The Dissertation Committee for Jamil Palacios Bhanji Certifies that this is the approved version of the following dissertation:

Bridging the Gap between Psychological and Neural Models of Judgment: Applying a Dual-Process Framework to Neural Systems of Social and Emotional Judgment

Committee:

Jennifer S. Beer, Supervisor

W. Todd Maddox

Marlone D. Henderson

Andrew D. Gershoff

David M. Schnyer

Bridging the Gap between Psychological and Neural Models of Judgment: Applying a Dual-Process Framework to Neural Systems of Social and Emotional Judgment

by

Jamil Palacios Bhanji, B.S., M.A.

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Dedication

To my wife, Emily Visher, for her unwavering support.

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Bridging the Gap between Psychological and Neural Models of Judgment: Applying a Dual-Process Framework to Neural Systems of Social and Emotional Judgment

Jamil Palacios Bhanji, Ph.D.

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Supervisor: Jennifer S. Beer

Psychological models of judgment and decision-making that focus on dual processes distinguish between two modes of judgment. One mode of judgment uses incomplete, probabilistic associations that lead to good-enough judgments for most situations. A second mode of judgment uses more complete information and applies deterministic decision rules to reason through a decision. The two modes operate in parallel but they can also interact and may be viewed as ends of a continuum. Although some psychology researchers have hypothesized that the two modes of information processing are carried out by distinct neural systems, neural research has not fully tested the distinctions that psychological research has drawn between the two modes. Three studies aim to address the gap between psychological and neural models of judgment and decision-making. Study 1 addresses the lack of neural research comparing judgments based on probabilistic information (characteristic of the first mode of judgment in dual-process models) with judgments based on deterministic rules (characteristic of the second mode of judgment in dual-process models). Specifically, Study 1 compares basic probabilistic judgments and deterministic rule-based judgments to identify neural regions that are preferentially associated with one mode of judgment. Study 2 moves toward a

more ecologically valid investigation of neural systems associated with judgments based on probabilistic associations. That is, Study 2 examines a probabilistic cue that is used in real-world judgments: affect. Study 3 examines neural regions associated with the interaction of the two modes of judgment in the underexplored domain of social evaluation. Modes of judgment may interact when the second mode of judgment uses new information to adjust a judgment previously driven by the first mode of judgment, as when a hiring manager uses information about a job candidate to adjust a first impression initially based on appearance. Study 3 examines the neural systems involved when people use newly available information to adjust a previously made affectively-driven judgment. Findings in the three studies contribute to scientific understanding of how neural regions support judgment, but do not definitively identify separable neural systems for dual-process modes of judgment.

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OVERVIEW AND BACKGROUND

How does a manager decide whether or not to hire a candidate? What kinds of information will be considered and how much of it will influence the hiring decision? Psychological models of judgment and decision-making that focus on dual processes suggest that two modes of processing influence judgment and decision-making. The first mode operates on probabilistic associations; this mode is exemplified by the manager who relies on an affective reaction to judge a candidate. The second mode operates by applying deterministic decision rules; this mode is exemplified by the manager who uses a set of rules to judge a candidate (e.g., certain number of years experience, certain threshold of test performance). Although they can operate in parallel, the modes may also interact. For example, a manager may consider his or her initial negative impression arising from a weak handshake but make a final judgment by adjusting the first impression in light of the applicant's impressive resume. Dual-process frameworks of judgment are prevalent in psychology because the different modes of processing apply in a wide variety of judgment domains, including judging people, persuasive arguments, risks, and consumer products (Chaiken, 1987; Gawronski & Bodenhausen, 2006; Kahneman & Frederick, 2002; Shiv & Fedorikhin, 1999; Sloman, 1996; Slovic, Finucane, Peters, & MacGregor, 2004; Strack & Deutsch, 2004). Dual-process frameworks often describe the modes of judgment as separate, but the two modes can also be viewed as the ends of a continuum (Chaiken, 1987; Petty & Cacioppo, 1986). Although dual-process frameworks have been widely applied in psychological research, neural research has not fully tested the distinctions drawn between the two modes of processing, especially in the area of social judgment. The proposed research examines whether psychological dual-process distinctions exist at the neural level, with a focus on social judgment. Do different neural regions underlie probabilistic association-based judgments compared to deterministic rule-based judgments (Study 1 and Study 2)? How do these regions interact when preliminary probabilistic association-based judgments are adjusted to consider additional information (Study 3)?

Psychological Models of Judgment and Decision-making: Dual-Process Frameworks

Many psychological models of judgment and decision-making distinguish between two modes of judgment, each associated with multiple characteristics (see Table 1) (Chaiken, 1987; Gawronski & Bodenhausen, 2006; Kahneman & Frederick, 2002; Sloman, 1996; Smith & DeCoster, 2000; Stanovich & West, 2000; Strack & Deutsch, 2004). A common distinction across these models is that one mode of judgment operates based on probabilistic associations whereas the other mode operates by applying deterministic rules. The two modes of judgment have been described as separate systems, but also as ends of a continuum characterizing information processing (Chaiken, 1987; Petty & Cacioppo, 1986). This dissertation does not make a claim as to whether the modes are separate or ends of a continuum, only that dual-process distinctions have not been fully tested in neural models of judgment and the distinctions may be useful to understand neural activity associated with judgment. For clarity, I describe each mode separately following the dual-process convention of Stanovich and West (2000) and use the term "System 1" to refer to the probabilistic mode and "System 2" to refer to the deterministic mode.

Table 1. Some characteristics associated with each processing mode described in dual-process frameworks

System 1	System 2
Probabilistic	Deterministic
Affective	Complex rule-based
Heuristic	Adjustment
Efficient	Resource demanding
Automatic	Deliberative
Associative	Propositional
Experience-based	Flexible
Intuitive	Inhibition
Slow-learning	Monitoring

SYSTEM 1 PROCESSING: PROBABILISTIC ASSOCIATIONS.

System 1 processing makes use of probabilistic associations (e.g., heuristics) that, although not perfect predictors, are likely to be useful in making a judgment. Probabilistic associations are theorized to drive judgments for a variety of reasons: people may have limited cognitive resources, limited information about the judgment, or limited motivation to make precise judgments (Chaiken, 1980; Gawronski & Bodenhausen, 2006; Stanovich & West, 2000; Strack & Deutsch, 2004). Research has shown that people use probabilistic associations in a variety of judgment domains such as judging other people, novel stimuli, persuasive arguments, financial risks, and consumer products (Kelley, 1950; Loewenstein, Weber, Hsee, & Welch, 2001; Martin, Seta, & Crelia, 1990;

Murphy & Zajonc, 1993; Shiv & Fedorikhin, 2002; Slovic, Finucane, Peters, & MacGregor, 2007; Winkielman, Berridge, & Wilbarger, 2005).

For example, one everyday source of probabilistic associations is affect. Affective reactions are often used as a basis for judgment; functional accounts of emotion suggest that these affective reactions may have evolved to provide probabilistic information that associates positive affect with stimuli that are likely to lead to benefits and negative affect with stimuli that are likely to lead to harm (Levenson, 1999). In fact, a large body of research on System 1 processing has shown that affect is used to provide probabilistic information for judgments in a wide variety of domains (e.g., an "affect heuristic," Slovic et al., 2007). For example, participants judge novel ambiguous symbols (Chinese ideographs) more positively when they are primed with happy faces compared to angry faces (Murphy & Zajonc, 1993). Affective primes have a similar effect on judgments of ambiguously described people. For example, a person who helps a friend on a test is judged positively (i.e, helpful) when the description is primed with a positive word and negatively (i.e., dishonest) when primed with a negative word (Strack, Schwarz, Bless, Kübler, & Wänke, 1993). In summary, research shows that one way people approach judgments is to use probabilistic associations and one common example is affective information.

SYSTEM 2 PROCESSING: COMPLEX AND RELATIVELY MORE DETERMINISTIC INFORMATION.

In contrast to judgments driven by System 1, judgments driven by System 2 processes are more likely to combine a number of relevant factors (Chaiken, 1987;

Gawronski & Bodenhausen, 2006; Petty & Cacioppo, 1986; Sloman, 1996; Slovic et al., 2004; Smith & DeCoster, 2000). For example, people may combine several variables to decide how to get to work in the morning (e.g., "Is it rush-hour? Is it raining? Did I wake up on time?"). This information is evaluated to determine whether it satisfies a decision rule (e.g., "If it is rush-hour and it is not raining and I woke up on time then take the local bus"). System 2 processing does not necessarily involve logical rules per se. For example, System 2 processing would characterize personality judgments that draw on a combination of several different relevant behaviors rather than a stereotype (Neuberg & Fiske, 1987). In contrast to judgments driven by System 1 processes, judgments driven by System 2 processes tend to occur when people have sufficient cognitive resources, information, and motivation to make precise judgments (Chaiken, 1987; Petty & Cacioppo, 1986). System 2 processes that combine a number of relevant factors drive judgments in the same domains as judgments that are driven by System 1 processes, underscoring the idea that the two modes of processing represent two ways to make the same kind of judgment (Chaiken, 1980; Neuberg & Fiske, 1987; Petty & Cacioppo, 1986; Slovic et al., 2004).

DUAL-PROCESS INTERACTION: MONITORING, INHIBITION, AND ADJUSTMENT.

System 1 and System 2 processes have been theorized to interact in at least three ways: monitoring, inhibition, and adjustment. Monitoring is when System 2 processes evaluate the output of System 1 processes for relevance and validity. For example, System 1 processes may lead you to judge an object as dangerous if it resembles a snake. System 2 processes may then monitor the output of System 1 to determine whether the object really is a snake or whether it is just a garden hose. One of the reasons monitoring is not considered redundant with inhibition or adjustment is that monitoring does not necessarily lead to a change in judgment. For example, if upon closer inspection the object really is a snake then you will still judge it as dangerous. Although monitoring does always lead to inhibition or adjustment, it is presumed to be a precursor to both.

Inhibition is when System 2 processes prevent initial System 1 processing from influencing judgment (Gawronski & Bodenhausen, 2006; Gross, 1998; Smith & DeCoster, 2000). System 1 processes may be inhibited for at least two reasons. First, System 1 processes may be irrelevant for a judgment. For example, participants will inhibit their first impression of a stimulus if they are instructed to reappraise its meaning (Gross, 1998). A second reason for inhibiting System 1 processes is that it may be undesirable to express a judgment that is driven by System 1. For example, System 1 processing might result in a negative judgment of a person based on their race, but expressing a negative judgment of a racial minority would be socially undesirable (Bodenhausen & Macrae, 1998; Gawronski & Bodenhausen, 2006). In such a case the negative judgment may be inhibited such that it is not expressed in a public judgment of the person.

Adjustment is when System 2 processes revise the output of System 1 processes to incorporate additional relevant information. The difference between adjustment and inhibition is that inhibition prevents System 1 processing from influencing judgment, whereas adjustment incorporates new information (via System 2) into a judgment. For inhibition, the goal is to eliminate the influence of System 1 as much as possible. For adjustment, the goal is to integrate System 1 and System 2 outputs. For example, System 2 processes may revise System 1 output such as the "beautiful is good" stereotype (Dion, Berscheid, & Walster, 1972). Research on the "beauty is good" stereotype shows that people automatically attribute desirable qualities to physically attractive people; even unrelated qualities such as competence are attributed to attractive people. Yet when people have information beyond a photograph, competence judgments are influenced both by the target's physical attractiveness as well as valid new information about the target's competence (Eagly, Ashmore, Makhijani, & Longo, 1991; Jackson, Hunter, & Hodge, 1995). The new information is used to adjust rather than inhibit the influence of attractiveness. Attractiveness information constitutes a starting point for a judgment, and new information adjusts the judgment away from that starting point. In other words, people will base their judgment of someone's competence on physical attractiveness but when more information is available they will adjust their judgments of an attractive target to incorporate explicit information about their competence as well (e.g., a high competence judgment of an attractive target will be adjusted downward if additional information indicates the target is incompetent).

Neural Systems for Dual Processes in Judgment and Decision-making

Although neural researchers have suggested that distinct neural regions may underlie System 1 and System 2 judgments, neural research has yet to fully test whether the modes described in dual-process frameworks play out independently at the neural level. The current neural research on judgment and decision-making suggests some distinctions but also some common regions that are associated with both System 1 and System 2 processes (see Table 2). Neural research on judgments that involve the use of probabilistic associations suggests that amygdala, striatum, ventromedial prefrontal cortex (VMPFC, including medial orbitofrontal cortex and ventral anterior cingulate) and lateral temporal cortex may be associated with System 1 processes (Bunge & Zelazo, 2006; O'Doherty, 2004; Sanfey, Loewenstein, McClure, & Cohen, 2006; Satpute & Lieberman, 2006; Trepel, Fox, & Poldrack, 2005). Neural research on behavioral rule-use and reasoning suggests that dorsolateral prefrontal cortex (DLPFC), ventrolateral prefrontal cortex (VLPFC), and parietal cortex may be associated with System 2 processes (Bunge, 2004; Bunge & Zelazo, 2006; Goel & Dolan, 2003; Sanfey et al., 2006; Satpute & Lieberman, 2006). Furthermore, some neural regions are associated with both System 1 and System 2 processes: dorsomedial prefrontal cortex (DMPFC), dorsal anterior cingulate (DACC), insula, and lateral orbitofrontal cortex (LOFC) (Botvinick, Cohen, & Carter, 2004; Bunge & Zelazo, 2006; Dosenbach, Fair, Cohen, Schlaggar, & Petersen, 2008; Kringelbach & Rolls, 2004; Satpute & Lieberman, 2006). The previous neural research on probabilistic associations, behavioral rule-use, and reasoning suggest that different neural regions may underlie System 1 compared to System 2 processes, however it is difficult to draw strong conclusions from this literature because few studies have been designed to manipulate System 1 processes, System 2 processes, or their interaction.

Table 2. Neural regions associated with each processing mode.

System 1	System 2
Probabilistic	Deterministic
Affective	Complex rule-based
Heuristic	Adjustment
Efficient	Resource demanding
Automatic	Deliberative
Associative	Propositional
Experience-based	Flexible
Intuitive	Inhibition
Slow-learning	Monitoring
Amygdala	DLPFC
Striatum	VLPFC
VMPFC*	Parietal
Lateral Temporal	VMPFC*
DMPFC	DMPFC
DACC	DACC
Insula	Insula
LOFC	LOFC

Note: DLPFC = Dorsolateral Prefrontal, VLPFC = Ventrolateral Prefrontal, DACC = Dorsal Anterior Cingulate, VMPFC = Ventromedial Prefrontal, DMPFC = Dorsomedial Prefrontal, LOFC = Lateral Orbitofrontal. * VMPFC refers to ventromedial prefrontal regions including medial orbitofrontal and ventral anterior cingulate.

NEURAL SYSTEMS UNDERLYING SYSTEM 1 PROCESSES: LEARNING PROBABILISTIC ASSOCIATIONS AND USING THEM IN JUDGMENT.

The neural regions that may underlie System 1 processes are suggested by two areas of research. First, neural research on probabilistic reward and punishment learning suggests neural regions that may be integral in forming the probabilistic associations that are used in System 1 processing. Second, affect is one common source of probabilistic information therefore neural regions underlying the use of affect in judgment may be important in System 1 processing.

Neural systems that underlie learning and using probabilistic cue-outcome relations in judgment are likely to be important underpinnings of System 1 processing. VMPFC, LOFC, striatum and amygdala are associated with learning that a cue probabilistically predicts a reward (e.g. monetary gain) or punishment (e.g., monetary loss, pain) outcome (Breiter, Aharon, Kahneman, Dale, & Shizgal, 2001; Delgado, Miller, Inati, & Phelps, 2005; Gottfried, O'Doherty, & Dolan, 2003; Knutson, Adams, Fong, & Hommer, 2001; LaBar, Gatenby, Gore, LeDoux, & Phelps, 1998; O'Doherty, Critchley, Deichmann, & Dolan, 2003; O'Doherty, Kringelbach, Rolls, Hornak, & Andrews, 2001). VMPFC, LOFC, insula, DMPFC, and DACC are associated with using probabilistic reward information to make a judgment, for example choosing an option that leads to reward more often than another option (Critchley, Mathias, & Dolan, 2001; Paulus, Rogalsky, Simmons, Feinstein, & Stein, 2003; Tobler, O'Doherty, Dolan, & Schultz, 2007; van Leijenhorst, Crone, & Bunge, 2006; Volz, Schubotz, & von Cramon, 2003). In summary, neural research examining probabilistic association learning and the use of learned probabilistic associations suggests that VMPFC, LOFC, striatum, amygdala, insula, and DACC are likely to play a role in System 1 judgments.

Neural regions that underlie affectively-influenced judgments may be important components of System 1 processing because affect is a commonly used source of probabilistic information (Levenson, 1999; Slovic et al., 2007). Neural research on affectively-influenced judgments has most often operationalized affective influence as judgments that diverge from optimal strategies specified by economic models. In other words, affect is not manipulated but instead inferred from suboptimal financial judgments. For example, a decision to play it safe rather than take a financial gamble might indicate anxiety if the gamble would have optimized expected reward (Kuhnen & Knutson, 2005). VMPFC, DACC, insula, striatum, and amygdala are associated with affectively-influenced judgments inferred from financial decisions (Camille et al., 2004; Coricelli et al., 2005; De Martino, Kumaran, Seymour, & Dolan, 2006; Kuhnen & Knutson, 2005; Sanfey, Rilling, Aronson, Nystrom, & Cohen, 2003; Shiv, Loewenstein, Bechara, Damasio, & Damasio, 2005). Research has rarely explicitly manipulated affective information to examine its influence on judgments. One study shows that LOFC is associated both with incorporating affective information in judgments and inhibiting the influence of affect, depending on whether it is appropriate to use affect or not in a given context (Beer, Knight, & D'Esposito, 2006). A second study suggests that striatum is involved when positive affect influences financial decisions toward more risky choices (Knutson, Wimmer, Kuhnen, & Winkielman, 2008). Taken together, these studies suggest that VMPFC, DACC, insula, striatum, amygdala and LOFC may underlie judgments influenced by System 1 affective information processing.

Neural systems underlying System 2 processes: Selecting, implementing, and reasoning with rules.

Neural systems underlying System 2 processes that drive judgment are suggested by at least two areas of research: neural systems related to decision rules and research on neural systems related to logical reasoning.

The research on decision rules is one way in which cognitive neuroscience research has tackled the issue of System 2 processes, which drive judgments by integrating a combination of multiple relevant factors. More specifically, the combination of multiple releveant factors is often operationalized by introducing and/or manipulating decision rules (e.g., “On workday mornings, if I am not running late and it is not raining then take the local bus to work”). Taken together this research suggests that VLPFC, DLPFC, and parietal cortex are important neural regions for applying decision rules to judgments. For example, VLPFC, DLPFC, and parietal cortex are engaged when participants use learned decision rules to determine their responses (e.g. “if a triangle appears on the screen press the left button, if a square appears press the right button”) (Bunge, 2004; Bunge, Kahn, Wallis, Miller, & Wagner, 2003). Furthermore, VLPFC and DLPFC activity increases when a greater number of variables must be considered to implement a rule (Bunge & Zelazo, 2006; Crone, Wendelken, Donohue, & Bunge, 2006; Sakai & Passingham, 2006). In summary, neural research on decision rules suggests that VLPFC, DLPFC, and parietal cortex may be important when System 2 processing drives judgments.

Cognitive neuroscience research on logical reasoning is a second literature that pertains to hypothesizing about neural systems that may underlie System 2 processes. Logical reasoning is another mechanism through which people combine several pieces of information into a judgment. For example, logic is used to reason about a combination of the propositions “criminals are dishonest” and “dishonest people are bad accountants” to judge whether the conclusion that “criminals are bad accountants” is valid. Taken together, neural research suggests that VLPFC, DLPFC, DACC, DMPFC and parietal cortex are important neural regions when logical reasoning is used to perform judgments.

For example, VLPFC, DLPFC, DACC, DMPFC and parietal cortex activation is associated with reasoning about logical propositions and judging whether conclusions are logically valid (Canessa et al., 2005; Fiddick, Spampinato, & Grafman, 2005; Goel, Buchel, Frith, & Dolan, 2000; Goel & Dolan, 2001, 2003; Noveck, Goel, & Smith, 2004). Convergent findings from research on neural systems associated with rule-use and logical reasoning suggest that VLPFC, DLPFC, DACC, and parietal cortex may be important in System 2 processing.

NEURAL SYSTEMS UNDERLYING DUAL-PROCESS INTERACTIONS: NEURAL REGIONS ASSOCIATED WITH MONITORING, INHIBITING, AND ADJUSTING SOCIAL JUDGMENTS.

Dual-process interactions may occur when System 2 processes monitor, inhibit, or adjust the output of System 1 processes. Of these three types of research, cognitive neuroscience has developed a large literature on monitoring as well as inhibiting of social judgment. Monitoring and inhibition in social judgment both tend to draw on similar regions of DACC, DMPFC, VLPFC and DLPFC. Monitoring processes additionally draw on insula and LOFC whereas inhibition processes additionally draw on VMPFC in social judgment. However, very little attention has been paid to neural regions associated with adjustment in social judgment.

When people must monitor and inhibit judgments that are incorrect or socially undesirable, they tend to draw on DACC, DMPFC, insula, LOFC, VLPFC and DLPFC (Botvinick et al., 2004; Dosenbach et al., 2006; Egner, Etkin, Gale, & Hirsch, 2008; Horn, Dolan, Elliott, Deakin, & Woodruff, 2003; Ochsner, Bunge, Gross, & Gabrieli, 2002; Ochsner, Hughes, Robertson, Cooper, & Gabrieli, 2009; Shafritz, Collins, &

Blumberg, 2006; Wager, Davidson, Hughes, Lindquist, & Ochsner, 2008). For example, when people must monitor highly salient information for its relevance to a judgment of facial expression, salient but irrelevant information tends to increase activation in DACC, DMPFC, insula, LOFC, VLPFC, and DLPFC (e.g., if the task is to identify the emotion expressed by a picture of an angry face, then the word "happy" printed over the face is irrelevant information) (Botvinick et al., 2004; Egner et al., 2008; Etkin, Egner, Peraza, Kandel, & Hirsch, 2006; Horn et al., 2003; Ochsner et al., 2009; Shafritz et al., 2006). The inhibition of irrelevant but salient internal emotion experiences is also associated with increased DACC, DMPFC, VLPFC and DLPFC as well as VMPFC activity (e.g., inhibiting a negative emotional reaction to an event after reappraising the event in a positive way) (Etkin et al., 2006; Ochsner et al., 2002; Ochsner et al., 2009; Wager et al., 2008). Similar neural regions are involved when monitoring and inhibiting socially undesirable judgments. For example, when people inhibit negative automatic evaluations of outgroup members, their success is associated with increased DLPFC, VLPFC, and DACC activation (Amodio et al., 2004; Cunningham et al., 2004; Richeson et al., 2003). In summary, DACC, DMPFC, insula, LOFC, VMPFC, VLPFC and DLPFC are likely to be involved when System 2 processes monitor and inhibit the output of System 1 processes for social judgment.

In contrast to the large literature that addresses the neural systems underlying monitoring and inhibition in social judgment, very little attention has been paid to an equally important interaction between System 1 and 2: adjustment. In fact, a search of the current literature yields only one study that begins to address adjustment of social judgment. In this study, participants had to judge the preferences of strangers with no information other than a picture of the stranger. Psychological research has shown that people faced with the need for judgment in the context of limited information will use a similarity heuristic. That is, people used perceived similarity between themselves and the stranger to account for ways that the other person's preferences might be different (e.g., I like chocolate but this person seems very different than me so they may not like it) (Epley, Keysar, Van Boven, & Gilovich, 2004). The extent to which participants perceived themselves to be similar to the stranger modulated the extent to which DMPFC and LOFC activated while they judged the strangers' preferences (Tamir & Mitchell, 2010). This experiment stands alone in its examination of adjustment processes that underlie social judgment and, as a first step, suggests that DMPFC and LOFC may be important for adjustment.

Bridging the gap between psychological and neural models of social judgment: Using a dual-process framework to develop neural models of social judgment.

Dual system models of judgment have become influential in behavioral research because they provide a powerful explanation of processes underlying judgments in a variety of social and non-social domains (Chaiken, 1987; Gawronski & Bodenhausen, 2006; Kahneman & Frederick, 2002; Shiv & Fedorikhin, 1999; Sloman, 1996; Slovic et al., 2004; Strack & Deutsch, 2004). Cognitive neuroscience research on social judgment has speculated that distinct neural regions are involved in System 1 compared to System 2 processes that may drive judgments (Sanfey et al., 2006; Satpute & Lieberman, 2006).

However, few studies have been explicitly designed to manipulate System 1 processes, System 2 processes, or their interaction. The proposed research will represent a few steps toward this goal by addressing three gaps between current dual-process psychological models of judgment and neural research on judgment.

Although neuroscientists have speculated that distinct neural regions are associated with System 1 compared to System 2 processes (Sanfey et al., 2006; Satpute & Lieberman, 2006), neural research has yet to manipulate System 1 versus System 2 approaches to social judgment in the same study. Even in non-social judgment, comparison between neural regions underlying System 1 processes and System 2 processes does not exist. For example, neural research has examined regions associated with using probabilistic information in judgments, and regions for using complex decision rules in other judgments, but there has been little research comparing the two pathways to judgment (Breiter et al., 2001; Bunge, 2004; Bunge et al., 2003; Critchley et al., 2001; Crone et al., 2006; Delgado et al., 2005; Gottfried et al., 2003; Knutson et al., 2001; LaBar et al., 1998; O'Doherty et al., 2003; O'Doherty et al., 2001; Paulus et al., 2003; Tobler et al., 2007; van Leijenhorst et al., 2006; Volz et al., 2003). Study 1 directly examines neural systems for using probabilistic information compared to a complex decision rule to make a judgment, making it possible to learn whether neural distinctions exist at different points of the continuum between System 1 and System 2 processes.

A predominant System 1 process involves basing judgments on an affective state, yet current neural research on affectively-influenced judgments is often difficult to clearly interpret. Specifically, it is difficult to strongly interpret neural activation as a reflection of affectively-influenced decision-making when affect is not manipulated. For example, many studies infer the influence of affect from financial decisions that deviate from the optimal strategy specified by an economic model (Camille et al., 2004; Coricelli et al., 2005; De Martino et al., 2006; Kuhnen & Knutson, 2005; Shiv et al., 2005). For instance, a conservative financial decision to avoid a gamble might indicate fear of loss if taking the gamble would optimize expected reward. However, decisions might deviate from optimal strategies not due to an affective response but instead due to an incorrect calculation or poor understanding of the optimal strategy. Study 2 manipulates affective primes prior to judgments in order to more clearly understand the neural systems underlying System 1 processes that may drive social judgments.

Another issue is that neural research on social judgment has rarely examined one of the main ways that System 1 and System processes interact: adjustment. Previous research typically examines neural regions that are associated with making judgments of people (e.g., how trustworthy is this person?) based on a picture or descriptions of their typical behaviors and has associated amygdala, insula, striatum, VMPFC and DMPFC regions with these judgments (Adolphs, Tranel, & Damasio, 1998, 2003; Engell, Haxby, & Todorov, 2007; Harris & Fiske, 2007; Kim, Adolphs, O'Doherty, & Shimojo, 2007; Rule et al., 2010, 2011; Schiller, Freeman, Mitchell, Uleman, & Phelps, 2009; Todorov & Engell, 2008). For example, DMPFC is associated with processing information about a person's typical behaviors (e.g., "this person always gives to charity") while amygdala is associated with distinguishing between behaviors that are relevant or not relevant for a judgment of the person's likeability (Schiller et al., 2009). In this typical social judgment paradigm there is no understanding of whether judgments of people based on pictures or behavior descriptions are driven by System 1 processes, System 2 processes, or their interaction. Furthermore, little attention has been paid to neural regions that may underlie dual-process interactions characterized by adjustment of System 1 output. Further neural research is needed that manipulates dual-processing modes and their interaction in social judgments. Study 3 manipulates System 1 processing for an initial heuristic-driven social judgment, and System 2 integration of additional relevant information to adjust a heuristic-driven judgment in order to better understand the neural regions that underlie System 1 and System 2 processes and their interaction in social judgment.

Overview of Studies

Figure 1

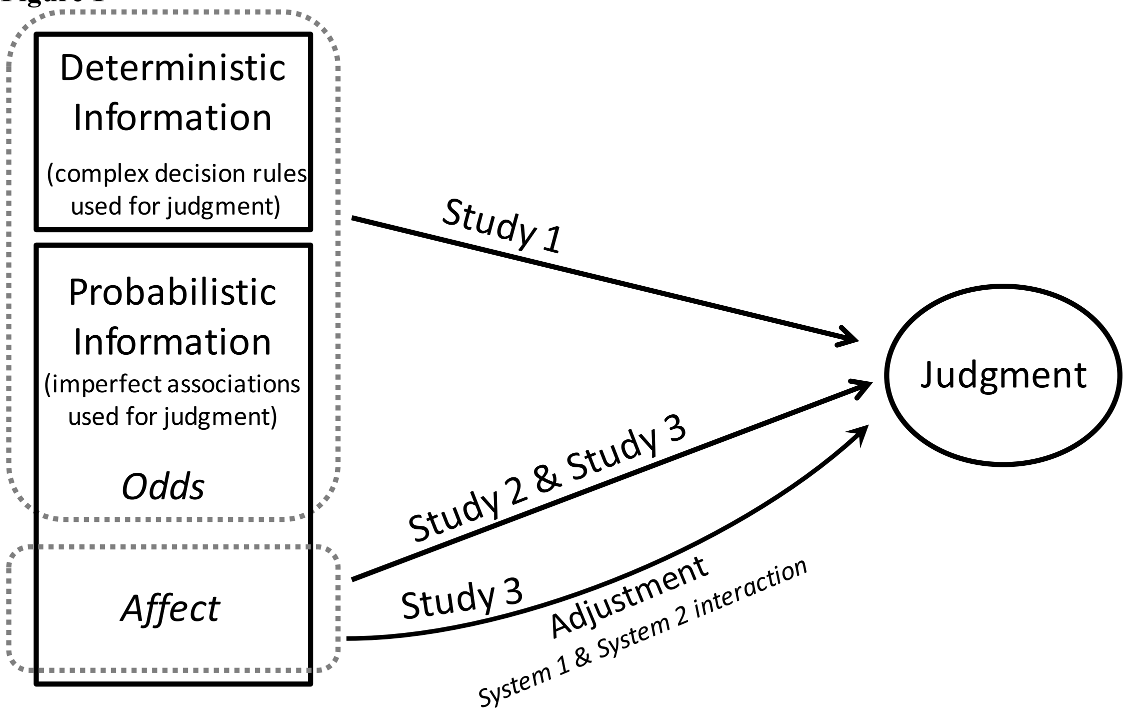

Figure 1. Study overview.

The proposed research uses a dual-process framework to motivate research that will further develop neural models of decision-making (see Figure 1). Study 1 is one of the first studies to directly contrast System 1 processes with System 2 processes by combining approaches that have previously been used independently of one another in the neural literature on decisions. Specifically, Study 1 examines the neural regions associated with judgments based on probabilistic information (odds of a receiving a reward) compared to complex decision rules. Study 2 builds on Study 1 by examining the use of probabilistic information in a more ecologically valid way. The probabilistic information examined in Study 1 provides experimental control but does not represent the kind of information people have for making many of the social judgments of everyday life. Therefore, Study 2 examines neural systems underlying affect-driven judgment because affect is a source of probabilistic information that people use in daily life (Schwarz, 1990; Slovic et al, 2007). Furthermore, Study 2 uses a novel paradigm to address confounds in previous neural research on affect-driven judgment. Study 3 builds on Study 1 and Study 2 in two ways. First, it takes an additional step toward ecological validity by examining judgments made from dynamic social stimuli (i.e., videos). Second, Study 3 examines neural systems associated with one form of dual-process interactions that has not been addressed in previous neural research: System 2 processes that adjust the output of System 1 processes. Specifically, Study 3 will identify neural regions associated with System 2 processes that adjust heuristic-driven judgments of people in light of additional information.

STUDY 1: USING A DUAL-PROCESS FRAMEWORK TO EXAMINE NEURAL REGIONS FOR DECISION MAKING

Introduction

Study 1 examines whether neural regions are preferentially associated with processing characteristics of System 1 compared to System 2 in judgment. Whether viewed as independent systems or ends of a continuum, System 1 is characterized by the use of probabilistic associations whereas System 2 is characterized by the use of relatively more complex deterministic rules (Chaiken, 1987; Gawronski & Bodenhausen, 2006; Kahneman & Frederick, 2002; Petty & Cacioppo, 1986; Sloman, 1996; Smith & DeCoster, 2000; Stanovich & West, 2000; Strack & Deutsch, 2004). Previous neural research has not yet examined whether neural regions are selectively recruited for judgments based on probabilistic associations versus judgments based on complex deterministic rules. That is, previous studies have examined neural regions associated with the use of probabilistic associations in judgment, and other studies have examined neural regions associated with the use of complex deterministic rules, but no neural studies have compared the two types of judgment. A direct comparison is needed to test whether neural regions are more closely associated with one type of judgment or the other. Study 1 addresses this gap in previous neural research by directly examining neural systems related to using probabilistic information compared to a complex decision rule to make a judgment.

Study 1 aims to bridge previous neural research on probabilistic associations with neural research on complex deterministic rule-use. Previous neural research has associated VMPFC, LOFC, striatum, amygdala, insula, and DACC with learning and using probabilistic associations in judgment (Breiter et al., 2001; Critchley et al., 2001; Delgado et al., 2005; Gottfried et al., 2003; Knutson et al., 2001; LaBar et al., 1998; O'Doherty et al., 2003; O'Doherty et al., 2001; Paulus et al., 2003; Tobler et al., 2007; van Leijenhorst et al., 2006; Volz et al., 2003). Other research has associated VLPFC, DLPFC, and parietal cortex with selecting and applying complex deterministic rules (Bunge, 2004; Bunge et al., 2003; Crone et al., 2006; Sakai & Passingham, 2006). Study 1 bridges these areas of research by comparing judgments based on probabilistic information with judgments based on complex decision rules to assess whether neural regions are preferentially associated with processes that are more characteristic of System 1 compared to System 2 processes in judgment. Participants made judgments either by using probabilistic information about the odds of reward for each response, or by applying a complex decision rule that specified the correct response. Results of this study are also reported in a published manuscript (Bhanji et al., 2010).

Methods

PARTICIPANTS

Fifteen right-handed participants were included in the study (7 females; ages 18-28 years, mean age = 21.9, *S.D.* = 3.09). Data from an additional participant was excluded from analysis due to excessive head movement (>4mm over the scanning session). All participants provided informed consent and the study was approved by the institutional review board of the University of California at Davis.

DECISION TASK

Participants learned to perform a binary choice task prior to scanning (Figure 2). Participants made decisions that varied in Choice Type (probabilistic versus complex decision rule). Probabilistic choices were based on information in a cue that indicated which response was most likely to receive a financial reward. Complex decision rule choices were based on information in a cue that indicated how to apply a rule to always receive a financial reward. All stimuli were presented visually. The cues were pictures of common objects: playing cards, billiard balls, highway route signs, tickets, sports jerseys, and football helmets. Embedded in each image was a number between 2 and 9. Participants pressed one of two response buttons on each trial, based on information provided by the cue. Correct responses were associated with a gain of either 20 cents or 1 cent, whereas incorrect responses were associated with a loss of either 20 cents or 1 cent. The total amount won on the task was provided to the participant at the end of the study, together with a fixed sum of $30 as compensation for getting involved in the study.

Figure 2.

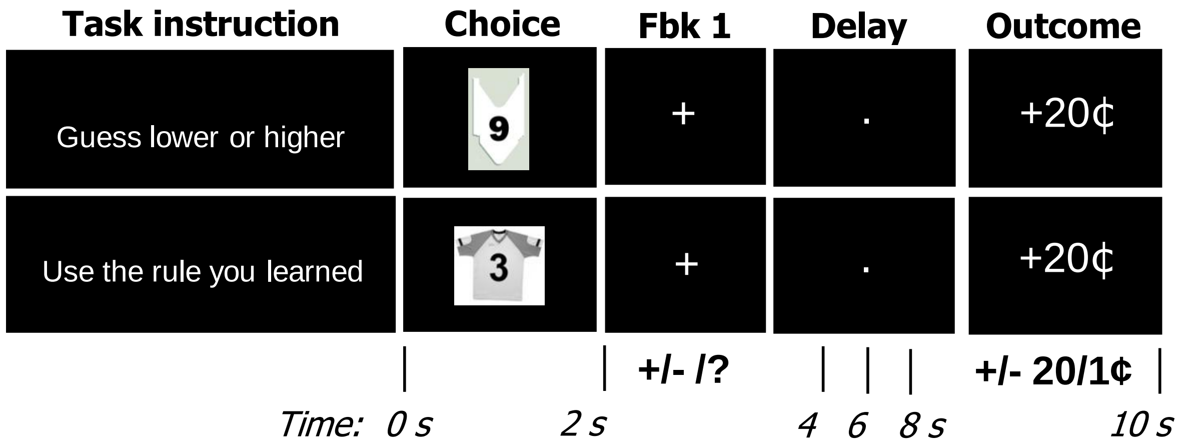

Figure 2. Stimuli and timing in binary choice task.

Participants saw a cue (Choice screen), made a response, saw an initial feedback stimulus (Fbk1 screen; +/-/?), waited through a delay (Delay screen), then received final feedback (Outcome screen) showing valence and magnitude of the trial outcome.

Choice Type was manipulated across blocks of probabilistic and complex decision rule choices (see Figure 2). In probabilistic blocks, the information in the cue probabilistically indicated the correct response in a guessing task that was modeled after previous research on probabilistic decision making (Critchley et al., 2001; Delgado et al., 2005; Delgado, Nystrom, Fissell, Noll, & Fiez, 2000). In probabilistic choices, participants pressed a 'lower' (index finger of right hand) or 'higher' (middle finger of right hand) response key to guess whether a randomly generated number between 1 and 10, inclusive, would be lower or higher than the number in the cue (participants were informed that this number would always be lower or higher but never equal to the number in the cue). This manuscript reports analysis of trials with cues with the numbers 2,3,8,or 9 that indicated the correct response with high probability. That is, cues with numbers 2 or 3 indicated that a random number 1-10 was likely to be higher (83% of the time) and cues with a 8 or 9 indicated that a random number 1-10 was likely to be lower (83% of the time). Analysis of trials with cues with numbers 4-7 is included in the full publication of this study (Bhanji et al., 2010). In complex decision rule choices, a response rule using information in the cue fully determined the correct response. The complex decision rule choices were modeled after previous research on rule-guided behavior (Bunge & Wallis, 2007; Wallis & Miller, 2003). The complex decision rule required consideration of two features of the cue. Specifically, in complex decision rule choice trials, participants were instructed to press the 'lower' response key if the cue was an even-numbered sports jersey or an odd-numbered football helmet, and to press the 'higher' response key if the cue was an odd-numbered sports jersey or an even-numbered football helmet. Choices that were made correctly according to the rule were rewarded every time and the rule remained constant throughout the session. Participants practiced making 20 probabilistic and 20 complex decision rule choices before the scan so that each type of choice was well-practiced before scanning began.

Each 10-second trial started with a 250 ms small green fixation point, followed by a cue that was presented for a 2000 ms choice phase (Figure 2, "Choice" screen), during which participants made their response. An initial feedback stimulus was presented for 500 ms (Figure 2, "Fbk 1" screen, followed by a large white fixation point presented for a 6500 ms delay period (Figure 2, "Delay" screen), and finally a second feedback stimulus for 750 ms (Figure 2, "Outcome" screen). The initial feedback stimulus indicated whether the choice was correct, incorrect, or whether they would have to wait until the end of the trial to know if it was correct. The second feedback stimulus indicated whether participants gained or lost 20 cents or 1 cent on the trial. Results reported here focus on neural activity related to probabilistic versus complex decision rule choices; neural activity related to feedback is reported as part of a larger study of including neural correlates of uncertainty after a choice has been made (Bhanji et al., 2010). Cue pictures in complex decision rule choices were always sports jerseys or football helmets, and those objects never appeared in probabilistic choices. Inter-trial intervals varied from 0 to 8 seconds, the order and length of inter-trial intervals was determined with an algorithm designed to maximize the efficiency of recovery of the Blood-Oxygen-Level-Dependent (BOLD) response (Dale, 1999).

FUNCTIONAL MAGNETIC RESONANCE IMAGING DATA ACQUISITION

Participants performed the task over the course of five functional scans. Each scan included one probabilistic block and one complex decision rule block. Each probabilistic block consisted of 18 trials with high probability cues (numbers 2, 3, 8 and 9) arranged in a pseudorandom order. Each complex decision rule block consisted of 9 trials with cues arranged in pseudorandom order. Probabilistic blocks and Rule blocks alternated, each block beginning with an instruction screen presented for 4000 ms followed by 4000 ms of blank screen. Over the course of the scanning session, participants performed 90 probabilistic trials and 45 complex decision rule choice trials.

Scanning was performed with a standard head coil on a 1.5 Tesla GE scanner at the UC Davis Imaging Research Center. Functional magnetic resonance imaging (fMRI) data were acquired using a gradient echo-planar pulse sequence (TR = 2 s, TE = 40 ms, 24 slices, 3.475 x 3.475 x 5 mm, 0 mm inter-slice gap, 304 volumes per scan). Functional volume acquisitions were time-locked to the onset of the cue at the beginning of each trial. The first five volumes of each scan were discarded. Coplanar and high-resolution T1 weighted anatomical images were also collected. Visual stimuli were projected onto a screen that was viewed through a mirror. Button presses were recorded from a response keypad in the participant's right hand.

FMRI DATA ANALYSIS

Data were preprocessed using SPM2 (Wellcome Department of Cognitive Neurology, London). Images were corrected for differences in timing of slice acquisition, followed by rigid body motion correction. Structural and functional volumes were normalized to T1 and EPI templates, respectively. The normalization algorithm used a 12-parameter affine transformation together with a nonlinear transformation involving cosine basis functions, and resampled the volumes to 2-mm cubic voxels. Templates were based on the MNI305 stereotaxic space (Cocosco, Kollokian, Kwan, & Evans, 1997). Functional volumes were spatially smoothed with an 8-mm full width at half maximum (FWHM) isotropic Gaussian kernel.

Statistical analyses were performed on individual participants' data using the general linear model (GLM) in SPM2. The fMRI time series data were modelled by regressors representing events convolved with a canonical hemodynamic response function and its temporal derivative.

Choice Type was hypothesized to influence regional brain activity at the onset of the choice phase. These effects were examined with a regression model consisting of regressors describing choice phase and outcome phase events (0 ms duration). Choice phase regressors of interest modelled activity beginning at the onset of the choice phase (see Figure 2) in two distinct trial types: 1) probabilistic choice and 2) complex decision rule choice. The immediate and delayed feedback conditions were collapsed in this model because a preliminary analysis showed no effects of feedback type at the onset of the choice phase, as expected. Regressors of non-interest included low probability choice cues (numbers 4-7), positive outcomes on all probabilistic choices, negative outcomes on all probabilistic choices, positive outcomes on all complex decision rule choices, instruction screen events (4 s duration), and error trials (10 s event duration). Error trials were trials on which participants failed to respond and complex decision rule block trials on which participants used the response rule incorrectly. These regressors were entered into a GLM along with a set of cosine functions that high-pass filtered the data (cut off at 128s) and a covariate for session effects. The least-squared parameter estimates for each condition were used to create contrast images comparing activity across different conditions.

To test whether regions responded differentially according to Choice Type, a contrast image compared probabilistic choices with complex decision rule choices. Group statistical maps were computed for each contrast by calculating one-sample t-tests on participants' contrast images (participants were treated as a random effect). Clusters were selected for further examination if they survived small volume correction (SVC, $p < .05$, family-wise error corrected) based on a priori volumes of interest from the Automated Anatomical Labeling (AAL) map (Tzourio-Mazoyer et al., 2002) (VLPFC based on triangularis AAL regions, DACC based on the middle and anterior cingulum regions, VMPFC based on the medial orbital AAL regions, striatum based on caudate and putamen AAL regions, amygdala based on the amygdala AAL regions). Based on specific interest in the anterior insula (Critchley et al., 2001; Paulus et al., 2003), small volume correction in anterior insula was based on voxels in the insula AAL regions with a y-coordinate greater than 0. The focus on these regions is motivated by previous research demonstrating that VLPFC is associated with complex decision rule-use (Bunge et al., 2003), and that VMPFC, DACC, and anterior insula are associated with learning and using probabilistic information in judgment (Critchley et al., 2001; Daw, O'Doherty, Dayan, Seymour, & Dolan, 2006; Gottfried et al., 2003; Hampton, Bossaerts, & O'Doherty, 2006; Paulus & Frank, 2003; Tobler et al., 2007; van Leijenhorst et al., 2006).

Choice and outcome phase parameter estimates were extracted from each region of interest using the Marsbar toolbox in SPM2 (Brett, Anton, Valabregue, & Poline, 2002). Choice phase parameter estimates from regions of interest were used for visualization of effects. For event-related response visualization, average raw signal change values were extracted for complex decision rule choices and probabilistic choices for 8 time points (16 s) following trial onset using the Marsbar toolbox in SPM2 (Brett et al., 2002).

Results

Behavioral Results

Complex decision rule-based decisions were expected to take longer than probabilistic decisions, because they require the consideration of two features of the cue stimulus (number and object), while probabilistic decisions require only the consideration of one feature (number). In contrast to hypothesized response time differences, participants were expected to select the optimal response with about the same frequency in probabilistic and complex decision rule choices because they were motivated to make choices that would lead to financial gain. Responses for the option with the higher probability of success were optimal in probabilistic choices, while responses according to the learned behavioral rule were optimal in complex decision rule choices. Average response times and average frequencies of the optimal response were compared for complex decision rule choices and probabilistic choices (Figure 3). As expected, response times were longer for complex decision rule choices (*M* ± *S.D.*: 1111ms ± 153ms) compared to probabilistic choices (841ms ± 111ms; $t(14) = 6.62$, $p < .05$). However, the frequency of optimal responses in the complex decision rule choice condition (*M* ± *S.D.*: 94.9% ± 4%) was not significantly different from the probabilistic choice condition (94.8% ± 10%, $t(14) < 1$, $p > .9$). In summary, responses for complex decision rule choices took longer than probabilistic choices, but participants made the optimal choice equally often in the probabilistic compared to complex decision rule conditions.

Figure 3.

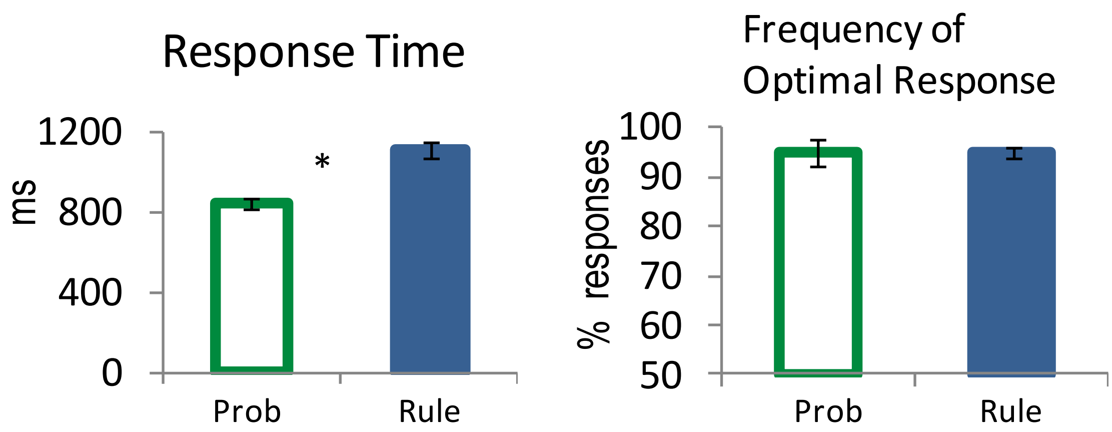

Figure 3. Behavioral results from the choice task.

Left bar graph shows mean response times, right bar graph shows mean frequency that participants selected the optimal response in the probabilistic (Prob) and complex decision rule (Rule) conditions. * indicates significant difference ($p < .05$). Error bars represent standard error of the mean.

FMRI RESULTS

Regional activity associated with Choice Type was examined by contrasting the probabilistic choice condition with the complex decision rule choice condition (Table 3). Exploratory analysis ($p < .001$, uncorrected) showed that probabilistic choice was associated with activity in left and right lateral temporal cortex, and ventral anterior cingulate cortex (BA 25) among other regions, but these regions did not survive correction. In contrast, complex decision rule choice was associated with increased activity in left VLPFC (BA 44/45), DACC (BA 24/32), and bilateral anterior insula (Figure 3, $p < .05$ SVC), among other regions in the exploratory analysis ($p < .001$ uncorrected).

Table 3. Activation foci: Probabilistic versus complex decision rule contrast

Region of Activation (Right/Left)	Brodmann Area	MNI Coordinates x	y	z	t Value
		Probabilistic – Complex decision rule			
Superior Frontal (R)	8/9	16	48	54	5.60
Ventral Anterior Cingulate (R)	25	6	30	0	4.46
Temporal Pole (L)	20	-38	18	-42	7.31
Inferior Temporal (R)	20	48	10	-42	4.61
Inferior Temporal (L)	20	-46	6	-50	4.84
Lateral Temporal (L)	21	-52	-6	-16	5.19
Parahippocampal (R)	35	14	-16	-30	6.10
Angular Gyrus (L)	39	-56	-70	32	5.75
		Complex decision rule –Probabilistic			
Lateral Prefrontal (R)	46	40	50	20	5.06
Lateral Prefrontal (L)	45	-42	46	12	4.09
Lateral Prefrontal (L)	45	-52	36	32	4.15
Dorsal Anterior Cingulate (R)	24/32	6	28	28	5.00
Anterior Insula (L)		-32	24	4	8.45
Anterior Insula (R)		32	22	-6	10.99
Lateral Prefrontal (L)	44/45	-40	22	24	6.83
Thalamus/Ventral Striatum (R)		10	4	-14	5.67
Supplementary Motor Area (L/R)	6	-2	0	68	5.37
Insula (R)		36	-2	16	4.95
Thalamus/Ventral Striatum (L)		-14	-4	-10	4.87
Precentral Gyrus (R)	6	52	-6	58	7.14
Superior Frontal (L)	6	-26	-8	76	8.83
Superior Frontal (R)	6	18	-10	70	5.39
Hippocampus (R)	27	20	-32	-2	5.87
Thalamus (L)		-8	-32	-2	5.73
Inferior Temporal (L)	20	-52	-48	-16	8.14
Inferior Parietal (L)	40/7	-38	-54	54	5.62
Occipital (L)	18	-28	-64	-8	4.21
Occipital (R)	18	20	-66	-4	4.14
Superior Parietal (L)	7	-14	-66	62	4.43
Precuneus (L)	7	-6	-70	34	4.31
Cerebellum (L/R)		-4	-70	-24	7.96
Occipital (L)	19	-42	-84	-2	5.31
Occipital (L)	18	-14	-92	-16	4.43

Occipital (R)	18	18	-98	-8	8.28

Note: Regions listed contain 10 contiguous resampled voxels with t value significant at p<.001, uncorrected (regions in bold p < .05, SVC). Approximate Brodmann's areas are shown. Regions are ordered from anterior to posterior by y-coordinate of the peak.

Figure 4.

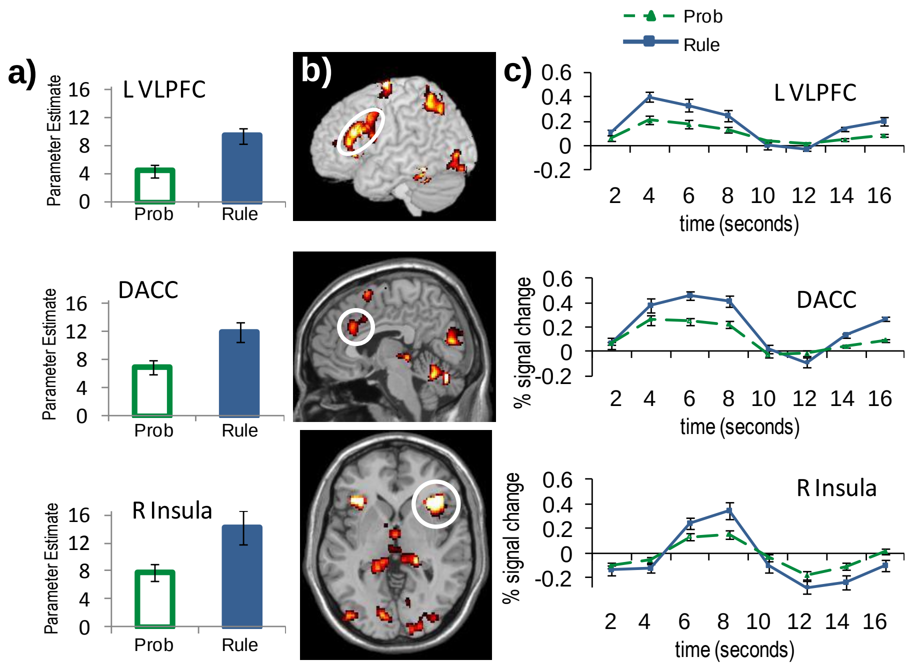

Figure 4. Regions of interest defined by the complex decision rule versus probabilistic choice contrast.

VLPFC, DACC, and right anterior insula regions show increased activity for complex decision rule choices compared to probabilistic choices. a) Choice phase parameter estimates for probabilistic (Prob) and complex decision rule (Rule) conditions. b) t-statistic maps from the complex decision rule choice versus probabilistic choice contrast (threshold at p<.001 uncorrected, 10 contiguous voxels). c) Activation time course for probabilistic (Prob) and complex decision rule (Rule) conditions. Onset of the choice phase corresponds to 0s. Error bars in each chart represent the standard error of the mean.

Discussion

Study 1 results suggest that distinct neural regions are preferentially recruited for judgments based on complex decision rules compared to judgments based on probabilistic information. Consistent with previous research, VLPFC was associated with implementing complex decision rules, a type of System 2 process (Bunge, 2004; Bunge & Zelazo, 2006; Goel & Dolan, 2003; Sanfey et al., 2006; Satpute & Lieberman, 2006). In the current study, DACC, and insula regions were also associated with implementing complex decision rules. Previous evidence has been mixed with regard to whether DACC and insula are associated with System 1 or System 2 types of processing (Botvinick et al., 2004; Bunge & Zelazo, 2006; Critchley et al., 2001; Dosenbach et al., 2008; Kringelbach & Rolls, 2004; Sanfey et al., 2006; Sanfey et al., 2003; Satpute & Lieberman, 2006). The current findings add support for the association of VLPFC, DACC, and insula with System 2 processing in judgment in a study that directly compares judgments based on complex decisions rules to judgments based on probabilistic associations.

Limitations of the current study make it difficult to draw inferences about neural associations with System 1 processing. No regions survived a corrected threshold that showed greater activity for decisions based on a probabilistic cue (System1 processing). One possibility is that the probabilistic decision condition in Study 1 may not have truly reflected System 1 processing. Dual-process modes can be viewed as ends of a continuum (Chaiken, 1987, Petty & Cacioppo, 1986), and the probabilistic decision condition in Study 1 may have fallen in between ends of the continuum. That is, participants may have implemented a deterministic rule based on the probabilistic cue (e.g., if the number is high then guess lower), instead of a more affectively based process (e.g., guess what feels right). Regardless of how participants might have implemented decisions in the probabilistic condition, the deterministic rule-condition required integration of multiple factors and thus is more characteristic of System 2 processing than the probabilistic condition. Thus, neural associations of VLPFC, DACC, and insula with System 2 processing should be valid although there are limitations to interpretation of the probabilistic condition. One possibility for future research would be to examine probabilistic judgments that might fall on different points on a continuum between System 1 and System 2. For example, behavioral research suggests that people may implement probabilistic judgments differently depending on the affective content of the subject matter (Rottenstreich & Hsee, 2001). Future research might examine neural associations of affect-laden probabilistic judgments compared to non-affect laden probabilistic judgments.

STUDY 2: NEURAL REGIONS ASSOCIATED WITH AFFECT-DRIVEN JUDGMENTS

Introduction

Whereas Study 1 examined judgments based on explicit probabilities and rules, those kinds of information are rarely available for many of the judgments we make in everyday situations. Therefore, Study 2 moves in a more ecologically valid direction by examining affect as an everyday source of probabilistic associations (Martin et al., 1990; Murphy & Zajonc, 1993; Slovic et al., 2007). Furthermore, Study 2 addresses a limitation of Study 1 by examining judgments that are more unambiguously associated with System 1. That is, Study 2 focuses on the use of affect in judgment as a characteristic of System 1 processing. Specifically, Study 2 uses a novel operationalization of emotion-congruent judgment that builds on previous research by more clearly identifying the neural regions underlying affect-driven judgments. Previous neural research that has examined affect-driven judgments is often difficult to interpret because the influence of affect is often inferred rather than manipulated. Study 2 tests whether neural regions identified in previous research (VMPFC, DACC, insula, striatum, and amygdala) are associated with affectively-driven judgments when affect is manipulated rather than inferred (Camille et al., 2004; Coricelli et al., 2005; De Martino et al., 2006; Kuhnen & Knutson, 2005; Shiv et al., 2005). Results of this study are also reported in a published manuscript (Bhanji & Beer, 2011).

Methods

PARTICIPANTS

The results from 17 participants [right handed; 12 females; ages 20–38 years, mean age=24.7, standard deviation (*S.D.*)=5.5] are reported. Data from three additional participants were excluded from analysis because the participants failed to perceive the rapidly presented stimuli. All participants provided informed consent and the study was approved by the institutional review board of the University of Texas at Austin. Participants were recruited for an experiment described as a study of emotional processing in the brain and compensated $15/h or course credit for their participation. All participants were native English speakers screened for psychological and neurological conditions as well as for medications that might influence the measurement of cerebral blood flow.

JUDGMENT TASK

Participants performed a primed-judgment task (see Figure 5) while undergoing fMRI. Each task trial consisted of a Prime, an Inter-Stimulus Interval (ISI), and a Judgment. For each Prime screen (2 s), two negative words or two neutral words were flashed on the top/bottom and left/right of the screen. The stimuli set included eight negative (e.g., cruelty) and eight neutral (e.g., copper) words previously used in neural research on emotion (Ochsner et al., 2009).

Figure 5.

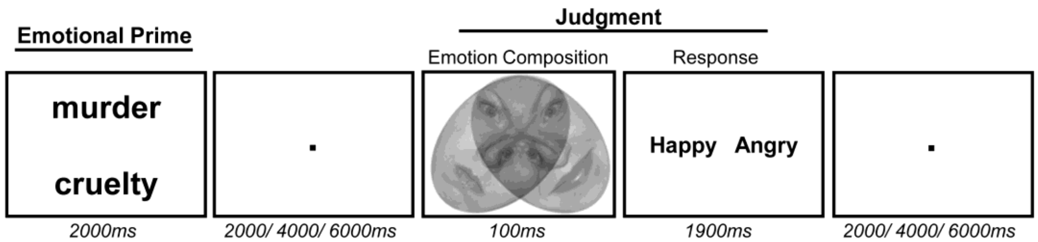

Figure 5. Primed-judgment task.

Participants viewed a negative or neutral word prime, and then judged whether they saw an angry or happy facial expression in a composition of emotive facial expressions. Judgments of ambiguous compositions (composed of one angry face and one happy face) constituted the critical trials for analysis of emotion-congruence effects. Judgments indicating the angry expression after a Negative Prime were classified as emotion-congruent, whereas judgments indicating the happy expression after a Negative Prime were classified as emotion-incongruent.

An ISI separated each Prime from a subsequent Judgment. For each ISI, participants were instructed to clear their minds while viewing a blank screen with a fixation point. The length of ISI screens were jittered between events to maximize independence of neural activity estimates related to Primes and Judgments (variable length ISI: 50% of trials 2s, 25% 4s, 25% 6s: Donaldson, Petersen, Ollinger, & Buckner, 2001).

After the ISI, participants then made Judgments about ambiguous facial stimuli. Each Judgment consisted of a rapidly-presented composition of emotive facial stimuli (100ms) followed by a probe for participants to judge whether they saw a happy or angry facial expression in the facial stimuli (Response: 1900ms). The compositions of emotive facial stimuli were two emotional faces tilted 45 degrees towards each other so that they were partially overlaid on each other with 50% transparency (Figure 6). This arrangement of the faces made it possible to direct attention to one face or the other but difficult to direct attention to both facial expressions simultaneously. Therefore, people were likely to prioritize processing of one facial expression over the other much the way they perceive ambiguously-oriented cubes as having different dominant orientations depending on where they focus their attention (Ellis & Stark, 1978). Each ambiguous facial stimulus was composed of one angry and one happy closed-mouth expression in grayscale from the NimStim image set (Tottenham et al., 2009) cropped to an oval shape to remove the hair and neck. The left-right placement of angry and happy faces was counter-balanced and gender was equally represented in stimuli. The facial stimuli were presented briefly (100ms) and then participants pressed a button to indicate which emotion, happy or angry, they identified first in the composition of faces. Participants were explicitly instructed not to make any guesses and to only respond when they identified a facial emotion in the composition. Participants were told that purpose of their responses was to let the experimenter know what facial expressions they saw on each trial and there were no incorrect answers. Participants were also specifically instructed that they should only look at the word primes but not respond to them. The experimenter verified that participants understood the instructions by asking about their responses after 10 practice trials. If participants asked the experimenter about the purpose of the word primes they were told that the study examines how the brain processes different kinds of emotion and they should pay attention to both the words and the faces but only respond to the faces.

Each trial was followed by a blank screen with a fixation point (variable length inter-trial interval (ITI): 50% of trials: 2s, 25%: 4s, 25%: 6s). The length of ITI screens were jittered between events to maximize independence of neural activity estimates (Donaldson et al., 2001). Participants completed 64 ambiguous judgment trials (32 Negative Prime followed by ambiguous facial stimuli, 32 Neutral Prime followed by ambiguous facial stimuli,) and 8 check trials (described more fully below: 4 Neutral Prime followed by only angry faces, 4 Negative Prime followed by happy faces). Trials were pseudo-randomly ordered and equally distributed across two consecutive functional scanning runs that lasted 8 minutes each.

Additionally, two manipulation checks were included. First, participants' processing of the rapidly presented stimuli (rather than just answering based on the valence of the preceding emotional prime) was verified by "check trials." In these trials, participants were presented with face compositions composed of two faces from the same emotion category. If participants were not actually processing the facial stimuli, then they would respond that they had seen a face from an emotion category that was not actually presented. Responses on "check" trials were significantly higher than chance (93.36% correct, $t(16)=22.91$, $p<.05$). Check trials were not included in the measure of emotion-congruent judgment and were modeled as events of non-interest in fMRI analysis. Second, behavioral data was collected from an additional group of participants to understand how judgments in our primed conditions compared to unprimed judgments. In previous research, unprimed facial emotion identification tasks have shown that happy faces tend to be identified before angry faces (Leppänen & Hietanen, 2004; Leppänen, Tenhunen, & Hietanen, 2003). This effect also characterized the unprimed version of our judgment paradigm. 18 new participants (14 Females; ages 18-24 years, mean age=19.4, *S.D.*=1.4) recruited from the same community as the fMRI study participants performed only the judgment portion of our experimental task. Each stimulus included equivocal amounts of happy and angry facial information. Compared to chance, participants indicated they saw the happy expression more of the time (*M*=53.37%, *S.D.*=7.90%, $t(17)=1.81$, $p<.05$, one-tailed, with the remaining 46.63% of the stimuli being identified as angry). The Results section reports comparisons of primed and unprimed judgments.

FMRI DATA ACQUISITION

All images were collected on a 3.0-T GE Signa EXCITE scanner at the University of Texas at Austin Imaging Research Center. Functional images were acquired with a GRAPPA sequence (TR=2000ms, TE=30 ms, FOV=240, 96 x 96 matrix, voxel size 2.5 x 2.5 x 3.3mm) with each volume consisting of 35 axial slices. Functional volume acquisitions were time-locked to the onset of the first screen at the beginning of each trial. A high resolution SPGR T1-weighted image was also acquired from each participant.

FMRI DATA ANALYSIS

All statistical analyses were conducted using SPM2 (Wellcome Department of Cognitive Neurology, London). Functional images were corrected for slice-timing skew using temporal sinc-interpolation and for movement using rigid-body transformation parameters. Structural and functional volumes were normalized to T1 and EPI templates, respectively, using a 12-parameter affine transformation together with a nonlinear transformation involving cosine basis functions that resampled the volumes to 2-mm cubic voxels. Templates were based on the MNI305 stereotaxic space (Cocosco et al., 1997). Functional volumes were spatially smoothed with an 8-mm FWHM isotropic Gaussian kernel and a high-pass filter with a cutoff period of 128 seconds was applied.

A fixed-effects analysis modelled event-related responses to Primes and Judgments for each participant. Neural activity related to the Prime and Judgment for each trial type were modelled as events using a canonical hemodynamic response function with a temporal derivative entered into a GLM analysis. The trial events were modelled to reflect the combination of the Prime (Neutral or Negative) and each participant's Judgment (Happy or Angry). Therefore, neural activity related to Primes was distinguished by (a) the emotional content of the prime and (b) the subsequent judgment of the stimuli that followed the prime (Prime Screen: Negative Prime followed by an Angry Judgment, Negative Prime followed by a Happy Judgment, Neutral Prime followed by an Angry Judgment, Neutral Prime followed by a Happy Judgment). Similarly, neural activity related to Judgments was distinguished by (a) the result of the Judgment and (b) the emotional content of the prime that preceded the judgment (Judgment Screen: Angry Judgment preceded by a Negative Prime, Happy Judgment preceded by a Negative Prime, Angry Judgment preceded by a Neutral Prime, Happy Judgment preceded by a Neutral Prime). Inter-stimulus and inter-trial intervals were modelled as baseline activity and the primes and judgments from unambiguous "check" trials were modelled as regressors of non-interest. Contrast images were calculated for each participant and used in a second-level analysis treating participants as a random effect. Group average SPM t-statistic maps were created for each contrast of interest.

Contrasts of interests focused on neural activity in relation to Prime screens and Judgment screens. First, a contrast was used to test whether neural activation associated with emotional primes differentiated whether subsequent Judgements were emotion-congruent or not. A contrast compared activation from the Negative Prime screen for trials in which participants indicated they later saw the angry face to activation from the Negative Prime screen for trials in which participants indicated they later saw the happy face (Prime screen: Negative Prime Angry Judgment > Negative Prime Happy Judgment). Therefore, this contrast and its inverse (Prime screen: Negative Prime Happy Judgment > Negative Prime Angry Judgment) yielded activation associated with the negative emotional primes that was differentiated by subsequent emotion-congruent (or emotion-incongruent) judgment rather than a difference of emotional prime valence. Second, an analogous approach tested neural activation associated with Judgment screens. To identify activity associated with making an emotion-congruent judgment, we compared activation from Judgment screens in which participants indicated they saw an angry face following a Negative Prime to activation from Angry Judgments following a Neutral Prime (Judgment screen: Negative Prime Angry Judgment > Neutral Prime Angry Judgment). In this way, activity differences to Angry Judgments indicated a relation to whether the preceding prime was emotion-congruent rather than a difference in the valence of the judgment. To identify activity associated with making an emotion-incongruent judgment, we compared activation from Judgment screens in which participants indicated they saw a happy face following a Negative Prime to activation from Happy Judgments following a Neutral Prime (Judgment screen: Negative Prime Happy Judgment > Neutral Prime Happy Judgment). Similarly, neural activity differences to Happy Judgments indicated a relation to whether the preceding prime was emotion-incongruent rather than a difference in the valence of the judgment. Results were interpreted using regions of interest (ROIs) derived from previous research on emotion-congruence and emotion interference in judgment (Bechara, Tranel, & Damasio, 2000; Beer et al., 2006; Bishop, Duncan, & Lawrence, 2004; Camille et al., 2004; Coricelli et al., 2005; Egner et al., 2008; Elliott, Rubinsztein, Sahakian, & Dolan, 2002; Etkin et al., 2006; Kuhnen & Knutson, 2005; Ochsner et al., 2009). Specifically, activation clusters were corrected for the size and shape of the relevant neuroanatomical volume of interest in the Automated Anatomical Labelling map (Tzourio-Mazoyer et al., 2002) (family-wise error corrected (FWE) $p<.05$ threshold, search volumes: lateral OFC, medial OFC, ventrolateral prefrontal (VLPFC: triangular and opercular part of inferior frontal gyrus), dorsolateral prefrontal (DLPFC: middle frontal gyrus), dorsomedial prefrontal (DMPFC: medial superior frontal gyrus), ACC, striatum, insula, and amygdala. Marsbar software was used to extract region of interest (ROI) parameter estimates from significant clusters for each event type (Brett et al., 2002). Furthermore, we tested these ROIs for an interaction between Prime (Negative or Neutral) and Judgment (Angry or Happy) to verify that activity was driven up in emotion-congruent trials (Negative Prime Angry Judgment) compared to the other conditions. Similarly, for regions associated with emotion-incongruent judgment, we tested the same interaction of Prime and Judgment to verify that activity was driven up in emotion-incongruent trials (Negative Prime Happy Judgment).

Finally, conjunction analyses were conducted using the Minimum Statistic compared to the Conjunction Null (Nichols, Brett, Andersson, Wager, & Poline, 2005) to test whether any of our significantly activated regions held for both Prime Screen and Judgment Screen contrasts.

Results

BEHAVIORAL RESULTS

Consistent with previous research, Negative Primes influenced judgments in an emotion-congruent pattern (Beevers et al., 2009; Joormann & Gotlib, 2007; Lewis et al, 2005; Murphy & Zajonc, 1993). Participants indicated that they saw the angry expressions more frequently in the Negative Prime condition (M=53.72% of judgments, $S.D.$=10.04%) compared to the Neutral Prime condition (M=43.83%, $S.D.$=10.61%; $t(16)=3.83$, $p<.05$) and unprimed judgments (M=46.63%, $S.D.$=7.90%, $t(33)=2.33$, $p<.05$). Judgments in the Neutral Prime condition were not significantly different from unprimed judgments ($t(33)=.89$, $p=.38$). Whereas participants who performed judgments without primes were significantly less likely than chance to indicate the angry face, participants in the primed study showed a marginally significant trend to indicate the angry face more often than chance in the Negative Prime condition ($t(16)=1.53$, $p=.07$, one-tailed).

Response times in the fMRI study did not significantly differ according to prime valence ($F(1,16)=.20$, $p > .05$), judgment valence ($F(1,16)=2.21$, $p > .05$), or the interaction of prime valence and judgment valence ($F(1,16)=2.95$, $p>.05$; Negative Prime Angry Response mean latency=900ms, *S.D.*=169; Negative Prime Happy Response mean latency=886ms, *S.D.*=148; Neutral Prime Angry Response mean latency=932ms, *S.D.*=161; Neutral Prime Happy Response mean latency=869ms, *S.D.*=161).

FMRI RESULTS

VMPFC negative prime and judgment activity distinguishes affectively-influenced judgments.

VMPFC activity relates to affectively-influenced judgments by showing activity related to emotion-congruent judgment, regardless of whether emotion-congruence is operationalized as negative primes that lead to negative judgments or as negative judgments following negative primes. VMPFC activity was greater for Primes that led to emotion-congruent judgments (Prime Screen: Negative Prime Angry Judgment > Negative Prime Happy Judgment: peak=-16, 36, -18, Brodmann Area (BA) 11, $t(16)=4.15$, $p<.05$ FWE). Additionally, VMPFC activity during Judgments was associated with emotion-congruent influences from preceding emotional cues. VMPFC activity was greater for Angry Judgments influenced by the Negative Prime compared to the Neutral Prime (Judgment Screen: Negative Prime Angry Judgment > Neutral Prime Angry Judgment: peak=-2, 44, -18, Brodmann Area (BA) 11, $t(16)=4.91$, $p<.05$ FWE). Further analyses confirmed that VMPFC activity is driven up by emotion-congruent judgment in comparison to all experimental conditions. Parameter estimates from the Prime contrast showed a significant interaction between Prime (Negative or Neutral) and Subsequent Judgment (Angry or Happy) ($F(1,16)=7.84$, $p<.05$). Figure 6A shows that

VMPFC derived from the Prime Contrast was most engaged by Negative Primes when they led to emotion-congruent judgments. Parameter estimates from the Judgment contrast showed a significant interaction between Prime (Negative or Neutral) and Judgment (Angry or Happy) interaction ($F(1, 16)=15.58$, $p<.05$). Figure 6B shows that VMPFC derived from the Judgment contrast was most engaged in relation to emotion-congruent Angry Judgments on Negative Primed trials. Finally, a conjunction analyses did not show significant overlap in theses VMPFC regions. That is, the regions of VMPFC that showed emotion-congruent activity related to the Prime (peak: -16, 36, -18) were distinct from those showing emotion-congruent activity related to Judgment (peak: 2, 44, -18).

Figure 6.

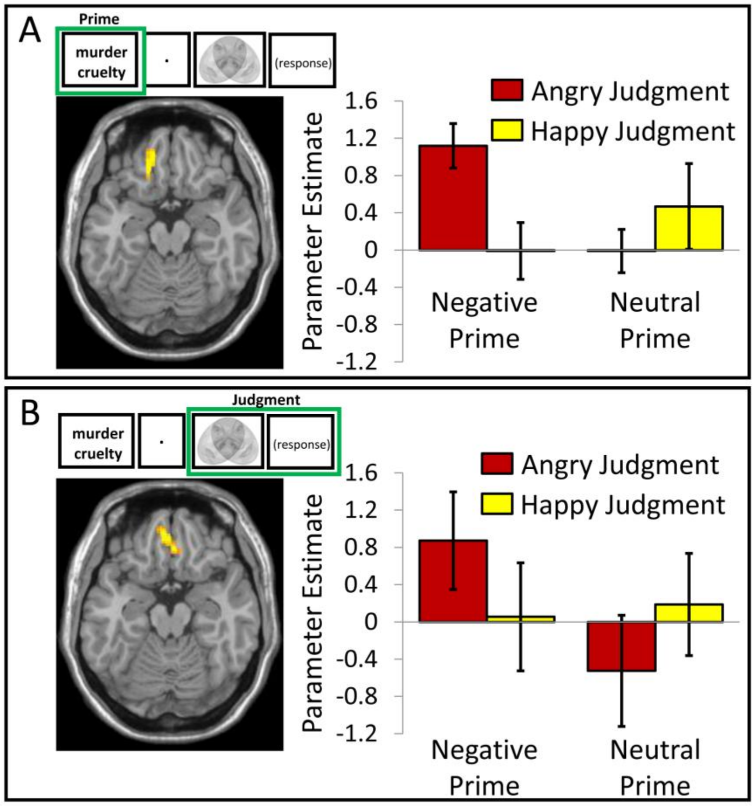

Figure 6. VMPFC emotion-congruent activity related to processing emotional primes and judging equivocally positive and negative stimuli.

A) Left column: A cluster of left VMPFC (peak = -16, 36, -18) shows increased activity to Negative Primes that lead to emotion-congruent judgments (Prime Screen: Negative Prime Angry Judgment > Negative Prime Happy Judgment, $p<.05$, FWE). Right column: parameter estimates for activity in this region related to Negative and Neutral Primes, split by whether the subsequent judgment was Angry or Happy. B) Left column: A cluster of bilateral VMPFC (peak = 2, 44, -18) shows increased activity during emotion-congruent judgments (Judgment Screen: Negative Prime Angry Judgment > Neutral Prime Angry Judgment, $p<.05$, FWE). Right column: parameter estimates for activity in this region related to Judgments following Negative and Neutral Primes, split by whether the judgment was Angry or Happy. Error bars represent standard error.

In summary, analyses of Prime-related and Judgment-related neural activity suggests that VMPFC regions are involved in emotion-congruent judgment in two ways:

processing emotional stimuli such that they predict subsequent emotion-congruence of judgment and in making valence judgments that are congruent with emotional primes.

DMPFC and right lateral prefrontal cortex are associated with emotion-incongruent judgment.

Bilateral DMPFC, right VLPFC, and right lateral OFC activity was greater for emotion-incongruent judgments (Judgment Screen: Negative Prime Happy Judgment > Neutral Prime Happy Judgment: left DMPFC peak=-4, 54, 34, BA 9, $t(16)=5.77$, $p<.05$ FWE; right DMPFC peak=10, 54, 24, BA 9, $t(16)=5.22$, $p<.05$ FWE; right VLPFC peak=44, 16, 26, BA 44, $t(16)=5.65$, $p<.05$ FWE; right lateral OFC peak=46, 36, -16, BA 47, $t(16)=5.29$, $p<.05$ FWE). Further analyses confirmed that activity in these regions is driven up by emotion-incongruent judgment in comparison to all experimental conditions. Parameter estimates of judgment activity derived from these regions were characterized by an interaction of Prime (Negative or Neutral) and Judgment (Happy or Angry) (left DMPFC: $F(1,16)=11.28$; right DMPFC: $F(1,16)=11.83$; right VLPFC: $F(1,16)=5.27$; right lateral OFC: $F(1,16)=7.75$; all $p<.05$). Activity in these bilateral DMPFC, right VLPFC, and right lateral OFC regions was most engaged for emotion-incongruent Happy Judgments on Negative Primed trials. Figure 7 shows that activity derived from the Judgment contrast was most engaged in relation to emotion-incongruent Happy Judgments following Negative Primes. In summary, bilateral DMPFC, right VLPFC, and right lateral OFC activity was associated with making valence judgments that were incongruent with emotional primes.

Figure 7.

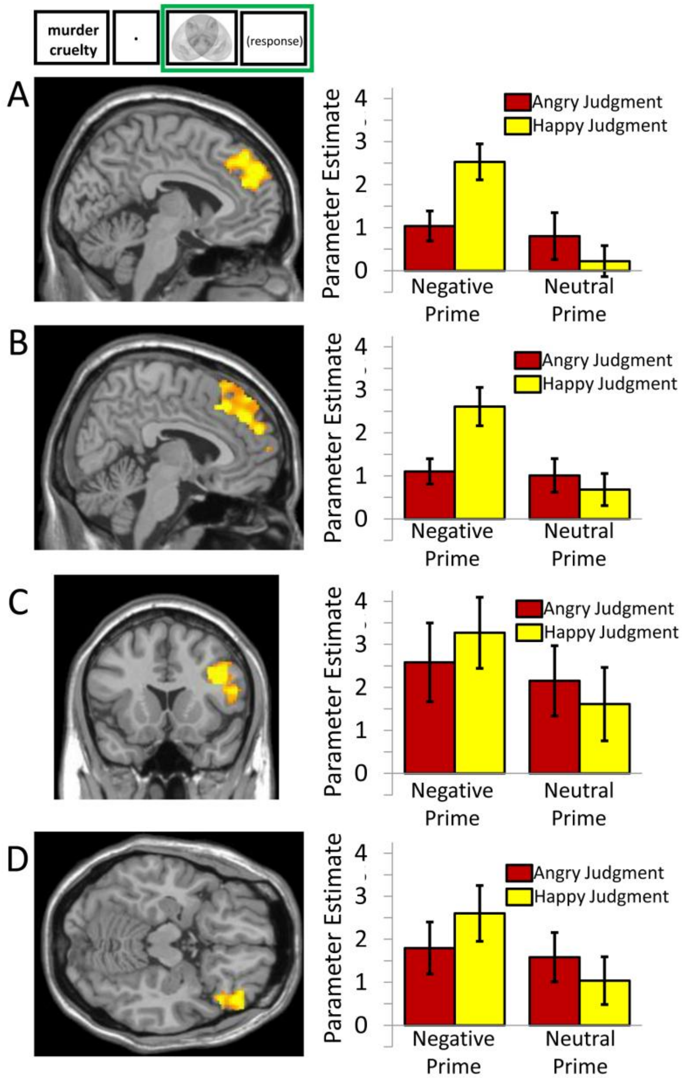

Figure 7. Emotion-incongruent neural activity related to judging equivocally positive and negative stimuli.

Left column shows clusters with increased activity during emotion-incongruent judgments (Judgment Screen: Negative Prime Happy Judgment > Neutral Prime Happy Judgment, p<.05, FWE). Right column shows parameter estimates for activity in each region related to Judgments following Negative and Neutral Primes, split by whether the judgment was Angry or Happy. A) Left DMPFC (peak=-4, 54, 34). B) Right DMPFC (peak=10, 54, 24). C) Right VLPFC (peak=44, 16, 26). D) Right lateral OFC (peak=46, 36, -16). Error bars represent standard error.

Discussion

Study 2 used a novel operationalization of emotion-congruent judgment to build upon previous neural research that has inferred rather than manipulated the influence of affect in judgment. Emotion-congruent processing was operationalized in two ways: neural activation associated with primes that lead to emotionally-congruent judgments and neural activation associated with judgments that were preceded by emotionally-congruent primes. Distinct VMPFC regions were associated with these patterns of emotion-congruent processing. These results suggest that VMPFC is important in System 1 processes that incorporate affective information into judgment. One VMPFC region may be involved in responding to an emotional event in a way that influences future judgments. Another VMPFC region may be involved in processing judgment information in a way that incorporates existing affective states.

One difference between Study 1 and Study 2 is that VMPFC was associated with affect-driven judgments but not non-affective probabilistic judgments. There are several explanations possible for this difference between Study 1 and Study 2 findings. For one, Study 2 addressed a limitation of Study 1 by eliciting judgments that were more unambiguously associated with System 1. That is, Study 1 probabilistic judgments may not have unambiguously elicited System 1 processing and thus VMPFC was activity was not associated with probabilistic judgments. It is also possible that VMPFC activity was simply not detected in Study 1 due to Type II error. A third possibility is that VMPFC is specifically involved in using probabilistic information that is affective in nature. Further research might directly compare neural systems underlying the use of affective compared to non-affective probabilistic information in judgment.

There were a number of parallels between the neural regions associated with emotion-incongruent judgment in Study 2 and neural regions previously associated with System 2 processes such as monitoring for interfering affective information. In Study 2, DMPFC, VLPFC, and LOFC activity increased when participants made judgments that were inconsistent with the valence of a preceding prime. Regions similar to the DMPFC, VLPFC, and lateral OFC emotion-incongruent judgment regions have been associated with monitoring for emotional information that interferes with a task (Bishop, Duncan, Brett, & Lawrence, 2004; Elliott, Dolan, & Frith, 2000; Etkin et al., 2006; Kringelbach, 2005; Ochsner et al., 2009). For example, in previous research, emotional information interfered when the task was to judge the valence of an angry facial expression that was imprinted with the interfering word ‘happy’. If negative affective primes interfered with participants making positive judgments, then emotion-incongruent judgments may have involved System 2 processing to monitor for interference from the affective prime. To the extent that emotion-incongruent judgments involve monitoring for interfering emotional information, then the current findings converge with previous research associating DMPFC, VLPFC, and LOFC with System 2 processes (Sanfey et al., 2006; Satpute & Lieberman, 2006).

STUDY 3: NEURAL REGIONS ASSOCIATED WITH DUAL-PROCESS INTERACTION

Introduction

Whereas Study 1 and Study 2 examined neural regions associated with judgments characteristic of System 1 and System 2, Study 3 examines neural associations with a form of dual-process interaction in judgment. One form of dual-process interaction is when System 2 processes adjust System 1 output to incorporate additional information into a judgment (Chaiken, 1987; Kahneman and Frederick, 2002; Petty & Cacioppo, 1986). One example is when a hiring manager makes a heuristic-based preliminary judgment of a job candidate's competence based only on the candidate's physically attractive appearance, but then re-evaluates the candidate after learning additional information (e.g., candidate's lack of work experience, poor reference letters). The manager *adjusts* her preliminary judgment to the extent that the re-evaluation is lower than the preliminary judgment of the candidate. That is, if the re-evaluation is the same as the preliminary judgment, then the manager did not incorporate additional information and did not adjust her preliminary heuristic-based judgment. If the re-evaluation is lower than the preliminary judgment, then the manager incorporated the additional information to adjust the preliminary judgment. The preliminary judgment is characteristic of System 1 because it is based on an imperfect association between attractiveness and competence. That is, people tend to use attractiveness-based heuristics in competence judgments even though physical attractiveness is a fallible indicator of job competence (Dion et al., 1972; Eagly et al., 1991; Feingold, 1992; Jackson et al., 1995). The adjustment of the preliminary judgment is characteristic of System 2 because the adjustment incorporates information about work experience and reference letters which is relatively more complex (multiple factors) and relatively more informative about competence. Study 3 examines the neural regions associated with adjusting heuristic-based preliminary judgments to incorporate additional information, which is an under-examined form of interaction between System 1 and System 2 processes in social judgment.

The examination of neural regions associated with adjusting heuristic-based judgments can contribute to a better understanding of how neural regions support social judgments. Amygdala, insula, striatum, VMPFC and DMPFC regions have been associated with social judgment but it is unclear whether regions are associated with System 1 or System 2-type processes, or their interaction (Adolphs, Tranel, & Damasio, 1998, 2003; Engell, Haxby, & Todorov, 2007; Harris & Fiske, 2007; Kim, Adolphs, O'Doherty, & Shimojo, 2007; Rule et al., 2010, 2011; Schiller, Freeman, Mitchell, Uleman, & Phelps, 2009; Todorov & Engell, 2008). There is some understanding of neural regions associated with dual-process interactions that involve monitoring and inhibition, but little understanding of interactions that involve adjustment. VLPFC, DLPFC, and DACC have been associated with System 2 processing to monitor and inhibit System 1 output in social judgments, such as the monitoring and inhibition of negative automatic associations with racial outgroups (Cunningham et al., 2004; Richeson et al., 2003). However, System 2 processing to adjust System 1 output has been relatively unexplored in neural research on social judgment. What neural regions are associated with System 2 processing of additional information to adjust a System 1-based social judgment? Are those neural regions engaged to the degree that people adjust their judgments? Are the neural regions associated with adjustment similar to regions associated with monitoring and inhibition in previous research?

To address these questions, Study 3 examines neural activity related to the manipulation of System 1 processing in preliminary social judgments, and neural activity related to the manipulation of System 2 processing in the adjustment of those preliminary judgments. Participants played the role of a hiring manager and judged the competence of candidates based on photographs and videos of the candidate making statements in a job interview. System 1 processing is operationalized by the use of a candidate's physical attractiveness (from the photograph) to make a preliminary judgment of the candidate's competence. System 2 processing to adjust System 1 output is operationalized by the incorporation of additional information (from the candidate's videos) into a re-evaluation that reflects adjustment of the preliminary judgment. The degree of adjustment is operationalized as the difference between the re-evaluation and the preliminary judgment. Information about the candidates in the videos is parametrically manipulated to elicit different degrees of adjustment. Preliminary judgments of the candidates' competence are hypothesized to be higher for physically attractive compared to less attractive candidates (Dion et al., 1972; Eagly et al., 1991; Feingold, 1992; Jackson et al., 1995). Adjustment of preliminary judgments is hypothesized to be related to the level of competence shown by the candidates in their videos.

Methods

PARTICIPANTS

Twenty five female students from the University of Texas at Austin underwent fMRI while judging job candidates based on pictures and videos displayed inside the scanner (ages 18-21 years, mean age = 18.6, *S.D.* = .82). Female participants made competence judgments of male candidates because meta-analyses of attractiveness effects on competence judgments have shown that the effect of attractiveness is strongest for female judges rating male targets (Eagly et al., 1991; Feingold, 1992). Participants were compensated $15 per hour or received course credit for their participation. Participants were native English speakers screened for magnetic resonance imaging safety-compatibility, psychological and neurological conditions and medications that might influence the measurement of cerebral blood flow. All participants provided informed consent and the study was approved by the institutional review board of the University of Texas at Austin.

SOCIAL JUDGMENT TASK

In the social judgment task, participants made judgments based on photos and video clips (with audio) of male job candidates interviewing for an open position at a hypothetical large corporation. Participants were instructed that they were to put themselves in the place of the hiring manager and judge each candidate's competence on a scale from 1 (low competence) to 5 (high competence). The open position was described as a general administrative position involving a variety of duties that help to keep the office running smoothly. Participants were instructed that they should give their honest impressions about each applicant based on whatever information was available to them.

Figure 8.

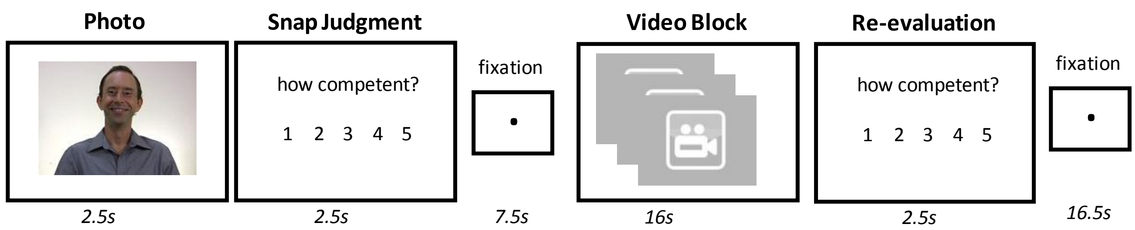

Figure 8. Social judgment task.

In each trial of the task, participants viewed a photo of a candidate manipulated for Attractiveness (2.5s), made a competence judgment of the candidate (2.5s), viewed a fixation screen (7.5s), viewed 3 video clips (with audio) of the candidate making job interview statements (parametrically manipulated for Competence Level) (16s), made a second competence judgment of the candidate, then viewed a fixation screen (16.5s) before the sequence of events repeated for the next trial with a new candidate.

Stimulus presentation and response collection was controlled by the E-Prime 2.0 software package (Psychological Software Tools, http://www.pstnet.com/eprime.cfm). On each trial of the task, participants rated one applicant's competence on two occasions: (1) after seeing only a photograph and (2) after seeing a block of 3 video clips of the applicant (see Figure 8). Specifically, for each social target, participants made a preliminary competence judgment (snap judgment) of the target based only on a photograph (five-point scale with anchors 1="not at all competent" and 5="extremely competent"). They then viewed three audio/video clips of the target (5.33s each, total duration of the three video clips was 16s) and finally made a re-evaluation of the target's competence on the same scale as the snap judgment. Blank fixation screens separated the snap judgment from the video block (7.5s), and the re-evaluation from the next trial

(16.5s). Two factors were manipulated within-participants in a 2 (Attractiveness: High or Low) X 4 (Competence: 4 increasing levels) design. The Attractiveness factor was determined by the physical attractiveness of the candidate (candidates were selected as high or low attractiveness based on ratings from a separate sample of participants from the same community as the fMRI study participants). The Competence factor was determined by the three video clips portraying the candidate at one of four levels of competence. Level of Competence was manipulated by changing the number of high (e.g., “I enjoy a challenge”) and low competence statements (e.g., “I don’t take criticism well”) made by each candidate. Specifically, the candidates were presented making zero high/three low competence statements (Competence Level 1), one high/two low (Competence Level 2), two high/one low (Competence Level 3), or three high/zero low (Competence level 4; see Table 4). Candidates were randomly assigned to each Competence level across participants so that candidates were equally associated with each Competence level. Participants viewed and judged 20 High and 20 Low Attractiveness candidates. Of those 20 candidates from each Attractiveness level, 5 targets were portrayed at each Competence level. Candidates and conditions were presented in a random order to each participant. Furthermore, the specific high and low competence statements made by each candidate were randomly selected from a bank of video clips and randomly ordered within each video block. Importantly, snap judgments occurred before video clips were shown, therefore Competence level was not relevant to participants’ photograph-based snap judgments. Participants performed two practice trials of the social judgment task before entering the scanner.

Table 4. Description of the Competence Level manipulation (an example)

Competence Level	Example statements made by candidate during video block
1	I have problems with authority; I don't like deadlines; I get anxious around people
2	I have problems with authority; I don't like deadlines; I appreciate criticism
3	I have problems with authority; I appreciate criticism; I enjoy a challenge
4	I appreciate criticism; I enjoy a challenge; I am a quick learner

Note: Candidates made three statements in each video block. Specific High and Low competence statements and their ratio were randomly selected from a list for each condition (see Appendix A) such that participants did not see any candidates make the same statement. Example statements are abbreviated versions of statements used in the study.

STIMULI

Stimuli were created by photographing and videotaping 50 male actors playing the role of a job candidate and making scripted high and low competence job interview statements (see Appendix A). All actors wore a solid color button-up dress shirt and were photographed and videotaped looking directly into the camera with only their head and upper chest visible in the frame. Each actor made 36 high competence statements and 36 low competence statements. Each statement was edited into a single video clip (with audio) 5.33s long (the final 0-.5s of each clip was a black blank screen), resulting in a total of 3600 video clips. High and low competence statement video clips were randomly selected to present to each participant so that no candidate was associated with a specific set of statements, and no statements were repeated for a participant. The stimuli used in the fMRI experiment were created from the 20 actors who were rated as most attractive and 20 actors who were rated as least attractive by a sample of 40 female judges who were drawn from the same general population (i.e., undergraduates at the University of

Texas at Austin) as the participants in the fMRI study. No judges were included as participants in the fMRI study.

FMRI DATA ACQUISITION

All images were collected on a 3.0-T GE Signa EXCITE scanner at the University of Texas at Austin Imaging Research Center. Functional images were acquired with an EPI sequence (TR=2500ms, TE=30 ms, FOV=220mm, 64 x 64 matrix, 32 axial slices 3mm thick with a .5mm gap, voxel size 3.44 x 3.44 x 3.5mm). Functional volume acquisitions were time-locked to the onset of the first screen at the beginning of each trial. A high resolution SPGR T1-weighted structural image was also acquired from each participant as well as a T2-weighted structural image coplanar with the functional scan. Functional images were collected in four consecutive 8 minute, 10s long scans (participants completed 10 trials of the social judgment task during each scan). fMRI data for one scan (10 trials out of 40) for one participant were lost due to hardware problems, analyses for this participant were conducted on the available data.

FMRI DATA ANALYSIS

Preprocessing and GLM analysis

Neuroimaging data were preprocessed and analyzed with the FSL software package version 4.1 (FMRIB's Software Library, http://www.fmrib.ox.ac.uk/fsl/). Functional images were corrected for head motion using rigid-body transformation parameters and then corrected for slice-timing skew using temporal sinc-interpolation. A high pass filter was then applied to remove low frequency noise (cutoff period 47.5s equal to the length of a full trial). Data was resampled to 2mm cubic resolution and spatially smoothed with a 5mm FWHM isotropic Gaussian kernel. For analyses across participants, functional images for each participant were spatially normalized into the Montreal Neurological Institute (MNI) standard brain template, using the T2-weighted coplanar structural image for initial registration and the high resolution T1-weighted structural image for registration to the MNI T1 template.

Statistical analyses were performed on individual participants' fMRI data using a GLM. For each of the four functional scans for each participant, events were modeled by regressors convolved with a canonical double-gamma response function in FSL's FEAT first-level analysis package. These regressors modeled fMRI signal changes related to a) viewing a photograph and making an initial judgment response (Snap Judgment: 5s duration), and b) viewing a block of videos and making a second judgment response (Re-evaluation: 18.5s duration). Snap Judgment regressors and Re-evaluation regressors were entered for High Attractiveness and Low Attractiveness conditions. The Re-evaluation regressors were parametrically weighted by the Competence Level of each trial (1-4), to model neural signal that increased or decreased as a linear function of Competence Level. The act of making a judgment response was not separated from the viewing of photos or videos because responses immediately followed photos or videos and there was no way of separating the act of responding from the processing of information for judgment due to the delay in the BOLD signal. The regressors were entered into the GLM along with 6 regressors of non-interest modeling the participant's head movement during the scan. The resulting least squares parameter estimates were used to create contrast maps (described below), which were averaged across the four scans for each participant with a fixed-effects analysis. Finally, contrast maps were spatially normalized and entered into a group level random-effects analysis to generate a z-statistic map for each contrast. Group level analysis utilized the FLAME (FMRIB's Local Analysis of Mixed Effects) approach in FSL. Group level z-statistic contrast maps were corrected for multiple comparisons using a cluster correction with a cluster determining threshold of $z > 2.57$ and a corrected cluster significance threshold of $p < .05$ (Worsley, 2003). In the amygdala, where there is a priori support for modulation by physical attractiveness and by social judgments (e.g., Adolphs et al., 1998; Engell et al., 2007; Kim et al., 2007; Rule et al., 2011; Schiller et al., 2009; Winston, O'Doherty, Kilner, Perrett, & Dolan, 2007), small volume corrections (SVC) were based on structurally-defined left and right amygdala masks from the Harvard-Oxford structural probability atlas distributed with FSL (Smith et al., 2004).

Examination of neural activity related to heuristic-based snap judgments of competence (System 1 processing).

Neural regions involved in making heuristic-based social judgments should show activity influenced by the information used in the heuristic (i.e., attractiveness). As a first step, neural contrasts were calculated to examine neural activity during snap judgments of competence that was influenced by the manipulation of candidate attractiveness. Neural activity was examined with a contrast of High Attractiveness Snap Judgments versus Low Attractiveness Snap Judgments (and vice versa). A further test examined whether this neural activity was more specifically related to the extent to which participants' used attractiveness information in their snap judgments of competence (i.e., each participant's average competence rating of High Attractiveness candidates and average competence rating of Low Attractiveness candidates). A percent signal change value was calculated for each participant in neural regions that passed the significance threshold in the snap judgment attractiveness contrast described above (using the Featquery function of FSL). Individual differences in percent signal change values for High and Low Attractiveness Candidates were then tested for significant correlation with individual differences in snap judgment competence ratings for High and Low Attractiveness participants, to examine whether greater differences in competence ratings were related to greater neural signal change related to the attractiveness of candidate photographs.

Examination of neural activity related to adjusting heuristic-based snap judgments (System 2 processing to adjust System 1 output)

Neural regions involved in the adjustment of a heuristic-based judgment must 1) process additional competence-relevant information (beyond information used in the heuristic), and 2) incorporate that additional information into a re-evaluation by adjusting the preliminary heuristic-based judgment. That is, neural activity related to adjusting heuristic-based snap judgments should show two patterns in the current study. First, the Competence Level manipulation should influence neural activity during re-evaluation. That is, neural activity should parametrically increase or decrease in relation to the parametrically manipulated Competence Level. Second, neural activity should be related to the amount of adjustment (i.e., the degree to which additional information influences re-evaluation). These patterns of neural activity were examined separately for the High and Low Attractiveness conditions because preliminary judgments were expected to differ by attractiveness and thus there would be different starting points for the process of adjustment. Analyses were done in two steps: one step to examine neural activity influenced by Competence Level and one step to examine neural activity related to the amount of adjustment.

In the first step, the influence of the Competence Level manipulation on neural activity was tested by contrasts describing the parametric relationship between Competence Level and neural activity. Specifically, parametric Competence Level contrasts (Re-evaluation regressor weighted by Competence Level) examined activity that increased or decreased as a linear function of Competence Level. To test whether neural regions were influenced by Competence Level similarly for each Attractiveness condition, a conjunction analysis identified regions that increased or decreased parametrically with Competence Level for High as well as Low Attractiveness candidates (using the Minimum Statistic compared to the Conjunction Null; Nichols et al., 2005).

In the second step, analyses tested the relationship between neural activity and the amount of adjustment (i.e., the degree to which additional information influences re-evaluation). These analyses were conducted at two complementary levels: one examining variance at the *trial-level* and one examining variance at the *participant-level*.

For the *trial-level* analysis, a procedure identified neural regions where activity was related to the amount that participants adjusted their snap judgments on each trial. First, Judgment Adjustment scores for each trial were calculated as the participant's re-evaluation competence rating minus her snap judgment competence rating of the candidate in each trial. Then, a GLM was setup identically to the GLM described above (in the "Preprocessing and GLM setup" section), except Re-evaluation regressors were weighted by the Judgment Adjustment score for each trial and contrast maps were calculated based on parameter estimates for each Judgment Adjustment-weighted Re-evaluation regressor. The group level contrasts were inclusively masked by voxels showing a significant parametric relation to Competence Level. An additional regressor of non-interest was added in the GLM (Re-evaluation regressor weighted by the participant's snap judgment of competence on each trial) to ensure that neural activity attributed to Judgment Adjustment was not driven by differences in initial snap judgments. This procedure identified neural regions where activity linearly related to the amount that participants adjusted their snap judgments on each trial.

For the *participant-level* analysis, a relationship was tested between summary measures of behavioral judgment adjustment for each participant and summary measures of neural activity related to judgment adjustment for each participant. First, *participant-level* Competence Influence Slopes were calculated to summarize how much each participant changed her re-evaluation as a function of the Competence Level. The Competence Influence Slopes were the slope of the regression of re-evaluation ratings against the Competence Level, such that a greater increase in re-evaluation as a function of Competence Level is indicated by a greater Competence Influence Slope. Next, a summary measure of neural activity related to judgment adjustment was calculated for each participant. Percent signal change values for the parametric Competence Level contrast were extracted for each participant in each region that showed a significant parametric effect of Competence Level (using the Featquery function of FSL). These percent signal change values in each region were tested for significant correlation with participants' Competence Level Slopes. This procedure identified relationships between neural regions and the degree to which participants changed their re-evaluations as a function of Competence Level.

The tests for *trial-level* relationships and *participant-level* relationships are both intended as convergent evidence of a relationship between neural activity in a region and the process of incorporating additional information to adjust a System 1-driven judgment. However, it would not be unusual to find a significant *trial-level* relationship in the absence of a *participant-level* relationship because 1) *trial-level* relationships are based on more observations (40 trials each for 25 participants) than *participant-level* relationships (25 participants) and 2) the manipulations were at the *trial-level* (within-subjects) and therefore the study was not designed to examine *participant-level* differences.

Results

BEHAVIORAL RESULTS

Attractive candidates are judged as more competent in snap judgments.

Although participants were asked to rate each candidate's competence during the scanning sessions, not their physical attractiveness, physical attractiveness did influence ratings. Consistent with previous research (Dion et al., 1972; Eagly et al., 1991; Feingold, 1992; Jackson et al., 1995), participants rated physically attractive candidates as more competent than physically unattractive candidates. Snap judgments of competence based on photographs of High Attractiveness candidates (*M*=3.71, *S.D.*= .64) were higher than competence judgments of Low Attractiveness candidates (*M*=3.03, *S.D.*=.62; t(24)=6.69, p<.05; Figure 9A). Response times for snap judgments did not differ for High (*M*=889ms, *S.D.*=264ms) or Low Attractiveness candidates (*M*=934ms, *S.D.*=241ms; t(24)=1.17, p=.26). Attractiveness ratings made by participants after the scanning session verified that the High Attractiveness candidates were actually seen as more attractive than the low attractiveness candidates by the fMRI study participants (High: *M*=2.81, *S.D.*=.52; Low: *M*=1.62, *S.D.*=.39; t(24) = 17.30, p<.05).

Figure 9.

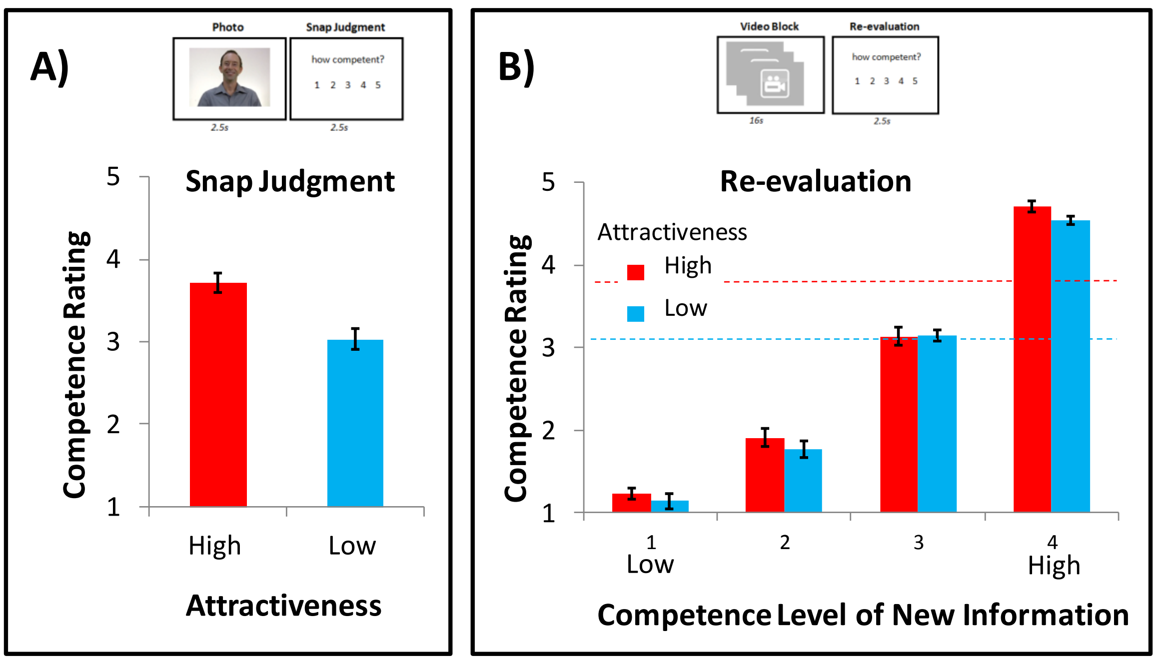

Figure 9. Snap judgments and re-evaluations of candidates’ competence.

Bar charts show mean judgments on a five-point scale of competence. A) Based only on a candidate’s photograph, snap judgments of competence were higher for High compared to Low Attractiveness candidates (p<.05). B) Re-evaluations were made after participants viewed videos that portrayed candidates at one of four Competence Levels. Dashed lines represent the average snap judgment for High and Low Attractiveness candidates (same as chart A) such that the distance from each bar to the corresponding dotted line represents how much participants adjusted their initial snap judgments after viewing additional information about the candidates. Re-evaluations showed a main effect of candidate Attractiveness (High Attractiveness candidates were rated more competent), and a main effect of Competence Level such that ratings increased significantly between increasing Competence Levels (all $p<.05$). Error bars represent standard error.

Competence level information is used to adjust snap judgments of candidate's competence.

Re-evaluations of candidates' competence showed influences of both competence-related information in the videos as well as attractiveness information from the photographs. That is, candidates portrayed as highly competent in videos were rated more competent than candidates portrayed as low competence. Furthermore, highly attractive candidates were still overall rated more competent than less attractive candidates. That is, competence information provided in video blocks had the expected influence on participants' re-evaluations of each candidate, and the influence of candidate attractiveness persisted in participants' re-evaluations even after they viewed equal competence-related information about High and Low Attractiveness candidates. A 2 (Attractiveness: High, Low) X 2 (Competence Level: 4 increasing levels) analysis-of-variance (ANOVA) on re-evaluations showed a main effect of Competence Level ($F(3,22)=490.84$, $p<.05$; Figure 9B) and a main effect of Attractiveness such that High Attractiveness candidates were rated more competent than Low Attractiveness candidates collapsing across Competence Levels ($F(1,24)=6.73$, $p<.05$). There was no significant interaction ($F(3,22)=1.11$, $p=.35$). Competence influenced re-evaluations in the expected direction, such that re-evaluations of both High and Low Attractiveness candidates increased significantly between each Competence level (High Attractiveness: comparison of lowest two competence levels Level 1 < Level 2 t(24)=7.38, middle two levels Level 2 < Level 3 t(24)=8.37, highest two levels Level 3 < Level 4 t(24)=12.24; Low Attractiveness: lowest two competence levels Level 1 < Level 2 t(24)=9.40, middle two levels Level 2 < Level 3 t(24)=14.63, highest two levels Level 3 < Level 4 t(24)=10.37; all p<.05).

Figure 10.

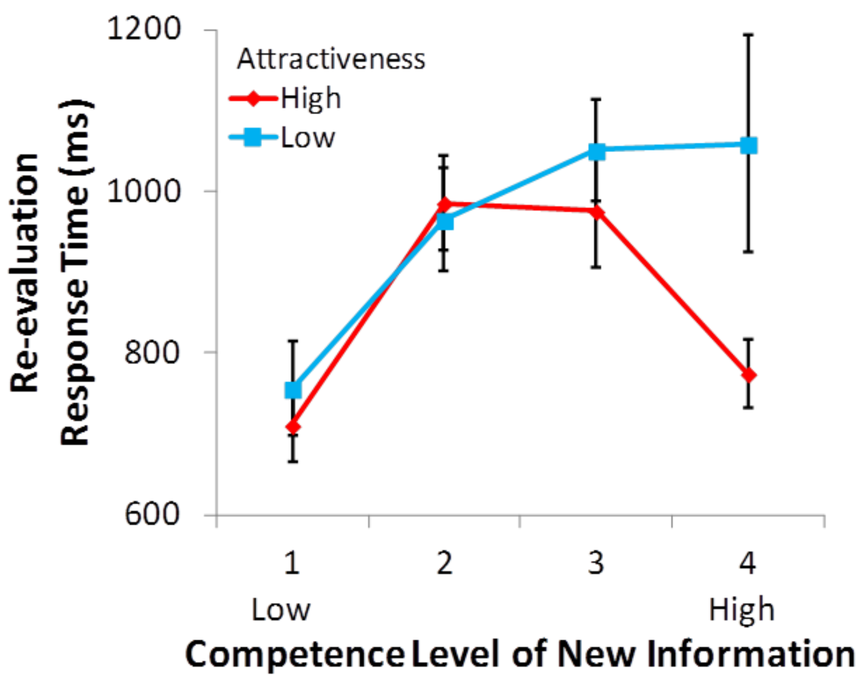

Figure 10. Re-evaluation response times are increased by ambivalent additional information and by additional information inconsistent with associations of low attractiveness with low competence.

Re-evaluations of High Attractiveness candidates take longer when additional information is ambivalent (i.e., a mix of high and low competence information in Competence Levels 2 and 3). Re-evaluations of Low Attractiveness candidates take longer when additional information shows they are high competence.

Additional information influenced how long participants took to re-evaluate candidates, but did so differently for High and Low Attractiveness candidates (see Figure 10). If additional information about attractive candidates was ambivalent (i.e., the candidate made a mix of high and low competence statements), re-evaluations of attractive candidates took longer than if additional information was univalent (i.e., the candidate made all high or all low competence statements). If additional information about low attractiveness candidates was high competence (i.e., inconsistent with the association of low attractiveness with low competence) re-evaluations took longer than if additional information was low competence. A 2 (Attractiveness: High, Low) X 2 (Competence Level: 4 increasing levels) ANOVA of re-evaluation response times showed a main effect of Attractiveness ($F(1,24)=4.25$, $p=.05$), a main effect of Competence Level ($F(3,22)=8.66$, $p<.05$), and an interaction of Attractiveness and Competence Level ($F(3,22)=3.64$, $p=.05$). Post-hoc tests of polynomial contrasts showed a quadratic effect of Competence Level for the High Attractiveness condition ($F(1,24)=31.33$, $p<.05$; linear effect not significant), and a linear effect of Competence Level for the Low Attractiveness condition ($F(1,24)=9.42$, $p<.05$; quadratic effect not significant). Re-evaluation response times increased with increasing levels of high competence information for Low Attractiveness candidates, but for High Attractiveness candidates response times increased when there was mixed high and low competence information (compared to all high or all low competence information). This pattern of response times suggested that the process of incorporating additional information to adjust a preliminary judgment was influenced by the ambivalence of the additional information and its inconsistency with associations of low attractiveness with low competence.

FMRI RESULTS

Left amygdala activity is associated with snap judgments.

Left amygdala activity was influenced by the manipulation of information used in heuristic-based snap judgments of competence. That is, left amygdala increased for snap judgments of Low compared to High Attractiveness candidates when participants made snap judgments of their competence (see Figure 11). Although participants judged competence and not attractiveness, Low Attractiveness candidates were judged as less competent than High Attractiveness candidates and left amygdala activity increased for Low compared to High Attractiveness candidates. However, the magnitude of left amygdala response to High or Low Attractiveness for each participant was not significantly correlated with the average snap judgments of High or Low Attractiveness candidates for each participant ($p>.20$). No other regions displayed a significant difference related to the manipulation of information used in heuristic-based snap judgments.

Figure 11.

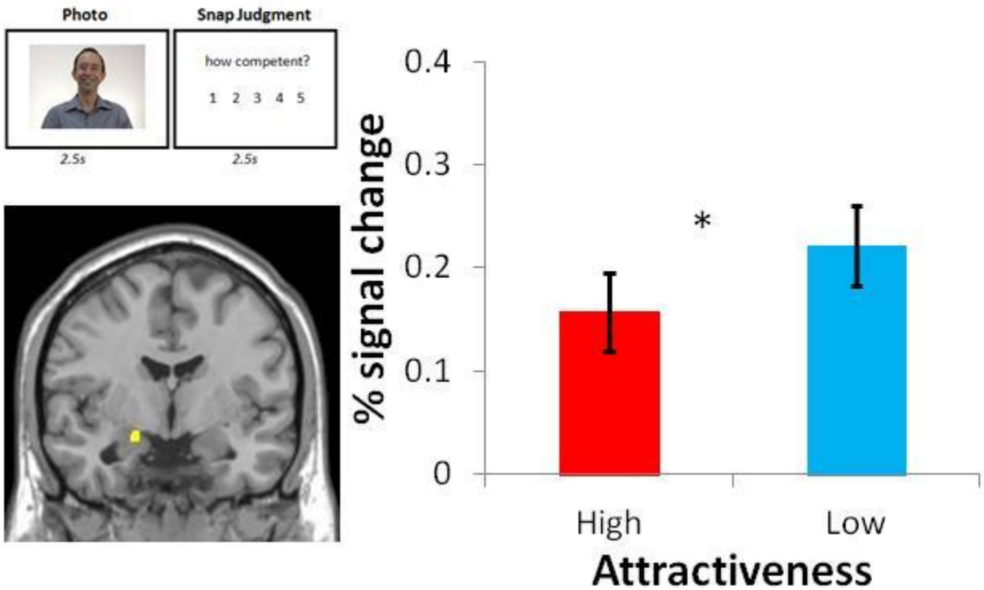

Figure 11. Left amygdala activity is influenced by the manipulation of information used in heuristic-based judgments of competence.

Left amygdala activity related to viewing photographs and making snap judgments is increased for Low compared to High attractiveness candidates (peak voxel at -20,-6,-16; $z = 2.15$, $p<.05$, SVC). Error bars represent standard error.

Neural regions associated with social judgment are activated to the degree that additional information is incorporated to adjust a snap judgment.

Left DMPFC, bilateral lateral temporal cortex and bilateral amygdala activity increased when participants adjusted initially high competence snap judgments of attractive candidates downwards to form a re-evaluation that the candidate was less competent than initially judged. These regions showed two patterns in the current study that were required for a relation to adjusting heuristic-based snap judgments. First, neural activity should be influenced by the Competence Level manipulation. Second, neural activity should be related to how far participants adjust their snap judgment when re-evaluating a candidate.

Related to the first pattern of neural activity, Table 5 lists neural regions that showed a parametric relation to Competence Level for either High or Low Attractiveness candidates, or both. DMPFC and bilateral lateral temporal regions showed a parametric relation to decreasing Competence Levels for both High and Low Attractiveness candidates. Bilateral amygdala and striatum showed a parametric relation to decreasing Competence Levels for High Attractiveness candidates but no significant relation for Low Attractiveness candidates. Regions that showed a parametric relation in the opposite direction (increasing Competence Levels) included VLPFC (for Low Attractiveness candidates only).

Table 5. Neural regions showing significant parametric change related to Competence Level

Region of Activation (Right/Left)	Brodmann Area	MNI Coordinates x	y	z	z-stat Value
		Parametric relation to decreasing Competence Level			
High Attractiveness condition					
DMPFC (L,R)	9/10	-8	52	32	3.91
Lateral Temporal (R)	20/21	52	-2	-30	4.97
Lateral Temporal (L)	20/21	-50	4	-28	5.37
Amygdala (R)		18	-4	-20	3.54
Amygdala (L)		-18	-6	-20	2.87
Lateral Temporal (L)	21/39	-46	-58	16	3.98
Lateral Temporal (R)	21/39	50	-64	24	4.43
Low Attractiveness condition					
DMPFC (L)	9/10	-6	50	28	5.22
Lateral Temporal (R)	20/21	52	2	-38	5.13
Amygdala (L)		-28	-2	-14	2.57
Lateral Temporal (L)	20/21	-52	-6	-32	5.36
Supramarginal/Postcentral Gyrus (L)	3	-52	-22	36	4.51
Precentral/Postcentral Gyrus (L)	4/6	-30	-38	56	4.02
Occipital (L/R)	17/18	0	-62	6	4.30
High and Low Attractiveness conjunction					
DMPFC (L)	9/10	-8	52	32	3.91
Lateral Temporal (R)	20/21	52	-2	-38	4.38
Lateral Temporal (L)	20/21	-52	-4	-28	4.69
Lateral Temporal (L)	21/39	-46	-58	16	3.98
		Parametric relation to increasing Competence Level			
High Attractiveness condition					
Occipital (R)	17/18	12	-80	-14	5.10
Low Attractiveness condition					
VLPFC (R)	45	42	32	12	4.33
Inferior Parietal (R)	40	36	-54	42	3.83
No regions for High and Low Attractiveness conjunction					

Note: Approximate Brodmann's areas are shown. Regions are ordered from anterior to posterior by y-coordinate of the peak.

Relevant to the second pattern of neural activity, Table 6 lists neural regions that were related to how far participants adjusted their snap judgment when re-evaluating a candidate. The trial-level analysis of neural activity related to adjustment showed that left DMPFC and bilateral amygdala activity increased to the degree that additional low competence information was incorporated to adjust snap judgments when making re-evaluations of a candidate's competence (Figure 12). No regions hypothesized to be involved in social evaluation were significantly associated with adjustment of initial snap judgments for Low Attractiveness candidates. The participant-level analysis showed no significant correlations (all p>.16) between the behavioral summary measure of judgment adjustment for each participant and the neural summary measures of activity related to processing additional information (described in the Methods section under fMRI Data Analysis).

Table 6. Neural activation foci related to adjustment of preliminary heuristic-based judgments of competence

Region of Activation (Right/Left)	Brodmann Area	MNI Coordinates x	y	z	z-stat Value
Increasing activity for lower re-evaluations of competence (snap judgment adjusted downward)					
High Attractiveness condition					
DMPFC (L)	9/10	-10	50	28	4.82
Striatum/Thalamus (L,R)		-6	-4	8	3.45
Lateral Temporal (R)	20/21	52	-2	-30	4.58
Lateral Temporal (L)	20/21	-48	6	-30	4.82
Lateral Temporal (L)	21	-56	-56	12	3.87
Amygdala (R)		18	-6	-20	3.00
Amygdala (L)		-24	-4	-26	2.87
Low Attractiveness condition					

DMPFC (L)	9/10	-6	50	28	4.84
Lateral Temporal (L)	20/21	-54	6	-30	4.62
Lateral Temporal (R)	20/21	52	2	-40	4.66
Amygdala (L)		-28	-2	-14	3.03
Precentral/Postcentral Gyrus (L)	4/6	-26	-24	56	3.78
Occipital (L/R)	17/18	-2	-64	4	3.80
High and Low Attractiveness conjunction					
DMPFC (L)	**9/10**	**-8**	**52**	**28**	**3.77**
Lateral Temporal (R)	20/21	50	0	-32	4.23
Amygdala (L)		**-28**	**-2**	**-14**	**3.03**
Lateral Temporal (L)	20/21	-60	-8	-20	4.50
Lateral Temporal (L)	21	-48	-58	16	3.63
Lateral Temporal (L)	21	-56	-56	12	3.87
Increasing activity for higher re-evaluation of competence (snap judgment adjusted upward)					
High Attractiveness condition					
Occipital (R)	17/18	14	-80	-14	5.23
Occipital (R)	19	14	-90	40	3.82
LowAttractiveness condition					
VLPFC (R)	45	44	46	6	4.12
Inferior Parietal (R)	40	36	-56	42	4.11

Note: Regions listed show a significant parametric relation to the difference between a re-evaluation and a snap judgment of competence on each trial (re-evaluation competence rating minus snap judgment competence rating). These activation foci were restricted to only include voxels that also showed a parametric relation to Competence Level, therefore, the listed clusters are contained within the clusters listed in Table 5. Approximate Brodmann's areas are shown. Regions are ordered from anterior to posterior by y-coordinate of the peak. Regions listed in bold are depicted in Figure 12.

Figure 12.

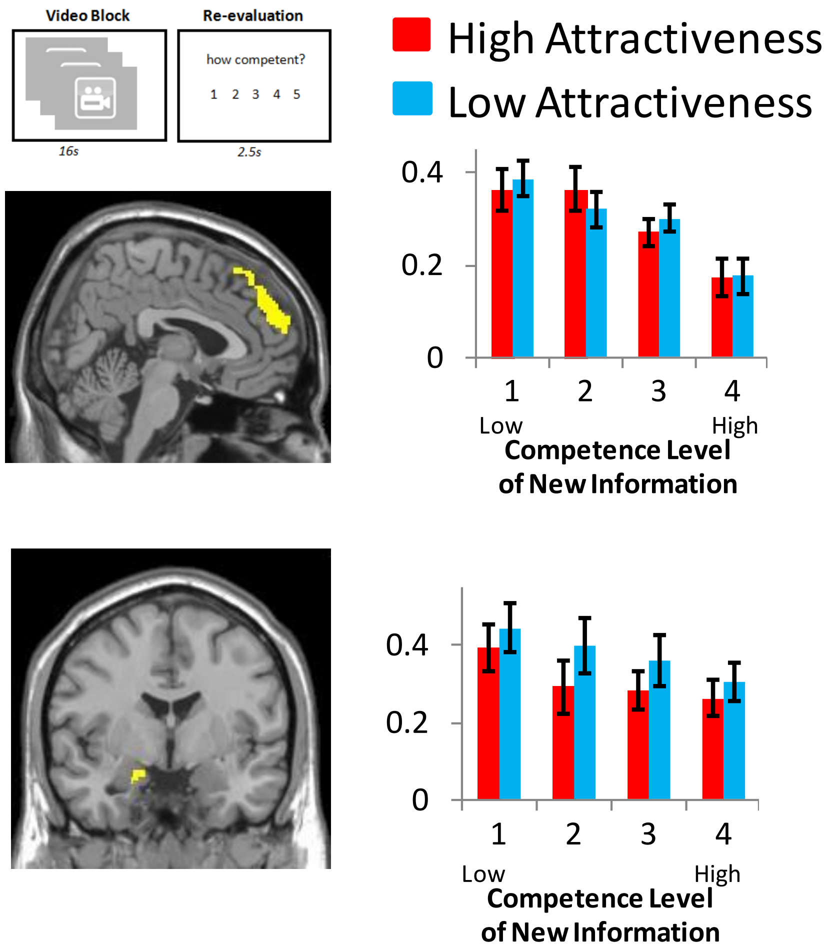

Figure 12. Neural activity related to incorporating additional information about attractive candidates to adjust initially high snap judgments of competence downward.

Left DMPFC and left amygdala activity related to viewing videos and making re-evaluations of candidates' competence. At lower Competence levels, participants adjust initially high snap judgments downwards, and activity in left DMPFC and bilateral amygdala increases. Neural maps depict voxels significantly related to Judgment Adjustment for High Attractiveness candidates. Bar charts indicate percent signal change from baseline at each Competence Level for High Attractiveness candidates. Error bars represent standard error.

Discussion

This study aimed to provide a deeper understanding of the neural regions involved in social judgment by examining neural activity associated with System 2 processes that adjust the output of System 1 processes. System 1 processes make use of imperfect associations, or heuristics, to make judgments. When additional information is available, System 2 processes may incorporate that information to adjust System 1 output. The current study elicited two competence judgments of each candidate so that there would be evidence of heuristic-based judgment, and evidence that participants adjusted those heuristic-based judgments. Although participants judged each candidate's competence, not attractiveness, attractive candidates were judged as more competent in initial snap judgments compared to less attractive candidates. This difference provided evidence that snap judgments were influenced by a heuristic based on imperfect associations between attractiveness and competence. After viewing additional information about a candidate, participants re-evaluated the candidate's competence. The difference between re-evaluation and a snap judgment of a candidate provided evidence that participants adjusted their heuristic-based judgments to incorporate additional information. Previous research has associated neural regions such as DMPFC, lateral temporal cortex, and amygdala with social judgment, but it is unclear whether these regions might be related to System 1 or System 2 processes. The study findings show that DMPFC, lateral temporal cortex, and amygdala are related to System 2 processes that adjust the output of System 1. Furthermore, the findings show that neural activity may be associated with processing that is characteristic both of System 1 and System 2. That is, amygdala activity is influenced by information used to make heuristic-based judgments, and influenced by adjustment of heuristic-based judgments. These findings provide more information to characterize how neural regions support social judgment.

DMPFC AND OTHER REGIONS PREVIOUSLY ASSOCIATED WITH SOCIAL JUDGMENT ARE RELATED TO DUAL-PROCESS INTERACTION

The findings of the current study provide a richer understanding of previous research demonstrating prominent roles for DMPFC in social judgment. Previous research suggests DMPFC is involved when we judge characteristics or mental states of other people but it is not clear whether judgments might involve System 1 or System 2 processes (Amodio & Frith, 2006; Gallagher & Frith, 2003; Mitchell, Macrae, & Banaji, 2005, 2006). In the current study DMPFC is associated with System 2 processes that adjust System 1-driven judgments, an example of interaction of System 1 and 2 processes. More specifically, DMPFC activity is associated with the degree to which additional information is incorporated to adjust heuristic-based social judgments. Only one previous study has suggested that DMPFC may be recruited to adjust a heuristic-based social judgment (Tamir & Mitchell, 2010). The findings from this previous study are difficult to interpret because there was no manipulation of the information on which the heuristic was based. Therefore, it is difficult to know if judgments truly reflected adjustment from a heuristic-based starting point. The current study builds upon previous research by demonstrating behavioral evidence of adjustment of heuristic-based judgments. In the current study, information for heuristic-based judgment was manipulated, and the influence of an attractiveness–based heuristic was evident in participants' snap judgments. Re-evaluations that differed from initial snap judgments provided evidence of how far participants adjusted their heuristic-based snap judgments. Furthermore, the attractiveness influence persisted even after participants viewed additional information (the information was equivalent for each attractiveness condition), suggesting that the heuristic-based snap judgments functioned as a starting point from which re-evaluations were adjusted. DMPFC activity increased to the degree that participants adjusted their starting points to incorporate negative information about a candidate. This finding provides evidence that DMPFC activity is associated with System 2 processing that adjusts the output of System 1, an example of dual-process interaction.

The current findings also provide further characterization of the role of lateral temporal regions and striatum in social judgment. Lateral temporal cortex (including superior temporal sulcus) and striatum (including ventral caudate and putamen) exhibited bilateral activity related to the adjustment of snap judgments that paralleled DMPFC activity. That is, activity in these regions increased when participants lowered their initially high snap judgments to incorporate low competence information about candidates. Lateral temporal cortex has previously been associated with judgments of people's traits and with understanding other people's intentions and beliefs from their actions and speech (Bzdok et al., 2011; Redcay et al., 2010; Saxe, 2006). Understanding the candidate's speech is certainly necessary for participants to adjust their snap judgments as they did in the current study. However, further research is needed to understand whether the mode of information (e.g., spoken statements rather than visual text) or inferences about the candidate's intentions or beliefs might play a role in the pattern of behavioral and neural findings. With regard to the social judgment, activity in striatum has been associated with processing social information that is not in line with expectations (Harris & Fiske, 2010). Further research is needed to understand whether participants' expectations about the candidates may have played a role in the findings.

AMYGDALA IS INFLUENCED BY INFORMATION USED IN SYSTEM 1-BASED JUDGMENTS AS WELL AS JUDGMENTS BASED ON DUAL-PROCESS INTERACTION

The current findings demonstrate that amygdala may not be exclusively characterized as exclusively related to System 1 versus System 2 processes. In the current study, the attractiveness manipulation influenced left amygdala activity such that it increased for initial snap judgments of competence for low compared to high attractiveness candidates. Initial snap judgments of candidates' competence were influenced by a heuristic based on attractiveness information. In this manner left amygdala may be related to System 1 processing in social judgment by responding to information that is used in a heuristic-based judgment. This finding is consistent with previous research showing that amygdala is associated with judgments of people's traits based on their appearance (Adolphs et al., 1998; Engell et al., 2007; Freeman et al., 2010; Rule et al., 2010, 2011; Todorov and Engell, 2008). However, the current findings also show that bilateral amygdala regions are associated with the adjustment of heuristic-based social judgments. Specifically, left amygdala activity increased to the extent that participants lowered their initially high snap judgments of both attractive and unattractive candidates. Right amygdala activity increased to the extent that participants lowered their initially high snap judgments of attractive candidates only. In general, when participants viewed evidence of an attractive candidate's low competence, they adjusted their judgments downward and their amygdala activity increased. This finding suggests that the role of the amygdala in social judgment is not limited to judgments based on System 1 processes, but is may also be involved in the interaction of System 1 and 2 processes as characterized by the adjustment of heuristic-driven snap judgments.

The involvement of the amygdala in both heuristic-based snap judgments as well as the adjustment of judgments helps refine our understanding of the amygdala's role in social judgment. One area of research has emphasized the role of the amygdala in judgments of people's traits based on their appearance, as in the snap judgments in the current study (Adolphs et al., 1998; Baron et al., 2011; Engell et al., 2007; Freeman et al., 2010; Rule et al., 2010, 2011; Todorov and Engell, 2008). Research has even shown that amygdala activity to another person's appearance may be associated with a failure to learn other information about that person (Baron, et al., 2011). However, research has not fully examined how the amygdala responds to social information that goes beyond appearance. In the current study, amygdala activity increased when people viewed additional information that an attractive candidate was not competent, and greater amygdala activation was related to the incorporation of additional information (beyond appearance) to adjust initial snap judgments. This finding brings together research emphasizing the amygdala's role in appearance-based judgments (Adolphs et al., 1998; Baron et al., 2011; Engell et al., 2007; Freeman et al., 2010; Kim et al., 2007; Rule et al., 2010, 2011) with research emphasizing the amygdala's role in detecting information relevant for making evaluations (Cunningham, Van Bavel, & Johnsen, 2008; Sander, Grafman, & Zalla, 2003; Schiller et al., 2009).

NEURAL REGIONS ASSOCIATED WITH ADJUSTMENT DIFFER FROM PREVIOUS NEURAL RESEARCH ON INHIBITION OF HEURISTIC-BASED SOCIAL JUDGMENTS

The adjustment of a heuristic-based social judgment is conceptually distinguishable from the inhibition of a heuristic-based social judgment, but there is no research investigating whether adjustment and inhibition might involve similar neural regions. There is no comparison between adjustment and inhibition in the current study, however it is noteworthy that the neural regions related to adjusting snap judgments in the current study differ from neural regions previously associated with inhibiting heuristic-based judgments. Previous research has shown that VLPFC, DLPFC and DACC regions are recruited when people inhibit socially undesirable heuristic associations such as negative associations of outgroup members (Amodio et al., 2004; Cunningham et al., 2004; Richeson et al., 2004). VLPFC, DLPFC and DACC were not among the neural regions associated with adjusting heuristic-based snap judgments in the current study. Further research that manipulates both inhibition and adjustment is needed to examine whether similar or different neural regions are involved in each form of dual-process interaction in social judgment.

The difference between adjustment and inhibition is that inhibition aims to suppress the influence of a heuristic in judgment whereas adjustment aims to incorporate additional information in a judgment. Thus, inhibition is distinguished from adjustment by a motivation to suppress the expression of System 1 processing. For example, heuristic processing might lead to a negative judgment of an outgroup member, but the expression of such a judgment might be suppressed because it is socially undesirable (Bodenhausen & Macrae, 1998; Gawronski & Bodenhausen, 2006). On the other hand, when people adjust away from a heuristic-based starting point rather than inhibit a heuristic-based judgment, the final judgment will show evidence of the original heuristic-based starting point. For example, re-evaluations were still influenced by attractiveness in the current study even though information about competence was equivalent across the attractiveness conditions. It might be argued that adjustment in the current study was really failed inhibition if participants tried but failed to inhibit the influence of the candidate's attractiveness in their judgments. However, the attractiveness difference in snap judgments and the pattern of response times for re-evaluation is not consistent with inhibition. If participants were trying to inhibit an attractiveness-based heuristic they would not likely show a snap judgment difference between attractiveness conditions. In explicit judgments such as the snap judgments in the current study, people who are motivated to inhibit heuristic-based judgments are able to do so (Greenwald et al., 2003). Furthermore, the pattern of response times for re-evaluation is inconsistent with inhibition. If participants were inhibiting attractiveness-based information from expression in judgment response times should be longer when attractiveness information was inconsistent with competence information (i.e., high attractiveness/low competence or low attractiveness/high competence). This pattern was not true for the high attractiveness condition (response times were shortest for low competence candidates), meaning that at least for high attractiveness candidates, re-evaluation response times did not suggest inhibition.

GENERAL DISCUSSION

This dissertation reports three studies that draw on a dual-process psychological framework to better understand how neural regions support social and emotional judgment. The three studies make use of some of the distinctions made by dual-process frameworks in an effort to understand the ways that different neural regions might support judgment and decision making rather than addressing claims about whether the dual-processes are independent systems (Satpute & Lieberman, 2006; Sloman, 1996; Smith & DeCoster, 2000) or ends of a continuum (Chaiken, 1987; Petty and Cacioppo, 1986). Dual-process models distinguish between two modes of information processing for judgment. One mode, System 1, is characterized by the processing of associations that are not guaranteed to lead to the best judgment. In some cases these associations may provide some valid probabilistic information, as when a cue predicts a probable outcome (e.g., dark clouds predicting probable rain). In other cases associations may have limited validity for judgments, as with associations between physical attractiveness and competence (Jackson et al., 1995). The other mode of judgment, System 2, is characterized by the integration of multiple variables to make a judgment, often in a more complete and relatively deterministic manner. For example, a hiring manager might favorably judge a candidate that has high test scores, three years of experience, and positive references. The three studies described in this dissertation aimed to address gaps in neural research where a dual-process framework might be useful to characterize neural regions involved in judgment. Study 1 addressed the lack of comparison between probabilistic judgment and rule-based judgment in the separate literatures on each type of judgment. Specifically, Study 1 addressed whether neural regions are preferentially involved in probabilistic compared to rule-based judgments. Study 2 addressed limitations in neural research with a novel operationalization of affectively-influenced judgment, which is one characterization of judgments driven by System 1 processing. Study 3 addressed the lack of specific characterization of neural regions involved in social judgments. Study 3 examined neural activity related to the adjustment of heuristic-based judgments, one way that System 1 and System 2 interaction is characterized. The findings of each study show that dual-process distinctions can be used to characterize neural activity involved in judgment, but also that not all neural regions involved in judgment may exclusively support System 1 versus System 2 types of information processing.

The studies reported here take a step toward better understanding associations between neural regions and information processing for judgment. Researchers have hypothesized that dual-process modes may relate to systems in the brain, but there has been little research that manipulates System 1 compared to System 2 processing, especially in the domain of social judgment (Sanfey et al., 2006; Satpute & Lieberman, 2006). Many typical associations between neural regions and dual-process modes of judgment have been based on inferred characteristics of judgments (e.g., affective, deliberative) rather than manipulating those characteristics modes of judgment. For this reason there is no clear agreement on neural systems associated with individual or both modes of judgment (Table 7). For example, in different studies, DMPFC has been associated with probabilistic decision making as well as with monitoring irrelevant information (Volz et al., 2003; Egner et al., 2008; Etkin et al., 2006). The three reported studies here each manipulate aspects of System 1 processing, System 2 processing, and their interaction, in order to provide clearer tests of neural associations with characteristics of dual-process modes of judgment. In Study 1, probabilistic compared to deterministic complex rule-based decision making was manipulated. In Study 2, affectively-driven compared to non-affectively-driven judgment was manipulated. In Study 3, adjustment of heuristic-based judgments was manipulated.

Table 7. Characteristics and neural associations with each processing mode

	System 1	System 2
Characteristics of Each Mode	*Probabilistic* *Affective* *Heuristic* Efficient Automatic Associative Experience-based Intuitive Slow-learning	*Deterministic* *Complex rule-based* *Adjustment* Resource demanding Deliberative Propositional Flexible Inhibition Monitoring
Neural Associations from Previous Research	Amygdala Striatum VMPFC Lateral Temporal DMPFC DACC Insula LOFC	DLPFC VLPFC VMPFC Parietal DMPFC DACC Insula LOFC
Neural Associations from Studies 1, 2, and 3	*Affective*: VMPFC (S2) *Heuristic*: Amygdala (S3)	*Deterministic, complex rule-based*: VLPFC, DACC, Insula (S1) *Adjustment*: DMPFC, Lateral Temporal, Striatum, Amygdala (S3)

Note: Characteristics of interest in Studies 1 (S1), 2 (S2), and 3 (S3) are italicized.

The results of the three studies agree with some of the neural associations with dual-process modes of judgment that may be inferred from previous literature, but disagree with others. In Study 1, VLPFC was associated with System 2 processing, as might be inferred from previous research on rule-based decision making (Bunge, 2004;

Bunge & Zelazo, 2006). However, DACC and anterior insula activity was also associated with System 2 processing, which might conflict with some previous studies that have associated DACC and anterior insula with probabilistic judgments without comparison to deterministic rule-based judgments (Critchley et al., 2001; Paulus et al., 2003). The comparison between complex deterministic rule-based judgment and probabilistic judgment in Study 1 provides a more direct test than in previous research. That is, Study 1 builds upon previous research by demonstrating neural associations in a single study where complex, deterministic decision rule-based processing was manipulated in comparison to probabilistic processing. Limitations of Study 1 make it difficult to draw inferences about neural associations with System 1 processing. Although the deterministic rule-condition required integration of multiple factors and thus is characteristic of System 2 processing, the probabilistic condition may not have optimally elicited System 1 processing for judgment. That is, if System 1 and System 2 are viewed as ends of a continuum, the probabilistic condition in Study 1 may fall in between the extremes.

Study 2 addressed this limitation of Study 1 by manipulating another characteristic of System 1 processing: affect. Where Study 1 failed to definitively show neural associations with System 1, Study 2 demonstrated that affectively influenced judgments are associated with VMPFC activity. This association of VMPFC with System 1 processing is consistent with the association that might be inferred from previous neural research related to affectively-influenced judgment (Camille et al., 2004; Coricelli et al., 2005; Kuhnen & Knutson, 2005; Sanfey et al., 2003; Shiv et al., 2005). Importantly, Study 2 demonstrated this association in a paradigm that manipulated, rather than inferred, the influence of affect in judgments. Previous research associating VMPFC with affectively-influenced judgment has often inferred the influence of affect from suboptimal financial risk decisions (e.g., a fearful person might put money in a savings account rather than an investment with some risk but high payoff). Study 2 builds on previous research associating VMPFC with affectively-influenced judgment by demonstrating the association is linked to affect rather than another factor that might influence risk preferences (Camille et al., 2004; Coricelli et al., 2005; Kuhnen & Knutson, 2005; Sanfey et al., 2003; Shiv et al., 2005). Furthermore, previous research has not distinguished between neural activity related to an affective reaction and neural activity specifically related to an affectively-influenced judgment. Study 2 makes this distinction and shows that VMPFC activity is specifically associated with judgments that are influenced by affect.

Study 3 showed neural associations with a form of dual-process interaction that had not previously been addressed in neural research. That is, Study 3 addressed neural associations with the incorporation of additional information to adjust heuristic-based (System 1-driven) judgments. Adjustment of System 1 output is an underexplored form of dual-process interaction. Importantly, Study 3 showed behavioral evidence that participants used a heuristic to make preliminary snap judgments, and showed behavioral evidence that participants adjusted those snap judgments to incorporate more complete information. Study 3 findings contribute to the understanding of neural regions involved in social judgment. The DMPFC, amygdala, lateral temporal, and striatal regions associated with adjusting heuristic-based snap judgments of others have all been associated with social judgment before, but have not been specifically linked to the process of adjustment (Adolphs et al., 1998; Amodio & Frith, 2006; Engell et al., 2007; Freeman et al., 2010; Gallagher & Frith, 2003; Harris & Fiske 2010; Mitchell, Macrae, & Banaji, 2005, 2006; Saxe, 2006; Rule et al., 2010, 2011; Todorov and Engell, 2008). It is interesting that regions hypothesized to be involved in social judgment were associated with adjusting initially high judgments downward. Future research could further explore factors such as direction of adjustment that might influence neural associations with impression formation.

The three studies were designed to examine different aspects of dual-process frameworks and to make different comparisons based on dual-process distinctions (see Figure 1). For this reason it is not particularly surprising that no regions are related to System 1 or System 2 in all three studies. For example, Study 1 compared System 1 processing with System 2 processing whereas Study 2 only examined System 1 processing. A more integrative future account of neural regions associated with dual-process characteristics could examine whether neural associations are consistent for different ways of manipulating System 1 compared to System 2 processing. For example, are neural associations between probabilistic and deterministic rule-based processing for judgment similar to neural associations between associative and propositional processing for judgment, or between efficient and resource-demanding processing? Further application of dual-process distinctions to neural research on judgment may help to build more complete neural models of judgment.

Characterizing neural activity underlying judgment: Directions for future research

Although this dissertation has focused on distinguishing neural regions associated with different modes of processing in judgment, the studies do not provide unambiguous evidence that information processing is split up between brain regions according to modes of judgment. Some dual-process frameworks have described the modes of judgment as ends of a continuum (Chaiken et al., 1987; Petty & Cacioppo, 1986). This continuum represents one dimension out of many that might describe information processing for judgment. Neural associations with different modes of dual-process frameworks may not be completely separable. In Study 3 there was evidence for amygdala involvement in both modes of judgment. Amygdala activation was related to information used for heuristic-based snap judgments as well as adjustment of heuristic-based judgments to incorporate additional information. Although this is only one finding it raises the issue that dual-process modes of judgment are not the only way to describe information processing for judgment. The amygdala has been described elsewhere as a signaler of affectively salient information that could be relevant to judgments and behavior (Cunningham et al., 2008; Sander et al., 2003; Schiller et al., 2009). Although this function might be attributed to System 1-like processing, it may be important in System 2 processing as well. After all, competence judgments are based on affective (valenced) assessments of information about the candidates, whether that information is the candidates' appearance or the statements they make. One possibility is that amygdala activity in Study 3 served to signal relevant pieces of information that can be combined to influence either a snap judgment or adjustment of a snap judgment. In this sense amygdala activity could relate to both System 1 processing as well as the adjustment of System 1 output. When relevant pieces of information are detected other neural regions such as DMPFC may be involved in appropriately adjusting a judgment. Future research might aim to disentangle different roles of amygdala, DMPFC, and other regions in the process of adjusting a heuristic-based judgment to incorporate additional information.

Another direction that future research might take would be to investigate how different modes of judgment might be implemented not by distinct neural regions, but by changes in communication between neural regions. Differences in judgments that are modeled by dual-process frameworks might not arise via processing in distinct neural regions, but instead via different patterns of communication between regions. For example, one speculation may be that amygdala is involved in implementing both modes of judgment, but it communicates information to different regions and receives information from different regions. A next step for future research is to examine how different patterns of communication between regions might be manifest as different modes of judgment.

Appendix A: Video Clip Statements

High Competence Statements

1. I appreciate constructive criticism from co-workers and superiors
2. I really enjoy exchanging ideas with others and getting feedback
3. I feel the project's success is a reflection of how much work I put in to it
4. I stay focused on projects despite everyday distractions and setbacks
5. I enjoy a challenge, I want to feel like I learn something everyday
6. Being punctual and carrying out tasks on time are two of my biggest strengths.
7. I am a quick learner and can do an effective job with little supervision.
8. I am very flexible and can adapt well to stressful situations that happen at work.
9. I am a good communicator and enjoy contributing to the team ethic.
10. I am willing to start at the bottom and work my way up to more responsibility
11. I'd want to take classes and training on my own time to sharpen my skills
12. I'm looking for a job where I can commit long-term and feel part of the company
13. I always try hard to set specific goals for the day and accomplish them
14. I think it's important to make decisions carefully and base them on the facts
15. One of my strongest skills is my ability to persevere and solve problems
16. I'm the type of person to keep trying even when things don't work out at first
17. I think it's really important to respect my co-workers and help them do their best
18. I learn very quickly and don't need to be told how to do things more than once.
19. I'm good with a lot of software programs and can pick up new skills quickly.
20. I think it's important to be careful but also complete tasks efficiently and move on.
21. I think that clear communication is a big part of working effectively in a group.
22. I handle pressure by focusing on clear targets and planning how to achieve them.
23. I'm an active person and I enjoy working and bringing in new ideas to a project.
24. I realize the importance of meeting deadlines and getting my work done on time.
25. I work at a steady pace so that I usually complete projects ahead of schedule.
26. I enjoy learning from everyone I work with, I think that makes me more effective.
27. I have strong organizational skills and can manage multiple projects at a time.
28. I like to explore alternative solutions to figure out what works the best.
29. I've learned to be persistent because sometimes the solution is just one step further.
30. I try to find a common ground with coworkers to get off to a good start that way.
31. I like getting work done ahead of schedule so I have more time to help others.
32. I pride myself in staying calm under pressure, so I'm able to make good decisions.
33. I pride myself on being diligent and conscientious in the work I do.
34. I like to set high goals and then do everything I possibly can to achieve them.
35. One of my strengths is my ability to focus on a task without losing the big picture.
36. While I'm looking for a new job I've been taking classes to learn new skills.
37. I look forward to contributing creative ideas to generate new projects.
38. I try to give my full attention to others so I can learn from them
39. I'm highly motivated to be on time everyday and reliable.
40. I am skilled at conflict resolution and find it easy to get along well with others.
41. I always have a positive attitude about whatever work needs to be done.
42. My biggest motivation is knowing how much I can achieve if I work hard.
43. I actively work to learn from feedback given to me so I can work more efficiently.
44. I've done some of my best work under tight deadlines when I become really determined

High Competence Statements (continued)

45. I don't mind working overtime when there's a key project deadline.
46. I love working in team environments and working for a common goal.
47. I enjoy giving presentations to teams and prospective clients
48. I go out of my way to return emails and phone calls within a day
49. I always appreciate and give credit to coworkers when they help me out
50. I like working with others and try to help them as much as I can
51. I'm willing to do more than what is expected of my position to get a job done.
52. My last boss would say I was a very dependable and reliable employee
53. I feel my extroverted personality and drive would be great for this job
54. I am very detail oriented, and work hard to make sure everything is correct
55. My experience has prepared me to address problems and find solutions
56. I would like the opportunity to learn from new experiences and challenges
57. I've been in this field many years and I'm proud of the work I've done
58. I want to show that I can take on more responsibility and handle it well
59. In my career I've tried to build on my experience at each step of the way
60. My experience working on team projects will help me contribute in this job
61. This is an exciting opportunity and I know I have the right qualities to succeed
62. My knowledge of this community will help me integrate well into the workplace
63. I get a lot of satisfaction out of completing a project and moving on to the next challenge
64. I'm excited to apply my skills to the job and to learn how to improve them.
65. I work well with others and enjoy overcoming challenges as a part of a team.
66. When I go the extra mile for a project I know that makes my colleagues work hard too
67. I deal with high pressure deadlines by staying positive and focusing on the task
68. I think about stress in a positive way as a kind of motivation to do a job well
69. My friends would describe me as an honest and genuinely helpful person
70. I'm looking forward to working hard and meeting the challenges at this job
71. I am willing to travel on weekends to help the company be successful
72. I think my qualifications show that I'm an excellent match for this position

Low Competence Statements

73. I don't have a reliable day care provider so sometimes I bring my kids to work
74. I don't work well with difficult co-workers, I won't work with someone I don't like
75. I don't take criticism well, I usually get very defensive when I get feedback like that
76. If the boss is out of the office I think it's okay to come in late and go home early
77. I deserve to have an office with a nice view or else I'm likely to fall asleep at work
78. I like to bring my dogs to work and I don't care if they bother my co-workers
79. I can't stand clients that demand more attention than my work hours could permit
80. I don't appreciate working for Type A bosses that are too concerned with details
81. I hate team group outings, I don't think it matters if people work as a team or not
82. I need to have a secretary to read my email and respond to client correspondence
83. I need a power nap every afternoon for one hour or else I can't function well
84. Don't ask me to help other employees with their projects, I put myself first
85. I have trouble working in a team if I'm not the team leader, I don't take orders well
86. I don't like having to work too hard for anything that doesn't come easily at first
87. I lost my last job for mis-using company funds, but no one told me about the rules
88. I have problems with authority, usually because I know I would be a better boss

Low Competence Statements (continued)

89. If I had a problem with a coworker, I would just expect them to get over it and move on
90. I don't think it's fair to require training classes, I should decide what classes I need
91. I left my last job because they tried to force me to attend anger management classes
92. Right now I just need a job until something better becomes available somewhere else
93. My biggest weakness is that I oversleep often and show up late to work a lot of the time
94. I have trouble staying at one job for a long time because I think I get bored easily
95. I'm definitely not going to take a job where the people don't look like they're having fun
96. I like to switch jobs frequently- otherwise co-workers start to get really annoying
97. My biggest weakness is that I can't keep to a work schedule, but at least I'm honest
98. My long term goal is to make a lot of money quickly so I can be a ski bum
99. I'm not willing to work hard until I have the salary that I think I deserve to be making
100. I think it's a waste of time to ask me to do any job that isn't in my personal interest
101. I know I don't have much education or experience, but I don't think that matters
102. My past boss was jealous of me because I was smarter than him and he knew it
103. My past coworkers were afraid of me because I work better and faster without them
104. I don't like to be the person responsible for getting things done all the time
105. If I don't know how to do something then I usually just ignore it until it goes away
106. I have a short fuse and sometimes I yell at my co-workers when they fail
107. I try to get a co-worker to do my work on days when I'm sleepy or not focused
108. I'd like to work somewhere that I can sneak away for a mid-day nap
109. I'm pretty grumpy in the morning, I'm not the most polite person
110. I don't really get along well with most of my co-workers because of my work habits
111. I don't like it when other people ask me for help with things that are not my job
112. I need to take a cigarette break every hour or I can get kind of cranky
113. Most assignments are really not important so I don't take work seriously
114. My last co-workers used to complain that I played my music too loud
115. I got fired from my last job for talking back to a client that was too picky
116. I don't want to work in a job where I have to be friendly all the time
117. I try to avoid taking on challenges because I don't want to fail at anything
118. I'd love a job where I don't have to smile and talk to other people
119. I can be really indecisive, I don't like to make the final decision on anything
120. When I fail to reach a goal I think the best thing is to lower my expectations
121. If my co-workers aren't working hard then I don't see why I should work hard
122. I need to work in a place with flexible deadlines since I tend to procrastinate
123. It's difficult for me to manage my time if there is too much expected of me
124. I think that the rules are made to be broken- that makes the job more fun
125. I hope to find a job that doesn't require me to think too much and lets me relax.
126. I'm really shy so I find it annoying when people want me to talk with them
127. If a meeting is scheduled too early in the morning then I'll just show up late
128. I don't believe people should work past 5pm, no matter what the task is
129. I often become too intimidated to present my ideas to coworker or clients
130. I like to play online poker at work because it improves my ability to read people
131. I will not spend extra time or work late to learn new skills, my time is for me only
132. Most of my previous bosses have told me not to bring my emotional issues to work
133. I'm probably overqualified for most jobs, but I need something to do for now
134. I need to have at least 6 weeks of vacation time per year or I go crazy

Low Competence Statements (continued)

135. I can't stand wearing stuffy clothes, most days I don't pay attention to the dress code
136. I think that all employee birthdays should be a corporate holiday
137. I hate it when business meetings are scheduled earlier than 10 in the morning
138. One of my best talents is being able to keep a straight face while telling a lie
139. My last boss had trouble understanding me. People don’t appreciate my talents.
140. I get nervous when I have to speak in front of other people, I sweat a lot
141. I don't like to work under the pressure of hard deadlines, I panic easily
142. My family has told me I need to work on my people skills to get along better
143. I get anxious in situations where I have to work with others on a team
144. I don't want a job where you have to be in an office at a desk all day

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