Neural Substrates and Social Consequences of Interpersonal Gratitude: Intention Matters

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Voluntary help during a time of need fosters interpersonal gratitude, which has positive social and personal consequences such as improved social relationships, increased reciprocity, and decreased distress. In a behavioral and a functional magnetic resonance imaging (fMRI) experiment, participants played a multiround interactive game where they received pain stimulation. An anonymous partner interacted with the participants and either intentionally or unintentionally (i.e., determined by a computer program) bore part of the participants' pain. In each round, participants either evaluated their perceived

and reciprocal behaviors toward the benefactor. There is also concern about the potential differences in the neural processing between third-person (vicarious) and first-person emotional experiences (Schilbach et al., 2013). Here, we developed a novel interpersonal task to elicit gratitude and measured its neural and behavioral consequences.

Social psychologists and philosophers have shown that the benevolent intention embedded in the help/gift is the essence of interpersonal gratitude, and it is such intention that distinguishes gratitude situations from other gift-giving situations, such as accepting bribery or winning a lottery (Berger, 1975; McConnell, 1993; Tesser, Gatewood, & Driver, 1968). These findings are in line with the words of the stoic philosopher Seneca, who points out, “what matters is not the deed or gift but the mentality behind them” (Seneca, 1995, p. 202). In the current study, we created different levels of gratitude by manipulating the intention of the benefactor. The participants received a pain stimulation on each bear in that trial. After another variable interval, pain stimulation was delivered to the participant (and the partner, ostensibly). After the pain stimulation, the participants were asked to rate stimulation on a discrete 1–8 scale.

The experiment had a 2 (decision agent: Human vs. Computer) 2 (decision: Share vs. NoShare) factorial design, with the four conditions being partner deciding to share pain (Share_Hum), partner deciding not to share (NoShare_Hum), computer deciding to share (Share_Com), and computer deciding not to share (NoShare_Com). We acknowledy.1(to)mSham rh-232.6edy.1“.2222 TDibeing of the four conditions on a scale of 0 (no sensation) to 10 (intolerably painful).

Neuroimaging data acquisition. Images were acquired using

Neuroimaging Results

Univariate analysis of fMRI data. On the whole-brain level, the interaction contrast “Hum_Share—Com_Share—Hum_NoShare—Com_NoShare” corresponding to the decision outcome stage only revealed activations in the supplementary motor area (SMA) and the left precentral gyrus (see Table 3). Given that all the participants were asked to respond with their right hand, this activation may reflect motor preparation for the allocation stage. The same contrast revealed significant activation in the vmPFC mask (MNI coordinates: [0, 38, 8]; k 14; p_{FWE} 0.015, small-volume corrected; Figure 3A) and in the VTA mask (MNI coordinates: [3, 13, 5]; k 22; p_{FWE} 0.021, small-volume corrected; Figure 3A). Moreover, the effect size of the interaction in the vmPFC parameter estimates positively correlated with the effect size of the interaction in gratitude ratings, rs, .41, p .034. To further investigate the relationship between the brain and behavioral responses to intentional help, we tested the indirect pathway from vmPFC via gratitude to money allocation (i.e., reciprocity). Results supported the existence of the indirect pathway via gratitude: the indirect effect estimate 0.19, SE 0.10, 95% confidence interval was [0.01, 0.43] (Figure 3C).

We further carried out whole-brain exploratory parametric analyses. For the interaction contrast corresponding to the decision outcome stage, we added the participants’ gratitude trait (as measured by The Gratitude Questionnaire-6, GQ-6; McCullough et al., 2001) and the interaction effect in postscan gratitude rating as group-level covariates in two separate models, respectively. As can be seen from Figure 3D, the activation magnitude in the PCC and the precuneus positively correlated with the gratitude trait (red cluster), while the activation in the PCC positively correlated with the interaction effect of the gratitude rating (blue cluster). Conjunction analysis (Nichols, 2007) showed that these two contrasts commonly activated the PCC. This area has been showed to be responsible for attracting attention to valuable items (Grueschow, Polania, Hare, & Ruff, 2015). Using the aforementioned method (Preacher & Hayes, 2008), we found that the indirect pathway from trait gratitude to gratitude self-reports via PCC activation did exist, with indirect effect estimate 0.08, SE 0.05, 95% confidence interval was [0.01, 0.21].

As for the pain delivery stage, we first checked the pain pertions (see Figure 5). We applied the Share classifiers (i.e., the multivariate pattern dissociating Hum_Share vs. Com_Share) to the maps corresponding to the four conditions and obtained pattern expressions for these classifiers. As can be seen from Figure 5, the mode of the pattern expressions is consistent both with the behavioral measures (gratitude rating and money allocation) and the neural activation in the valuation system. These findings indicated that the value- and affiliation-related brain structures contained information specific and sensitive to intentional help and interpersonal gratitude.

Discussion

The feeling and expression of gratitude as a response to others' help/gift is a common feature of human sociality and a basic moral principle in many cultures (Mauss, 1950/2002; McConnell, 1993; McCullough et al., 2001). Although theoretical and psychological studies on the nature and antecedence of gratitude are abundant (for a collection of these work, see Emmons & McCullough, 2004), the investigation into the neurobiology of gratitude is just beginning (Decety & Porges, 2011; Fox et al., 2015; Zahn et al., 2009). A number of features of our study allow for novel contributions to the understanding of the psychological and neural substrates of the feeling and expression of gratitude beyond the scope of the previous studies. First, instead of using scenario-based imagination, we adopted an interpersonal interactive (or "reactive," in the terminology of Hari, Henriksson, Malinen, & Parkkonen, 2015) paradigm where the participants interacted with real human partners and received real help (or "gift"). Given the social nature of interpersonal gratitude, it is crucial to elicit and measure gratitude in a social context and to make sure that the participants experience such emotion from a first-person perspective (Schilbach et al., 2013). Compared with a scenario-based approach, "being a participant in an interaction may entail a commitment towards being responsive created by important difference in the motivational foundations of 'online' and 'offline' social cognition" (Pfeiffer, Timmermans, Vogeley, Frith, & Schilbach, 2013). Recent studies combining interpersonal paradigms and neuroimaging have g (ne223.3325eadvaencd23.3325e(our).3325e(understanding).3325e

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Huffman et al., 2014), improved social relationships (Algoe, 2012; Bartlett, Condon, Cruz, Baumann, & Desteno, 2012) and enhanced prosocial/reciprocal behaviors (McCullough & Tsang, 2004; Tsang, 2006), which are difficult to test with the scenario-based approach.

Gratitude, Reciprocity, and Reward System

A grateful beneficiary has positive evaluations about the benefactor's helping behavior and benevolent intention (Fredrickson, 2004; McConnell, 2016). Here we found that the reward-related brain structures (e.g., vmPFC, VTA, and caudate) exhibited the highest activation in the most grateful condition (Figure 3A), had predictive power to sensitively and specifically dissociate intentional versus unintentional help (Figure 5D and 5G), and showed positive association with gratitude ratings across participants (Figure 3C). Thus, the positive feeling/evaluation interpretation is in line with the role of the reward system in computing abstract subjective value (Bartra et al., 2013; Rangel, Camerer, & Montague, 2008) and representing praiseworthy social intention (Cooper, Kreps, Wiebe, Pirkl, & Knutson, 2010; Izuma, Saito, & Sadato, 2008; Ruff & Fehr, 2014), including gratitude (Fox et al., 2015). It should be noted, however, that the subregion of M computer program) context (van den Bos et al., 2007; compare their Figure 5A and 5C with our Figure 3A; see also Lin et al., 2012). This dissociation may be inherent in the design: in both van den Bos et al.'s (2007) study and in ours, the gift is delivered to the participants themselves (self-regarding value), while in Fox et al.'s (2015) study, the participants were asked to imagine situations in which other people received help (other-regarding value). Recently, it has been shown that the representation of self-regarding value and other-regarding value exhibit a ventral-dorsal gradient with self-regarding value being represented in a more ventral part and other-regarding value being represented in a more dorsal part of the MPFC (Nicolle et al., 2012; Sul et al., 2015). The discrepancy of the neural findings derived from scenario-based and interaction-based studies may also arise from the fact that the brain processes related to social cognition are modulated by the extent to which human participants perceive themselves as being involved in an ongoing interaction (Schilbach, 2010).

showed that in the settings where learning of the interactive partner's character is possible, individuals' emotional and behavioral responses are not solely determined by the benefits and suffering that resulted from the partner's current action; who performs that action also counts. Participants can gradually learn the characters of different interactive partners and treat their behaviors differently, despite the fact that at a given encounter the objective benefits or suffering induced by those partners are identical. This feature of social learning is also highly relevant to social emotions like gratitude, as previous empirical and theoretical studies have shown that the same gift/benefit may induce either gratitude or indebtedness contingent on who provides that gift/benefit (McConnell, 1993; Watkins et al., 2006). Future studies could incorporate learning procedures and mathematical modeling to address this question.

Conclusion

By combining an interpersonal paradigm with fMRI, we documented the neural substrates of experiencing interpersonal gratitude in real social interaction. Compared with previous studies on the neurobiology of gratitude using scenario-based approach, our study made novel contributions in that we not only measured the neural correlates of the grateful experience, but also showed how such neural processes may give rise to important social consequences of receiving help, namely, alleviated negative experience of pain, improved interpersonal relationships, and increased reciprocal/prosocial behavior. In a broader sense, these contributions underlie the benefits of using interpersonal paradigms in the investigation of the psychological and neurobiological mechanisms of complex social cognition and emotion.

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