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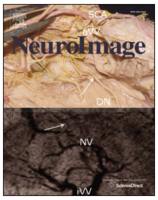

When “Your” reward is the same as “My” reward: Self-construal priming shifts neural responses to own vs. friends' rewards

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ABSTRACT

Is it possible for neural responses to others' rewards to be as strong as those for the self? Although prior fMRI studies have demonstrated that watching others get rewards can activate one's own reward centers, such vicarious reward activation has always been less strong than responses to rewards for oneself. In the present study we manipulated participants' self-construal (independent vs. interdependent) and found that, when an independent self-construal was primed, subjects showed greater activation in the bilateral ventral striatum in response to winning money for the self (vs. for a friend) during a gambling game. However, priming an interdependent self-construal resulted in comparable activation in these regions in response to winning money for the self and for a friend. Our findings suggest that interdependence may cause people to experience rewards for a close other as strongly as they experience rewards for the self.

Introduction

Vicarious reward, a sense of pleasure derived from watching others gain rewards, has been implicated in a number of basic processes from altruism (Ainslie, 1995) to learning (Bandura, 1977). The experience of vicarious reward may also be a psychological mechanism that is necessary for the evolutionary process of kin selection to occur (Campbell-Meiklejohn and Frith, 2012; Mobbs et al., 2009). Although vicarious reward has been described as “a raw feel, as robust as food or pain”, (Ainslie, 1995, p. 395), no evidence suggests that people experience others' rewards as strongly as they experience those same rewards directly. In fact, a review of the neuroimaging literature failed to find any published study in which vicarious rewards produced equal or stronger activation in the reward network than rewards for the self.

That said, there have been a handful of functional magnetic resonance imaging (fMRI) studies that have demonstrated that social factors can modulate vicarious reward. For example, Mobbs et al. (2009) found that people show greater activation in the ventral striatum (VS) when watching socially desirable others (as opposed to socially undesirable others) win at a card-guessing game. In addition, connectivity between the VS and the anterior cingulate cortex (ACC) while watching others' win was positively correlated with perceived similarity between oneself and the target. In another study in which participants played a card-guessing game where they shared their rewards either with a friend, a stranger, or a computer, Fareri et al. (2012) found greater VS activation in response to winning rewards when their partner was a friend, though this effect was confined to participants who were high in subjective closeness to that friend.

Given that similarity and closeness to the other party appear to strengthen neural response to vicarious reward, perhaps if subjects are induced to construe the self in an interdependent fashion (that is interconnected with and encompassing close others) as opposed to an independent fashion (that is autonomous and bounded; Markus and Kitayama, 1991; Varnum et al., 2010) then vicarious reward and reward for the self might produce comparable activation in neural regions involved in reward. fMRI studies have demonstrated comparable activation in the medial prefrontal cortex (mPFC) involved in representation of one's own traits and a close other's traits in a society where interdependent self-construal is common (Zhu et al., 2007), and that priming interdependence has a similar effect (Chiao et al., 2010; Ng et al., 2010). Here we tested whether vicarious reward and reward for the self might produce comparable activation in the neural regions involved in reward when interdependence is primed.

The present study tested the prediction that priming an interdependent self-construal will lead to equal response to rewards for the self and a friend, whereas priming an independent self-construal would lead to greater responses to own rewards vs. a friend's rewards. Given the fact that previous research on reward has consistently shown that

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the VS responds to rewards for the self (e.g. Bjork and Hommer, 2007; Delgado et al., 2000; Fareri et al., 2012; Mobbs et al., 2009; O'Doherty et al., 2003) and to vicarious rewards (

whole brain were acquired using the following parameters: $64 \times 64 \times 32$ matrix with $3.75 \times 3.75 \times 5$ mm^3 spatial resolution, inter-slice gap = 1 mm, field of view (FOV) = 24×24 cm^2, repetition time (TR) = 2000 ms, echo time (TE) = 30 ms, flip angle (FA) = 90°. For each run, a total of 154 volumes were acquired in the main study and 184 volumes in the localizer study.

SPM8 (Wellcome Trust Centre for Neuroimaging, London, UK) was used to preprocess and analyze the imaging data. Images were adjusted for slice timing, realigned to the first scan to correct for head motion, normalized into stereotactic Montreal Neurological Institute (MNI) space with 3-mm cubic voxels, and spatially smoothed by a Gaussian filter with full-width/half-maximum parameter (FWHM) set to 8 mm. We then modeled trials of different conditions by including regressors convolved with canonical hemodynamic response function (HRF) at the onset of the presentation of outcomes. For the main study, five regressors were generated for Self Win, Self Loss, Friend Win, Friend Loss, and neutral trials. For the localizer study, three regressors were generated for Win, Loss, and neutral trials. Six motion parameters (translation: x, y, z; rotation: pitch, roll, yaw) and run-specific constant terms were also included in the model to account for effects of no interest, and whole-brain intensity was normalized using global scaling. Linear contrasts were used to identify regionally specific effects in individual participants with a fixed effect model. Random effect analyses were then conducted based on contrast images to allow population inference. For the localizer study, brain regions encoding monetary reward, specifically bilateral VS, were identified at a corrected $p < 0.05$ threshold (using a combined threshold of uncorrected $p < 0.001$ and cluster extent >21 voxels, determined by a 1000-iteration Monte-Carlo simulation; Slotnick et al., 2003) for the contrast of Win > Loss in the localizer study. This threshold was also used for other exploratory whole-brain analyses. Regions of interest (ROIs) were defined as spheres centered at the peak voxels of activations with radii of 5 mm using MarsBaR (http://marsbar.sourceforge.net). Contrast values in the main study were extracted from the ROIs by subtracting the coefficient estimates of the neutral condition from those of the experimental conditions.

Results

Behavioral results

Participants were highly accurate in their pronoun judgments during independent and interdependent self-construal priming, and accuracy did not differ across priming conditions (independent: M = 84.1%, SD = 7.2%; interdependent: M = 85.3%, SD = 5.0%; $t(14) = -0.96$, $p = 0.35$). Reaction times (RTs) were also comparable during independent and interdependent self-construal priming (independent: M = 5375 ms, SD = 84 ms; interdependent: M = 5401 ms, SD = 86 ms; $t(14) = -0.75$, $p = 0.46$).

The RTs during the card-guessing game (M = 626 ms, SD = 167 ms) did not differ across different conditions as shown by a $2 \times 2 \times 2$ repeated-measures ANOVA involving Prime (Independent/Interdependent), Target (Self/Friend), and Outcome (Win/Loss) ($Fs < 2.90$, $ps > 0.11$). There was also no difference between the RTs of any experimental condition and those of the neutral condition ($ts < 1.52$, $ps > 0.15$).

Self-report measures

On the 8-point Likert scale of closeness between self and friend (1: no overlap; 8: fully overlap), the participants' rating scores ranged from 3 to 8 (M = 5.07, SD = 1.49).

Results from the Self-Construal scale and the Horizontal and Vertical Individualism and Collectivism scale showed that the participants were more interdependent than independent (M = 5.31, SD = 0.64 vs. 4.82, SD = 0.55, $t(14) = 3.44$, $p < 0.005$), and were more collectivistic than individualistic (M = 5.64, SD = 0.52 vs. M = 4.98, SD = 0.59, $t(13) = 3.13$, $p < 0.01$; one participant did not complete the scale). These results suggest collectivistic cultural orientation among our Chinese sample.

We conducted a 2×2 ANOVA to test the effect of Target (Self/Friend) and Outcome (Win/Loss) on subjective reports of feeling happy. The participants felt significantly more happy for Win than for Loss trials ($F(1,14) = 65.55$, $p < 0.001$), and there was no significant effect of Target ($F(1,14) = 3.80$, $p = 0.07$). Moreover, We found a significant interaction between Target and Outcome ($F(1,14) = 10.33$, $p < 0.01$). Whereas participants reported similar feelings of happiness in response to Self Win and Friend Win trials (M = 1.87, SD = 1.55 vs. M = 1.93, SD = 0.88, $t(14) = -$

Table 1
Brain activities to monetary win and loss in the localizer study and the main study. VS: ventral striatum; SMA: supplementary motor area.

Region	x	y	z	k	Z
Localizer study, Win vs. Loss					
Left VS	−12	5	−8	34	4.11
Right VS	12	8	−8	29	4.56
Main study, Win vs. Loss					
Left VS	−12	8	−14	152	5.09
Right VS	12	11	−11	256	5.63
Posterior cingulate cortex	3	−34	37	668	5.06
Medial prefrontal cortex	3	44	1	374	4.56
Right middle frontal gyrus	48	47	10	35	4.16
Left inferior parietal gyrus	−51	−70	52	44	3.97
Right superior frontal gyrus	24	38	49	34	3.88
Left inferior temporal gyrus	−54	−61	−11	127	3.87
Left inferior temporal cortex	−51	−49	−26	21	4.11
Right parietal cortex	33	−70	43	22	3.59
Localizer study, Loss	−			. ILocal(a52.241Td52.294s)	

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insula encodes monetary loss (e.g. Delgado et al., 2000; Paulus et al., 2003), while the supplementary motor area underlies reward-related decision-making (e.g. Gläscher et al., 2008; Haruno et al., 2004; Kouneiher et al., 2009). Although none of these regions showed a significant Prime ×Target × Outcome interaction ($Fs < 3.13$, $ps > 0.09$), we did observe a marginally significant Prime × Target interaction in the right insula in the Loss condition ($F(1,14) = 3.95$, $p = 0.067$), such that the activation tended to be stronger for self trials vs. friend trials ($M = 0.55$, $SD = 0.24$ vs. $M = 0.21$, $SD = 0.25$) after Independent self-construal priming, and tended to be stronger for friend trials vs. self trials ($M = 0.37$, $SD = 0.19$ vs. $M = 0.19$, $SD = 0.23$) after Interdependent self-construal priming. However, pair-wise comparisons failed to reach statistical significance ($ps > .15$).

We also conducted correlation analyses to test whether the magnitude of the Prime × Target × Outcome interaction at the bilateral VS was associated with participants' subjective reports of happiness when winning for their friends, closeness to their friends, and trait-level measures of self-construal. However, none of these self-report measures were significantly correlated with neural activation in these regions ($rs = -0.33$ to 0.16, $ps > 0.22$).

Discussion

The present study investigated whether neural responses to personal vs. vicarious rewards and losses are affected by how people construe the self in a given moment. We found that priming interdependence led to equal bilateral VS responses to rewards for the self and a friend (and in fact the trend was such that responses to friends' rewards were greater), whereas priming independence induced greater bilateral VS responses for rewards for the self than for a friend. These findings suggest that inducing a notion of self that includes close others causes rewards for the self and those others to be processed in a similar fashion, whereas inducing a notion of the self as autonomous and bounded leads to greater response to personal rewards. Although previous studies have used fMRI to explore vicarious reward, the present study provides the first evidence that neural response to vicarious rewards may be comparable to response to one's own rewards (if an interdependent self-construal is primed). Our findings suggest that self-construal may affect motivation (self vs. other-oriented) to experience rewards for a close other as strongly as they experience rewards for the self. These findings extend the literature on how self-construal may affect neural function (i.e. Chiao et al., 2009, 2010; Han et al., 2013; Lin et al., 2008; Ma et al., 2012; Ng et al., 2010; Sui and Han, 2007; Wang et al., in press; Zhu et al., 2007) by showing that vicarious reward can be modulated by temporary self-construal. Previous studies found that self-construal priming affected neural activity in cortical structures such as the mPFC (Chiao et al., 2010; Ng et al., 2010; Wang et al., 2013) and the lateral frontal cortex (Sui and Han, 2007). The current work, however, provides one of the first demonstrations that manipulating self-construal may affect the function of subcortical structures.

We should also note that although the Loss condition produced reduced activity in the VS (consistent with Delgado et al., 2000), we did not observe a Prime × Target interaction in the VS in the Loss condition. This suggests that the results we observed in the VS were not due to

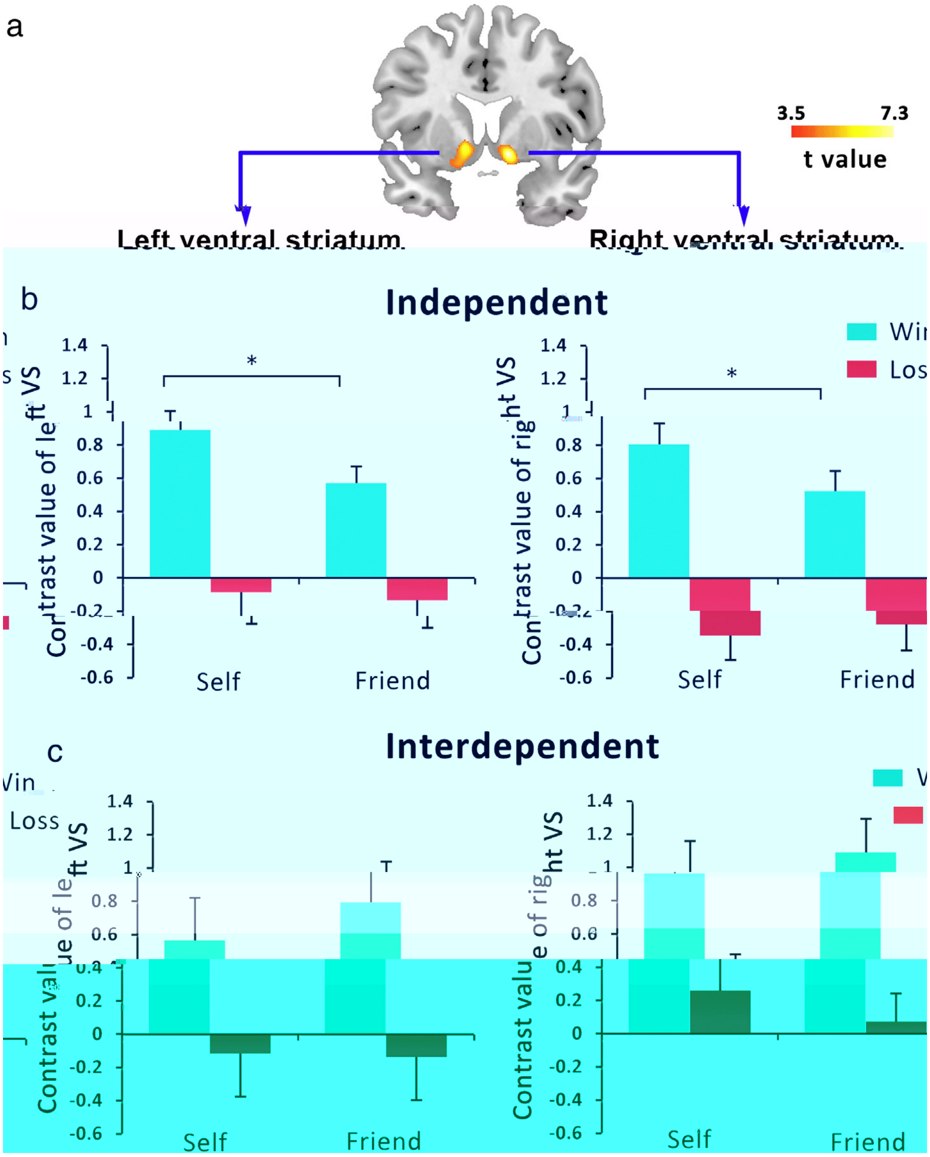

Fig. 3. Neural response in the bilateral ventral striatum. (a) Bilateral ventral striatum activation identified in localizer study (y = 8); (b) & (c) Left ventral striatum (left panel) and right ventral striatum (right panel) activation in Independent and Interdependent self-construal priming condition. (All compared to neutral condition). VS: ventral striatum.

changes in response to outcome feedback in general, but rather were specifically linked to reward feedback.

We did find a marginally significant interaction between Prime and Target on activation in the right insula during the Loss condition, such that losses for one's friend (vs. the self) produced greater activation after Interdependence priming, whereas the opposite was the case after Independence priming. Given that the insula has been implicated in empathy (for a review see Bernhardt and Singer, 2012), these results suggest that priming interdependence may have heightened empathic responses to losses for one's friend. This is broadly consistent with the previous finding that trait-level interdependence was correlated with increased error-related negativity (ERN) in response to trials where one lost points for a friend (Kitayama and Park, 2013). However, we should note that the pair-wise contrasts were not significant in the present study. This may be due to relatively limited power. We should also note that in Kitayama and Park's (2012) study, participants completed a flanker task and incorrect answers led to losses for a friend; whereas in our paradigm incorrect guesses were framed as having to do with chance rather than ability or performance (and in fact in our case feedback was rigged). Further, our study was designed such that loss trials were of smaller monetary magnitude than win trials, thus losses in general may not have been particularly painful. Future research with a larger sample (and hence greater statistical power) might explore whether modifying the relative value of loss vs. reward trials or perceived (or actual) responsibility for trial outcomes in order to test whether this might magnify the effects of self-construal priming on regions like the insula or ACC.

The present study did not measure subjective responses to individual trials (due to time constraints). As a result it was not possible to map the neural effects of the priming that were observed in the current study onto subjective reports. Future research may address this limitation by gathering real-time subjective ratings of pleasure and distress. It would also be useful in future work, if trial-by-trial ratings prove impractical, to measure subjective ratings of pleasure and distress after each set of runs (independent vs. interdependent) as this would be expected to confirm the neural results observed. In addition, it would be interesting to measure participants' physiological responses during the gambling game to assess the relationship between their autonomic and neural responses to monetary reward.

We should also note that we chose to employ a block design rather than varying the primes trial-by-trial. A trial-by-trial may be especially useful given the trend evident in the VS in the interdependent prime condition where wins for friends produced larger activations than wins for the self, as it might increase power to detect such effects. Although interspersing the trials may have increased power and decreased noise, self-construal primes are likely to have strong carry-over effects. Considering these trade-offs, we opted to employ a block design as we felt it would provide a better chance to capture the priming effects we were interested in.

Although the present study was conducted within a single culture, because of the observed effects of manipulating self-construal (a key dimension of cultural difference) the results raise the possibility that the reward system may be culturally influenced. In fact it may be that chronic cultural differences in self-construal and reward system responses to self and close others are mutually reinforcing. Our results may also have implications for research on culture and in-group/out-group phenomena. For example, the greater levels of in-group trust and favoritism that are present in interdependent societies (Yamagishi and Yamagishi, 1994; Yamagishi et al., 1998) may in part reflect greater sensitivity of the reward system to vicarious rewards for close others. Future studies might explore whether default neural responses to vicarious reward differ across cultures that differ in which type of self-construal is predominant, and whether the effects of priming are similar across different cultures. It may be illuminating to examine the effects of self-construal priming on bi-cultural participants for whom both types of self-construal may be defaults. It would also be worthwhile to test whether manipulating people's focus on their own rewards vs. rewards for close others may shift how people construe the self. That is, it would be interesting to see if having people focus on vicarious reward might lead to a more interdependent construal of the self (and whether focusing on personal rewards may lead to the self being construed in a more independent fashion). Finally, it would be interesting to test whether inducing an interdependent view of the self may also motivate people to engage in altruistic behavior toward close others, and whether individual differences in neural response to vicarious reward may be a useful predictor of future altruistic behavior.

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