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Attitudes and evaluations: a social cognitive neuroscience perspective

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Automatic evaluations are crucial for survival, but conscious self-reflection enables the formulation of nuanced evaluations to serve long-term goals. To operate effectively, both automatic and reflective evaluative processes need to integrate stored representations from previous experience (attitudes) with current contexts and goals, but contexts and goals have a more prominent role in reflective evaluation. Recent neuroimaging data provide new insights into the structure and function of evaluation and the dynamic ways that attitudes and reflective processing contribute to evaluation. In this paper, we propose a new iterative-reprocessing (IR) model of the neural bases of evaluation that highlights the role of the prefrontal cortex in the reprocessing of evaluative information. This model makes predictions that inform social-cognitive and cognitive-neuroscientific accounts of evaluation.

Introduction

It is difficult to think of social psychological concepts that are more central to a comprehensive understanding of human behavior than attitudes and evaluations. Attitudes (i.e. relatively stable ideas about whether something is good or bad) exert powerful influences on people's evaluations – their current appraisals – and these, in turn, influence people's choices (e.g. their choices of friends, careers, consumer products and presidents). During the past half century, attitudes and evaluations, or more generally evaluative processes, have been studied extensively [1,2], and much has been learned about their structure and function.

An important advance in attitude research came in the 1980s. Borrowing from research in cognitive psychology, specifically research on implicit and explicit memory [3], social psychologists began to explore the differences between automatic and controlled evaluative processes. This distinction between automatic and controlled processes now lies at the heart of several of the most influential models of evaluative processing, which can be referred to collectively as the dual-attitude framework [4–6]. According to the strong form of these models, automatic and controlled processes are generated by two dissociable cognitive (and, presumably, neural) systems that have distinct representational stores: an implicit attitude system and an explicit attitude system. Whereas the implicit system is rapid, unconscious and robust across situations, the explicit system is slower, conscious and more likely to generate evaluations that vary as a function of current contexts and processing goals.

These dual-attitude models have generated considerable interest and they have highlighted the fact that evaluative processes are potentially complex and multifaceted. For example, they have provided a framework for discovering and interpreting dissociations between people's self-reported attitudes (e.g. about race) and their often incongruous responses in tasks such as the implicit association test [7,8]. However, recent data suggest that dual-attitude models, at least in their strong form, are too simple to capture the dynamic way in which affective attitudes and reflective processing interact and contribute to evaluations. In this article, we propose a new model, the iterative-reprocessing (IR) model, which highlights the interaction among automatic and reflective processes and, importantly, the reprocessing of evaluative information about valenced stimuli (Figure 1). According to the IR model, evaluative processing occurs on a continuum from relatively automatic to relatively reflective processing; additional reprocessing enables a stimulus to be construed *vis-à-vis* a wider range of contexts and considerations.

The iterative-reprocessing model

The terms 'attitude' and 'evaluation' are often used interchangeably, but we use them here to refer to different aspects of evaluative processing: whereas an attitude is a relatively stable set of representations of a stimulus (only some of which might be active at any time), an evaluation reflects one's current appraisal of the stimulus, including whether it should be approached or avoided. When rendering an evaluation, one draws upon pre-existing attitudes (in particular, those aspects of the attitude that are currently active), together with novel information about the stimulus, contextual information and current goal states. We suggest that stimuli (e.g. people, objects and abstract concepts) initiate an iterative sequence of evaluative processes (the evaluative cycle) through which the stimuli are interpreted and reinterpreted in light of an increasingly rich set of contextually meaningful representations. Whereas evaluations that are based on few iterations of the evaluative cycle are relatively automatic, in that they are obligatory and might occur without conscious monitoring [9,10], evaluations based on additional iterations and computations are relatively reflective.

In the IR model, we propose that the neural networks that are involved in evaluation are hierarchically

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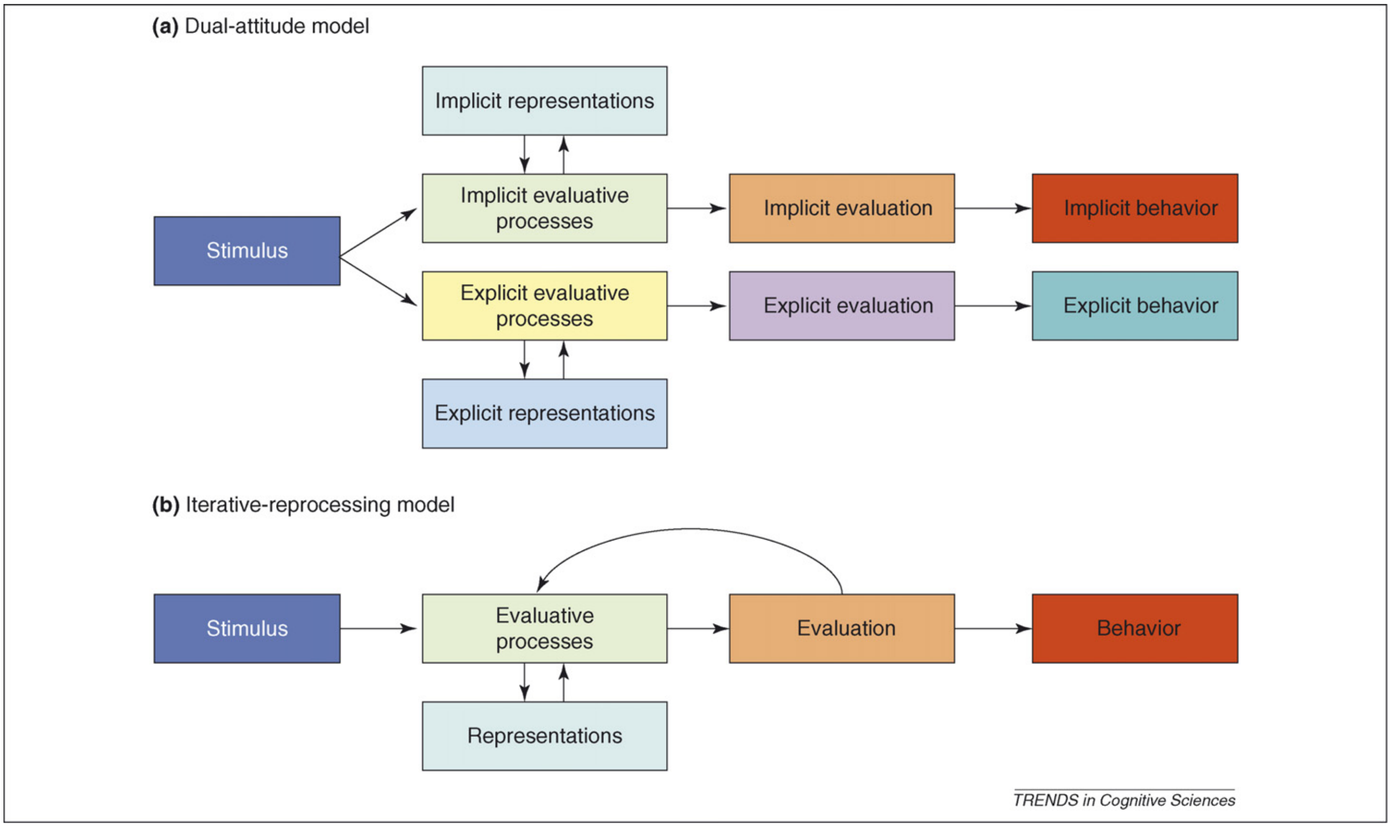

Figure 1. Dual-attitude and iterative-reprocessing models of evaluation. A comparison of the proposed processes that are involved in the dual-attitude **(a)** and iterative-reprocessing **(b)** models of evaluation. Whereas the dual-attitude model suggests separate representations, processes and realms of behavioral prediction, the iterative-reprocessing model proposes that these can be reduced to a single system with iterative loops. In this context, 'implicit' evaluations have fewer iterations and recruit fewer processes than 'explicit' evaluations.

arranged, so a common set of processes continues to be involved in generating evaluations throughout the cycle. We hypothesize that lower-order evaluative processes continue to provide affectively laden information about valence (good and bad) and the arousal value of the evaluation (i.e. fundamental aspects of affective states [11]), even as higher-order processes are recruited during subsequent iterations. With each additional iteration, this information is passed back to the relatively lower-order processes and the evaluation is recalculated; new attitude representations and contextual information can then be activated or foregrounded to help construct a more carefully considered evaluation. For example, one way in which evaluation changes as a function of the reprocessing of evaluative information is through changes in the construal of the stimulus. Suppose a person has a complex attitude about Bill Clinton. If positive aspects of this attitude are activated, a positive evaluation is likely to follow, which then influences the construal of Clinton during further iterations (e.g. Clinton might be more likely to be construed as a great president than as an adulterer). This process has been referred to as 'reseeding the evaluative cycle' [12].

According to the IR model, the number of iterations that contribute to an evaluation depends on a variety of personal and situational variables, including, but not limited to, individual differences in ability (e.g. reflectivity), motivation (e.g. the consequences of one's appraisal) and opportunity (e.g. the time available for responding). However, two competing motivational drives are hypothesized to influence the extent of evaluative processing across situations: (i) a drive to minimize the discrepancy between one's evaluation and the hedonic environment (i.e. to minimize error), and (ii) a drive to minimize processing demands. These opposing drives create a dynamic tension that can propel us to move beyond our initial 'gut' response to generate an affective model that is more complex but not computationally catastrophic.

Neural mechanisms of evaluative processing

Building on recent work in affective neuroscience, as well as neuroimaging data on evaluative processing, we propose a tentative model of the neural networks that underlie evaluation. As will become clear, these processes overlap considerably with those that are involved in affect and emotion, and emotion regulation, as well as executive function and reflective processing in general [12,13].

Our proposed neural implementation is depicted as a circuit diagram in Figure 2. For the first pass, perceptual information about a stimulus is processed via the thalamus and fed forward to the amygdala and other limbic structures, such as the ventral striatum. In fMRI studies, the amygdala has consistently been found to respond to a wide range of valenced stimuli, including faces, scenes, words, odors and tastes [14–19]. In one study, amygdala activity was associated with the trial-by-trial affective intensity of pictures that were presented in the scanner [20]. Furthermore, studies that used subliminal presentations of fearful faces or angry faces conditioned with an aversive stimulus have shown that the amygdala responds even when participants are unaware of the eliciting stimulus

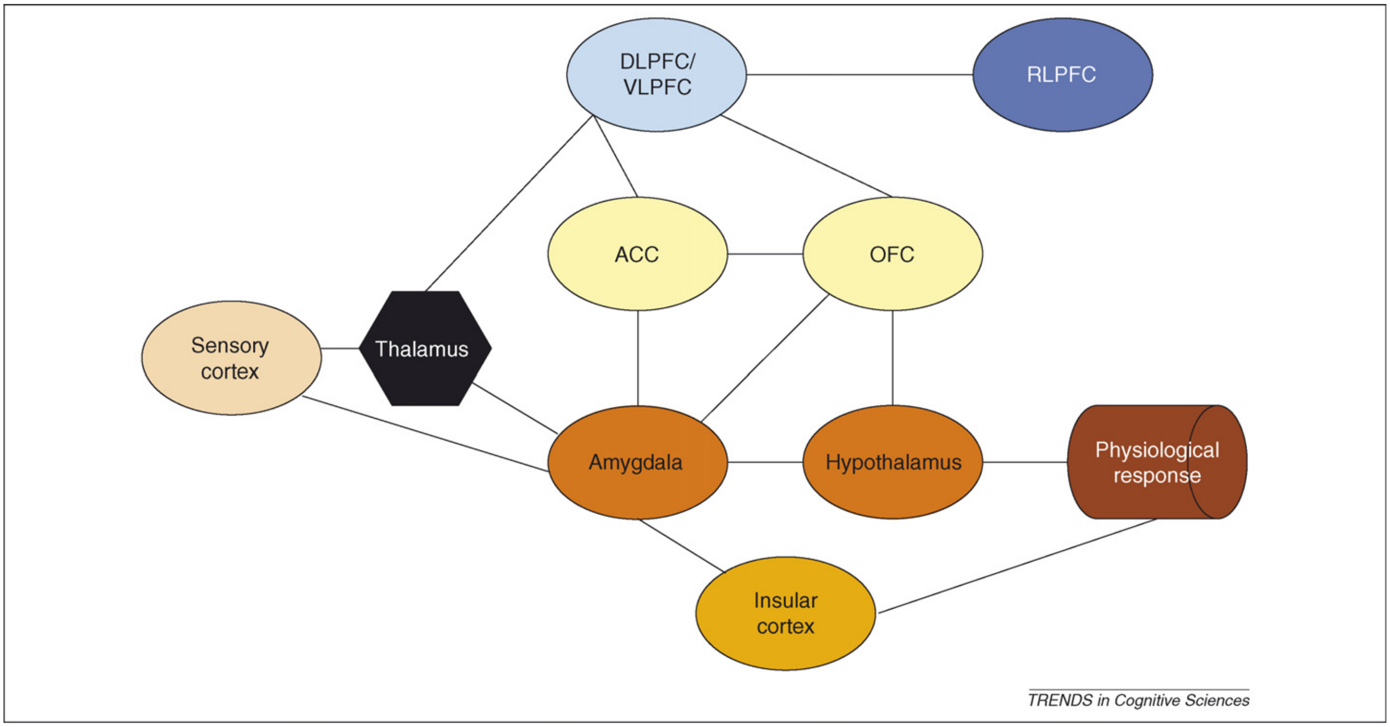

Figure 2. Neural circuitry that underlies evaluation – a simplified neural model of the iterative-reprocessing model. Links between regions that are discussed in this paper are illustrated. We acknowledge that not all anatomical links are represented. Information about a stimulus is processed by the thalamus and projected to the amygdala, which leads to an initial evaluation that is associated with a tendency to approach or to avoid the stimulus. Additional iterations can include processing that is informed by insular cortex, orbitofrontal cortex (OFC) and anterior cingulate cortex (ACC) processing, as well as detailed sensory processing. Visceral changes that follow evaluation are guided by the hypothalamus and other regions that are associated with autonomic control. Additional recruitment of the prefrontal cortex, particularly regions of the ventrolateral prefrontal cortex (VLPFC), dorsolateral prefrontal cortex (DLPFC) and rostrolateral prefrontal cortex (RLPFC), might have a role in strategic reprocessing of stimuli and might serve to regulate evaluative processing by amplifying or suppressing attention to certain aspects of the situation.

[21–23] (see Box 1 for additional fMRI data on evaluative processing).

At this point in evaluative processing, evaluations are likely to be determined primarily by the most accessible aspects of one's attitude [24]. However, in light of the widespread connections from the limbic system, initial responses can serve to direct further processing in regions that are associated with sensory and attentional processing [25]. Moreover, given connections with regions that are proposed to be involved in autonomic function (e.g. the hypothalamus), the generation of evaluation (and a tendency towards approach or avoidance) can be followed by visceral responses that can prepare the body for action [26].

Although quick responses have an obvious survival value, we suggest that evaluations continue to be refined through additional iterations. In addition to the thalamus, the amygdala receives information from throughout the brain that can help to inform a more nuanced evaluation. For example, areas of the sensory cortex have projections to the amygdala that enable affective processing following a more detailed identification of the stimulus. Furthermore, visceral bodily changes are encoded in areas of the somatosensory cortex (and perhaps particularly in the anterior insula) that, it has been proposed, enable a cortical representation of the current autonomic state [27,28]. As processing continues, information from these areas can be used as input for the reprocessing of the current evaluation. That is, we propose that areas such as the amygdala are used at each stage of evaluative processing, with each cycle receiving more detailed information.

In addition, the amygdala has projections to the orbitofrontal cortex (OFC), which is associated with aspects of affective processing, such as representing rewards and anticipating the affective outcomes of behavior – processes that are necessary for arriving at an accurate evaluation of a stimulus or situation [29–31]. The OFC might provide a relatively early form of regulation by integrating amygdala output with a learned context (and simple approach–avoidance rules). Because of direct reciprocal connections between the OFC and amygdala, and projections from the OFC to hypothalamus, OFC activation can modulate responses to a stimulus to fit with a particular context.

However, not all evaluations can be constructed easily from accessible attitudes or situational constraints. Some evaluations occur when relatively little is known about a stimulus (i.e. non-attitudes) or when attitudinal representations contain conflicting positive and negative information (i.e. ambivalence) [32]. Additionally, personal or situational variables might suggest the need for a more carefully considered assessment. The persistence of a problem, which is indicated by lingering uncertainty or the detection of conflict, might be associated with activation of the anterior cingulate cortex (ACC) [33–35]. This activation might signal the need for additional reprocessing of the stimulus.

This additional reprocessing of stimuli and attitudes enables a person to construe a stimulus *vis-à-vis* a wider range of contexts and considerations [36]. Instead of being based on a relatively superficial gloss of a stimulus – one

Box 1. fMRI correlates of implicit and explicit evaluation

To delineate the brain processes that are involved in automatic evaluation, fMRI studies have examined neural activity when participants respond in a non-reflective fashion; for example, when stimuli are presented too rapidly to be consciously perceived or when participants are required to attend to a non-evaluative dimension of a stimulus. Presumably, the brain systems that are as active when people are not attending to their evaluation as when they are attending to it are likely to be involved in automatic evaluation. In such cases, the intention to generate an evaluation is not crucial for the activation of the brain region.

We review a study that directly compared explicit and implicit evaluative processing of stimuli and correlated brain activation patterns with attitude ratings of particular stimuli. On each trial, participants were instructed to indicate whether various valenced stimuli were good or bad (evaluative task), or abstract or concrete (non-evaluative task) during scanning [49]. Following scanning, participants rated each of the stimuli on several attitude dimensions, such as positivity–negativity and emotionality, and were asked 'When you have more time to think about or reflect upon your attitude, how much do you try to control or change your initial response?', which is referred to as the 'control' rating. These attitude ratings were correlated with brain activation for individual attitude objects to determine which brain regions were engaged in different aspects of evaluative processing regardless of task (i.e. automatically) and which processes were engaged only with reflective intent.

In this study, activity in areas of the bilateral amygdala, orbitofrontal cortex (OFC) and right insula correlated with attitude ratings identically for both the evaluative and non-evaluative task (Figure Ia). Whereas amygdala and OFC activity correlated with emotionality ratings equally for positive and negative stimuli, right insula activity was associated with the processing of negative stimuli more than the processing of positive stimuli. Additionally, the emotionality rating correlated with activation in areas of the brain stem. This pattern of data suggests that these areas are involved in automatic stages of evaluative processing – a deliberate goal to evaluate was not necessary for their activation.

A different pattern of activity was correlated with participants' reported motivations to control or modify their initial responses. Activity in the anterior cingulate cortex (ACC), ventrolateral prefrontal cortex (VLPFC), dorsolateral prefrontal cortex (DLPFC) and rostrolateral prefrontal cortex (RLPFC; Figure Ib) was correlated with this 'control' rating in evaluative, good–bad tasks more than in non-evaluative, abstract–concrete tasks. In a related study, participants made good–bad or past–present responses about famous names [50]. Greater activation was found in areas of the prefrontal cortex for ambivalent names (e.g. Bill Clinton) but, again, only in the good–bad task (Figure Ic). Similar to the previous study, rendering good–bad evaluations for ambivalent stimuli required controlled processes to modify and resolve initial responses. Whereas limbic brain areas seem to be involved in the processing (and reprocessing) of aspects of valence and arousal, these studies suggest cortical brain areas are involved in the processing of stimulus complexity. Importantly, these processes are only fully activated when people have the intention to generate complex evaluations.

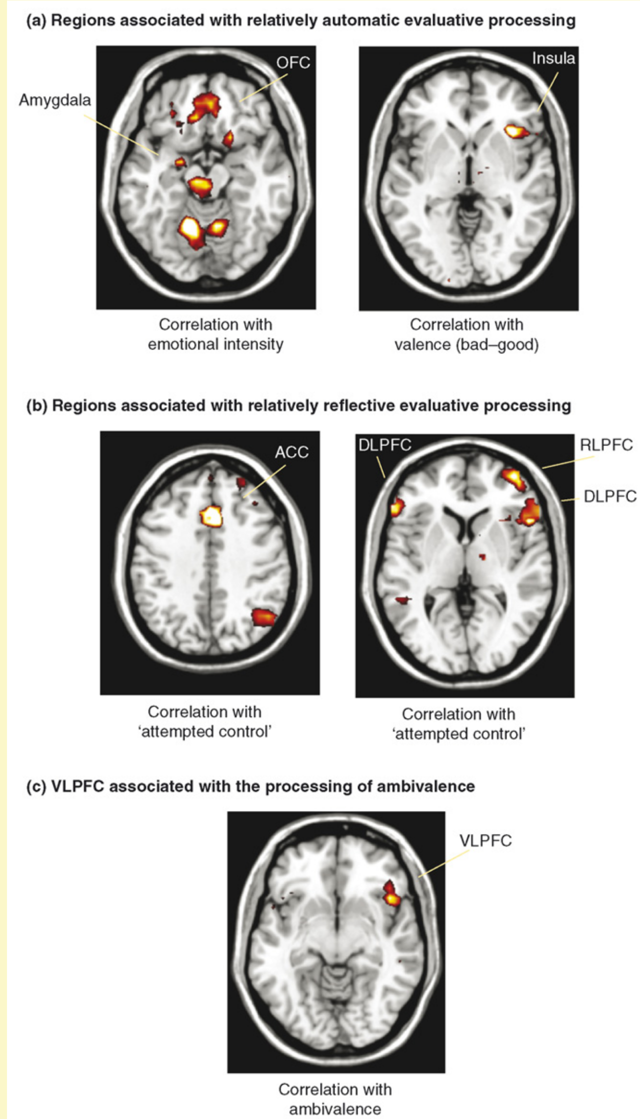

Figure I. fMRI maps associated with the processing of evaluative information. **(a)** Activation maps represent the significant regression parameters that are associated with participants' ratings of emotional intensity and valence (valence is defined here as the difference between bad and good ratings). These maps represent activity that is significant for both the good–bad tasks and the abstract–concrete tasks. **(b)** Activation maps represent the significant regression parameters that are associated with participants' 'control' ratings. These regions are the ones in which activation was greater for the good–bad tasks than for the abstract–concrete tasks. **(c)** Activation map shows an area of the ventrolateral prefrontal cortex (VLPFC) that was associated with increasing attitudinal ambivalence (the coactivation of positive and negative information). Activation in this area was significant only for the good–bad task. Abbreviations: ACC, anterior cingulate cortex; DLPFC, dorsolateral prefrontal cortex; OFC, orbitofrontal cortex; RLPFC, rostrolateral prefrontal cortex. (a) and (b) reproduced from Ref. [49]. (c) reproduced from Ref. [50].

that extracts only its most salient, low-resolution aspects – subsequent iterations yield more nuanced stimulus and context construals and have the potential to be based on a wider range of aspects of one's attitude about the stimulus.

According to the IR model, reflective evaluations are hypothesized to depend on the recruitment of regions of the lateral prefrontal cortex (PFC) into an increasingly complex, hierarchical network of activations. Research suggests that different regions of the lateral PFC are involved in representing rules at different levels of complexity – from sets of conditional rules [ventrolateral prefrontal cortex (VLPFC) and dorsolateral prefrontal cortex (DLPFC)] to explicit consideration of task sets [rostrolateral prefrontal cortex (RLPFC)] [37]. In the context of evaluation, complex networks permit more carefully considered stimulus construals, in part because additional information about the stimulus and the context in which it occurs can be integrated into the construal on each iteration, and in part because these networks support the formulation and use of higher-order rules for selecting certain aspects of a stimulus on which to attend. That is, iterations that involve the recruitment of the lateral PFC enable the foregrounding and backgrounding of particular stimulus aspects [38]. Importantly, this lateral-PFC-mediated reprocessing fulfils the dual functions of working memory (i.e. keeping aspects of the stimulus in mind) and inhibitory control (i.e. backgrounding some aspects of a stimulus and refraining from responding impulsively on the basis of an initial, automatic evaluation); these are key cognitive functions that support reflective evaluations and enable 'emotional up- and down-regulation' [39].

Evaluative reprocessing and race-based attitudes

An important example of evaluative reprocessing comes from the study of race-based attitudes, which has had a key role in the development of theories of dual attitudes. Typically, social-cognitive research has found discrepancies in mean differences and low correlations between direct (self-report) and indirect (millisecond-response latency) attitude measurements. These results have been taken as evidence for dual attitudes. Recently, research using fMRI has investigated these attitudes to understand better the dynamics of evaluative processing. Studies using fMRI to study race attitudes have suggested a role for the amygdala in automatic prejudice [40–45]. For example, greater amygdala activation to black than to white faces has been shown to correlate with the implicit association test (IAT), a response latency measure of automatic attitudes [7].

Additional research has suggested important interactions between limbic and cortical regions when participants have the opportunity to reflect or reframe. Greater amygdala activation to black than to white faces was found when participants used social categories for their judgments, but there was greater activation to white than to black faces when people treated the faces as individuals [44]. In another study [43], subliminal stimuli were presented for 30 ms and masked by an abstract image for 525 ms; supraliminal stimuli were presented for 525 ms (and the mask then appeared briefly for 30 ms). When stimuli were presented subliminally, white participants showed greater activation to black than to white faces; this difference was correlated with participants' IAT scores (Figure 3a). When stimuli were presented supraliminally, there was no longer a significant difference in amygdala activation, but there was increased activation in areas of the ACC and lateral PFC (DLPFC and RLPFC; Figure 3b). Importantly, the decrease in amygdala activation between conditions was predicted by an increase in DLPFC activation, which provides evidence of interactions between limbic and cortical regions during evaluation. Moreover, the degree to which participants were conflicted (indexed by the discrepancy between performance on implicit and explicit measures of attitudes about blacks and whites) was correlated with activity in the VLPFC. This study provides preliminary evidence of the iterative reprocessing of racial evaluations as a function of opportunity.

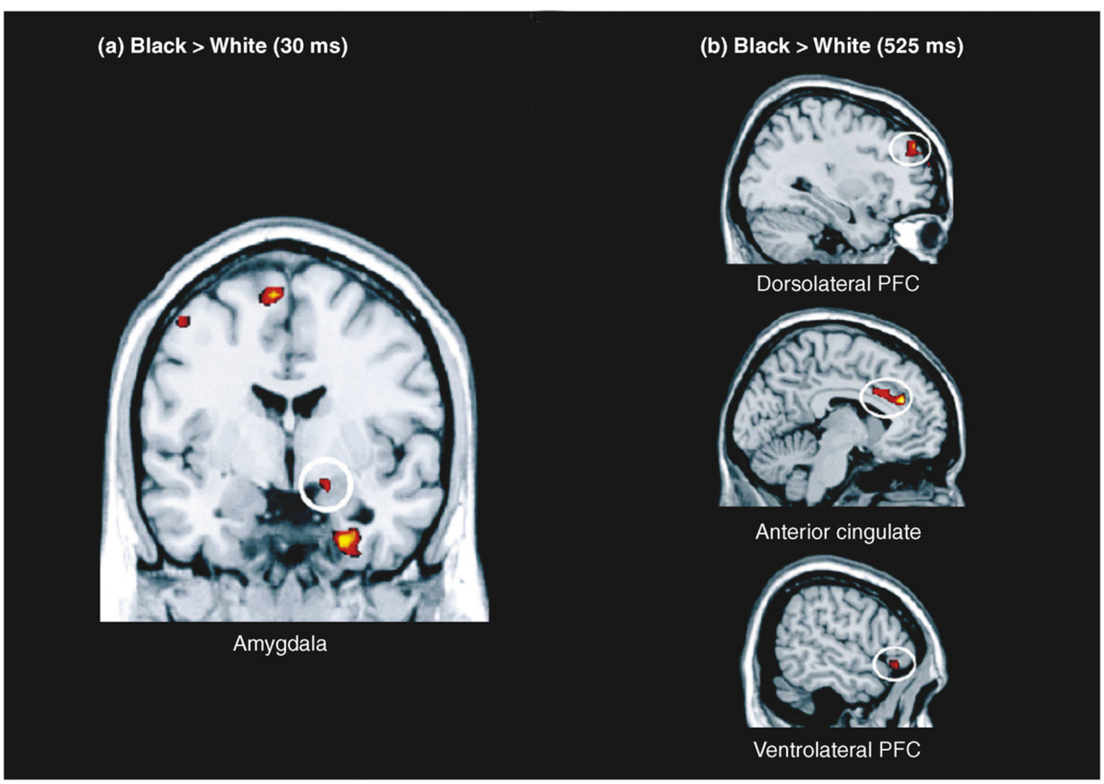

Figure 3. Differential activation to black and white faces. **(a)** The activation map illustrates areas that show greater activation to black faces than to white faces in the subliminal 30 ms condition. The amygdala activation is circled. **(b)** The activation maps illustrate areas that show greater activation to black faces than to white faces in the 525 ms condition. Abbreviation: PFC, prefrontal cortex. Reproduced from Ref. [43].

Reflective processes do not need to lead to a decrease in affective processing. Like the findings for race, there was greater activity in the amygdala and insula when participants were presented with images of members of stigmatized groups (e.g. obese people and transsexual people) [45]. Whereas participants had personal goals to inhibit negative responses to black faces in the studies on race-based attitudes, a negative response to these stigmatized groups might be normatively acceptable [46]. It is perhaps for this reason, and consistent with our foregrounding hypothesis, that greater activity in the ACC and lateral PFC was found in response to the stigmatized images. In terms of the IR model, lateral-PFC-mediated foregrounding might have led to increases in negative evaluations.

Box 2. Evaluative timing

A key aspect of our proposal is that information is reprocessed iteratively through the evaluative system. An important, and currently unstudied, question surrounds the speed at which iterative reprocessing occurs. Using current research on working memory as a basis, we postulate specific speculative claims about the speed of the iterations within the IR model – how quickly an evaluation can be generated and updated. Research using various methodologies suggests that the processing of valenced information occurs rapidly in the processing stream. For example, Kawasaki and colleagues found that the processing of valence occurred 120–160 ms after stimulus presentation in single-cell recordings of the human orbital frontal cortex [51]. Similarly, depth electrodes have found that amygdala activity can occur ~200 ms after stimulus presentation [52].

Research also suggests the timings at which reflection might begin to alter the observed patterns. In one study, participants were presented with valenced stimuli and asked to make either good–bad or abstract–concrete judgments [53]. A lateralized late positive potential (LPP), larger in the right anterior electrodes for stimuli rated as bad and larger in the left anterior electrodes for stimuli rated as good, began ~450 ms after stimulus presentation for both evaluative and non-evaluative trials. Although the onset of the hemispheric asymmetries were not influenced by whether the task was explicitly evaluative, the amplitude of the effects, as measured later in processing (starting at ~800 ms post stimulus), was greater for the evaluative trials. This suggests an automatic initiation of evaluative processing followed by, in this case, an increase in response as a result of reflective reprocessing of the stimulus.

Borrowing from the working-memory literature, we propose a novel hypothesis that subsequent iterations of the evaluative cycle occur in the theta band (4–8 Hz). That is, iterative reprocessing of evaluative information might occur in cycles lasting ~200 ms (5 Hz) each. Current computational models suggest that the contents of working memory are updated in the theta band [54]. To the extent that reprocessing involves working-memory systems, this suggests that the reprocessing of evaluation occurs with the updates in information. Based on axonal connection speeds, recursive loops from the hippocampus to the cortex take between 120 ms and 200 ms, or one period of theta [55]. This proposed theta-band timing is consistent with activity that has been recorded in limbic structures, such as the hippocampus [56], cingulate [57] and hypothalamus [58]. For example, recordings of intracranial field potentials from depth electrodes in the amygdala found discrete changes in gamma power amplitudes in the theta band at ~200 ms, 400 ms and 600 ms following the presentation of positive, negative and neutral images (a period of ~5 Hz) [59]. Furthermore, synchronization in the theta band was found between the hippocampus and amygdala during the retrieval of fearful events [60]. Overall, these findings suggest that evaluations can be updated up to eight times per second, with the first few iterations likely to occur automatically and before conscious awareness of the triggering stimulus.

Concluding remarks

In understanding how brain processes give rise to complex cognition, neuroscientists have increasingly pointed to processing circuits that involve multiple neural regions [12,47,48]. According to this view, information is processed dynamically through recursive feedback loops that progressively recruit additional regions of the cortex (see Box 2 for a discussion on evaluative timing). In this paper, we have suggested one such circuit that might be involved in the generation and shaping of an evaluative response. Within this framework, the generation of evaluations involves processes that occur throughout the information-processing stream, as well as iterative processes that transform relatively automatic evaluations into evaluations that are better suited to current situations and goals. Central to this hypothesis is that evaluations reflect a dynamic interaction between limbic and cortical structures. Automatic evaluations (which occur earlier in the processing stream) are linked more to limbic processing, whereas reflective evaluations additionally recruit and use several cortical systems.

This framework enables a reinterpretation of previous work that has been conducted from a dual-attitudes perspective. Often, attitudes (and thus evaluations) are thought to be relatively static and, as such, research that has revealed different attitudes using different attitude measures has raised a problematic question: which is the true attitude? One solution has been the dual-attitude framework [4–6]. However, if the brain processes information more dynamically and in a more interactive fashion

Box 3. Questions for future research

- How do the systems described in this article give rise to the conscious experience of evaluation (the sense that something is good or bad)? Which aspects of evaluative processing are accessible to conscious awareness?
- When reflective processes are recruited to foreground additional information, can these processes retrieve information that is not accessible to purely automatic processes? That is, is some information only accessible to a reflective evaluative system (e.g. higher-order ideologies and chronic goal states)?
- Are there separate regions for the processing of valence and arousal? Can the processing of valence be broken down into separate systems for processing positivity and negativity? If so, can these systems be activated in such a way that one has simultaneous positive (approach) and negative (avoidance) feeling states? Do these processes use the same representational store, or are there separate affective representational stores for positive and negative information? How do specific emotions (e.g. anger, fear, hate and love) contribute to relatively abstract notions of 'good' or 'bad'?
- How do individual differences relate to preferences to engage in different evaluative processes? For example, are open people more likely to process risky stimuli in a deep fashion rather than a shallow fashion? Are people who have a high need for cognition more likely to engage in higher-level evaluative processes?
- How are problems in the evaluative system linked to psychopathology? Although we have discussed how evaluative processing can become more complex with additional iterations of the evaluative cycle, this need not be the case. People might perseverate on a particular stimulus construal, cycling through additional iterations without considering additional aspects of the stimulus or the relevant attitude. This type of cyclical processing without elaboration might be tantamount to rumination and could be characteristic of anxiety and depression.

than is supposed by this framework, then an alternative interpretation seems more plausible. To the extent that these evaluations reflect particular combinations of elements at different times to satisfy different constraints, each evaluation is 'true' for that particular moment. Although discrepancies might be observed between relatively quick and relatively deliberate evaluations, these discrepancies do not imply a fundamental dissociation between implicit and explicit 'systems' of evaluation. Instead, these discrepancies might be accounted for by the number and nature of cognitive and affective processes that are brought to bear on evaluative information (e.g. attitudes).

However, there is still much to learn about evaluative processing (see Box 3 for outstanding research questions). For example, what specific computations are performed by each component (i.e. what are the actual structure–function relationships)? If evaluative information is processed in various component sub-systems, how is this information integrated to form a unified sense of good or bad? And how do these systems give rise to the conscious experience of evaluation (the sense of goodness and badness)? As social neuroscientific investigations of attitude and evaluation continue, a clearer picture of this dynamic system is likely to emerge, yielding a better understanding of how important aspects of attitudes arise from the intersection of affective and cognitive processes.

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