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The neural basis of social influence and attitude change

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Human attitudes and preferences are susceptible to social influence. Recent social neuroscience studies, using theories and experimental paradigms from social psychology, have begun to elucidate the neural mechanisms underlying how others influence our attitudes through processes such as social conformity, cognitive inconsistency and persuasion. The currently available evidence highlights the role of the posterior medial frontal cortex (pMFC) in social conformity and cognitive inconsistency, which represents the discrepancy between one's own and another person's opinion, or, more broadly, between currently inconsistent and ideally consistent states. Research on persuasion has revealed that people's susceptibility to persuasive messages is related to activation in a nearby but more anterior part of the medial frontal cortex. Future progress in this field will depend upon the ability of researchers to dissociate underlying motivations for attitude change in different paradigms, and to utilize neuroimaging methods to advance social psychological theories of social influence.

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Introduction

Attempts to influence or change another person's attitudes are pervasive in all societies. These attempts range in scale from daily interactions with friends, to corporate advertising and political campaigns. How an individual's attitude or preference is altered by social influence has long been a central topic in social psychology [1,2], and past behavioral studies have identified a variety of processes by which an individual's attitude is modulated.

Recent studies in social neuroscience have begun to shed light on the neural mechanisms underlying such social influence and attitude change. This review focuses on human social neuroscience research and summarizes recent findings that show neural processes of attitude/preference change induced by three processes: first, social conformity (attitude change to match group opinions), secondly, cognitive consistency motivation (attitude change to reduce cognitive dissonance), and thirdly, persuasion (attitude change in response to persuasive messages).

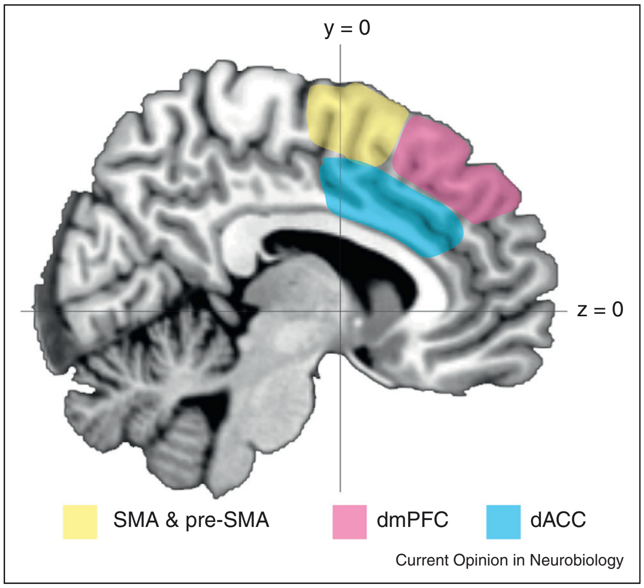
Social conformity

Social conformity refers to changing one's attitudes, beliefs or behaviors to match group norms that are implicitly or explicitly shared by a group of individuals [3]. Its effect has been well documented in social psychology experiments, and people sometimes conform to a group opinion even if the opinion is clearly wrong [4].

Berns *et al.* [5] was the first to examine the neural processes underlying social conformity using a neuroimaging method (functional magnetic resonance imaging: fMRI). In this study, while subjects performed a mental rotation task, they were shown a response from a group of peers. Responses from peers were sometimes wrong in order to induce conforming behavior. This experimental situation is similar to Asch's original conformity study [4], and the study provided initial evidence for changes in basic perceptual processes during social conformity (differential activity in an occipital-parietal network). Klucharev *et al.* [6] used a face attractiveness rating task and tested how subjects' ratings were influenced by others' ratings. They found that when a subjects' rating conflicted with the group rating, the posterior medial frontal cortex (pMFC) [7] (Figure 1) and insula, among other regions, were more activated than when the subject's rating matched the group rating (Figure 2a). Furthermore, activations in these regions were significantly associated with subsequent change in self-report attractiveness ratings. Another study [8] also reported heightened activation in the pMFC and insula when the subject's own preference was mismatched with two experts' preferences for pieces of music, an effect especially marked for those who exhibited a stronger tendency to conform to other people's opinions. Similarly, Berns *et al.* [9] reported that those who have a stronger conformity tendency showed higher activations in pMFC and insula when other people's opinions were shown, regardless of the degree of the mismatch. A transcranial magnetic stimulation (TMS) study further demonstrated that the pMFC plays a critical role in social conformity [10••].

In contrast to pMFC activation in response to the discrepancy between a subject's ratings and group ratings,

Figure 1



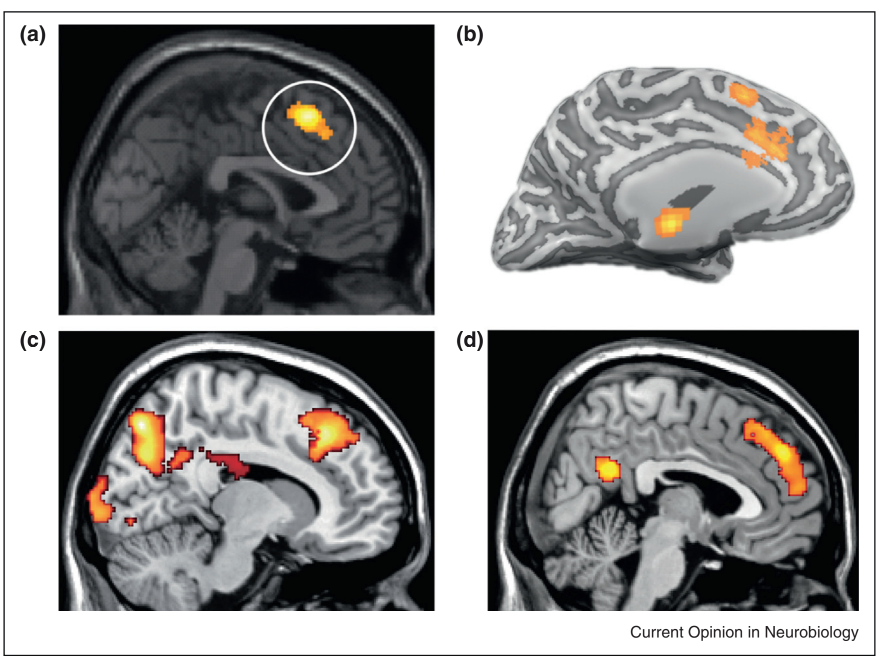
posterior medial frontal cortex (pMFC) and its subdivisions. Supplementary motor area (SMA) and Pre-SMA include Brodmann Area (BA) 6. Dorsal medial frontal cortex (dmPFC) includes BA 8 and 9. Dorsal anterior cingulate cortex (dACC) includes BA 24 and 32.

studies report reduced striatal activation when the subject's own preference mismatches the majority opinion [6] or the opinion of two experts [8] (see also [11]). Thus, when subject's opinion differs from others' opinion, the pMFC is activated, while the striatum is deactivated.

One possible interpretation of pMFC and striatum involvement in social conformity is that conforming to the opinion of others might share similar neural mechanisms with reinforcement learning [6]. It is thought that pMFC and striatum activations reflect a prediction-error signal (difference between expected and actual reward outcome), which is used to adjust subsequent behavior [12,13]. These regions may play a similar role in social conformity by generating an error signal representing a difference between one's own opinion and the group's opinion, which in turn is utilized for subsequent adjustment of one's preference. Consistent with this idea, three recent electroencephalography (EEG) studies [14–16] showed that when the subject's own opinion conflicted with the group's opinion, the pMFC generated a response similar to a feedback-related negativity (FRN), that is, a signal associated with negative feedback [17].

Additional evidence comes from a study using methylphenidate [18•], a catecholamine reuptake inhibitor that indirectly increases extracellular dopamine and noradrenaline levels in the brain (e.g. striatum), especially in response to appetitive stimuli [19]. Relative to those

Figure 2



The pMFC activations reported in previous studies on social conformity and cognitive consistency theories. **(a)** The pMFC activation in response to discrepancy between one's and the group rating. Adapted from Klucharev *et al.* [6]. **(b)** The pMFC area involved in cognitive dissonance in the induced compliance paradigm. Adapted from van Veen *et al.* [39]. **(c)** The pMFC area activated by cognitive dissonance in the free-choice paradigm. Adapted from Izuma *et al.* [21•]. **(d)** The pMFC area activated by cognitive imbalance. Adapted from Izuma and Adolphs [11••].

who received placebo, individuals who received methylphenidate exhibited significantly more conformity, especially when the difference between the subject's opinion and the group opinion was moderate [18•]. However, it should be noted that the results of this study do not necessarily indicate that the striatum is responsible for the effect of methylphenidate. Compared to the pMFC [10••], it is relatively less clear whether the striatum plays an active role in inducing attitude change. It might well be that the striatum activity reflects the reward value of agreeing with others [8] (see also [11••]).

Another line of research on social conformity investigated whether opinion modulates not only self-reported preference but also its neural representation. Social psychologists distinguish two types of attitude change [1,3,20]: 'public compliance' versus 'private acceptance.' Public compliance refers to demonstration of conformity in public without a change in one's true attitude, whereas private acceptance refers to a genuine change in one's attitude to match the opinion of others. The striatum and ventromedial prefrontal cortex (vmPFC) are known to track subjects' preferences for various stimuli [9,21•,22,23], even when tasks do not require subjects to explicitly think about how much they like each item [22,24]. This suggests that activity in these areas is unlikely to be affected by exogenous factors and is thus likely to reflect the subject's true preference for stimuli (i.e. private acceptance). Two studies [25,26•] have demonstrated that changes in self-reported preference for abstract symbols [25] and female faces [26•], induced by others' opinions, were accompanied by changes in striatum and vmPFC activity levels (see also [8]). These findings suggest that conformity leads to private acceptance of the group's normative opinion rather than simple public compliance (however, see [9] for conflicting evidence). Private acceptance of social influence is also demonstrated by a study investigating the effect of social conformity on memory. Others' opinions could induce persistent change in subjects' memory and also modulated its neural representations (e.g. amygdala and hippocampus activities) [27].

A recent study also demonstrated that oxytocin, a neuropeptide implicated in a variety of social behaviors [28], affects social conformity, especially in relation to one's ingroup [29•]. In addition, a study reported that grey matter volume in lateral orbitofrontal cortex (OFC) is correlated with people's tendency to conform to the opinion of experts [30].

Cognitive consistency

Cognitive consistency [31] is a class of theories in social psychology that stems from the following principle: individuals prefer incoming information to be cognitively consistent with already existing cognitions, beliefs and attitudes; and if there is inconsistency, people are motivated to reduce it. Among cognitive consistency theories, two of the most influential theories are cognitive dissonance theory [32] and balance theory [33]. Recent studies have begun to reveal the neural mechanisms underlying these types of cognitive inconsistency and the subsequent preference change that may result.

According to cognitive dissonance theory [32], inconsistency between attitude and behavior causes an uncomfortable emotional state called 'cognitive dissonance,' and most people are motivated to reduce it by changing their attitude. For example, after performing an unpleasant action, such as eating fried grasshoppers [34] or writing an essay in favor of tuition increase (by a student) [35], people are more likely to have a positive attitude toward the action if there was insufficient justification for doing it.

How is cognitive dissonance represented in the brain? It has been proposed [36] that because cognitive dissonance can be considered a type of conflict, it may evoke activity in the pMFC, an area known to be activated during response conflict in simple speeded-response tasks such as a Stroop task [37]. Using an experimental paradigm called 'induced compliance [38],' van Veen *et al.* [39] provided initial evidence for this hypothesis and showed that cognitive dissonance activates an area within the pMFC, the dorsal anterior cingulate cortex (dACC; Figure 2b). Other fMRI studies [21•,23,40–43] used the 'free-choice' paradigm [44] to investigate the neural bases of cognitive dissonance and subsequent preference change, and found the involvement of several brain regions including pMFC, insula, inferior frontal gyrus, and striatum. However, it has recently been discovered that the traditional free-choice paradigm has a serious methodological flaw [45•] (see also [46]), and the validity of findings from those studies [23,40–43] that used the original free-choice paradigm may need to be re-established. Nonetheless, after addressing the problem, a study found that cognitive dissonance activated the dACC (and also dorsomedial prefrontal cortex [dmPFC]; Figure 2c) [21•]. In addition to the pMFC, the left dorsolateral prefrontal cortex (DLPFC) is involved in dissonance reduction, according to EEG studies [36,47].

In balance theory [33], cognitive inconsistency or 'imbalance' is defined by a triadic relationship among self, another person(s), and an object. For example, having a different preference from someone whom you like creates cognitive imbalance (e.g. 'I like it, but my friends do not like it'), and having the same preference as someone whom you dislike is also cognitively imbalanced. In both cases, people are motivated to restore a balanced state by changing their preference.

Izuma and Adolphs [11••] investigated whether cognitive imbalance also activates the pMFC, as does cognitive dissonance. After subjects rated t-shirts according to their preference, they were presented with the ratings of fellow students (liked group) or sex offenders (disliked group) for the same t-shirts. The results showed that activity in an area within pMFC, namely dmPFC (Figure 2d), tracked the degree of cognitive imbalance on a trial-by-trial basis over and above simple expectation violation (i.e. difference between others' actual response and what a subject expected others' response to be) [11••]. The dmPFC activity was also associated with subsequent preference change. Thus, extending the previous study on social conformity [6], pMFC activation appears to be modulated by the discrepancy between one's own preference and the group's preference, and it also depends on how a person feels about that group. This study further suggested that cognitive conflicts studied in social psychology (e.g. cognitive dissonance, imbalance) do not have the same neural basis as response conflict [36]. Rather, the neural basis of preference change following cognitive inconsistency may be similar to that of reinforcement learning [6]. Thus, much like pMFC neurons signal reward prediction error, which induces subsequent behavioral adjustments during reward-based decision-making tasks [48–50], the pMFC may also play a similar role in social influences on preference change by signaling the discrepancy between actual outcome and outcomes that would be the most cognitively consistent, which induces subsequent preference modulation.

As reviewed above, studies on social conformity [6,8,9,14–16] and cognitive consistency [11••,21•,39] commonly report the involvement of pMFC (Figure 2). It has been recently proposed [51••] that the pMFC plays an even larger role in inducing palliative responses following many other types of inconsistency or threat described in social psychology, including worldview defense following mortality salience [52] or subliminal (non-death related) threat [53], proximity-seeking following a threat to self-esteem [54], etc. Although currently available evidence is generally consistent with this view, the theory [51••] seems to need at least one modification. Proulx *et al.* [51••] argued that these phenomena have the same neural basis as does the representation of prediction errors (as conceived in reinforcement learning) and general conflict monitoring mechanisms. However, consistent with suggested functional distinctions within pMFC for these two processes [7,55,56], the findings from Izuma and Adolphs [11••] suggest that at least one type of inconsistency defined in balance theory is not the same as response conflict. Nonetheless, it will be interesting to see in future research whether other palliative responses to a variety of threats [57] also involve pMFC.

Persuasion

Persuasion is a process aimed at changing the beliefs, attitudes or behavior of another person [1]. A number of studies have attempted to investigate the neural basis of attitude change following persuasion [58••,59,60•,61,62••,63–65]. Persuasion is not a uniform process, and people are persuaded for different reasons in different situations. One potential advantage of a neuroimaging approach to persuasion is that it allows researchers to pin down a specific process for attitude change after exposure to persuasive messages. Recent neuroimaging studies seem to highlight a role for the anterior part of medial frontal cortex in persuasion [58••,59,60•,61,62••,63].

One way to make persuasive messages more effective is to make them more relevant to individuals in the target audience. Medial prefrontal cortex (mPFC; an anterior part of the medial frontal cortex) is a brain area involved in self-referential processing [66], and therefore activity in this area may reflect the degree of self-relevance felt by the receiver of the persuasive message. Consistent with this idea, anti-smoking messages tailored to specific needs of each smoker activated this area [59], and recent studies commonly report that mPFC activation during exposure to persuasive messages can be used to predict subsequent attitude/behavior changes such as shifts in cigarette smoking [58••,62••] or sunscreen use [61]: the higher the mPFC activation when viewing messages, the more likely individuals were persuaded. In one study, this effect was found above and beyond self-report measures [62••]. Furthermore, the degree of mPFC activation in response to different ad campaigns promoting smoking cessation more accurately predicted how successful each campaign was at the population level than did self-report measures [60•].

Another variable known to influence the effectiveness of persuasive messages is communicator expertise [3]. Klucharev *et al.* [64] found that when a product was paired with an expert versus a non-expert (e.g. a professional athlete vs. an actress paired with sport shoes), the product was better remembered and perceived as more attractive. These behavioral effects were paralleled by brain activations in reward-related (striatum) and memory-related (hippocampus and parahippocampal gyrus) brain regions [64].

Conclusion and future directions

Findings from social neuroscience studies indicate that brain regions such as pMFC, mPFC and striatum are involved in social influence on preference and attitude. However, compared with the long history of research on social influence and attitude change in social psychology [1,2], the investigation of neural mechanisms underlying such processes is still in its infancy. An important point that should be emphasized is that people change their opinions for different reasons, and dissociating underlying motivations for attitude change is critical for a clear understanding of the neural basis of attitude change. Three common motivations for attitude change have been previously identified [1,3]: first, to be accurate, secondly, to obtain social approval from others (or avoid social rejection), and thirdly, to maintain a positive self-concept (including cognitive consistency motivation). The relative importance of each of these motivations seems to vary depending on the experimental paradigm. For example, the possibility of future interaction with others (e.g. whether other group members are present in the same experiment [5,14,29•]) seems to influence a subject's motivation to obtain social approval from those people. The motivation to be accurate, on the other hand, comes into play when performance in an experimental task depends on objective criteria (tasks with an objective correct answer, such as a mental rotation task [5] or a line judgment task [14]). Although the suggested role of pMFC (detecting a conflict between an ideal state and reality, and inducing preference change accordingly) may be the same regardless of underlying motivation, the involvements of other brain regions, neurotransmitters (dopamine) or neuropeptides (oxytocin) are likely to differ.

Another important direction for future research is to apply neuroscience methods (e.g. fMRI) to questions in social psychology, and to discover whether those methods can be used to advance psychological theories on social influence and attitude changes [67,68]. One good example here is the use of striatum activity levels as a measure of preference or positive attitude (e.g. dissociating private acceptance and public compliance) [25,26•]. Another possibility would be to use pMFC activation as a measure of cognitive inconsistency (e.g. neural 'dissonance thermometer'). Although pMFC is known to involve in a variety of cognitive processes (e.g. response conflict, negative outcome, error, etc.) [69], making it particularly challenging to correctly attribute its activation to a specific psychological process, it may still be possible to ensure the selectivity of the pMFC activation to cognitive inconsistency by carefully designing an experimental paradigm. The above-mentioned studies on persuasion [60•,62••] also suggest that neural measures could be more accurate than self-reports in evaluating how effective persuasive messages are, suggesting its utility in advancing theories on persuasion.

Finally, although the present review focused on social influence processes only in humans, there is evidence that other animals (fish, rats, and non-human primates) also show conformist behavior [70] (see also [71]) and preference modulation consistent with cognitive dissonance theory (e.g. [72]). As researchers begin to elucidate the neural bases of social behaviors at the single-cell level using animals in a variety of social contexts [73], it will be interesting to see how future animal research on this topic provides insights into its neural bases.

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