveness judgment.

To examine this third account for which affect-related activations are thought to be an epiphenomenal byproduct of the self-descriptiveness judgment, we conducted an analysis of covariance that covaried out individual differences in the tendency to identify high-experience domain words as self-descriptive and found little change in the pattern of activations. In other words, individuals who judged more of the high-experience domain words as self-descriptive did not produce stronger activations in the affect regions. These results suggest that our results are not explained well by this affect account. Moreover, such an account cannot easily explain why the activity in these regions was associated with faster reaction times. Given that trial onset time was highly predictable, there would be little advantage from affect-driven orienting effects. Nevertheless, a conclusive answer for this issue cannot be given until word positivity is controlled for, presumably in an event-related fMRI study designed to intermix positive, negative, and neutral trait words.

A second potential limitation of our study is that our trait words consisted of both nouns and adjectives. It is possible that part of speech might interact with domain experience because trait adjectives are fundamentally more difficult to judge than trait nouns. There are less clear-cut boundaries for deciding whether one is "imaginative" than there are for deciding if one is "a comic." This distinction between dichotomous and continuous self-knowledge labels will be of interest in its own right in future studies, especially using event-related paradigms. For the current study, we merely note that if judging trait nouns is less likely to differentiate intuition-based from evidence-based self-knowledge, then noun trials would represent noise in our data. If that is the case, this would have lowered our statistical power to detect effects, increasing the likelihood of Type II errors. It would not, however, have increased the likelihood of Type I errors, and thus we believe it is safe to consider the effects we have observed to be "real" effects.

Conclusion

The results of the current study suggest that there are multiple self-knowledge systems. An evidence-based self-knowledge system was associated with judgments in low-experience domains and produced activations in C-system regions, including lateral prefrontal cortex, posterior parietal cortex, and the hippocampus. Alternatively, an intuition-based self-knowledge system was associated with judgments in high-experience domains and produced activations in X-system regions, including ventromedial prefrontal cortex, basal ganglia, and amygdala. Using neuroimaging to identify these neural correlates and drawing inferences from what is already known about the processing characteristics of these regions, we were able to generate new insights regarding the affec-

tive, slow-changing nature of intuition-based self-knowledge and its potential resistance to external feedback. Such insights suggest that a social cognitive neuroscience approach, rather than merely charting the neural geography of social processes, can advance social psychological theory in new directions.

References

Adolphs, R. (1999). Social cognition and the human brain. *Trends in Cognitive Sciences, 3,* 469–479.

Adolphs, R., Tranel, D., & Damasio, A. R. (1998, June 4). The human amygdala in social judgment. *Nature, 393,* 470–474.

Bargh, J. A. (1982). Attention and automaticity in the processing of self-relevant information. *Journal of Personality and Social Psychology, 43,* 425–436.

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, February 28). Deciding advantageously before knowing the advantageous strategy. *Science, 275,* 1293–1294.

Bem, D. J. (1972). Self-perception theory. In L. Berkowitz (Ed.), *Advances in experimental social psychology* (pp. 1–62). New York: Academic Press.

Brewer, J. B., Zhao, Z., Desmond, J. E., Glover, G. H., & Gabrieli, J. D. E. (1998, August 21). Making memories: Brain activity that predicts how well visual experience will be remembered. *Science, 281,* 1185–1187.

Cabeza, R., & Nyberg, L. (2000). Imaging cognition: II. An empirical review of 275 PET and fMRI studies. *Journal of Cognitive Neuroscience, 12,* 1–47.

Campbell, J. D. (1990). Self-esteem and clarity of the self-concept. *Journal of Personality and Social Psychology, 59,* 538–549.

Collins, A. M., & Loftus, E. F. (1975). A spreading-activation theory of semantic processing. *Psychological Review, 82,* 407–428.

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.

Curran, T., & Keele, S. W. (1993). Attentional and nonattentional forms of sequence learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19,* 189–202.

Damasio, A. R. (1994). *Descartes' error: Emotion, reason, and the human brain.* New York: Putnam.

Eisenberger, N. A., Lieberman, M. D., & Williams, K. D. (2003, October 10). Does rejection hurt? An fMRI study of social exclusion. *Science, 302,* 290–292.

Fink, G. R., Markowitsch, H. J., Reinkemeier, M., Bruckbauer, T., Kessler, J., & Heiss, W. (1996). Cerebral representation of one's own past: Neural networks involved in autobiographical memory. *Journal of Neuroscience, 16,* 4275–4282.

Forman, S. D., Cohen, J. D., Fitzgerald, M., Eddy, W. F., Mintun, M. A., & Noll, D. C. (1995). Improved assessment of significant activation in functional magnetic resonance imaging (fMRI): Use of cluster-size threshold. *Magnetic Resonance in Medicine, 33,* 636–647.

Friston, K. J., Holmes, A. P., Worsley, K. J., Poline, J. P., Frith, C. D., & Frackowiak, R. S. J. (1995). Statistic parametric maps in functional imaging: A general linear approach. *Human Brain Mapping, 2,* 189–210.

Garrard, P., & Hodges, J. R. (2000). Semantic dementia: Clinical, radiological and pathological perspectives. *Journal of Neurology, 247,* 409–422.

Graf, P., & Mandler, G. (1984). Activation makes words more accessible,

but not necessarily more retrievable. *Journal of Verbal Learning and Verbal Behavior, 23,* 553–568.

Greenwald, A. G., & Banaji, M. R. (1995). Implicit social cognition: Attitudes, self-esteem, and stereotypes. *Psychological Review, 102,* 4–27.

Grosbras, M., Leonards, U., Lobel, E., Poline, J., LeBihan, D., & Berthoz, A. (2001). Human cortical networks for new and familiar sequences of saccades. *Cerebral Cortex, 11,* 936–945.

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.

Hetts, J. J., Sakuma, M., & Pelham, B. W. (1999). Two roads to positive regard: Implicit and explicit self-evaluation and culture. *Journal of Experimental Social Psychology, 35,* 512–559.

James, W. (1950). *The 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.

Jueptner, M., Stephan, K. M., Frith, C. D., Brooks, D. J., Frackowiak, R. S. J., & Passingham, R. E. (1997). Anatomy of motor learning: I. Frontal cortex and attention to action. *Journal of Neurophysiology, 77,* 1313–1324.

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,* 785–794.

Klein, S. B., Chan, R. L., & Loftus, J. (1999). Independence of episodic and semantic self-knowledge: The case from autism. *Social Cognition, 17,* 413–436.

Klein, S. B., Cosmides, L., Costabile, K. A., & Mei, L. (2002). Is there something special about the self? A neuropsychological case study. *Journal of Research in Personality, 36,* 490–506.

Klein, S. B., & Kihlstrom, J. F. (1998). On bridging the gap between social–personality psychology and neuropsychology. *Personality and Social Psychology Review, 2,* 228–242.

Klein, S. B., & Loftus, J. (1993). The mental representation of trait and autobiographical knowledge about the self. In T. K. Srull & R. S. Wyer Jr. (Eds.), *The mental representation of trait and autobiographical knowledge about the self* (pp. 1–49). Hillsdale, NJ: Erlbaum.

Klein, S. B., Loftus, J., & Kihlstrom, J. F. (1996). Self-knowledge of an amnesic patient: Toward a neuropsychology of personality and social psychology. *Journal of Experimental Psychology: General, 125,* 250–260.

Klein, S. B., Loftus, J., Trafton, J. G., & Fuhrman, R. W. (1992). Use of exemplars and abstractions in trait judgments: A model of trait knowledge about the self and others. *Journal of Personality and Social Psychology, 63,* 739–753.

Klein, S. B., Rozendal, K., & Cosmides, L. (2002). A social–cognitive neuroscience analysis of the self. *Social Cognition, 20,* 105–135.

Knowlton, B. J., Mangels, J. A., & Squire, L. R. (1996, September 6). A neostriatal habit learning system in humans. *Science, 273,* 1399–1402.

Knowlton, B. J., & Squire, L. R. (1996). Artificial grammar depends on implicit acquisition of both abstract and exemplar-specific information. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 22,* 169–181.

Koole, S. L., Dijksterhuis, A., & van Knippenberg, A. (2001). What's in a name: Implicit self-esteem and the automatic self. *Journal of Personality and Social Psychology, 80,* 669–685.

Kroger, J. K., Sabb, F. W., Fales, C. L., Bookheimer, S. Y., Cohen, M. S., & Holyoak, K. J. (2002). Recruitment of anterior dorsolateral prefrontal

cortex in human reasoning: A parametric study of relational complexity. *Cerebral Cortex, 12,* 477–485.

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.

Lewicki, P., Czyzewska, M., & Hoffman, H. (1987). Unconscious acquisition of complex procedural knowledge. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 13,* 523–530.

Lieberman, M. D. (2000). Intuition: A social cognitive neuroscience approach. *Psychological Bulletin, 126,* 109–137.

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., 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. R., Jarcho, J. M., Eisenberger, N. I., & Bookheimer, S. (2004). *The impact of explicit race-based categorization on the amygdala.* Unpublished manuscript, University of California, Los Angeles.

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., Ochsner, K. N., Gilbert, D. T., & Schacter, D. L. (2001). Do amnesics exhibit cognitive dissonance reduction? The role of explicit memory and attention in attitude change. *Psychological Science, 121,* 135–140.

Lieberman, M. D., & Pfeifer, J. (in press). 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.* Philadelphia: Psychology Press.

Lieberman, M. D., Schreiber, D., & Ochsner, K. N. (2003). Is political thinking like riding a bicycle? How cognitive neuroscience can inform research on political thinking. *Political Psychology, 24,* 681–704.

Lightman, A. P. (1993). *Einstein's dreams.* New York: Pantheon.

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.

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,* RC151–RC156.

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, USA, 96,* 1680–1685.

Muller, R., Kleinhans, N., Pierce, K., Kemmotsu, N., & Courchesne, E. (2002). Functional MRI of motor sequence acquisition: Effects of learning stage and performance. *Cognitive Brain Research, 14,* 277–293.

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.

Neely, J. H. (1989). Experimental dissociations and the episodic/semantic memory distinction. In H. L. Roediger & F. I. M. Craik (Eds.), *Varieties of memory and consciousness: Essays in honour of Endel Tulving* (pp. 229–270). Hillsdale, NJ: Erlbaum.

Nisbett, R. E., & Wilson, T. D. (1977). Telling more than we can know: Verbal reports on mental processes. *Psychological Review, 84,* 231–259.

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 Neuroscience, 14,* 1215–1229.

Ochsner, K. N., & Lieberman, M. D. (2001). The emergence of social cognitive neuroscience. *American Psychologist, 56,* 717–734.

Pasley, B. N., Mayes, L. C., & Schultz, R. T. (2004). Subcortical discrimination of unperceived objects during binocular rivalry. *Neuron, 42,* 163–172.

Pelham, B. W., Mirenberg, M. C., & Jones, J. T. (2002). Why Susie sells seashells by the seashore: Implicit egotism and major life decisions. *Journal of Personality and Social Psychology, 82,* 469–487.

Petersen, S. E., van Mier, H., Fiez, J. A., & Raichle, M. E. (1998). The effects of practice on the functional anatomy of task performance. *Proceedings of the National Academy of Sciences, USA, 95,* 853–860.

Phelps, E. A., O'Connor, K. J., Cunningham, W. A., Funayama, E. S., Gatenby, J. C., Gore, J. C., & Banaji, M. R. (2000). Performance on indirect measures of race evaluation predicts amygdala activation. *Journal of Cognitive Neuroscience, 12,* 729–738.

Poldrack, R. A., Wagner, A. D., Prull, M. W., Desmond, J. E., Glover, G. H., & Gabrieli, J. D. (1999). Functional specialization for semantic and phonological processing in the left inferior prefrontal cortex. *NeuroImage, 10,* 15–35.

Ranganath, C., & D'Esposito, M. (2001). Medial temporal lobe activity associated with active maintenance of novel information. *Neuron, 31,* 865–873.

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.

Roediger, H. L. I., Rajaram, S., & Srinivas, K. (1990). Specifying criteria for postulating memory systems. In A. Diamond (Ed.), *The development and neural bases of higher cognitive functions* (pp. 572–595). New York: New York Academy of Sciences.

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.

Satpute, A. B., Sellner, D., Waldman, M. D., Tabibnia, G., Holyoak, K. J., & Lieberman, M. D. (2004). *An fMRI study of causal judgment.* Unpublished manuscript, University of California, Los Angeles.

Schacter, D. L. (1992). Understanding implicit memory: A cognitive neuroscience approach. *American Psychologist, 47,* 559–569.

Schacter, D. L., & Badgaiyan, R. D. (2001). Neuroimaging of priming: New perspectives on implicit and explicit memory. *Current Directions in Psychological Science, 10,* 1–4.

Schneider, W., & Shiffrin, R. M. (1977). Controlled and automatic human information processing: I. Detection, search, and attention. *Psychological Review, 84,* 1–66.

Seger, C. A. (2003). *Learning of pairwise and higher order contingencies in single task and dual task forms of the serial reaction time task.* Unpublished manuscript, Stanford University.

Shadmehr, R., & Holcomb, H. H. (1997, August 8). Neural correlates of motor memory consolidation. *Science, 277,* 821–825.

Smith, E. E., Patalano, A. L., & Jonides, J. (1998). Alternative strategies of categorization. *Cognition, 65,* 167–196.

Spalding, L. R., & Hardin, C. D. (1999). Unconscious unease and self-handicapping: Behavioral consequences of individual differences in implicit and explicit self-esteem. *Psychological Science, 10,* 535–539.

Squire, L. R. (1987). *Memory and brain.* London: Oxford University Press.

Straumann, T. J., & Higgins, E. T. (1987). Automatic activation of self-discrepancies and emotional syndromes: When cognitive structures influence affect. *Journal of Personality and Social Psychology, 53,* 1004–1014.

Tulving, E. (1993). Self-knowledge of an amnesic individual is represented abstractly. In T. K. Srull & R. S. Wyer Jr. (Eds.), *The mental representation of trait and autobiographical knowledge about the self* (pp. 147–156). Hillsdale, NJ: Erlbaum.

van Mier, H., Tempel, L. W., Perlmutter, J. S., Raichle, M. E., & Petersen, S. E. (1998). Changes in brain activity during motor learning measured with PET: Effects of hand of performance and practice. *Journal of Neurophysiology, 80,* 2177–2199.

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., Koutstaal, W., Maril, A., Schacter, D. L., & Buckner, R. L. (2000). Task-specific repetition priming in left inferior prefrontal cortex. *Cerebral Cortex, 10,* 1176–1184.

Wagner, A. D., Pare-Blagoev, E. J., Clark, J., & Poldrack, R. A. (2001). Recovering meaning: Left prefrontal cortex guides controlled semantic retrieval. *Neuron, 31,* 329–338.

Wagner, A. D., Schacter, D. L., Rotte, M., Koutstaal, W., Maril, A., Dale, A. M., et al. (1998, August 21). Building memories: Remembering and forgetting of verbal experiences as predicted by brain activity. *Science, 281,* 1188–1191.

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., & Schooler, J. W. (1991). Thinking too much: Introspection can reduce the quality of preferences and decisions. *Journal of Personality and Social Psychology, 60,* 181–192.

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.

Appendix

Words Used in the Study

Acting words	Athlete words	Neutral words
Actor	Active	Anxious
Ad lib	Aggressive	Bored
Artist	Agile	Caring
Comedian	Athletic	Contented
Comedic	Ball handler	Envious
Comedic actor	Competitor	Frugal
Comic	Dexterous	Generous
Creative	Endurance	Hasty
Dramatic	Fast	Hospitable
Funny	Fit	Idealistic
Imaginative	Healthy	Indecisive
Improvisational	Muscular	Liberal
Improvisator	Physical	Messy
Improvisor	Play sports	Meticulous
Performer	Soccer player	Organized
Quick witted	Sportsperson	Patient
Spontaneous	Stamina	Perfectionist
Stand-up comedian	Strong	Pessimistic
Theatric	Swift	Political
Theatrical	Team player	Prompt
		Reliable
		Sensible
		Tense
		Trusting
		Trustworthy
		Unique
		Unsatisfied