Common and distinct neural correlates of personal and vicarious reward: A quantitative meta-analysis

Sylvia A. Morelli [a,*], Matthew D. Sacchet [a,b], Jamil Zaki [a,*]

[a] Department of Psychology, Stanford University, Stanford, CA 94305, USA
[b] Neurosciences Program, Stanford University, Stanford, CA 94305, USA

ABSTRACT

Individuals experience reward not only when directly receiving positive outcomes (e.g., food or money), but also when observing others receive such outcomes. This latter phenomenon, known as *vicarious reward*, is a perennial topic of interest among psychologists and economists. More recently, neuroscientists have begun exploring the neuroanatomy underlying vicarious reward. Here we present a quantitative whole-brain meta-analysis of this emerging literature. We identified 25 functional neuroimaging studies that included contrasts between vicarious reward and a neutral control, and subjected these contrasts to an activation likelihood estimate (ALE) meta-analysis. This analysis revealed a consistent pattern of activation across studies, spanning structures typically associated with the computation of value (especially ventromedial prefrontal cortex) and mentalizing (including dorsomedial prefrontal cortex and superior temporal sulcus). We further quantitatively compared this activation pattern to activation foci from a previous meta-analysis of *personal* reward. Conjunction analyses yielded overlapping VMPFC activity in response to personal and vicarious reward. Contrast analyses identified preferential engagement of the nucleus accumbens in response to personal as compared to vicarious reward, and in mentalizing-related structures in response to vicarious as compared to personal reward. These data shed light on the common and unique components of the reward that individuals experience directly and through their social connections.

Introduction

Humans are physically separate, but psychologically intertwined. *Empathy* – the ability to share and understand others' internal states – intimately connects us, such that we "co-experience" the feelings of those around us. Empathy often involves sharing others' pain and suffering, but applies equally to our sharing of others' positive states. Adam Smith (1790/2002), whose *Theory of Moral Sentiments* paved the way for modern theories of empathy, recognized such *positive empathy*. Smith even suggested that people could re-ignite their enjoyment of, for instance, theater performances by capitalizing on shared enjoyment with others who had not seen these performances before:

> We enter into the surprise and admiration which it naturally excites in him, but which it is no longer capable of exciting in us… and we are amused by sympathy with his amusement which thus enlivens our own (p. 9).

Although not the center of empathy research, positive empathy has received increasing attention for years (Batson et al., 1991; Gable and Reis, 2010; Morelli et al., under review; K. D. Smith, Keating, and Stotland, 1989). Scientists have demonstrated, for instance, that other-reported positive empathy tracks the health of close relationships (Gable, 2006). Further, individuals reap psychological rewards from their own prosocial behaviors, reporting higher degrees of happiness after acting prosocially, as compared to selfishly (Dunn et al., 2014). Indices of positive empathy track individuals' tendency to engage in prosocial behaviors, which suggests that positive empathy plays a functional role in driving generosity (Harbaugh et al., 2007; Mobbs et al., 2009; Morelli et al., in press; Zaki and Mitchell, 2013). Finally, neuroimaging studies suggest that individuals may share the positive emotional and bodily states of others during positive empathy (Jabbi et al., 2007; Mobbs et al., 2009; Morelli et al., 2014; Perry et al., 2012).

Thus, positive empathy appears to foster both prosociality and personal well-being. That said, a number of key questions about this phenomenon remain unanswered. Recent theoretical models suggest that empathy involves experience sharing (i.e., vicariously sharing targets' internal states), mentalizing (i.e., explicitly considering and potentially understanding others' emotional states), and motivation to help others (Davis, 1994; Singer and Klimecki, 2014; Zaki, 2014; Zaki and Ochsner, 2012). However, the psychological structure of this first process –

* Corresponding authors at: Department of Psychology, Stanford University, 450 Serra Mall, Jordan Hall (Bldg. 420), Stanford, CA 94305, USA.
E-mail addresses: smorelli@stanford.edu (S.A. Morelli), jzaki@stanford.edu (J. Zaki).

vicarious positive affect – remains at least partially unclear. In particular, to what extent does vicarious enjoyment share affective mechanisms with "personal" reward (i.e., positive events that occur to the self)? Neuroscientific data provide a powerful lens through which to examine this question. In particular, scientists have robustly characterized the brain systems underlying positive affect, and reward processing in particular (Knutson et al., 2005; Liu et al., 2011). This literature suggests ways in which personal and vicarious reward might both overlap and dissociate.

On the one hand, the experience of valuable outcomes reliably engages neural structures such as ventromedial prefrontal cortex (VMPFC) and nucleus accumbens (NAcc). These responses, especially in VMPFC, (i) track the subjective value that individuals associate with outcomes (Bartra et al., 2013), (ii) occur irrespective of the particular qualities of rewarding stimuli (Chib et al., 2009; D.J. Levy and Glimcher, 2011), and (iii) occur even when rewards are not the result of specific actions (I. Levy et al., 2011; Wunderlich et al., 2010). As such, these regions might be expected to respond even to rewarding events that occur to others. Indeed, several studies have identified brain activity in NAcc and VMPFC that track a number of classes of "social rewards" (Fehr and Camerer, 2007; Sanfey, 2007). These include positive evaluation by or consensus with others (Izuma et al., 2008, 2010; Klucharev et al., 2009; Zaki et al., 2011), acting prosocially (Dawes et al., 2012; de Quervain et al., 2004; Moll et al., 2006; Zaki and Mitchell, 2011), observing behaviors that conform to social norms such as equity and reciprocity (Rilling et al., 2002; Tricomi et al., 2010 and – crucially – observing others receiving rewarding outcomes (Hare et al., 2010a; Mobbs et al., 2009; Morelli et al., 2014; Zaki et al., 2014). As such, one might expect vicarious and personal reward to resemble each other in these key structures.

By contrast, other brain structures are strong candidates for dissociation between these reward types. Two such examples bear emphasis. First, dorsal striatum often responds to rewarding events, but in a manner specific to decision-making and action planning (Rangel and Hare, 2010; Rushworth et al., 2011). Second, vicarious sharing of others' rewards often requires *understanding* the extent to which others value a particular outcome, especially when observers and social targets' preferences diverge. For instance, an ice cream-loving observer can simply savor frozen desserts themselves, but might need to engage in *mentalizing* – or inferences about others' mental states. Mentalizing produces activity in a system of brain regions, including dorsomedial prefrontal cortex (DMPFC), temporoparietal junction (TPJ), posterior superior temporal sulcus (pSTS), and posterior cingulate cortex (PCC), involved more broadly in projecting one's self outside of the present moment and location (Buckner and Carroll, 2007; Lieberman, 2010; Mitchell, 2009; Spreng et al., 2009; Zaki and Ochsner, 2012). To the extent that vicarious, but not personal, reward involves mentalizing, these regions might be engaged preferentially by vicarious reward.

Over the last 10 years, the neuroscientific study of vicarious reward has experienced considerable growth, and in many cases supported the foregoing predictions. Here, we take a step towards more formally organizing this information through a quantitative, whole-brain, coordinate-based meta-analysis. Specifically, we employed an activation likelihood estimate (ALE) meta-analysis, surveying 25 functional magnetic resonance imaging (fMRI) studies that included contrasts between vicarious reward and a neutral control condition. We then quantitatively compared the results of this analysis (i.e., patterns of brain activity consistently associated with vicarious reward) to the results of a recent meta-analysis of personal reward (Bartra et al., 2013). This allowed us to isolate brain regions that were common to both vicarious and personal reward, as well as regions preferentially engaged by each type of reward.

Materials and methods

We conducted two coordinate-based meta-analyses of task-based fMRI studies of vicarious and personal reward in order to understand the spatial signature of activation foci for these two sets of studies. We

also assessed the overlap and dissociation between vicarious and personal reward using conjunction and contrast analyses.

Study selection for vicarious reward

We initially identified candidate studies by searching Google Scholar for combinations of key words including: "vicarious," "reward," "fMRI," and "empathy." We identified additional studies by examining papers that cited a seminal paper on vicarious reward (Mobbs et al., 2009). We further extended this corpus of studies to identify other studies that examined vicarious reward, but framed it as another phenomena (e.g., observational learning), and to include various types of vicarious rewards (e.g., monetary, social, sensory, emotional). Thus, follow-up searches included terms including "observational learning," "donation," "win," "gain," "money," "reputation," "social reward," "touch," "taste," "smell," "happiness," "joy," and "positive" combined with the original search terms.

We selected a final set of studies for inclusion in our analysis using a number of criteria. We required that all studies employ fMRI to measure BOLD signal in healthy human adults. Further, studies qualified only if participants directly observed, imagined, or saw a cue indicating that another person received a reward *outcome*. Therefore, we excluded studies that focused on the *anticipation* of vicarious reward or simply depicted targets experiencing positive emotion (e.g., smiling faces). We also excluded any studies in which participants competed with, disliked, or envied the target receiving rewards (e.g., Cikara and Fiske (2011); Dohmen et al. (2011); Dvash et al. (2010); Fareri and Delgado (2014)). We also did not include studies in which the participant and target shared rewarding outcomes (e.g., Fareri et al. (2012)) so as not to confound personal and vicarious reward.

We also required that studies include whole-brain analysis comparing a vicarious reward condition to a neutral condition (e.g., no reward) or baseline (e.g., fixation), with the exception of one study that did not have a baseline condition (i.e., Kätsyri et al. (2013)). Therefore, all region of interest (ROI) analyses were excluded. All included studies utilized a binary contrast (rather than a parametric or correlational analysis) statistically thresholded by the authors of the original papers. These studies included the observation of social targets experiencing a variety of reward types, including pleasant touch, tastes, and smells; monetary payoffs; positive social feedback (e.g., praise); and positive emotional events (e.g., getting engaged). Social distance between the participant and target varied across studies, ranging from strangers (Morelli et al., 2014) to friends and ingroup members (e.g., Braams et al. (2013); Molenberghs et al. (2014); Varnum et al. (2014)) to family (e.g., Telzer et al. (2013); Telzer et al. (2010)).

Because many studies did not report coordinates from whole-brain contrasts of vicarious reward compared to control conditions in published tables, we obtained several contrasts from personal correspondence with study authors. However, not all authors could supply their whole-brain coordinates (e.g., Albrecht et al. (2010, 2013); Canessa et al. (2009, 2011); Cooper et al. (2012); Harbaugh et al. (2007); Kawamichi et al. (2013); Mitchell et al. (2011); Mobbs et al. (2009); Moll et al. (2006); Suzuki et al. (2012)). For all included publications, we selected the most relevant contrast from the study. However, one publication included two separate studies (Morrison, Björnsdotter, & Olausson, 2011), so we selected one contrast from each study. Thus, the final set of 24 publications included a total of 25 studies, 25 analysis contrasts, 575 participants, and 358 activation foci. See Appendix A for a full list of included studies, task descriptions, reward stimuli, and contrasts.

Study selection for personal reward

Drawing from a recent meta-analysis on subjective value (Bartra et al., 2013), we selected studies that closely paralleled the criteria