Neurosci. Bull. February, 2023, 39(2):328–342
https://doi.org/10.1007/s12264-022-00960-4

www.neurosci.cn
www.springer.com/12264

REVIEW

Brain Systems Underlying Fundamental Motivations of Human Social Conformity

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Received: 26 January 2022 / Accepted: 11 July 2022 / Published online: 26 October 2022

Abstract From birth to adulthood, we often align our behaviors, attitudes, and opinions with a majority, a phenomenon known as social conformity. A seminal framework has proposed that conformity behaviors are mainly driven by three fundamental motives: a desire to gain more information to be accurate, to obtain social approval from others, and to maintain a favorable self-concept. Despite extensive interest in neuroimaging investigation of social conformity, the relationship between brain systems and these fundamental motivations has yet to be established. Here, we reviewed brain imaging findings of social conformity with a componential framework, aiming to reveal the neuropsychological substrates underlying different conformity motivations. First, information-seeking engages the evaluation of social information, information integration, and modification of task-related activity, corresponding to brain networks implicated in reward, cognitive control, and tasks at hand. Second, social acceptance involves the anticipation of social acceptance or rejection and mental state attribution, mediated by networks of reward, punishment, and mentalizing. Third, self-enhancement entails the excessive representation of positive self-related information and suppression of negative self-related information, ingroup favoritism and/or outgroup derogation, and elaborated mentalizing processes to the ingroup, supported by brain systems of reward, punishment, and mentalizing. Therefore, recent brain imaging studies have provided important insights into the fundamental motivations of social conformity in terms of component processes and brain mechanisms.

Keywords Social conformity · Motivation · Information seeking · Social acceptance · Positive self-concept · Brain mechanisms

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Introduction

Imagine on an ordinary weekday morning, you get into the elevator only to find that everyone is facing the back of the elevator except you. Would you turn to the back of the elevator like everyone else? Almost all of the respondents answered this question “No, I wouldn’t be that stupid.” However, Candid Camera, an American television show caught images that many people followed this strange behavior in an elevator. Not only on TV shows, but in our daily life, from birth to adulthood, we often align our behaviors, attitudes, and opinions with the majority of others. Babies cry when other babies are crying, children drop their toy dinosaurs and join in the LEGO set that other children are constructing, adolescents keep their dress and hairstyle in line with what is popular among peers, and adults go to the restaurant with the longest line. All of these are examples of social conformity, which refers to adjusting one's behaviors or attitudes to group opinions [1, 2].

Contemporary empirical studies of human social conformity originate from the seminal work of Muzafer Sherif and Solomon Asch. The study of Sherif took advantage of the autokinetic effect (Fig. 1A), i.e., the apparent movement of a stationary light viewed in a dark room. Participants were asked to estimate the distance that a stationary light moved along a wall individually or with others. Individual estimates in the alone context varied considerably across participants (e.g., from 20 cm to 80 cm), however, individual estimates in the group context converged to a common estimate over a small number of

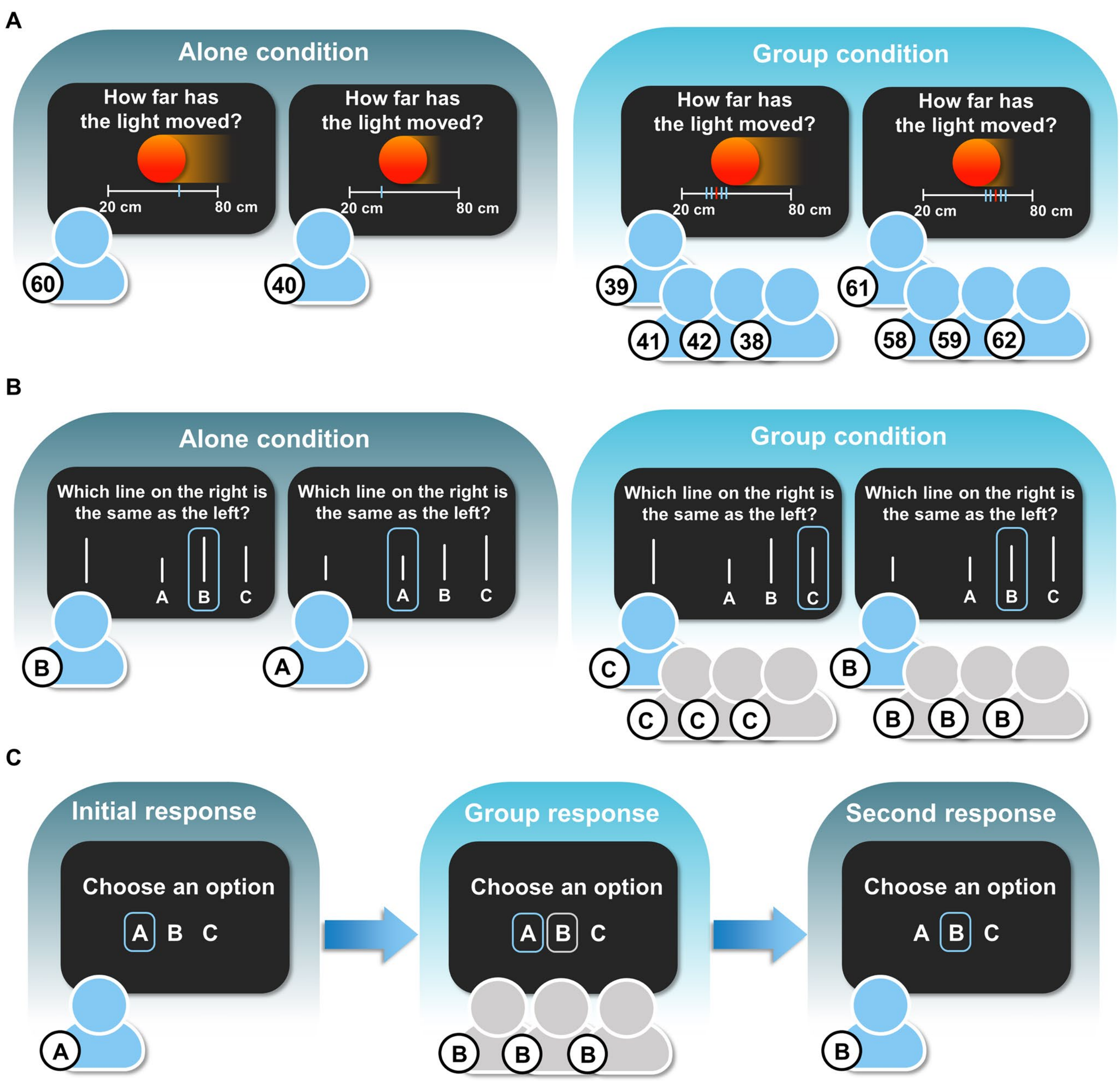

Fig. 1 Experimental paradigms of social conformity. **A**–**C** The paradigms applied by Muzafer Sherif (**A**), Solomon Asch (**B**), recent brain imaging studies (**C**) (blue silhouettes, participants; gray silhouettes, confederates).

trials [3]. Asch's experiment took a step further to determine whether people follow group opinions even when there is an obvious answer to a line judgment task (Fig. 1B). Participants were able to make correct judgments when they completed the task alone. However, in the presence of others, about one-third of participants gave up their correct judgments and followed the wrong, unanimous judgments of their peers [4, 5]. These initial experiments have provided a framework and paradigm by which to examine human social conformity in the laboratory, and following-up studies have identified conformity behavior in a variety of domains [2, 6–8]. For example, conformity behaviors have often been examined in a paradigm in which participants are exposed to many others' opinions that are congruent or incongruent with one's own (Fig. 1C). As such, it has been consistently demonstrated that individuals adjust their initial behaviors to match group opinions when there is a discrepancy between oneself and the group [9–16].

A seminal framework has proposed that conformity behaviors are mainly driven by three fundamental motives, including a desire to gain more information to be accurate, to obtain social approval from others, and to maintain a favorable self-concept [1]. First, most of our decisions are made in a social context, in which people often only have asymmetric information. Therefore, integrating social information might help to exploit the informational content and optimize decisions [13, 17, 18]. Second, human society generally reinforces compliance with social norms by rewarding those who obey [19, 20] and punishing those who violate social norms [21–23]. Therefore, when most people reach a consensus, following this group norm is an effective way to gain social acceptance [24]. Third, people tend to see themselves in a positive light [25], and are motivated to maintain a favorable self-concept. Accordingly, people often integrate social information relevant to the self in a biased manner [26, 27]. Besides, self-concept is largely shaped by social identity based on one's group membership [28, 29]. Accordingly, another essential approach to maintaining positive self-assessment is to identify with and conform to ingroup members in support of self-categorization considerations [30, 31]. Together, the motivations underlying human social conformity have been an important topic in the field of social psychology in the past decades and have provided essential insights into the psychological mechanisms of conformity behavior. Despite recent extensive interest in neuroimaging investigation of social conformity, the relationship between the brain systems involved in conformity behaviors and the three fundamental motivations has yet to be established, and a unified framework to integrate previous brain imaging results is still lacking.

Indeed, the past decades have seen intense interest in identifying and delineating the neural substrates of social conformity [10–12, 32–36]. These neuroimaging studies have shown that social conformity is not a single, unitary construct, but instead engages multiple neurocognitive processes, including brain networks important in reward or punishment processing, mentalizing, and cognitive control [2, 6, 7, 11]. Specifically, brain regions implicated in conflict and punishment processing, including the dorsal anterior cingulate cortex (dACC) and anterior insula (AI), are recruited by the discrepancy between oneself and the group [37, 38]. In contrast, brain regions associated with reward processing, including the ventral striatum (VS) and ventromedial prefrontal cortex (vmPFC), are involved when individuals adjust their behavior in line with normative opinions [9, 12, 39]. In addition, brain areas related to information integration, including the dorsolateral prefrontal cortex (dlPFC) and inferior parietal lobule (IPL), are frequently engaged by social conformity [13, 14]. Lastly, social conformity involves the engagement of brain areas important for mentalizing, such as the temporo-parietal junction (TPJ) and dorsomedial prefrontal cortex (dmPFC) [40–43]. Previous brain imaging findings of social conformity have been largely accounted for by the reinforcement learning (RL) account, asserting that people's conformity behaviors are driven by prediction errors defined as the differences between self and group opinions. That is, conformity behaviors can be regarded as behavioral adjustments to reduce the discrepancy between oneself and the group [2, 12]. However, the RL account does not explicitly provide the motivations that drive people to reduce the discrepancy, and the motivational account is essential to fill the gap. Therefore, the motivational account and the RL account are not exclusive; instead, they provide insights into human conformity at different levels. In short, although previous brain imaging findings have provided important insights into the neural correlates underlying human social conformity and essential components (e.g., prediction error) in the RL account, their relationship with fundamental motivations of conformity behaviors has yet to be uncovered.

Here, we aimed to review recent behavioral and neuroimaging evidence of social conformity according to fundamental motivations of conformity behaviors, with the purpose of establishing the relationship between conformity-related neuropsychological processes and fundamental motivations that drive conformity behaviors across various contexts. In this regard, the current review aimed to provide a unified theoretical framework to better understand neuropsychological functions underlying human social conformity from the perspective of fundamental motivations. Notably, it is beyond the scope of the current review to establish the relationships between different motivations, as few imaging studies have directly examined the neural mechanisms underlying different motivations of social conformity. In other words, the current review used fundamental motivations as a new framework to synthesize previous neuroimaging findings, that is, to delineate different neuropsychological processes related to each motivation. This approach by no means implies that different motivations are completely distinct in terms of underlying component processes; instead, as detailed below, it is clear that different motivations share common neuropsychological processes.

Empirical Evidence

Gaining Information

Information can be thought of as the resolution of uncertainty [44, 45]. People are usually motivated to seek information to optimize their decisions due to information asymmetry [16, 46–48]. In addition, individuals often show an intrinsic preference for information-seeking [49], even if the information obtained cannot optimize decisions [50–52]. For example, individuals are willing to spend money to seek information that does not have any impact on decision-making [53, 54]. Similarly, recent brain imaging studies have found that the reward processing system, such as the orbitofrontal cortex (OFC), represents information in a manner analogous to the processing of monetary rewards [49, 55]. In short, individuals are driven to seek information, either by the need to optimize decision-making or by intrinsic preferences [56, 57].

Many studies have demonstrated that gaining information is one of the key motivations underlying social conformity [1, 58]. For example, individuals are more likely to conform to group opinions in a high-ambiguity context than in a low-ambiguity context, in line with the idea that people have a stronger incentive to obtain information in a more ambiguous situation [12, 59]. Likewise, people follow the actions of other people as well as computers during decision-making [60–63]. These findings can be attributed to the uncertainty and information asymmetry inherent to risky decisions; therefore, the choices of others (either humans or computers) provide important additional information about decision-making. Moreover, instead of conforming to others routinely, people adjust the weights of social information in their decision-making flexibly [64–66], such that conformity behavior can be considered as the optimal response to make decisions based on social information in uncertain situations [67]. In particular, individuals integrate private and social information in a Bayesian fashion according to their reliability to optimize decisions [13, 14, 56, 57, 68, 69]. For instance, when social information is invalid to guide optimal decisions, people adaptively increase the weight of private information, indicating that people are trying to obtain valid information from others' behavior by conformity [16, 70]. In addition, individuals often pay more attention to information that is considered to be more important, while ignoring unimportant social information [71]. Compared with disconfirming information, social information that confirms one's point of view is more likely to be integrated and has a greater impact on decisions, i.e., confirmation bias [60, 72, 73]. Similarly, people are more likely to follow others who have more confidence in the opinions they hold than those with weaker confidence, because high-confidence opinions are endowed with higher reliability than low-confidence opinions [13, 14, 74–79]. In the same vein, people weigh social information based on its consistency with other social information, given that agreement among peers reliably signals accuracy [80]. Taken together, gaining information is an important motive for social conformity, such that people integrate social information according to their credibility and significance during social conformity.

Bayesian models provide a promising framework for studying the motive of gaining information in the context of social influence [81, 82], assuming that people process their private information and social information as discrete probability distributions supposing the likelihood of the optimal choice [67]. Therefore, one strategy to optimize decisions is to make use of uncertainty estimates, weighting information from individual and social sources based on their respective reliabilities in a manner approaching Bayes optimal integration [68]. The reliability of social information is encoded in the brain regions related to value processing such as the vmPFC, frontopolar cortex, and VS [13, 14, 78, 83, 84]. The integration of social information is implemented in cognitive control regions such as the dlPFC, IPL, and dmPFC, such that the activity of these regions scale with the degree of belief updating estimated from the Bayesian model, that is, the Kullback-Leibler (KL) divergence [13, 14, 61]. The association of activity in the dlPFC, IPL, and dmPFC with KL divergence indicates that these cognitive control regions integrate different sources of information in a Bayesian manner according to credibility, resulting in private updates of belief.

These cognitive control regions might also down-regulate neural representations in regions associated with the task at hand [16, 61]. For example, conformity behaviors in the visual rotation task are paralleled by altered perceptual representations of visual stimuli in occipital–parietal regions [32]. Likewise, social influence leads to long-lasting alterations in memory *via* modifying neural mnemonic representations in the hippocampus and amygdala [10, 85]. Moreover, opinions of others readily affect our valuation of objects, such that behavioral adjustments towards social influence in object evaluation are accompanied by modulated engagement of regions important in subjective value coding, including the vmPFC, VS, and OFC [9, 39, 86, 87]. Similarly, options chosen by others are assigned additional utilities encoded in the vmPFC [60]. Notably, it is conceivable that those altered representations in task-related regions induced by social influence are coupled with regulation by higher-level brain regions. For instance, changes in risk preferences due to peer influence are mediated by the neural representation of risk in the caudate through functional connectivity with the dlPFC [61]. Together, these findings indicate that people integrate and internalize the judgments and preferences of others, based on which they update beliefs and make decisions accordingly [2, 7, 67].

In short, social conformity can reflect a motivation to obtain information from the actions of others to optimize decision-making, which engages the evaluation of the credibility of social information and credibility-based information integration. In this regard, social influence not only changes overt behaviors but also internal beliefs. These psychological components are supported by brain systems implicated in valuation (e.g., vmPFC, VS), cognitive control (e.g., dlPFC, IPL), and the task at hand (e.g., visual cortex).

Gaining Social Acceptance

As social creatures, human beings are fundamentally motivated to establish and maintain positive and lasting interpersonal relationships [88]. In the course of human evolution, our ancestors depended on group living to protect themselves from predators, making it adaptive to be accepted by the group [89]. Therefore, human beings have a universal motive to gain social acceptance and avoid social rejection [90, 91]. As positive reinforcement, social acceptance usually leads to positive emotions, while social rejection usually leads to negative emotions [92–94]. In accord with this, imaging studies have shown that social acceptance or endorsement from others activates brain regions associated with reward processing, such as the VS [95–97], whereas social rejection results in activation associated with social pain processing such as the dACC and AI [98]. Accordingly, people are willing to sacrifice financial costs to gain approval from others [99–102]. For example, participants observed by others (compared with an anonymous situation) are more willing to forgo money for altruism [103], accept a donation to charity at their own cost [104], and reduce antisocial behavior [105]. Such "watching eyes" effects can be attributed to the need for social acceptance and/or avoidance of social rejection, which can be readily induced by subtle social cues (e.g., eyes, cameras) [106–108]. In short, the need for belonging plays an important role in human social behaviors, which drives people to obtain social acceptance and avoid social rejection in diverse social contexts.

Social conformity is a feasible way to realize the motivation of social acceptance [109]. For example, compared to anonymous conditions, people have a stronger motivation to cater to others in public, even if they do not agree with others, i.e., mere public compliance [110]. Notably, people are more likely to conform to others in public than in private situations even at the expense of monetary payouts [24]. For instance, participants exhibit a preference for suboptimal options endorsed by a majority of putative other gamblers, although they have near-perfect knowledge of the objective reward probabilities [111]. Moreover, social exclusion generally enhances the need for belonging [112–114], which in turn increases subsequent conformity behaviors [115, 116]. Similarly, people are more likely to follow peers who approve of them, even if they can get more accurate information from computers [117]. Finally, individuals with a greater need for social acceptance are more likely to follow the crowd [108], such as people from collectivist countries [118], people scoring high in loneliness [119, 120] or social anxiety [121], and people with low economic status [122]. In summary, the prospect of social acceptance and rejection, which might be respectively associated with positive and negative emotion experiences, constitutes a key motivation of human conformity as norm compliance [67, 123].

Previous neuroimaging studies have provided complementary evidence on gaining social acceptance as one of the fundamental motives of social conformity. On the one hand, deviation from group opinions leads to expectations of social exclusion, and the resulting social pressure drives people to adjust behaviors in line with social norms [124]. At the neural level, deviations from group norms (i.e. disconformity) and associated emotional experiences are thought to be encoded in the dACC, AI, and amygdala [125, 126], such that the activity of these regions is stronger when people choose not to conform to social norms compared to the condition where they comply with norms [32, 40, 127]. Notably, people who disagree less frequently with others exhibit stronger brain activity in the dACC and AI when they disagree, which can be attributed to enhanced social pressure experienced by individuals who have more trouble disagreeing [128, 129]. In addition, in the case where social norms are explicitly set, the activity of the dACC and AI encodes norm violations regardless of whether the explicit norms require people to conform or not to conform [127]. Lastly, the activity of the dACC is stronger when people follow the incorrect group responses than in the condition where they follow correct group responses, suggesting that this region contributes to encoding social pressure rather than information-gathering [127, 129]. In the same vein, the activity of the dACC is higher for the condition of mere public compliance compared to private acceptance [10]. On the other hand, compliance with group norms can lead to the prospect of being accepted by the group, inducing a sense of belonging that motivates people to agree with others. For example, compared to sticking to one's own opinions, aligning one's opinions with group norms induces activity in regions associated with reward processing, including the VS, vmPFC, and OFC [43, 130]. Moreover, the extent to which one conforms to social norms increases in proportion to the deactivation of the VS in response to disagreement between self and group norms [12].

The ability to infer the mental states of others also plays a critical role in obtaining social acceptance [6]. Accordingly, compared to the absence of social information, the presence of group opinions consistently recruits the engagement of regions important for mentalizing, including the TPJ and dmPFC [40–43], the activity of which predicts the degree of subsequent conformity [42]. Moreover, the activity of the dmPFC and the strength of dmPFC–TPJ connectivity are further increased by explicit norms compared to the mere presence of social information [127]. Finally, functional connectivity patterns between the mentalizing network (dmPFC, TPJ) and the punishment network (dACC, AI) induced by social exclusion can predict the degree of subsequent conformity [131], further supporting the idea that the need for belongingness is embedded in these brain networks.

In summary, the need for social acceptance constitutes one of the fundamental motivations for social conformity, which mainly engages the recruitment of interactive systems important in reward/punishment processing (e.g., dACC, AI, amygdala, VS, and vmPFC) and mentalizing (e.g., dmPFC and TPJ). These networks contribute to the encoding of positive and negative emotional experiences respectively associated with the prospect of social acceptance and rejection as well as modeling the mental states of others during norm compliance.

Maintaining a Positive Self-concept

Self-enhancement enables people to feel good about themselves and maintain self-esteem, which is one of the core goals and basic needs of human survival [132]. Compared with maintaining an accurate self-concept, people tend to maintain an exaggerated and positive self-concept [133]. For example, people often flatter themselves during self-evaluation [134–136], identify positive traits as better descriptions of themselves than negative traits [137, 138], and believe they are better than the average [139, 140]. Accordingly, self-affirmation induces activation of the VS [141], and self-relevant processing recruits similar neural representations with reward processing in the vmPFC [142]. Furthermore, people usually attribute their failure to the external environment and their success to personal ability and efforts [143, 144]. Finally, people recall more positive autobiographical memories than negative ones [145, 146] and exhibit an optimism bias during prospection, i.e., believing that positive events will be more likely to happen to oneself, while negative events will be more likely to happen to others [147–150]. In short, people view self-related events in a positive light and integrate the information into their self-concept in a biased manner. In addition, as social animals, social identities are regarded as an essential part of self-concept, such that social identity—i.e., group members of certain social categories in contrast to other social categories—is the social categorical self [29, 151]. In other words, the self-concept is integrated by social identity [152], such that individuals lacking social identities (e.g., those with autism) are unable to develop a positive self-concept [153]. Social identity rests on intergroup social comparisons that seek to confirm or establish ingroup-favoring evaluative distinctiveness between ingroup and outgroup, motivated by an underlying need for self-esteem [31, 151, 154, 155]. Therefore, people are motivated to think and act in ways that achieve or maintain a positive distinctiveness between ingroups and outgroups during social comparison, in order to strive for a positive social identity [28]. In short, the optimism bias and ingroup bias of conformity behaviors have been regarded as manifestations of the motivation to maintain a positive self-concept.

First, participants assign higher weights to favorable social feedback than unfavorable social feedback about themselves, demonstrating a positive bias in updating their self-concept [26, 27]. Similarly, people integrate different sources of information according to their credibility for good news in a Bayes optimal manner, while they systematically deviate from Bayes optimal choice for bad news [156, 157]. There is a similar bias when people update beliefs about important others, such that people update more good news about candidates they support and ignore bad news related to them [158]. On the contrary, people exhibit a negative bias to follow undesirable feedback about unfamiliar others more than they follow desirable feedback about unfamiliar others [86, 121, 159], which can be attributed to the motivation to maintain a positive self-concept by devaluing others [160–162].

At the neural level, positive social feedback about oneself induces stronger activity in the VS and vmPFC [26]. Moreover, the responses of the vmPFC to self-relevant information predict a positive bias in self-concept updates, i.e., assigning higher weights to desirable social feedback (peers' ratings are higher than participants' first own ratings) than undesirable social feedback [27]. Notably, evidence from the optimism bias literature also sheds light on the neural mechanisms underlying the motive to maintain a positive self-concept. In particular, the experimental paradigm applied for examining optimism bias is essentially similar to those in the social conformity literature, except that congruent or incongruent information is provided as statistics rather than opinions from a group of others. It is conceivable that people have similar motivations to preserve a positive self-concept in response to information about themselves, regardless of whether they are from statistics or the opinions of others. Brain imaging studies on optimism bias have indicated that undesirable feedback about oneself is tracked by the inferior frontal gyrus (IFG), such that the worse the information is than one expects, the stronger deactivation is identified in the IFG. Moreover, diminished neural coding of unfavorable information in the IFG predicts higher scores in trait optimism as well as the extent of valence-dependent asymmetry in belief updating (i.e., optimism bias) [163]. In contrast, patients with depression compared with healthy controls exhibit a stronger encoding of undesirable information in the IFG, which mediates the absence of biased belief updating that supports a positively skewed view of the future [164]. In summary, people often exhibit an optimism bias in updating self-related concepts or beliefs, which is associated with the enhanced neural tracking of favorable information in the vmPFC and diminished encoding of unfavorable information in the IFG.

Second, self-concept is closely related to social identity based on one's group membership [165], which in turn drives individuals to maintain positive self-assessments by identifying with and conforming to their valued groups [30, 31]. Adolescents are more likely to align themselves with their peers rather than adults or children [166–169]. Similarly, adults make more reference to the feelings or preferences of ingroup members, ignore whether their behavior is consistent with that of outgroup members [170–172], and even behave contrary to the group they disapprove of [11, 173]. Notably, the ingroup bias of social conformity is evident even with the experimental control of motives to gain information or social acceptance [174], implicating the close association between positive self-concept and ingroup bias.

Indeed, incongruence with ingroup views decreases self-esteem, which in turn motivates subsequent alignment with ingroup opinions [30, 175]. Likewise, people feel uncomfortable to express public opinions opposed to the political group they belong to, and they prefer to withstand the social pressure and stick to their political positions [176]. In contrast, disagreement with outgroup opinions has no impact on self-esteem [177]. Accordingly, the degree of the association between the self-concept with the group determines the levels of ingroup bias in conformity [178–180], corroborating the idea that self-enhancement plays an essential role in the ingroup bias of social conformity. In summary, ingroup bias of conformity behaviors is an essential manifestation of maintaining a positive self-concept.

At the neural level, consensus between oneself and ingroup members recruits activation of the VS and vmPFC [11, 170, 171]. Conversely, agreement with out-group members induces activity in the dACC and AI, whereas disagreement with out-group members enhances the activity of the VS [11]. These results suggest that ingroup bias in social conformity, which is thought to reflect the motivation of maintaining a favorable self-concept [1, 30], might result from both ingroup favoritism and outgroup derogation [181]. Furthermore, conforming to the ingroup compared with the outgroup engages the dmPFC and posterior superior temporal sulcus (pSTS) [170, 171], implying a more elaborated perspective taken from ingroup members [182–184].

In short, there are at least two manners of maintaining a positive self-concept, manifested as optimism bias and ingroup bias in social conformity. Optimism bias is associated with enhanced coding of favorable information in the reward-related network (e.g., vmPFC) and reduced coding of unfavorable information in the punishment-related network (e.g., IFG). Ingroup bias might be supported by brain networks implicated in reward (vmPFC, VS), punishment (dACC, AI), and mentalizing (dmPFC, pSTS).

Summary

We propose a componential model to map the fundamental motivations of human conformity and ample neuroimaging evidence of social conformity accumulated in the past decades (Fig. 2). First, responses of a majority of others provide an important source of social information that is valuable for decision-making, and the value of information is encoded in the reward network. The cognitive control network contributes to integrating reliable social information to update one's belief, which in turn regulates neural representations in task-related brain systems. Collectively, social conformity driven by information-seeking engages valuation, information integration, and task-related processing. Second, social conformity driven by obtaining social acceptance is mainly mediated by brain networks of reward, punishment, and mentalizing. These networks encode anticipations of social acceptance/rejection and contribute to mental state inference, which together constitute key components of conformity for social approval. Third, conformity driven by maintaining a positive self-concept is manifested as optimism bias and ingroup bias. The neural encoding of positive self-related information is enhanced in the reward network, whereas the neural tracking of negative self-relevant information is attenuated in the punishment network, leading to optimism bias in belief updates of the self-related concept. Moreover, ingroup bias might be supported by the responses of the reward/punishment network to agreement/disagreement with the ingroup and disagreement/agreement with the outgroup (i.e., ingroup favoritism and outgroup derogation) and facilitates

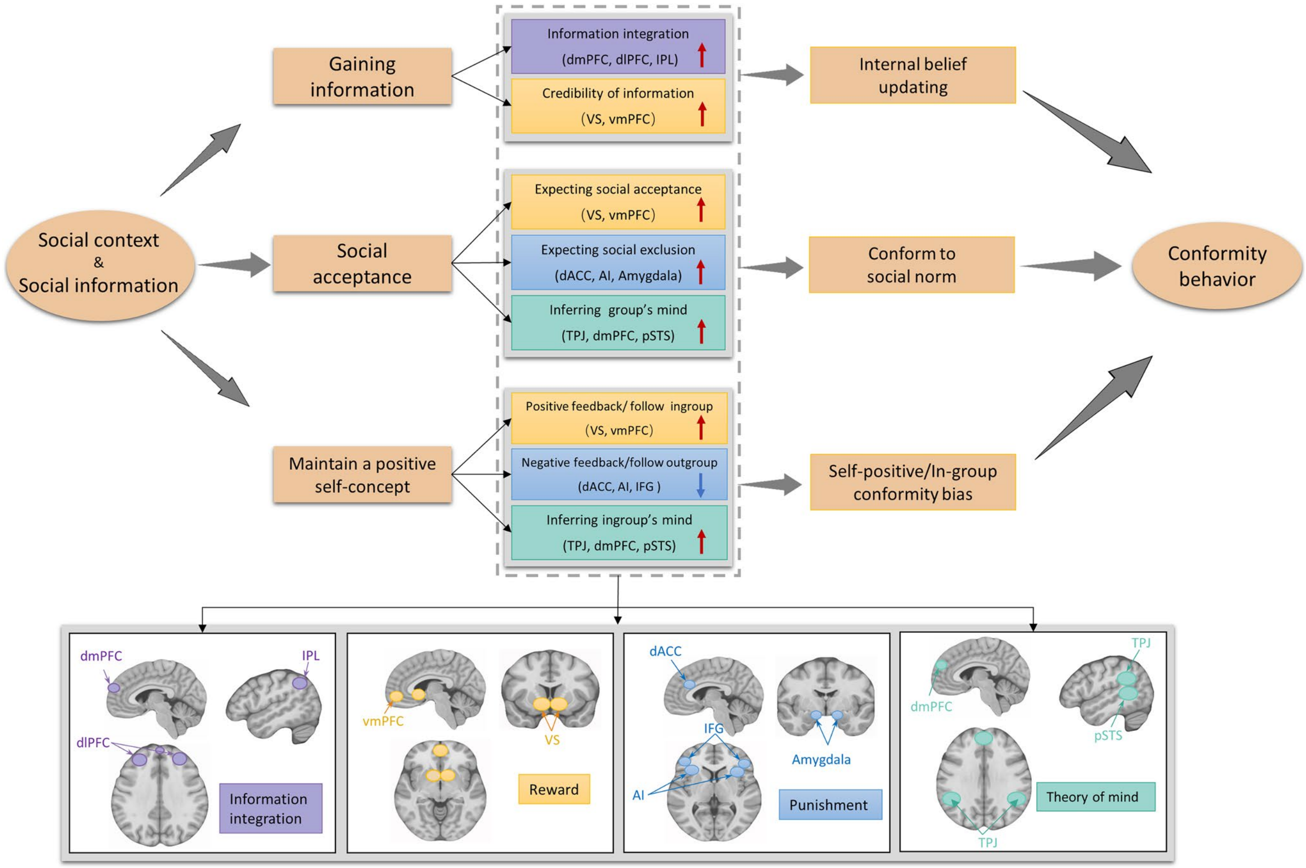

Fig. 2 Brain networks underlying fundamental motivations of social conformity. The fundamental motivations of social conformity may vary according to the specific social context and information, which in turn engage different but interactive neuropsychological processes embedded in distributed brain networks, including reward processing, punishment processing, mentalizing, cognitive control, and task-related processes. First, information valuable to the decision is encoded in the reward network. The cognitive control network integrates reliable social information to update one's internal beliefs, thereby regulating neural representations in task-related brain systems. Second, social conformity motivated by social acceptance is driven primarily by the anticipation of social acceptance/rejection, which corresponds to the neural processes of reward/punishment, collaborating mentalizing processes to properly infer the mental state of others in order to better cater to the social norms. Finally, conformity driven by maintaining a positive self-concept is manifested as optimism bias and in-group bias. Adaptation to or violation of these conformity biases results in neural networks of reward and punishment, respectively, and facilitates perspective taking from in-group members implemented in the mentalizing network. Different colors represent different neural systems involved in conformity (purple, information integration system; yellow, reward system; blue, punishment system; green, theory of mind system). Note that different motivations can share common neuropsychological processes. dmPFC, dorsal medial prefrontal cortex; dlPFC, dorsolateral prefrontal cortex; IPL, inferior parietal lobule; VS, ventral striatum; vmPFC, ventromedial prefrontal cortex; dACC, dorsal anterior cingulate cortex; AI, anterior insula; TPJ, temporo-parietal junction; pSTS, posterior superior temporal sulcus; IFG, inferior frontal gyrus. ↑, positive predictor; ↓, negative predictor.

perspective taking from in-group members implemented in the mentalizing network.

Notably, different motivations engage both common and distinct neuropsychological processes. On the one hand, brain regions previously implicated in reward processing are commonly engaged by all of the three motivations, presumably because the seeking of information, social acceptance, or positive self-concept is valuable. On the other hand, the seeking of both social acceptance and positive self-concept engages mentalizing- and punishment-related areas, while information-seeking involves the cognitive control regions. Therefore, future studies are needed to directly compare the neural mechanisms underlying different motivations (see also "Future directions"). For instance, future studies could examine the functions of the adjacent/overlapping regions engaged by different motivations with more fine-grained techniques (e.g., multi-voxel pattern analysis) or specifically designed task paradigms (e.g., the repetition suppression paradigm), which allow for comparison of the neural patterns of adjacent/overlapping regions at the sub-voxel level [185].

In sum, human social conformity can be induced by different motivations depending on specific social contexts, which in turn evoke distinct but interactive neuropsychological processes embedded in distributed brain networks, including reward processing, punishment processing, mentalizing, cognitive control, and task-related processes. Depending on specific motivations, these processes modulate conformity behaviors to different extents and directions.

Limitations

Several limitations of the current review should be noted. First, the interpretation of brain imaging findings inevitably involves inverse inference, although many studies included in the current review have used experimental designs to improve the inference of the psychological functions of the revealed regions. The issue of inverse inference might be addressed in the imaging literature with increasing open access to large-scale datasets, such as Neurosynth [186] and Brainmap [187]. Related to this, the relationship between each motivation and the experimental conditions of reviewed studies was inferred according to previous theoretical frameworks and empirical evidence. In this regard, the fundamental motivations provide a heuristic integrative framework to understand previous brain imaging findings from the perspective of the component process.

Future Directions

As the most common form of social influence, social conformity has long been an important topic in the field of social psychology and recently in social neuroscience. Previous behavioral and neuroimaging studies have provided important insights into the underlying motivations, psychological subcomponents, and neural substrates of human social conformity. The relationships between these conformity-related constructs are important for an integrative understanding of conformity behaviors, which, however, remain largely unknown. Specifically, several key open questions await further investigation (Table 1).

First, theoretical and empirical association and distinction among the three fundamental motivations of social conformity remain controversial. For instance, it is possible that both motivations of information acquisition and social acceptance act in service of a third underlying motive to maintain one's positive self-concept, in which case the three motivations are empirically inseparable [188–192]. Likewise, the current review reveals overlaps in neuropsychological processes among different motivations of social conformity. Therefore, future research needs to reveal both similarities and differences between different motives at both conceptual and methodological levels. Computational modeling could be a promising approach to uncovering both common and distinct component processes underlying different motives of social conformity. Instead of focusing on raw overt behaviors, computational modeling can help to decompose distinct processes underlying conformity behaviors and capture latent variables that are not directly observable [193]. Moreover, combining computational modeling with neuroimaging techniques can further uncover how distinct computational subcomponents are implemented at the biological level and provide insights into how a particular cognitive process is implemented in a specific brain area as opposed to merely identifying where a particular process is located [194]. Future studies can take an interdisciplinary approach to integrate psychological experimental design, brain imaging, and computational modeling to distinguish different motivations of conformity from multiple levels.

Second, studies on social conformity often assume that the current conformity behavior is driven by one or another motivation, despite the fact that human behaviors can be concurrently driven by multiple and even conflicting motivations [67, 110, 159]. Future studies are needed to examine tradeoffs and interactions among multiple motives and their concurrent influence on human social conformity as well as associated brain functions. In this regard, a recent imaging study has indicated that the dACC is involved in the integration of informational and normative conformity [195].

Third, brain imaging studies have mainly focused on the role of isolated regions in social conformity, with few efforts from the perspective of systems neuroscience. It is becoming increasingly acknowledged that human social

Table 1 Summary of future directions

Key questions	Approaches
Whether and how can different motivations be distinguished?	Multi-voxel pattern analysis, repetition suppression paradigm, computational modeling
How do people trade off different motivations?	Novel experimental design
How are different motivations supported by large-scale brain networks?	Brain network analysis
Which motivational dysfunctions support abnormal conformity in clinical populations?	Further investigations from the perspective of motivation

behaviors can be better understood in terms of interactions across large-scale brain networks comprising distributed brain locations rather than in terms of specific structures [76, 196–199]. Therefore, future studies can leverage exciting advances in human brain functional connectomics research to examine how social conformity emerges from interactions within and between brain networks identified in the current review; this will advance our understanding of motivations of social conformity in terms of network integration rather than regional specification.

Finally, future studies on the neuropsychological processes underlying motivations of social conformity entail clinical implications. Abnormal conformity behaviors are presented across a variety of neuropsychiatric disorders, including social anxiety, depression, schizophrenia, and autism [120, 121, 164, 200–205]. That is, patients with these disorders exhibit insufficient or excessive integration of social information, which might be mediated by aberrant social motivations and related neuropsychological processes. Therefore, further investigations from the perspective of motivation could provide new insight into the deficits in social functioning among diverse neuropsychiatric conditions.

Acknowledgements This review was supported by the National Natural Science Foundation of China (32271126, 31900757, 32020103008, and 31920103009), Natural Science Foundation of Guangdong Province (2021A1515010746), the Major Project of National Social Science Foundation (20&ZD153), and Shenzhen-Hong Kong Institute of Brain Science–Shenzhen Fundamental Research Institutions (2019SHIBS0003).

Conflict of interest The authors declare that they have no conflict of interest.

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