Affective Influence on Judgments and Decisions: Moving Towards Core Mechanisms

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This article reviews psychological accounts of affective influence on judgments and decisions and argues that these accounts can be enriched by insights from biopsychology. The authors show how biopsychological research helps (1) reveal the sources of values and feelings; (2) predict when affect will influence attentional, perceptual, memorial, and decision processes; and (3) identify precise mechanisms underlying the interaction between affective and cognitive systems. The authors also propose a specific biopsychological model of affective priming phenomena and show how this model deals with data that are hard to explain with purely psychological accounts. The authors conclude that a multilevel biopsychological perspective will ultimately provide a more constrained and plausible foundation for understanding psychological processes underlying affect, judgment, and decision.

Keywords: emotion, cognition, neuroscience, biopsychology, decision

How do affect and emotion influence cognition, judgment, and decision? This question is intensively investigated by psychologists and neuroscientists. Yet, there is little crosstalk between the two literatures. In this article, we aim to show how current psychological accounts of affective influence can be enriched by adopting a biopsychological framework grounded in research from affective neuroscience. The article is organized as

follows. We start with some conceptual clarifications. Next, we briefly review the dominant psychological accounts of affective influence. Then, we propose a more biopsychological framework for thinking about affective influence. We illustrate its value with several studies from our lab and related labs, focusing especially on the affective influences on decision making and the mechanisms underlying affective priming.

Some Conceptual Clarifications

Researchers studying affective influence use a variety of terms, and it is useful to briefly clarify their meaning. Arousal typically refers to a hedonically undifferentiated state of general activation (i.e., nonspecific arousal), but is also used to refer to the activation dimension of emotion, ranging from low to high. Valence refers to the hedonic dimension of a state, ranging from positive to negative. *Mood* refers to a low-intensity, diffuse, and relatively longlasting state that is primarily differentiated on valence (e.g., feeling good or feeling bad). Affect can function as an umbrella term for all states, but typically refers to states that are primarily differentiated on valence and arousal. Emotion is also used as an umbrella term, but often refers to

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an intense and relatively brief state with qualitatively differentiated phenomenology (e.g., within negative states, one can differentiate between fear, anger, sadness, and disgust).

It is also worthwhile to clarify the distinction between emotional stimuli, emotional states. and different components of an emotional response. Affective influence on decision-making has typically been proposed to involve a sequence of events, starting with the perception of the emotional stimulus, through some underlying affective state, and terminating with behavior. However, note that in many cases only some parts of the sequence might be "emotional" and that the specific nature of "emotion" may vary in different parts of the sequence. Thus, a stimulus might be "emotional" in the sense of being semantically related to emotion, but not elicit any real "hot" response (e.g., seeing the word "love" may or may not induce an emotional reaction). Further, if an emotional reaction is induced, it may not carry the same quality as that associated with the stimulus (e.g., seeing an angry face may not induce anger, but rather fear, or a generalized negative state).

Finally, when an emotional state occurs, it is important to consider which components are present and causally responsible for emotion's impact on subsequent behavior. Researchers generally agree that emotional states include several components. The cognitive component refers to changes in perceptual, attentional, and semantic aspects of emotion (e.g., attentional biases, primed appraisals). The behavioral component refers to activated motor programs and action tendencies (e.g., prepared reflexes, changed facial or postural expressions). The physiological components refers to underlying changes in emotion-relevant bodily and brainresponses (e.g., hormonal or cardiovascular state, activation of subcortical circuitry). Finally, the experiential component refers to the subjective feeling, or the phenomenal aspect of emotion. Theories of affective influence on decision differ in which components are deemed crucial for affective influence (e.g., cognitive, behavioral, or experiential).

Psychological Approaches to Affective Influence

We now briefly review a few dominant psychological accounts of how affect influences judgment and decision. Importantly, we do not intend to provide a comprehensive review, but rather aim to provide a context for the subsequent discussion of our own biopsychological approach and supportive empirical work.

Dominant models of affective influence can be divided into two very general categories. The first category includes associative models (e.g., semantic memory model and action model), which view affective influence as resulting from spreading activation, either in a memory network or in a motor network. The second category includes inferential models (e.g., affect-asinformation model, affect regulation model), which view affective influence as resulting from inferences drawn from the current or anticipated presence, or absence, of an affective experience.

Associative Models

Semantic Memory Models

One class of models proposes that affective states are associatively linked to related cognitive categories within a network of semantic memory (Bower, 1991; Forgas, 1995). Thus, inducing an affective state can prime categories that guide the encoding, retrieval, and use of information in judgment. Evidence for this model comes primarily from studies reporting affective influence on cognitive variables, such as attention, perception, memory, reasoning, and judgment. The most frequently reported finding in this literature is affective congruency. For example, participants in positive rather than negative moods are more likely to interpret ambiguous information in a positive way (Niedenthal, 1990), make more optimistic esti-

¹ Note that the impact of an emotional stimulus is importantly determined by the amount of its processing and time available to produce a response (Scherer, 2005). With minimal processing, the stimulus may elicit only a nonspecific orienting response, and perhaps nonspecific mobilization, with its strength dependent on unexpectedness and importance (Ohman, Hamm, & Hugdahl, 2000). Additional stimulus processing may lead to differentiation of general valence, triggering general biphasic responses, with negative stimuli facilitating avoidance and positive stimuli facilitating approach (Cacioppo & Berntson, 1999; Hamm, Schupp, & Weike, 2003; Lang, 1995). Finally, as more features are extracted from the stimulus and the stimulus is considered in its situational context, the resulting response becomes differentiated into a specific emotional state (Ellsworth & Scherer, 2003).

mates of risk (Johnson & Tversky, 1983), and act in a more cooperative and confident manner (Forgas, 2006). There is also some evidence that affect influences encoding and retrieval of memory, though this literature is not entirely consistent (Blaney, 1986).

Early versions of semantic memory models emphasized that affective influence on judgment is fairly valence-general. This conclusion was based on evidence that moods exert rather broad priming effects across widely divergent semantic associations. For example, bad mood enhances perceived risk of fire, flood, and other accidents (Johnson & Tversky, 1983). However, later work using inductions of emotional state, rather than general mood, found some evidence for specificity. Thus, Niedenthal and Setterlund (1994) found that emotion influences perception of concepts that are specifically related to the induced emotion. In their study, happy, as opposed to sad participants, made faster lexical decisions on happiness-related words (e.g., "delight" as opposed to "weep"), but not on general positive words (e.g., "love" as opposed to "death"). Finally, recent research indicated that inducing an emotional state can prime "appraisals" (beliefs) that are specifically associated with the induced emotion. For example, Lerner and Keltner (2001) contrasted the judgmental impact of induced states of fear, anger, and happiness. Note that both fear and anger have negative valence, but fear is associated with an appraisal of lower certainty and control, andanger is associated with an appraisal of higher certainty, like happiness (Smith & Ellsworth, 1985). Consistent with the idea of appraisal priming, fearful participants made more pessimistic risk assessments and more risk-averse choices than both angry and happy participants, who did not differ in their estimates (Lerner & Keltner, 2001).

Action Model

In contrast to the semantic memory model, which focuses on spreading activation within a person's conceptual network, action models emphasize priming within a perception-action network (Dijksterhuis & Bargh, 2001; see also an "impulsive" model by Strack & Deutsch, 2004). In one of the first studies exploring the impact of stimulus valence on motor behavior, Solarz (1960) asked participants to move cards

with words that were mounted on a movable stage either toward or away from themselves. Participants responded faster with the pulling (approach) movement to positive than to negative words, and faster with the pushing (avoidant) movement to negative than to positive words (see also Chen & Bargh, 1999).

Although findings like these may suggest a relatively direct link between valence and movement, the relationship between affect and motor activation is more complicated (Niedenthal, Barsalou, Winkielman, Krauth-Gruber, & Ric, 2005). For example, in a similar paradigm, Wentura, Rothermund, and Bak (2000) asked participants to respond to positive and negative words by either reaching out their hand to press a button or by withdrawing their hand from the button. Note that in this case pressing the button required an extension movement away from the body and withdrawing required a flexion movement toward the body. However, participants pressed the button faster for positive than for negative stimuli, but withdrew their hand faster for negative than positive stimuli. This finding suggests that there is no simple connection between positive/negative valence and flexion/extension (pull/push) movements. Instead, the connection depends upon participants' understanding of what the movement "means" in terms of the relation between the stimulus and the participant. Further, Markman and Brendl (2005) recently demonstrated that the relation to "physical body" is not critical, but rather the relation to the more abstract representation of the "self." Specifically, they found that positive valence facilitates any motor action (push or pull) that brings the stimulus closer to the self, even when the self is represented as participants' name on a screen.

Inferential Models

Neither semantic memory nor action priming accounts assign special status to the experiential "felt" component of emotion. Further, these models assume that affective influence operates via fairly automatic, context-free, knowledge activation processes. In contrast, inferential models (affect-as-information and affect regulation) emphasize the experiential "felt" component of affect and allow for a more strategic and flexible use of affect in guiding judgments and decisions.

Affect as Information

The affect-as-information model (AIM) proposes that a person often forms a judgment of a target by asking herself "How do I feel about it?" and then uses her current feeling as a shortcut to judgment. However, in doing so, the individual may mistake (mis-attribute) her feeling because of a preexisting state for a reaction due to the target, unless she questions the source of the feeling (Schwarz & Clore, 2003). The AIM is supported by findings that affectcongruency effects are often eliminated when subjects are given an alternative explanation for the presence of their feelings, thus undermining their diagnostic value for judgment (without presumably reducing semantic accessibility). For example, a classic study showed that the affectively congruent influence of good versus bad weather on life satisfaction judgments is eliminated when participants are subtly reminded of the surrounding weather conditions (Schwarz & Clore, 1983). Similarly, although arousal induced by some previous context (e.g., exercise, scary bridge, caffeine) can influence judgments ranging from attractiveness to aggressiveness, this influence can disappear when participants are alerted to the actual source of arousal (Martin, Harlow, & Strack, 1992).

Affect Regulation

Affect regulation models propose that affective influence on decision occurs because people perform actions to manage (i.e., maintain, change, or remove) their emotional experience (for reviews, see Andrade, 2005; Baumeister, Vohs, DeWall, & Zhang, in press; Erber & Markunas, 2006). These accounts suggest that people manage their emotions (sometimes automatically, sometimes for strategic reasons) in order to (1) restore a previous emotional state, (2) get into an emotional state that maximizes performance, or (3) make their emotional state congruent with situational demands.

In the domain of mood, the regulation idea was explored by Erber, Wegner, and Therriault (1996). These authors first made participants happy or sad and then told them to expect they would be working on an unrelated task either alone or with another participant. Next, participants were asked to indicate their preference for a set of newspaper stories, identified by their

headlines as uplifting, depressing, or neutral. Participants who expected to work alone showed the standard mood-congruency pattern—happy participants chose cheerful stories while sad participants chose depressing ones. However, participants who expected to work with a stranger showed the opposite preference—happy participants chose depressing stories while sad participants chose cheerful ones, presumably reflecting an attempt to neutralize their mood before a novel social interaction. In the domain of emotion, the regulation idea was explored by Raghunathan and Pham (1999). These authors hypothesized that sadness may occasionally promote active seeking of reward, while fear would motivate the need to reduce uncertainty of a situation. Consistent with these ideas, inducing sadness resulted in high risk/ high reward choices, while inducing fear led to low-risk/low reward choices.

Psychobiological Underpinning of Affective Influence

The psychological accounts of affective influence shed light on a variety of findings in the literature. However, they cannot explain a number of major findings and do not make many predictions that easily fall out of more biopsychological models. In what follows, we demonstrate how biopsychological considerations lead to more complete answers to several central questions, including (1) where do values and feelings come from, (2) how does affect influence attention, perception, memory, and decision, and (3) how is cognition integrated with emotion? To further illustrate the value of biopsychological perspective, we also discuss in more detail how affective neuroscience can enrich our understanding of affective priming. The next few sections refer to several brain structures underlying affective influence (see Figure 1 for approximate locations). Because our description of these structures and their many roles in affect and cognition is necessarily simplified, we invite readers to additionally consult more comprehensive physiological reviews (e.g., Berridge, 2003; Phelps, 2005).

Where Do Values and Feelings Come From?

The psychological models, especially the associative model, assume that "values" and

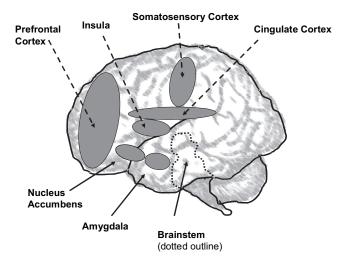


Figure 1. Approximate locations of neural regions implicated in affective influence on decision-making. Regions indicated with dashed lines are believed to play critical roles in affective experience. The figure shows only the left side of the brain and does not indicate the depth or connectivity of any structure (see Berridge, 2003, for a detailed presentation).

"feelings" basically reflect the number and extremity of cognitively accessible positive and negative attributes. If biological factors are considered, they are typically thought of as contributing to "nonspecific" arousal that acquires value only when it is interpreted in the light of semantically activated concepts (Schachter & Singer, 1962). In contrast, affective neuroscience encourages investigators to ask about neural coding of "value" and the neural basis of feelings. This framing can lead to interesting and novel insights, as we discuss next.

Representation of Rewarding Outcomes and Experiences

The neural representation of reward is a highly debated topic, but there is good evidence that at least some aspects of reward are represented by nuclei rich in dopamine and opioid neurotransmitters that lie near the bottom of the front of the brain, in the area called the basal forebrain. One of those nuclei, the nucleus accumbens (NAcc) became subject of intense research attention, long after Olds and Milner (1954) discovered that a rat with an electrode implanted near the NAcc would work vigorously to self-administer stimulation to the point of exhaustion, and to the exclusion of all other activities (e.g., eating, drinking, sex, and sleep).

Subsequent research in humans and other animals indicated that many of these studies supporting self-stimulation involved the neurotransmitter dopamine, either housing the bodies of dopamine neurons (i.e., deep in the midbrain), or their projection areas (i.e., to subcortical areas like the NAcc and cortical areas like the prefrontal cortex; Falck & Hillarp, 1959). Subsequent work demonstrated that brain microinjections of drug droplets that activate opioid receptors in the accumbens caused increased "liking" for sweetness in rats (Pecina & Berridge, 2000). In humans, dopamine release in the ventral striatum caused by amphetamine injection correlates with self-reported positive arousal (e.g., euphoria), but not with negative arousal (e.g., fear; Drevets et al., 2001; Mawlawi et al., 2001; Volkow et al., 1999).

One of the most interesting emerging discoveries from affective neuroscience is the remarkable similarity with which the brain codes different types of rewards. Specifically, fMRI studies on humans suggest that the accumbens and related areas activate not only in response to drug cues, but also to cues for other rewarding stimuli, including tasty foods and drinks (O'Doherty, Deichmeann, Critchely, & Dolan, 2002), and pictures of desirable social or sexual partners (Knutson & Cooper, 2005). Even more interesting, these regions might even be in-

volved in representing rewarding aspects of social interactions, suggesting that perhaps the brain transforms socially constructed rewards into the same "common currency" as "natural rewards." Thus, the NAcc and related structures activate during anticipation of monetary gain (Knutson, Adams, Fong, & Hommer, 2001), to signals of cooperation in prisoner's dilemma games (Rilling et al., 2002), and even prior to exacting "altruistic punishment," as when a person punishes a transgressor against her group in spite of personal costs (de Quervain et al., 2004).

If positive expected value is somehow coded by activity in these "reward regions," then investigators should be able to predict participants' choice behavior based on activation in these regions. This idea was recently explored by Kuhnen and Knutson (2005) who hypothesized that an increase in gain anticipation would promote risky choices, whereas an increase in loss anticipation would instead promote riskless choices. Accordingly, using a financial trading task in combination with fMRI, they found that anticipatory NAcc activation preceded switches to a risk-seeking strategy (i.e., choosing stocks rather than bonds), whereas anterior insula preceded switches in the opposite direction to a risk-avoidant strategy (i.e., choosing bonds rather than stocks; Kuhnen & Knutson, 2005). Thus, evidence is beginning to suggest that anticipatory NAcc activation may modulate subsequent behavior in ways that promote gainseeking.

Finally, recent evidence suggests that putative reward regions might be involved in the influence of affect on memory. In an fMRI experiment, Adcock et al. showed subjects cues for high (\$5.00) or low (\$0.10) rewards followed by a delay and then outdoor scenes that they were instructed to memorize for the cued amount. At a memory test one day later, subjects correctly remembered more high value scenes. Analysis of fMRI data revealed that enhanced encoding was preceded by coactivation of NAcc, ventral tegmental area, and hippocampus (a region implicated in memorization) before subjects saw the high-value scenes (Adcock, Thangavel, Whitfield-Gabrieli, Knutson, & Gabrieli, 2006). Thus, NAcc activation predicted that subjects would be more likely to remember upcoming scenes, even before the subject had seen them. Note that this finding cannot be predicted from

purely psychological accounts that do not consider the neural connectivity between the reward and memory systems.

Representation of Aversive Outcomes and Experiences

Research in affective neuroscience has also contributed to our understanding of aversive outcomes and experiences, and their role in attention, perception, memory, and judgment. Traditionally, this research focused on two regions of the brain, the amygdala and the insula, although those regions are also involved in coding of nonaversive experiences.

Amygdala. The amygdala is an almond-shaped structure located in the medial temporal lobe, just anterior to the hippocampus. The amygdala is richly and reciprocally connected to several cortical areas involved in cognitive and affective processing, as well as subcortical areas involved in physiological regulation (sympathetic and parasympathetic control of cardiovascular activity, respiration, hormone levels, muscular responses, etc.). As a result, the amygdala is involved in many important affective phenomena, including affective modulation of attention, perception, and memory.

Research on the amygdala contributed to better understanding of the "attention-grabbing" power of affective stimuli—a challenging issue for purely psychological accounts. One example comes from the phenomenon of attentional blink, in which detection of a first target temporarily impairs detection of a second target. Normally, attentional blink is reduced for important affective stimuli, but this reduction is eliminated after amygdala damage, suggesting that this subcortical structure encodes salient affective information (Anderson & Phelps, 2001).

Research on the amygdala also led to better understanding of how people can perceive affective stimuli even under minimal exposure conditions (Atkinson & Adolphs, 2005). Note that this possibility has been debated for years in psychology, but did not receive a satisfying answer until the emergence of affective neuroscience (Zajonc, 2000). However, there are now many studies documenting amygdala response even in the absence of conscious recognition of the stimulus, such as when fearful or angry facial expressions are presented subliminally (Whalen et al., 1998), under

conditions of binocular rivalry (Williams, Morris, McGlone, Abbott, & Mattingley, 2004), or with anger expressions presented to a patient's "blind field" (Morris, DeGelder, Weiskrantz, & Dolan, 2001; Morris, Öhman, & Dolan, 1999).²

Similarly, there is now a very large literature suggesting that affective memory benefits from the amygdala's contribution. In the amygdala, neurons can rapidly adjust their activity to reflect both positive and negative value of an external stimulus, which predicts how quickly monkeys learn to respond to a stimulus (Paton, Belova, Morrison, & Salzman, 2006). Patients with amygdala damage (but intact hippocampus) are impaired on acquisition of conditioned fear responses, as measured by skin conductance, but relatively unimpaired on declarative memory (Bechara et al., 1995). Such patients also do not show the typical memory advantage for emotionally arousing stimuli, such as taboo words (Anderson & Phelps, 2002). Again, these neural findings severely challenge purely associative models of affective memory that assume little difference in processing of cognitive and affective content (Phelps, 2005).

Finally, and somewhat surprisingly, some research suggests that amygdala may not always be necessary for the subjective experience of emotion. Specifically, patients with amygdala damage show little, if any, impairment in the magnitude and frequency of self-reported positive or negative affect (Anderson & Phelps, 2002). This interesting finding highlights a possible dissociation between the mechanisms by which salient emotional stimuli influence attention, perception, and memory, for which the amygdala plays an essential role, and the mechanisms underlying subjective experience, which may require additional recruitment of cortical circuits, as discussed below. If further confirmed, this observation would be especially challenging for the psychological models proposing that conscious feelings, and inferences from these feelings, play a primary causal role in the impact of affect on judgment and decision.3

Insula. The insula typically comprise five gyri that are covered by cortex bordering anterior to the orbitofrontal cortex, superior to the prefrontal and parietal cortices, and posterior to the temporal cortex (Augustine, 1996). The insula maintain bidirectional connections with subcortical structures, such as the amygdala and

all cortical structures, especially the orbitofrontal cortex, the parietal cortex, and the anterior cingulate. Research suggests that the insula might be particularly involved in reactions to aversive stimuli and representation of aversive experiences, especially those related to fear and anxiety. Thus, functional neuroimaging studies have linked insular cortex to processing of supraliminal expressions of fear (Morris et al., 1998) and disgust (Phillips et al., 1998), anticipation of electric shocks (Chua, Krams, Toni, Passingham, & Dolan, 1999), sad mood (Liotti et al., 2000), aversive Pavlovian conditioning (Buchel, Morris, Dolan, & Friston, 1998), perceptual awareness of threat (Critchley et al., 2000), and penalty-related activation (Elliott, Friston, & Dolan, 2000).

Interestingly, there is also evidence that somatosensory cortices and the insula might be crucial to generate conscious emotional experiences, particularly aversive ones. Hearkening back to the writings of William James (1884), one proposed mechanism for this involves building a model of the current bodily state, including the hormonal, muscular, and visceral milieu (Damasio, 1999). Specifically, an internal representation of a "visceral homunculus" may be maintained in the posterior insula bilaterally, which primarily projects to the right anterior insula (Craig, 2003). Activation of this circuitry has consistently been associated with aversive bodily sensations, including noxious heat or cold stimuli (Becerra et al., 1999; Tracey et al., 2000) and pain (Ploghaus et al., 2001;

² Some earlier reports have suggested that the amygdala is particularly important for processing fear-related stimuli, as indicated by the impairments of the amygdala patients in recognizing fearful facial expressions (Adolphs, Tranel, Damasio, & Damasio, 1994). More recent work suggests that this specificity is explained by the role that facial information from the eye region plays in fear recognition (Adolphs et al., 2005). In fact, the amygdala seems particularly important in processing of gaze information (Adams, Gordon, Baird, Ambady, & Kleck, 2003) and can be activated even by rudimentary eye features, such as the increases in the sclera, or the whites of the eyes (Whalen et al., 2004).

³ Conversely, some neuroscientists, who see the amygdala as the center of "emotional brain," doubt that conscious feelings are causally imporant in affective influence. For example, LeDoux (1996) views feelings as a nice but ineffective "icing" on an emotional cake. In contrast, we believe that feelings play an imporant causal role in many, though not all influence phenomena.

Sawamoto et al., 2000). Consistent with the idea of a visceral basis of emotion experience, neuroimaging studies show that recall of emotional memories is associated with extensive activation of the insula and somatosensory cortex (Damasio et al., 2000), whereas damage to these regions is associated with reduction in the intensity of affective feelings (Craig, 2003; Critchley, 2005). However, the present literature has not yet clarified whether insular activation is more related to the arousal or valence component of emotional experience.

Assuming that insular activation correlates with negative valence, activation of this region should predict subsequent behavior. This implication was explored by Paulus, Rogalsky, Simmons, Feinstein, & Stein (2003) in a decision-making game. They found that activity in the right insular cortex was greater during risky gambles (Paulus et al., 2003), and that insular activation correlated with later risk aversion, as well as with trait measures of negative arousal. These findings were extended by Kuhnen and Knutson (2005), who found that insular activation preceded switches to risk averse strategies in an investment task. Together, these findings suggest that insular activation (particularly on the right) may play a critical role for the processing of aversive emotions during decisionmaking.

Integration and Regulation of Emotion and Cognition

Affective neuroscience also leads to new insights on how affect gets integrated into cognitive processing and how cognition can regulate affect. Most of the research in this area has focused on the role of the prefrontal cortex, especially orbitofrontal, ventromedial, and lateral areas.

Orbitofrontal Cortex

Orbitofrontal cortex (OFC) is the bottom third portion of prefrontal cortex, situated just above the eyes. OFC is hypothesized to play a role in one of the most fundamental aspects of affect-cognition interactions—linking cognitive representation of a stimulus with the representation of its corresponding value. The OFC may play an important role in this process, as sug-

gested by selective firing of OFC neurons in monkeys to stimuli associated with rewards or punishments (Rolls, 1999). A subset of these neurons is highly flexible in their coding properties, changing their firing rate when the reward properties of a stimulus change (e.g., when a stimulus that previously predicted food delivery no longer does so). Further, some OFC neurons only fire to motivationally relevant stimuli. For example, neurons that fire during presentation of a particular food (e.g., a banana) when the animal is hungry, no longer fire in the presence of that food after the animal is satiated (Rolls, 1999).

Ventromedial Prefrontal Cortex

A more circumscribed, ventral section of the medial prefrontal cortex (vmPFC) has been hypothesized to play a unique role in the ability to incorporate emotional factors into decisions (Damasio, 1999). For instance, Bechara and colleagues (1997) compared performance of controls and vmPFC-lesioned patients on a money gambling task in which an initially attractive option was later associated with occasional but substantial losses. The vmPFC patients chose the risky option more frequently and ultimately made less money, presumably because of their inability to process loss-related somatic feedback.

Interestingly, given the right task, vmPFC patients can also make more profit-maximizing decisions (Shiv, Loewenstein, Bechara, Damasio, & Damasio, 2005). Specifically, in a myopic loss aversion task, typical participants show excessive caution about choosing risky, though profitable options (Gneezy & Potters, 1997). In this task, participants start with an endowment (e.g., \$20) and decide on each subsequent round to either invest \$1 or to advance to the next round without investing. If the participant decides to invest, they have a 50% chance of losing their \$1 or a 50% chance of winning an additional \$1.50. Thus, from a profit-maximizing perspective, it is better to invest than to pass (expected value = \$1.25 vs. \$1). However, typical participants often fail to invest, and particularly if they have lost money on the previous trial—consistent with the notion of loss aversion. Using the myopic loss aversion paradigm, Shiv et al. (2005) showed that compared to healthy controls, vmPFC patients invested more frequently and ultimately made more money, presumably because the absence of negative feedback reduced their risk aversion.

Finally, fMRI studies have repeatedly implicated medial PFC in processing financial gain outcomes, with increases in mPFC activation when the outcome is better than expected and decreases when outcome is worse than expected (Knutson, Fong, Bennett, Adams, & Hommer, 2003). This finding, which recently has been verified with electrophysiology (Oya et al., 2005), highlights that understanding how value (affect) and expectation (cognition) is incorporated in the decision requires consideration of both psychological and biological factors.

Lateral Prefrontal Cortex

Affective neuroscience is also beginning to investigate a possible role of lateral PFC in strategic control of emotion. Such control could involve descending projections from the dorso-lateral PFC to the medial and orbital PFC, which then project to the amygdala and to the accumbens (Phan, Wager, Taylor, & Liberzon, 2002; Davidson, Jackson, & Kalin, 2000). Thus, recent research reported lateral PFC activation during tasks in which subjects were asked to increase or decrease their affective reactions to negative pictures (Ochsner & Gross, 2005; Schaefer et al., 2002).

Mechanisms of Affective Priming: Psychological and Biopsychological Account

One specific demonstration of how affective neuroscience elucidates affective influence phenomena involves "affective priming"—the impact of preceding affective stimuli on responses to subsequent neutral stimuli. One robust examples of this phenomenon is the affect congruent influence of emotional facial expressions on subsequent judgments (Murphy & Zajonc, 1993; Niedenthal, 1990). Importantly, such affective priming can be obtained with actual behavior. For example, in a study by Winkielman, Berridge, and Wilbarger (2005) participants subliminally exposed to happy, as opposed to angry, faces poured and drank more of a pleasant drink and also rated the drink as more desirable and financially valuable afterward. This study also revealed two additional important findings. First, the priming effects depended on motivation, such that thirsty participants showed the greatest increases in pouring, consumption and ratings after exposure to happy faces. Second, changes in behavior and ratings were not accompanied by conscious changes in mood. Recently, we also obtained similar results with even more complex subsequent decisions, such as choices between risky gambles (Trujillo, Knutson, Paulus, & Winkielman, under review). These findings indicated that participants were more likely to choose a risky option after exposure to positive (happy) versus negative expressions (anger, fear, or disgust). Once again, the influence of facial expressions on risky gambles did not depend on changes in participants' conscious experience.

Traditional psychological models have difficulty in fully explaining affective priming. For instance, the affect-as-information view proposes that affective priming involves a misattribution of a conscious affective experience induced by a subliminal prime to a neutral target (Schwarz, 1990). However, our work showed that subliminal affective primes do not change conscious mood (Winkielman et al., 2005). Further, unlike the many misattribution studies (Schwarz & Clore, 2003), participants continue to show subliminal affective priming effects even when invited to attribute their emotional reaction to an alternative source, such as background music or "hidden pictures" (Winkielman, Zajonc, & Schwarz, 1997). The associative semantic memory model proposes that affective priming is just a type of semantic priming with participants interpreting neutral targets in light of affective concepts activated by the prime (Forgas, 2006). This model can explain the absence of conscious feelings. However, it cannot explain why priming effects are easily obtained with pictures of emotional faces or emotional scenes, but are hard to elicit with valence and intensity matched affective words (Winkielman & Gogolushko, under review). Similarly, the associative model cannot explain why priming with nonaffective attributes of the face, like gender and age, fails to produce comparable effects as those seen with emotional expressions (Murphy & Zajonc, 1993). Finally, the associative model cannot explain why affective priming generalizes to behavioral measures, but not to participants' ratings of their own mood, nor can

the model explain why motivational state amplifies the impact of affective primes (Winkielman et al., 2005).

Given the inability of traditional psychological models to account for affective priming, we have recently offered a model that incorporates considerations from affective neuroscience (Winkielman et al., 2005). Specifically, we propose that salient emotional stimuli, such as facial expressions (but not words), activate subcortical circuits, such as the amygdala or NAcc. This can occur either when salient stimuli are presented subliminally (Whalen et al., 1998) or supraliminally, and even when participants' attention is not focused on the emotional content of the stimuli (Critchley et al., 2000). These subcortical circuits project to other subcortical regions involved in processing incentives (Berridge, 2003) and to prefrontal cortex, involved in representation of expected value and probability (Knutson & Wimmer, 2007). Thus, an emotionally expressive face activates the amygdala or NAcc, which then alters the readiness of regions involved in perception and behavior to respond to subsequent incentive stimuli (e.g., a novel beverage or risky gamble). Finally, as discussed earlier, while these neural events may eventually be important for conscious experience, they also have the potential to operate independently from conscious experience (Anderson & Phelps, 2002). Thanks to their connectivity with brain regions implicated in perception, attention, memory, and motor preparation, these subcortical regions have the capacity to push an organism toward or away from stimuli, even without the mediation of reflective insight or emotional feeling.

Importantly, these biopsychological considerations generate interesting predictions about when affective stimuli should influence subsequent behavior and feeling. For example, the degree to which an affective stimulus, or a task, activates the neural incentive system should predict its influence on subsequent incentive-related processing and behaviors, and how individual and motivational differences will modify the observed effects.

Conclusion

In this article, we argued that dominant psychological models of affective influence on judgment and decisions (including the major associative and inferential models) cannot capture and predict many phenomena that are more gracefully accommodated by biopsychological models. We illustrated this point by showing that biopsychological models shed light on how values and feelings arise, and how they subsequently influence perception, attention, memory, judgment, and choice. Of course, existing psychological models of affective influence are not inherently deficient. In fact, we strongly believe the primary relevance of affective neuroscience hangs on its ability to inform the psychological level of explanation. However, as we have tried to demonstrate, the psychological models can only partially capture variables that are relevant to the phenomenena they are trying to explain, and they sometimes hold untenable assumptions in light of biopsychological findings. Finally, many functional algorithms may lead to the same software implementation, but it is now necessary to "crack open" the hardware to determine which algorithm is instantiated. For all these reasons, the time is ripe for pairing psychological research on affective influence with affective neuroscience. We hope that the current overview provides a step toward that goal.

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