Cognitive, Affective, & Behavioral Neuroscience (2022) 22:1199–1214
https://doi.org/10.3758/s13415-022-01006-y

THEORETICAL REVIEW

Comparing gratitude and pride: evidence from brain and behavior

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Accepted: 30 March 2022 / Published online: 18 April 2022

Abstract
Gratitude and pride are both positive emotions. Yet gratitude motivates people to help others and build up relationships, whereas pride motivates people to pursue achievements and build on self-esteem. Although these social outcomes are crucial for humans to be evolutionarily adaptive, no study so far has systematically compared gratitude and pride to understand why and how they can motivate humans differently. In this review, we compared gratitude and pride from their etymologies, cognitive prerequisites, motivational functions, and brain regions involved. By integrating the evidence from brain and behavior, we suggest that gratitude and pride share a common reward basis, yet gratitude is more related to theory of mind, while pride is more related to self-referential processing. Moreover, we proposed a cognitive neuroscientific model to explain the dynamics in gratitude and pride under a reinforcement learning framework.

Keywords Gratitude · Pride · Positive emotions · Reward · Neuroimaging

Introduction

Positive emotions have long been considered less differentiated than negative emotions (Smith et al., 2014). For example, the broaden-and-build theory believed that positive emotions, such as gratitude and pride, share similar elevated subjective experience and the motivational action tendency to broaden cognitive functions and build resources (Fredrickson, 2001, 2004a). According to Fredrickson (2004b, 2013), gratitude and pride both promote temporary enhanced state-action repositories and long-term benefits of accrued resources. Nevertheless, gratitude and pride seem to generate from distinct cognitive appraisals and followed by some unique motivational urges. Specifically, despite the fact that both of them often are evoked by positive outcomes (reward or success), people attributing success to external sources (e.g., others' help) may experience a feeling of gratitude, while people attributing success to internal sources (e.g., one's ability) may experience a feeling of pride (Weiner, 1985; Weiner et al., 1979). People who feel grateful are more likely to engage in prosocial behaviors (Bartlett & DeSteno, 2006; Tsang, 2006), whereas people who feel proud are more likely to engage in self-enhancing behaviors promoting self-esteem and social status (Tracy & Robins, 2007a; Witkower et al., 2021). Therefore, although gratitude and pride broaden-and-build as other positive emotions, they may as well have different psychological constructs and corresponding neural substrates. Understanding such differences would help us to better understand why and how these high-level positive social emotions could motivate us beyond simple positivity. Despite the significance of the two emotions for social and personal well-being, no review has so far systematically compared them and given mechanistic explanations.

In the current article, we mainly reviewed previous behavioral and neuroimaging studies on gratitude and pride regarding the psychological constructs (definitions on state and trait levels, motivational functions, common basis, and specific cognitive prerequisites) and neural substrates. By integrating the evidence from behavioral and neuroimaging studies, we delineated the common and specific features of gratitude and pride, and proposed a mechanistic model under reinforcement learning framework to explain how the

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specific features contribute to the common system to generate different motivational functions.

Notably, this article would not cover some psychological constructs closely related to gratitude or pride. For example, appreciation and gratitude were conceptualized to be a unitary personality trait (Wood, Maltby, Stewart, & Joseph, 2008b). On the emotional level, however, they are not exactly the same. Appreciation is defined as a simple cognitive process that involves acknowledging the value of something or somebody (Janoff-Bulman & Berger, 2021), during which emotions like gratitude may follow (Watkins, 2014). Therefore, it seems that appreciation is like a cognitive prerequisite for gratitude and it may not be an emotion at all (Watkins, 2014). Likewise, self-efficacy is the belief of one's ability to achieve certain tasks (Bandura, 1997), whereas pride is the affective state of achievements (Williams & DeSteno, 2008). Because we are more interested in studying positive emotions and understanding their differential motivational functions, we focused on gratitude and pride—two typical positive social emotions that carry significant motivational functions to others and oneself.

Definitions of gratitude and pride

Gratitude

The word gratitude originates from the Latin root "gratia," meaning grace, thankfulness, and pleasure. The words linked with "gratia" are always positive in nature, e.g., grace, ex gratia, ingratiation, which is in line with modern psychological studies that gratitude belongs to positive affects (McCullough et al., 2002; Watkins et al., 2003).

Gratitude has been defined as an emotional state (Weiner, 1985), a moral virtue (Algoe et al., 2013; McCullough et al., 2001), a personality trait (McCullough et al., 2002), a habit, and a coping strategy in different contexts (Emmons & McCullough, 2003; Folkman & Moskowitz, 2000). It could be toward a particular benefactor (Tesser et al., 1968) or toward life in general (McCullough et al., 2002; Wood et al., 2010).

As an emotion, gratitude is a positive response acknowledging and appreciating blessings in life (Wood et al., 2010). In many real-life situations, gratitude is more of an emotional response toward a benefactor. From this perspective, gratitude is commonly triggered to people when "something good has happened to them, and they recognize that someone else is largely responsible for this benefit" (Watkins, 2014). In such situations, two factors are essential: (1) a reward is given, and (2) the credit is attributed to others. Gratitude has few nonverbal expressions. It is mainly expressed verbally—with words (75.0%) and voice (64.8%), compared with face, body, and touch (37.0–55.3%) (Manokara et al., 2021). In line with this, an experimental study failed to find any distinctive facial expression for gratitude (Campos et al., 2013). Another review (Keltner et al., 2019) of positive emotions also confirmed that, among the modalities of face, head, bodily action, voice, touch, and music, the only identifiable expression was touch (Hertenstein et al., 2006, 2009).

As a moral emotion (McCullough et al., 2001), the feeling of gratitude could foster the habit to express thankfulness, such as saying thank you or acting for the benefits of the benefactor or other people. In many cultures and religions, it is considered to be a moral virtue promoting prosocial behaviors (Algoe et al., 2013).

As a personal trait or disposition, gratitude is defined as a "life orientation towards noticing and appreciating the positive in the world" (Wood et al., 2010) and a "generalized tendency to recognize and respond with grateful emotion to the roles of other people's benevolence in the positive experiences and outcomes that one obtains" (McCullough et al., 2002). The grateful individuals are generally more extroverted, open, agreeable, conscientiousness, and less neurotic (McCullough et al., 2002; Wood, Joseph, et al., 2008). Trait gratitude is also positively correlated with subjective well-being, relationship, and physical health (for a review, see Wood et al., 2010). Notably, compared with the individual differences in trait gratitude, in the current study, we care more about the cognitions, affective motivations, and action tendencies linked with the emotion of gratitude. Therefore, we will mainly discuss the behavioral and neuroscientific studies on the gratitude emotion in the following paragraphs.

Pride

The word "pride" comes after the adjective form of "proud," which originated before the 12th century from the old French word "prud" or "prouz," meaning valiant or brave. At that time, it was used positively by the Norman knights to describe themselves. Yet later, the word was used by the Anglo-Saxons to describe their invading army in a negative tone, meaning conceited and self-aggrandized (Tracy et al., 2010).

Pride often arises when one appraises a positive, socially valued outcome (e.g., success) to his or her own contribution, such as efforts, personalities, and abilities (Leary, 2007; Tracy et al., 2010; Williams & DeSteno, 2008). People also could feel pride for owning valuable objects (Leary, 2007), good outcomes from other people they are identified with (e.g., their family members and friends), and even on a more collective level, such as pride for their country (Tracy et al., 2010). Nevertheless, most research investigated pride on an individual level as a self-consciousness emotion.

As an emotion, pride has unique nonverbal expressions. Many studies have reliably found that pride has universally recognizable bodily and facial expressions, which are

distinct from those in other similar emotions, such as happiness and excitement (Tracy et al., 2010; Tracy & Robins, 2004b, 2007a). The typical nonverbal expressions of pride include: a small smile, slightly tilted head, raised arms, and visible expanded posture of upper body. The recognition of the nonverbal expressions of pride is as fast and accurate as that of basic emotions (Tracy & Robins, 2008). Moreover, even congenitally blind individuals across cultures showed these typical nonverbal pride expressions during success as well (Tracy & Matsumoto, 2008). These studies suggest that pride may be an innate and evolutionary adaptive emotion.

As a self-consciousness emotion, the experience of pride involves a self-evaluation process. This process requires two cognitive prerequisites (Lewis et al., 1992). One is objective self-awareness, which directs attention introspectively and treats oneself as an evaluable object; the other is internalized standard of behavior, a reference point to be compared with one's current achievement. Thus, the evaluation process is self-referential and associated with one's own values.

Pride serves two highly divergent effects. Historically, Aristotle considered pride as the "the crown of the virtues" (Ross, 1925), whereas in Christian traditions it was the greatest of "the seven deadly sins" (Alighieri, 2003). Therefore, some researchers differentiate pride into two facets: authentic and hubristic (Mercadante et al., 2021; Tracy & Robins, 2004a, 2007b). The authentic facet is based on actual achievement. It is positively correlated with self-esteem and adaptive personal traits, such as extraversion, agreeableness, and conscientiousness (Carver & Johnson, 2010; Cheng et al., 2010; Shi et al., 2015; Tracy et al., 2009). The hubristic facet is less attached to one's actual achievement but more out of conceited self-aggrandizement. It is associated with high narcissism, shame-proneness while low implicit self-esteem, as well as low agreeableness and conscientiousness in the "Big Five" personality traits (Carver & Johnson, 2010; Cheng et al., 2010; Shi et al., 2015; Tracy et al., 2009). In terms of mental health and social functioning, people with high authentic pride are less likely to suffer from depression, anxiety, social phobia, and rejection sensitivity; they also have a high level of relationship satisfaction, a secure attachment style, strong social support, prestige social rank, and prosocial and achievement-oriented behaviors (Tracy et al., 2010; Witkower et al., 2021). However, people with high hubristic pride are more likely to suffer from chronic anxiety, aggression, hostility, rejection sensitivity, Machiavellianism, low dyadic adjustment, low perceived social support, dominance social rank, and maladaptive behaviors, such as drug abuse and dishonesty (Mercadante & Tracy, 2021; Tracy et al., 2010). Therefore, authentic pride is a prosocial, evidence-based view of oneself. It brings achievement and genuine self-worth, whereas hubristic pride is a maladaptive, narcissistic view of oneself, and probably a self-defensive mechanism of low self-esteem. In the current review, we will mainly discuss pride in terms of authentic pride, the positive one, as a proper comparison to gratitude.

Motivational roles of gratitude and pride

Motivational role of gratitude

Prosocial behavior Unlike simple positive emotions, such as joy or happiness, gratitude has a unique conceptualization as a moral affect. It plays three major roles in social interactions (McCullough et al., 2001). First, it serves as a moral barometer—a positive emotional response to indicate that we have recognized the benefits from others' good behavior. Second, it motivates us to act prosocially toward the benefactors and people around us. Third, the expression of gratitude reinforces the benefactors to behave prosocially in the future. Therefore, gratitude not only contributes to the well-being of both the beneficiaries and benefactors, but also creates a virtuous circle of prosocial behaviors in society.

Empirical studies have revealed that gratitude promotes more prosocial behavior and inhibits immoral behavior in beneficiaries than neutral and even other positive emotions. In Bartlett and DeSteno (2006)'s study, participants who were helped to restore the test computer spent significantly more time to help the benefactor with a long mentally taxing survey than a neutral emotion condition, and even more than the amusement condition. Similarly, another study also demonstrated that people who had received more help from the other player in a distribution game allocated more resource to the other player than those received the same positive outcome simply by chance (Tsang, 2006). Besides, people who feel grateful have much lower rate of cheating behaviors and competitive behaviors than those who feel happy or in a neutral state (DeSteno et al., 2019; Sasaki et al., 2020). These studies show that gratitude carries a unique prosocial action tendency than a general positive emotion.

Evidence also shows that expressing gratitude reinforces the benefactors to engage in prosocial behaviors. The most remarkable evidence is that, participants who simply received a "thank you" from the confederate would continue to voluntarily take more electrical shocks for her (McGovern et al., 1975). Another study found that writing "thank you" on the back of the check by the server in the restaurant increased tips significantly (Rind & Bordia, 1995). Similarly, other studies have found that a simple appreciation call to former customers could increase sales (Carey et al., 1976). In health care, receiving thank-you letters improved the case manager's visiting rate to residential clients (Clark et al., 1988). Furthermore, the improved social worth rather than self-efficacy mediated gratitude expression and prosocial behavior (Grant & Gino, 2010).

Interpersonal relationship According to Algoe's find-remind-and-bind theory, the experience of gratitude serves as an emotional glue to help individuals find new valuable relationship partners or remind them of the old ones and bind them in a closer relationship (Algoe, 2012; Algoe et al., 2008). A study of married couples (mean relationship length more than 20 years) showed that gratitude predicted both one's own and the spouse's relationship satisfaction (Gordon et al., 2011). In short-term relationships, such as cohabiting couples, increased gratitude was predictive of subsequent enhanced relationship quality (Algoe et al., 2010). Moreover, an increase in gratitude expression could predict the increase in future communal strength—a basis of stable and mature relationships that orientates one to meet the needs of the partner (Lambert et al., 2010).

The motivating and rewarding nature of gratitude creates a prominent effect on relationship maintenance than any other positive emotions. People who feel grateful are more likely to approach their benefactors, spend time with them, express their feelings, and do things to create, maintain, and deepen the relationship rather than simply engage in acts of reciprocity. Algoe and Haidt (2009) have found that, compared with recalling joy and admiration experiences, recalling grateful memories promote participants' willingness to associate with and spend time with their partners in the future. Apart from the motivation to approach and affiliate, gratitude also increases trust in others, which is an essential part in forming a relationship. A series of studies conducted by Dunn and Schweitzer (2005) found that people who wrote about their past grateful situations gave significantly higher ratings in a subsequent trust judgment task toward unfamiliar others than people who wrote on pride, guilt, and anger. Moreover, some other studies suggest that expressing gratitude could make the beneficiaries appear more trustworthy (Bartlett et al., 2012; Gordon et al., 2011).

In summary, gratitude's motivating and rewarding nature enables it to make many more unique contributions to prosocial behaviors and interpersonal relationships than simple positive emotions. It motivates and reinforces people to conduct more prosocial behaviors, build meaningful relationships, improve relationship quality, and develop interpersonal trust.

Motivational role of pride

Pride is a self-consciousness emotion that is psychologically and evolutionally important (Tracy et al., 2010). Unlike basic emotions, self-consciousness emotions are closely linked to self-representation, and they can help to attain complex social goals (Tracy & Robins, 2004a). Among the self-consciousness emotions (i.e., shame, pride, guilt, envy, and embarrassment), pride is the only positive emotion that makes us feel good about ourselves. The positive feeling of our global "self" reinforces us to repeat the behaviors that lead to feeling proud and motivates us to pursue higher achievements. In the long-term, pride increases self-worth. In social interactions, the nonverbal expression of pride signifies success to other people in society and promotes social status (Tracy et al., 2010; Tracy & Robins, 2004b).

Achievement motivation and performance Feeling proud is not only the result of achievement and good social conduct but also the motivator of more pride-eliciting behaviors in the future. Although much theoretical work (Tracy & Robins, 2004a, 2004b, 2007a) had predicted the motivational role of pride in achievement and socially valued behaviors, the first empirical evidence was provided by Williams and DeSteno (2008); participants were asked to perform cognitive tasks, and those who felt proud of themselves were more perseverant working on the subsequent task than other control conditions. Consistently, another study (Pekrun et al., 2009) also found that high levels of pride can predict good academic performance. On the other hand, some researchers investigated the motivational effect of low pride on achievement (Weidman et al., 2016). They found that athletes and students who did not perform well in the initial test had a lower level of pride, which predicted higher intention to change their training/studying plans and habits. Subsequently, these achievement-related behavioral changes predicted better performance in later tests (Weidman et al., 2016). Taken together, the motivational effect of pride on achievement could be through two paths: one is with high level of pride, which reinforces people to maintain or persevere on subsequent challenges; the other is with low level of pride, which drives people to change their old behavior patterns for more adaptive ones.

Self-esteem Several studies have demonstrated the close relationship between pride and self-esteem. Brown and Marshall (2001) first found that pride, rather than any other emotions, such as shame, inspiration, and enthusiasm, has the highest correlation with self-esteem. Tracy and her colleagues further distinguished two kinds of pride and found that only achievement-based authentic pride was positively correlated with self-esteem (Tracy et al., 2009; Tracy & Robins, 2007b). Subsequent studies replicated the positive correlation between pride and self-esteem and pointed out the mediating effect of pride between positive affect and self-esteem (Stanculescu, 2012). The influence of pride on self-esteem is evolutionally adaptive. From a functionalist view, after certain achievements one would feel proud as a response; and this positive feeling informs one's self-worth and social value, which may promote positive feelings and thoughts about one's global self and thus result in high self-esteem (Tracy et al., 2010).

Social status Studies have shown that people have a stereotype that pride is a sign of high social status. A person described as proud was believed to have a higher social status than someone described as appreciative (Tiedens et al., 2000). Besides, feeling proud influences how one acts in a social group, e.g., behaving in a more dominating style. That will influence the judgment of other group members on one's social status. In a social interaction experiment (Williams & DeSteno, 2009), participants who were manipulated to be in a proud status by being praised of their good performance were perceived as more dominating in a subsequent group problem-solving task than the control condition. Meanwhile, they also were more often liked by their interaction partners. The results suggest that the pride increased perceived social status and value in a group by promoting dominating behaviors. Moreover, the nonverbal expression of pride is proven to be an automatic indicator of high social status (Shariff & Tracy, 2009). A series of studies using Implicit Association Test and Affect Misattribution Procedure found that people reacted significantly faster when pairing high status words with photos of nonverbal proud expression than any other emotion expressions, such as shame, happiness, disgust, anger, and fear. It cannot be explained by the artifact of aggrandized posture size, such as outstretched arms (Shariff & Tracy, 2009).

Common basis of gratitude and pride

Gratitude and pride are both positive emotional responses to reward. Nevertheless, how one perceives the reward—the cognitive evaluation of the reward is different in gratitude and pride contexts: in gratitude it is the "benefit appraisal" and in pride it involves a self-evaluation process. Furthermore, expectation (high or low) also may play a role in appreciating or depreciating the same reward. To better visualize the common and specific constructs related with gratitude and pride, we have illustrated their relationships in Fig. 1.

Reward and gratitude

Gratitude is a response to acquiring reward from others. As for the form of the reward, it could be either material, such as gifts and financial support, or nonmaterial, such as love and emotional support (Emmons & McCullough, 2003).

Few studies have worked on the relationship between reward and gratitude. So far, two theories have explained how reward could influence gratitude. In Wood's social-cognitive theory of gratitude (Wood, Maltby, Stewart, Linley, et al., 2008), benefit appraisal is the key cause to generate state gratitude, and the benefits given should be perceived as valuable, costly, and of genuine motivation. First, the benefit must be of something valuable to the recipient, either the person is in need of or desire to have. Second, the benefit related with higher cost (time, effort, money) is correlated with higher level of gratitude. Last, people must recognize the good intention behind the benefit. The appraisal process thus requires certain level of theory of mind, which we will discuss in details in Section 5.

Even though more help generally leads to more gratitude, the relative rank theory believes that the relative rank of the current reward compared with other offers will influence the valuation in gratitude benefit appraisal. An empirical study

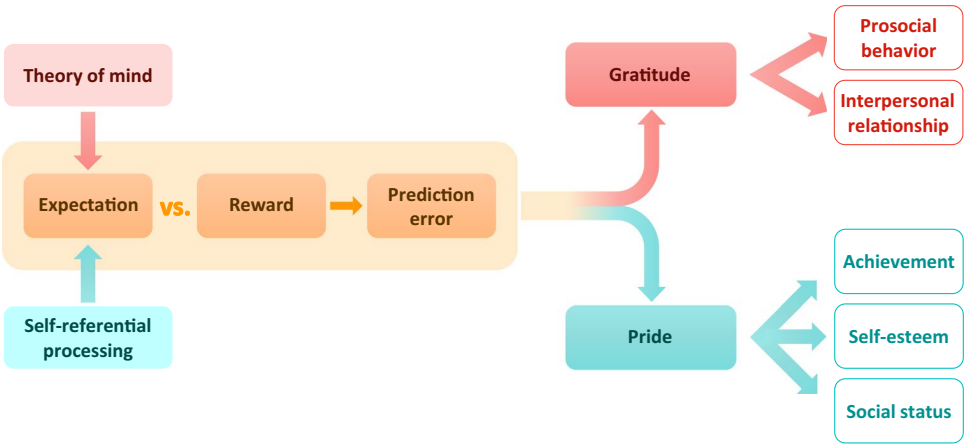

Fig. 1 Integrated framework of the psychological constructs for gratitude and pride emotions. The central part in the color yellow refers to the reward computation system. The discrepancy between one's expectation and the actual gained reward creates a reward prediction error, which is modulated in the brain's reward system. Theory of mind influences the reward processing by forming the expectations of others' benevolence, while the self-referential processing influences the reward processing by forming the expectations of one's own achievements. As a result, gratitude and pride show different motivational effects: the former elicits more socially reinforcing behaviors, while the latter elicits more self-reinforcing behaviors.

(Wood et al., 2011) has validated that the level of gratitude elicited by certain amount of help (a loan of 35 euro or 30 min of help) depends on the relative rank of all the help participants can get from their friends. Wood et al. (2011) proposed that people who received more help from others may have a higher expectation on the benefactor, making it less easy to hit the threshold of gratitude. Indeed, a high expectation on family members and friends also may make individuals take help for granted, thus less likely to feel grateful (Bar-Tal et al., 1977; Rotkirch et al., 2014; Wood et al., 2011).

Reward and pride

Pride by nature is usually triggered by acquiring a reward on one's own. The reward could either be an achievement, such as accomplishing one's goals and acquiring more possessions, or social approvals, such as compliments from others.

The valuation of a reward is a subjective cognitive appraisal process for pride. It is first self-referential: the reward for pride has to be related to one's identity and ideal self-representations (Tracy et al., 2010; Tracy & Robins, 2004a). For example, an honest person would not feel proud even if he gets a lot of money by lying to others. A woman also would not take pride in the compliment of her beauty if she does not care about her appearance. Only when the reward aligns with one's values and can add to one's self-worth would it lead to the feeling of pride. Moreover, the subjective value of accomplishing a task also depends on the task difficulty. Greater responses of pride were observed after the success on difficult tasks than easy tasks (Belsky et al., 1997; Lewis et al., 1992).

Reinforcement learning mechanistic view

The reinforcement learning model proposes that individuals learn from the environment through reward prediction error, i.e., the differences between the expected reward and actual reward (Sutton & Barto, 2018). The prediction errors signals are linked with brain activities in the ventral striatum—a major dopamine projected brain region (O'Doherty et al., 2003; Pessiglione et al., 2006; Schultz, 2016). When the actual reward is more than expected, then a positive reward prediction error is generated, which is associated with activation of dopamine neurons and positive emotions. Whereas when the actual reward is less than expected, a negative reward prediction error is generated, which depresses dopamine activity (Schultz, 2016). Reinforcement learning has been an increasingly popular machine learning model in affective neuroscience in recent years (Zhang et al., 2020). For example, it has been used to explain happiness and state self-esteem (Blain & Rutledge, 2020; Keren et al., 2021; Rutledge et al., 2014; Villano et al., 2020; Will et al., 2017; Will et al., 2020).

As both gratitude and pride involve reward processing, we hypothesize that the reward prediction error could explain the emotional fluctuations in gratitude and pride as well. As shown in Figure 1 in the central orange cube, the reward prediction error for gratitude is the difference between the expectation of help (i.e., the estimation of the potential help from the benefactor based on the past social interactions) and the actual received help. A high expectation on others would likely drive a negative prediction error, thereby depressing grateful feelings. This hypothesis could explain the negative effect of expectation on gratitude (Wood et al., 2011, see Section 4.1 for details). As for pride, the prediction error is the difference between the expectation of achievement (i.e., the estimation of success chance on the current challenge based on the past experience on similar tasks) and actual task performance. Lower expectation of success, for example in difficult tasks, may lead to a positive prediction error following success, resulting in a higher sense of pride. The observations of high pride in difficult tasks (Belsky et al., 1997; Lewis et al., 1992) thus could be interpretated by the positive prediction error in the reinforcement learning model as well.

Special cognitive prerequisites of gratitude and pride

Special role of theory of mind in gratitude

To feel grateful to another person, one must realize the good intentions behind others' helping behavior. According to Wood's social-cognitive theory of gratitude (Wood, Maltby, Stewart, Linley, et al., 2008), a key component in benefit appraisal is the appreciation of genuine motivation for the welfare of the recipient. The ability to attribute mental states to others, represent others' thoughts and beliefs, and identify action intentions is referred as the theory of mind (Frith & Frith, 1999; Premack & Woodruff, 1978). From a developmental perspective, this ability crystalizes earlier than gratitude (Emmons & Shelton, 2002; Froh et al., 2007), and it keeps developing with age (Happé et al., 1998). McAdams and Bauer (2004) first proposed the hypothesis that theory of mind is a necessary cognitive prerequisite for developing gratitude; however, there are scant developmental studies examining the relationship between gratitude and theory of mind.

For gratitude understanding, studies have reported that children's (age 3-5) theory of mind ability can predict their understanding of gratitude (Freitas et al., 2009; Freitas et al., 2012; Nelson et al., 2013). Gratitude understanding was tested through two verbal stories: one story is about a

girl who lost her cat, and an aunt spent a long time to help her find the cat; another story is about a boy who felt cold at school and a girl lent a sweater to him. Theory of mind was measured through three tests: visual perspective-taking, false belief, and second-order false belief. Results showed that, understanding gratitude was significantly correlated with theory of mind. Notably, however, some children who did not pass the second-order false belief task also showed an understanding of gratitude, which indicates that gratitude may only require a primary level of theory of mind.

More recently, research on gratitude feeling showed that, theory of mind ability developed with age and predicted gratitude expressions and experiences through intention understanding in children aged 3-6 years (Shoshani et al., 2020; Shoshani et al., 2021). Moreover, manipulating the intention of the benefactor affects children's gratitude and subsequent helping behavior (Shoshani et al., 2020). Similarly, in adult studies where the intention of the given help was manipulated, more gratitude was elicited in the intentional compared to unintentional conditions (Liu et al., 2020; Xiong et al., 2020).

In addition to theory of mind ability, the propensity of perspective taking is found associated with gratitude as well. Dispositional gratitude is positively correlated with perspective taking, empathetic concern, and fantasy scores (McCullough et al., 2002; Pang et al., 2022) in the scale of Interpersonal Reactivity Index (Davis, 1983). Furthermore, a higher level of perspective taking or cognitive empathy is associated with more gratitude in romantic partners (Gordon & Chen, 2013), children (Poelker & Kuebli, 2014), adolescents (Poelker et al., 2019), and students (Chen et al., 2020, 2021; Oriol et al., 2020; Shi & Du, 2020).

Special role of self-referential processing in pride

Pride is considered a self-conscious emotion (Leary & Tangney, 2011; Zinck, 2011). As we discussed in the definition of pride, pride involves a self-evaluation process that requires self-awareness and an internalized standard. The latter is generated through self-referential processing. Self-referential processing relates information from the external world to oneself, and it makes the self-relevant information a priority in cognitive processing (Zhao et al., 2018). From the self-related information collected during development, one gradually forms the estimation on how good he/she can perform on certain kinds of tasks. This results in the internalized standard that we use as a reference point to judge whether an achievement is adequate to make us feel proud. In fact, although there is a lack of behavioral evidence on the relationship between pride and self-referential processing, the two shared largely overlapped neural substrates: they both involved the default mode network (DMN), especially the cortical midline structures (CMS) (Gilead et al., 2016; Roth et al., 2014; Simon-Thomas et al., 2012; Stolz et al., 2020; Takahashi et al., 2007; Zahn et al., 2009). We will discuss this in details later in the neural basis part.

Neural basis of gratitude and pride

Neural correlates of gratitude

Given the significant social and psychological benefits of gratitude, it is intriguing to understand the neural mechanism how gratitude works. So far, several neuroimaging studies have made important attempts to uncover the neural substrates of gratitude.

An early study of social values using a sentence reading task (Zahn et al., 2009) reported gratitude-related brain region in the hypothalamus, which was implicated in affiliative rewards. In this task, participants read one sentence (e.g., "Tom (participant's best friend's name) acts generously toward Sam (participant)") and judged their feelings as pleasant or unpleasant. However, in this paradigm, there is no guarantee that the participants really experienced a specific gratitude feeling during the task. Later researchers such as Fox et al. (2015) think it is a moral judgment task which may involve gratitude, and Kini et al. (2016) think the paradigm is more about identifying emotions in a social narrative, rather than experiencing emotions per se. To solve these issues, Fox and his colleagues (2015) developed a new task in which participants were asked to imagine that they were the survivors of the Holocaust and then reflected on how they would feel if they were being helped in different situations. Results showed that gratitude ratings correlated with brain activities in a large cluster of the medial prefrontal cortex (mPFC), including the orbitofrontal cortex (OFC) and anterior cingulate cortex (ACC). The dorsal part of the mPFC (dmPFC) has been involved in theory of mind tasks (Matthias et al., 2014; Rachel & Louise, 2015), which is useful to understand the good intentions of the benefactors, whereas the ventral part of the mPFC (vmPFC) and OFC were often reported in value judgments (D'Argembeau, 2013; Kringelbach, 2005).

Furthermore, gratitude interventions also were studied with neuroimaging. First, the neural correlates of gratitude expression and the effects of gratitude expression intervention on neural activities were studied on patients with anxiety and depression (Kini et al., 2016). The functional magnetic resonance imaging (fMRI) experiment used a "pay it forward" task, in which participants were asked to donate to a charity cause according to how grateful they felt. The study found that gratitude modulated brain activities during donation decision (expression of gratitude) in the left superior parietal lobule, which is close to a region (the temporoparietal junction) that was typically involved in theory of

mind (Saxe & Kanwisher, 2003). Second, compared with the control group, the gratitude intervention group had greater gratitude-modulated brain activities in the pregenual ACC, which was consistent with the ACC activations in empathy, theory of mind, and moral cognition (Fox et al., 2015; Singer et al., 2004). Another study (Karns et al., 2017) found increased brain activation in the vmPFC after a 3-week gratitude writing intervention in a healthy population.

The cognitive antecedents of gratitude (value, cost, intention) were well studied by a series of studies with a pain alleviation task (Liu et al., 2020; Xiong et al., 2020;Yu et al., 2017 ; Yu et al., 2018). In the task, the benefactor will help share or reduce the painful electric shocks for the participants, while varying on the intention level (e.g., voluntary vs. forced), the value of the help (how much pain was reduced), or the cost (monetary cost). Results showed that the cognitive antecedents were represented in different parts of the brain. Specifically, value were represented in reward-related regions, such as the ventral striatum, caudate, and putamen (Liu et al., 2020; Yu et al., 2018); benefactor' cost mainly in the temporoparietal junction (TPJ), a typical theory of mind region (Yu et al., 2018); intention was mostly related with the vmPFC, posterior cingulate cortex (PCC), and precuneus, which were commonly involved in theory of mind (Liu et al., 2020; Xiong et al., 2020; Yu et al., 2017). Moreover, the pregenual ACC may integrate the signals from brain regions representing value and cost and generate gratitude (Yu et al., 2018).

Besides the neural activities induced by state gratitude, the neuroanatomical basis of gratitude also is investigated. The first structural MRI study involving gratitude (Zahn et al., 2014) found that grey matter volumes in the right inferior temporal gyrus were positively correlated with individual differences in gratitude, which could be due to the differences in the ability to interpret other's intentions (Lewis et al., 2011). Later another structural MRI study using the Gratitude Questionnaire-6 as a measure of trait gratitude found that, the grey matter volumes in brain regions related with theory of mind—the TPJ and posterior superior temporal sulcus (pSTS)—were positively correlated with trait gratitude (Liu et al., 2018). Even though the brain regions were different in the two structural MRI studies, they all shared a similar function in understanding others' mental states.

Taken together, previous neuroimaging studies mainly applied narrative-based imaginary tasks or social interactive tasks to induce gratitude. The results have highlighted brain regions that are involved in theory of mind (mPFC, TPJ, pSTS, PCC, precuneus; Fox et al., 2015; Liu et al., 2020; Liu et al., 2018; Xiong et al., 2020; Yu et al., 2017; Yu et al., 2018), reward processing (vmPFC, OFC, ventral striatum, putamen, and caudate; Fox et al., 2015; Karns et al., 2017; Kini et al., 2016; Liu et al., 2020; Xiong et al., 2020; Yu et al., 2017; Yu et al., 2018), moral cognition (mPFC, ACC; Fox et al., 2015; Kini et al., 2016), and predicting the effects of others' action (ACC; Kini et al., 2016).

However, there were several limitations of previous studies. First, some studies claiming theory of mind involvement (Fox et al., 2015; Liu et al., 2020) used verbal narratives or imaginary scenarios to elicit gratitude, which inherently already required a third-person perspective. Therefore, it is unclear whether theory of mind is involved as a result of understanding the social narratives or from the feeling of gratitude. Second, for the social interactive tasks, participants were forced to receive money (Kini et al., 2016) or bear pain (Yu et al., 2017; Yu et al., 2018) repeatedly in each trial. It was very unnatural and very different from gratitude generated in real social interactions; thus some brain activities were likely to be task-specific (e.g., insula in the pain alleviation task). Third, the role of expectation could be worth consideration. Participants may raise their levels of expected help after being helped repeatedly during the course of experiment. Fourth, the observed effect sizes of brain activations were small (e.g., results did not pass whole brain multiple comparison correction) in previous studies (Zahn et al., 2009, 2014). Therefore, more research using well-defined and high ecological validity tasks is needed to shed light on the neural basis of gratitude.

Neural correlates of pride

To investigate the neural substrates of pride, some studies contrast it as a self-conscious emotion with some basic emotions, such as joy and anger. The first neuroimaging study of pride comes from a comparison of pride and joy in a scenario imaginary task (Takahashi et al., 2007). Pride scenarios included sentences, such as "I was awarded a prize for my novel." Pride compared with the neutral condition induced greater activations in the right pSTS and left temporal pole; pride compared with joy condition yielded greater activations in the right pSTS. Besides, the subjective rating of pride also was positively correlated with the activities in the pSTS. As we have discussed before, the pSTS and temporal pole were related to theory of mind; here the imaginary task might likely require the participants to take a different perspective, thus involving theory of mind. Another study using imaginary scenarios found that compared with emotions of guilt, joy, and anger, pride showed greater activations in a cluster in the vmPFC extending to the OFC (Gilead et al., 2016). The vmPFC is part of the CMS, and it is typically involved in self-related processing (Denny et al., 2012; van der Meer et al., 2010). Moreover, the vmPFC is associated with values from revealing information about the self (Tamir & Mitchell, 2012) and changes in self-esteem (Will et al., 2017, 2020). A recent study of pride and controllability also

found that vmPFC engaged in success and internal control, as well as pride ratings (Stolz et al., 2020).

Studies also compared the brain activations associated with pride and other self-conscious emotions, such as shame and guilt. In one fMRI study (Roth et al., 2014), participants were asked to recall events during which they either felt ashamed/guilty or proud when they saw certain visual cues. Results showed that both pride and shame/guilt involved emotion-processing circuits such as the amygdala, and also brain regions of self-referential processing such as the mPFC. Compared with shame/guilt, pride was associated with more emotion-processing brain regions, possibly as a result of stronger involvement in the hedonic experience recall or a self-positivity bias. In another fMRI study that we mentioned before (Gilead et al., 2016), comparing pride to guilt also showed greater activations in ventral part of the mPFC.

Besides, a study compared pride as a self-focused emotion to an others-caring emotion—compassion (Simon-Thomas et al., 2012). Results showed that pride compared with compassion condition was associated with greater activations in the posterior medial cortex, which also was part of the CMS, involved in self-referential processing, as well as the parahippocampal gyrus and inferior temporal gyrus, which were engaged in autobiographical memory (Simon-Thomas et al., 2012).

The neural activity and anatomical basis of pride have also been investigated treating pride as a moral sentiment by Zahn and his colleagues (2009, 2014). Results from the structural MRI study showed that, grey matter volumes in the cuneus and precuneus were negatively correlated with individual differences in pride. The precuneus is also part of the CMS, which is the foundation of self-referential processing (Northoff & Bermpohl, 2004). In the fMRI study by Zahn et al. (2009), the pride condition was specifically associated with neural activities in the septum, which is part of the reward system, involving in pair bonding, affiliative reward, and reward learning (Depue & Morrone-Strupinsky, 2005; Insel & Young, 2001; Moll et al., 2006). Consistently, a recent study found that the neural correlates of professional pride in the reaction to uniform photos involved reward regions, such as the striatum (Hong et al., 2019).

Kong et al. (2018) distinguished the resting state neural activity of authentic and hubristic pride. Results showed that the individual differences in authentic pride were positively correlated with the fractional amplitude of low-frequency fluctuations (fALFF) in the bilateral superior temporal gyrus, which often is involved in social cognition, including self-recognition (Kircher et al., 2001; Platek & Kemp, 2009). These functions may serve to build authentic pride on the "objective self-awareness," which is a cognitive prerequisite of pride (Lewis et al., 1992). The hubristic pride is associated with low frequent brain activities in the OFC and PCC. The OFC often is involved in valuation (Padoa-Schioppa & Assad, 2008; Sescousse et al., 2010) and hedonic processing (Kringelbach, 2005). The engagement of the OFC in hubristic pride might imply abnormal reward and hedonic processing. As for the PCC, which is part of the CMS, is commonly involved in self-referential processing, such as autobiographical memory (Maddock et al., 2001). Therefore, the low resting-state activities in PCC might be related to abnormal self-referential processing.

Taken together, the neuroimaging studies of pride have used verbal narratives (Gilead et al., 2016; Takahashi et al., 2007; Zahn et al., 2009; Zahn et al., 2014), video clips (Hu et al., 2019), uniform photos (Hong et al., 2019), reward tasks (Stolz et al., 2020), others' success scenario pictures (Simon-Thomas et al., 2012), and recalling participants' own pride memories (Roth et al., 2014) to elicit pride, despite one study (Kong et al., 2018) using questionnaires to measure the individual differences in pride. Converging neuroimaging evidence has shown that pride could probably involve the self-referential processing (mPFC, PCC, and precuneus), reward processing (caudate, vmPFC, septum, and OFC), memory retrieval (PCC, temporal pole, parahippocampal gyrus, and inferior temporal gyrus), social cognition (right pSTS, superior temporal gyrus), affective processing (amygdala, insula, and ventral striatum), and theory of mind (mPFC, pSTS, and temporal pole).

However, the studies have a few limitations. First, the success scenarios depicted in the verbal narratives and pictures could be far from the participants' own life experience and may require a third-person perspective to imagine how they would feel if they were in that situation. That could be the reason why the theory of mind brain regions were involved. Second, for the recalling success task, it was not possible to explicitly control whether participants were thinking about proud experience or anything else. Meanwhile, it was not clear whether the involvement of the memory regions (e.g., the parahippocampal gyrus) was due to the nature of the task or the feeling of pride. Third, pride as an emotional response of success or compliments could be fundamentally different from reflecting on it with the narratives (Schilbach et al., 2013). Yet most of the previous neuroimaging studies have not used achievement tasks to elicit pride directly.

Shared and different neural substrates

To better visualize the shared and different neural substrates of gratitude and pride, Fig. 2 plotted the peak coordinates from previous neuroimaging studies relevant to gratitude (marked in red dots) and pride (marked in turquoise dots) using the BrainNet viewer (http://www.nitrc.org/projects/bnv/; Xia et al., 2013). We see both red and turquoise dots in the lower part of the brain, marked with a cycle that labeled the "reward system" (Fig. 2d and

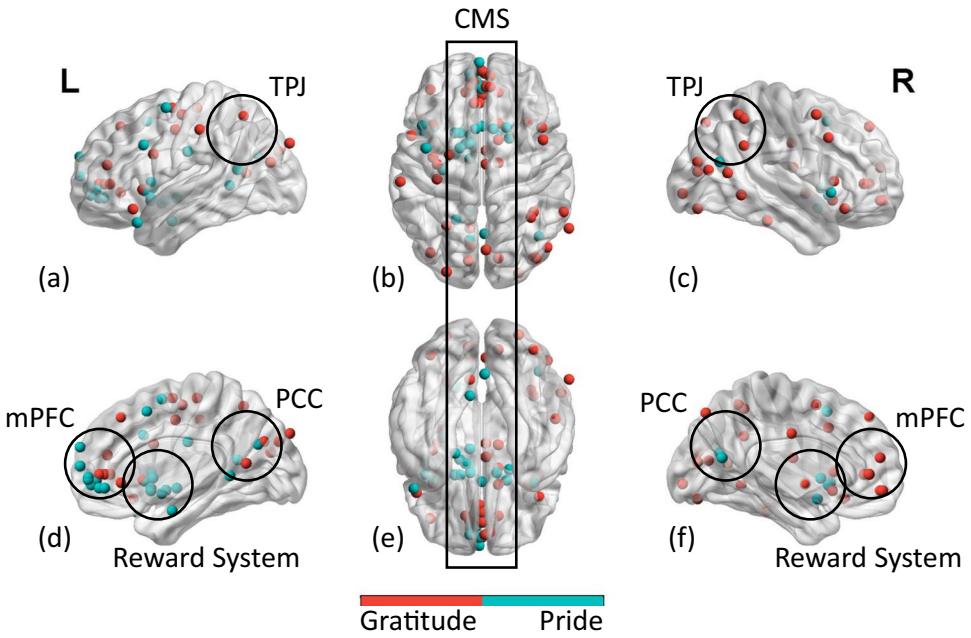

Fig. 2 Marked shared and different neural correlates of gratitude and pride. The dots are from the peak coordinates of previous neuroimaging studies of gratitude and pride (see https://osf.io/zn3yj for the raw data). Red dots stand for gratitude and turquoise dots stand for pride. Lateral views of the brain (**a** and **c**); medial views (**d** and **f**); dorsal view (**b**); and ventral view (**e**). TPJ, temporoparietal junction; CMS, cortical midline structures, including the medial prefrontal cortex (mPFC); PCC, posterior cingulate cortex.

f). Neural activities associated with gratitude and pride both involved brain regions processing reward, such as the vmPFC, OFC, and striatum (Fox et al., 2015; Karns et al., 2017; Liu et al., 2020; Xiong et al., 2020; Yu et al., 2017; Yu et al., 2018). These brain regions in the reward system control or adjust the levels of dopamine, which is essential in forming positive experience. This is in line with our former discussion in the psychological constructs that reward serves as a common basis of gratitude and pride. Consistent with the discussion, a recent study (Hu et al., 2019) using functional near-infrared spectroscopy (fNIRS) found that ten emotions, including gratitude and pride, can be clustered into three categories based on distinct frontal neural activity patterns. Gratitude and pride were clustered to the "encouragement" group, together with awe, hope, and inspiration and differentiated from the emotions in the "playfulness" and "harmony" clusters.

As for the different neural substrates, first, it is important to notice that the mPFC is a key brain region implicating in both the theory of mind and self-referential processing. Therefore, we can see gratitude studies reporting large cluster in the mPFC explaining gratitude in the context of theory of mind (Fox et al., 2015), which we can see in Fig. 2d and f located more in the dorsal part of the mPFC; pride studies reporting the mPFC refer it as part of the CMS, which is commonly involving in self-referential processing (Gilead et al., 2016; Stolz et al., 2020), located more in the ventral part the mPFC (Fig. 2d and f).

Apart from the mPFC, gratitude reliably activated other brain regions involving theory of mind, such as the TPJ (Yu et al., 2018) and ACC (Fox et al., 2015; Kini et al., 2016). In Fig. 2a and c around the bilateral TPJ, there are more red dots than turquoise dots, indicating the preferential role of theory of mind in gratitude processing. Although we have seen pride-related brain regions also include theory of mind brain regions, such as the pSTS, it is highly likely to be paradigm-specific (Takahashi et al., 2007): one has to take a third-person perspective to understand the story scenario—that process per se demands on theory of mind, rather than the pride emotion.

Pride-preferential brain regions are more associated with the self-referential processing, typically the CMS, including the mPFC (Gilead et al., 2016; Stolz et al., 2020), PCC (Kong et al., 2018), and precuneus (Zahn et al., 2014). In Fig. 2b and e—the brains in ventral and dorsal views—there are many densely populated turquoise dots along the cortical midline structures, whereas the red dots appeared sparsely scattered along the bilateral sides. Besides, brain regions involving pride include memory retrieval regions, such as the PCC, temporal pole, parahippocampal gyrus, and inferior temporal gyrus (Simon-Thomas et al., 2012). This could result from a potential underlying function to

use past experience as a reference to evaluate the current achievement. Nevertheless, it may result from the recalling paradigm per se as well.

Integrating the behavioral and neuroimaging evidence from sections 4, 5, and 6, we propose a cognitive neuroscientific model (Fig. 3) under a reinforcement learning framework to explain the emotional dynamics in gratitude and pride. Simply put, when the results are better than expected, a positive prediction error is generated in the reward system. When the good outcomes are from others' benevolence, the brain regions processing theory of mind will be involved; thus, the intention information is integrated with the value information to generate the feeling of gratitude. When the good outcomes are from one's own endeavor, the brain regions involving self-referential processing will be activated to connect to the value information to generate the feeling of pride.

Following the model, we expect to see the dynamics in gratitude and pride associated with the prediction error signals in the brain. Combining the reward updating signals from ventral striatum, the vmPFC (Bouret & Richmond, 2010; Gardner et al., 2019; Pessiglione & Daunizeau, 2021) may integrate the value dynamics and the intrinsic knowledge regarding oneself through the functional connectivity within the CMS (Xu et al., 2022) or others through the functional connectivity with the dmPFC and TPJ (Cole et al., 2019) to form the subjective valuation and feelings for gratitude and pride, subsequently, as illustrated in Fig. 3.

Future directions

For future studies, a few, specific questions may be interesting to work on. First, previous studies did not investigate the fluctuation of gratitude or pride over a long-time scale, during which the reward could increase or decrease all the time. More importantly, past experience also may influence the expectation and evaluation of the current reward (Rutledge et al., 2014). Therefore, the expectation of the upcoming reward and the reward prediction error may influence gratitude or pride irrespective of the actual reward. Using different reward probabilities, we can experimentally explore how gratitude and pride computationally updated along with reward and help. Moreover, we can check for the corresponding neural basis for such processes in the brain to support the hypotheses in Fig. 3: in particular, how the information of others and self transforms to expectations, how the reward is appraised and integrated into values, and how the prediction error signals are connected to other brain regions (e.g., the motor cortex) to generate prosocial or achievement-seeking behaviors.

Second, previous research did not separate and quantify the contributions of the objective reward and subjective valuation in gratitude or pride. For example, achieving on a difficult task is always more rewarding than achieving on an easy task and elicit more proud feelings (Lewis et al., 1992), even if they have the same objective value. This may be explained by the low expectation in difficult tasks. Further research is needed to elucidate the contributions of objective and subjective value and the mediating role of expectation in gratitude and pride.

Third, most neuroimaging studies discussed the specific brain functions that may involve in gratitude or pride. There is a lack of studies concerning the functional networks as a whole in processing gratitude and pride. For example, how the functional connectivity of the reward system and theory of mind, or self-referential processing, work together to form gratitude or pride is yet unknown. Taking a network perspective, knowing how the reward signals are being compared and evaluated in the other-vs.-self network will help to explain how the brain works with different functional modules.

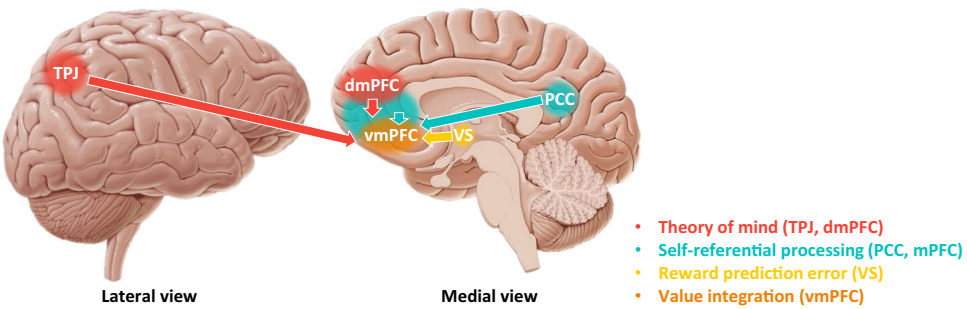

Fig. 3 Cognitive, neuroscientific model of gratitude and pride. Brain activities involving theory of mind (in red, mainly the dmPFC and TPJ) and self-referential processing (in turquoise, mainly the CMS, including the mPFC and PCC) offer top-down information to form the expectation for others and oneself. The brain activities in the ventral stratum (VS; in yellow) offer bottom-up information of reward prediction error signals. The vmPFC (in orange) integrates the information from both channels (others/self, reward) to form general subjective value and feelings of gratitude or pride. mPFC: medial prefrontal cortex, including the dorsal part of the mPFC (dmPFC); and the ventral part of the mPFC (vmPFC). TPJ, temporoparietal junction; PCC, posterior cingulate cortex.

Future studies could build tasks that have dynamic gain or loss in helping or nonhelping situations to compare the mechanisms behind gratitude and pride. Model-based approaches, such as reinforcement learning, could be applied to test how expectations influence gratitude and pride, and whether gratitude and pride fluctuate based on the same reward prediction error as happiness (Blain & Rutledge, 2020; Keren et al., 2021; Rutledge et al., 2014). Furthermore, advanced brain imaging analyses, such as representational similarity analysis (Kriegeskorte et al., 2008; Kriegeskorte & Kievit, 2013) and effective connectivity (Friston, 2011), could be applied to understand how common and specific brain regions in gratitude and pride are represented in the brain and the information flow between the functional networks involved.

Conclusions

The current study compared two positive emotions——gratitude and pride, in particular their psychological constructs and neural substrates, in the context of behavioral and neuroimaging findings. We summarized that gratitude and pride are both built on the reward system, while having different cognitive appraisals to credit reward to others or oneself. Based on the evidence from brain and behavior, we propose a cognitive, neuroscientific model under a reinforcement learning framework. We hypothesize that both emotions were based on a bottom-up reinforcement learning mechanism backed by the brain's reward system. However, the theory of mind is an important cognitive prerequisite for gratitude to form the expectation for others; yet self-referential processing is essential to form the expectation for oneself in pride. This information regarding others or oneself is integrated to the reward system to generate subjective valuations and feelings of gratitude or pride. Future studies could work on developing social interactive paradigms with different reward probabilities to compare gratitude and pride in the same experiment and test this model. The review may help us to relate psychological theories to specific brain functions to better understand why gratitude and pride have different motivational drives, and why they are so important in social interaction and self-esteem.

Acknowledgments This work was supported by grants from National Natural Science Foundation of China (31600928), The Project of Philosophy and Social Science for the 13th 5-Year Planning of Guangdong Province (GD20XXL03), Shenzhen Basic Research Project (JCYJ20190808154209286), Liyuan Excellent Youth Project, and Shenzhen-Hong Kong Institute of Brain Science-Shenzhen Fundamental Research Institutions (2021SHIBS0003).

The authors declared no conflicts of interest with respect to their authorship or the publication of this article. KD drafted the manuscript, and JL revised it critically and approved the final version of the manuscript.

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Open practices statement This review was not preregistered. The data used are available through the Open Science Framework repository: https://osf.io/zn3yj.