OXFORD

Social Cognitive and Affective Neuroscience, 2018, 14–21

doi: 10.1093/scan/nsx132
Advance Access Publication Date: 6 November 2017
Original article

The functional role of ventral anterior cingulate cortex in social evaluation: disentangling valence from subjectively rewarding opportunities

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Abstract

Despite robust associations between the ventral anterior cingulate cortex (vACC) and social evaluation, the role of vACC in social evaluation remains poorly understood. Two hypotheses have emerged from existing research: detection of positive valence and detection of opportunities for subjective reward. It has been difficult to understand whether one or both hypotheses are supported because previous research conflated positive valence with subjective reward. Therefore, the current functional magnetic resonance imaging study drew on a social evaluation paradigm that disentangled positive valence and subjective reward. Participants evaluated in-group and out-group politicians in a social evaluation paradigm that crossed trait valence with opportunity for subjectively rewarding affirmation (i.e. a chance to affirm positive traits about in-group politicians and affirm negative traits about out-group politicians). Participants rated in-group politicians more positively and out-group politicians more negatively. One subregion of vACC was modulated by positive valence and another relatively posterior region of vACC was modulated by opportunity for subjective reward (i.e. a politician × valence interaction). The current findings demonstrate the importance of incorporating vACC function into models of social cognition and provide new avenues for sharpening our understanding of the psychological significance of vACC function in social evaluation and related domains such as reward and affect.

Key words: vACC; motivation; valence

Introduction

The ventral Anterior Cingulate Cortex (vACC) has been robustly implicated in reward processing in social evaluation, but its precise role remains poorly understood. Two hypotheses have emerged from existing research. The vACC has been hypothesized to support the detection of positive valence in social evaluation and also hypothesized to detect subjectively rewarding opportunities such as affirming desired attributes about the self or well-liked others (Moran *et al.*, 2006; Flagan and Beer, 2013; Kuzmanovic *et al.*, 2016). It has been difficult to draw strong conclusions about these two hypotheses because the existing experiments tend to conflate subjective reward with positive valence. Therefore, it is possible that vACC activation in the domain of social evaluation is modulated by positive valence, the detection of opportunities to affirm subjectively desired attributes (i.e. subjective reward) or both. This study aims to understand the role of the vACC in social evaluation by disentangling positive valence from the detection of opportunities to affirm subjectively desired attributes.

In the domain of social evaluation, the role of vACC has typically been studied in paradigms that require participants to rate the extent to which attributes are descriptive of themselves or

Received: 1 June 2017; **Revised:** 16 October 2017; **Accepted:** 28 October 2017

other people. In these experiments, participants are not asked to rate whether an attribute is positive or negative, yet comparisons between positive *vs* negative stimuli are associated with increased vACC activation (e.g. Moran *et al.*, 2006; Sharot *et al.*, 2007; Beer and Hughes, 2010; Hughes and Beer, 2012). Therefore, it may be that vACC detects positive valence even when valence detection is not the explicit focus of the social evaluation.

However, additional findings raise the possibility that vACC plays a role in subjective reward in social evaluation, that is, detecting a chance to affirm desired attributes to a social target. Decades of research have shown that people are motivated to affirm positive attributes and outcomes for themselves and well-liked others (Alicke, 1985; Brown, 1986; Taylor and Brown, 1988; Kunda, 1990; Robins and John, 1997; Murray, 1999). The opportunity to affirm desired attributes about social targets is one component of subjective reward; the opportunity to deny undesired attributes is also subjectively rewarding. Although both are subjectively rewarding, opportunities to affirm desired attributes are psychologically processed in a distinct manner from opportunities to deny undesired attributes (e.g. Ditto and Lopez, 1992; Ditto *et al.*, 1998; Alicke and Sedikides, 2009). The existing research on social evaluation suggests that it is the detection of opportunities to affirm traits in a desired manner that may modulate vACC activation. For example, vACC activation is associated with detecting the positive valence of attributes to the extent that they are affirmed as descriptive of the self (Moran *et al.*, 2006; Sharot *et al.*, 2007) or affirmed about well-liked others (e.g. Hughes and Beer, 2012). Furthermore, vACC differentiation between positive and negative valence of future life events is associated with individual differences in trait optimism (i.e. individuals who are motivated to affirm positive future life events as descriptive of their own lives, Sharot *et al.*, 2007) and with individual differences in the subjective use of base rates to affirm the likelihood of positive life outcomes (i.e. incorporate base rates into estimations to the extent that base rates reflect positively on the self's outcomes, Kuzmanovic *et al.*, 2016). Therefore, it is possible that vACC detects opportunities where people can affirm desired attributes about social evaluation targets instead of or in addition to detecting positive valence. While the hypothesis that vACC may play a role in detecting opportunities for desired affirmation has been posited (rather than successful affirmation itself, e.g. Flagan and Beer, 2013), it has yet to be empirically tested.

The broader literature on vACC function lends support to both the valence and subjective reward hypotheses. For example, vACC has been associated with detecting the positive valence of stimuli in studies of emotion regulation, financial reward and social reward (e.g. Mobbs *et al.*, 2009; Smith *et al.*, 2010; Vrticka *et al.*, 2011; Winecoff *et al.*, 2013). Additionally, vACC has been associated with subjective reward in financial decision-making (e.g. Fitzgerald *et al.*, 2009; Park *et al.*, 2011; see Levy and Glimcher, 2012 for a review). For example, vACC activation is modulated by individual differences in perceptions of whether choice options have the opportunity to be rewarding (Fitzgerald *et al.*, 2009). VACC also plays a role in modulating subjective perceptions of the potential for reward in other domains as well. For example, a hippocampal–prefrontal circuit (which includes the vACC) has been implicated in the extinction of conditioned fear associations (e.g. Quirk and Beer, 2006; Ahs *et al.*, 2015). Therefore, the broader literature on vACC function does not tip the scales toward one hypothesis over another in the social evaluation domain; it is consistent with both detecting valence and detecting opportunities for subjective reward.

How can the two hypotheses regarding vACC function in social evaluation be reconciled? It has been difficult to tease apart the relative role of vACC in valence detection and detection of subjective reward because previous research on social evaluation tends to conflate these two variables. Specifically, social evaluation research tends to involve paradigms in which the conditions that participants find affirmation to be subjectively rewarding also happen to be positive in valence (i.e. affirming positive traits or positive future outcomes about themselves or well-liked others: Moran *et al.*, 2006; Sharot *et al.*, 2007; Hughes and Beer, 2012). Therefore, a deeper understanding of the role of vACC in social evaluation requires an evaluation paradigm in which positive valence is disentangled from subjectively rewarding opportunities to affirm attributes.

Previous research suggests that the evaluation of political candidates provides a well-established avenue for disentangling positive valence and desired affirmation. National survey research, Bayesian modeling of voting patterns and empirical lab research consistently show that both Democrats and Republicans want to affirm positive attributes of politicians or political arguments that align with their political affiliation and want to affirm negative attributes of politicians or political arguments that do not align with their political affiliation (Bartels, 2002; Munro *et al.*, 2002; Pew Research Center, 2016; Brandt *et al.*, 2014; Duarte *et al.*, 2015). Previous research suggests that people may accomplish partisan evaluations of political candidates and issues by drawing on their emotional reactions (Munro *et al.*, 2002) and/or selectively exposing themselves to information that fits with their desired views (Galdi *et al.*, 2008; Taber *et al.*, 2009; Galdi *et al.*, 2012; Crawford *et al.*, 2013; Tappin *et al.*, 2017). Taken together, previous research and national survey data suggest that people find it subjectively rewarding to affirm good things about in-group politicians and affirm negative things about out-group politicians. Therefore, a paradigm in which participants are asked to evaluate political candidates provides an opportunity to test whether vACC is modulated by the detection of positive valence, the detection of an opportunity to affirm positive attributes about in-group members and affirm negative qualities about out-group members or both.

This study investigated whether vACC activation is modulated by positive valence, detection of opportunities to affirm subjectively desired attributes or both in the domain of social evaluation. Valence was disentangled from subjectively rewarding affirmation by asking participants to evaluate the descriptiveness of positive and negative personality traits for in-group and out-group members. Specifically, participants in the USA were pre-screened for Democratic political party affiliation and asked to make trait attributions for Democratic politicians and Republican politicians. The American Trends Panel (a survey conducted by the Pew Research Center, 2016) finds that people are motivated to affirm negative attributes about the opposing political party yet affirm positive attributes to their own political party. If a subregion of vACC is modulated by positive valence, then activation in that subregion should increase when participants evaluate positive traits compared to negative traits regardless of political party (i.e. a comparison of trait valence when politician condition is held constant). If a subregion of vACC is modulated by opportunities for desired affirmation in social evaluation, then activation in that subregion should increase when participants have the opportunity to affirm positive traits for Democratic politicians and affirm negative traits for Republican politicians compared to opportunities to rate negative traits for Democratic politicians and positive traits for Republican politicians (i.e. a crossover interaction between

valence of trait word and politician condition). A third possibility is that different subregions within the vACC will show modulation by valence and opportunities for desired affirmation. That is, the paradigms in previous studies may have elicited both the detection of positive valence and opportunities for desired affirmation making it difficult to know if the reported activation may have reflected different subregions within vACC elicited by each. In contrast to previous research which conflated positive valence with opportunities to affirm desired traits, this study's factorial design makes it possible to test for the effect of each variable within the vACC.

Materials and methods

Participants

Analysis was conducted for 36 participants (26 females, $M_{age} = 22.06$ years, s.d. = 3.46; 4 additional participants were excluded due to head motion >3 mm). Participants were prescreened for Democratic political party affiliation, right-handedness and to eliminate history of psychological or neurological issues. Participants received monetary compensation for their time ($15/h). All participants gave informed consent in compliance with the human subject regulations of The University of Texas at Austin.

Procedure

Participants evaluated the personality traits of well-known politicians. In each trial, participants saw a picture of a politician, the politician's political party affiliation and a prompt to rate how much each politician possessed a trait (Figure 1A). Participants used a four-point scale (1 = Not at all; 2 = A little; 3 = Somewhat; 4 = Very) to rate all six politicians (three per political party: Republican and Democratic) on each of 60 trait words (30 per valence: positive and negative). Trait words were taken from a list of words standardized for valence (Anderson, 1968). Politicians were matched for age and gender across party to control for visual and social features of the stimuli. Democratic politicians consisted of Barack Obama, Bernie Sanders and Wendy Davis. Republican politicians consisted of Donald Trump, Ted Cruz and Sarah Palin. In a pilot test of this evaluation procedure, Democratic and Republican participants reported significantly different evaluations of each of these politicians in all trait categories (see Supplementary Material).

Functional magnetic resonance imaging (fMRI) data were collected while participants performed five functional runs that each included 18 blocks (12 experimental blocks, 6 baseline blocks). Each experimental block consisted of six 3 s trials (18 s) and focused on one politician and one word valence (e.g. block 1 might be positive traits paired with Barack Obama; block 2 might be negative traits paired with Ted Cruz, etc.) with every combination of valence and politician being represented within a given run (Figure 1B; Desired Affirmation: Democrat-Positive, Republican-Negative; Undesired Affirmation: Democrat-Negative, Republican-Positive). Blocks were presented randomly across participants with the caveat that blocks from the same condition were never consecutively presented. Each baseline block (18 s) consisted of a fixation cross. Experimental blocks were also followed by a 9 s inter-block interval which depicted a fixation cross to ensure that participants finished thinking about the previous block and cleared their minds before beginning a new block.

Prior to entering the scanner, participants completed 10 practice trials that were identical to the scanner task with the exception that they were asked to rate different politicians. The practice trials ensured that participants understood how to complete the task before beginning the experiment. After exiting the scanner, participants answered four questions about their political values. Specifically, participants used a seven-point scale (1 = Not at all; 4 = Somewhat; 7 = Very) to rate the extent to which they see themselves as liberal, conservative and politically engaged. They also rated the likelihood (0–100%) that they would vote in the upcoming 2016 US national election.

MRI data acquisition

All images were collected on a 3T Siemens Skyra scanner at The University of Texas at Austin Imaging Research Center. Functional images were acquired with an EPI sequence with a multi-band factor of 2 [time repetition (TR) = 1500 ms, time echo (TE) = 30 ms, field of view (FOV) = 230 mm, voxel size = 3 mm × 3 mm × 3 mm, flip angle = 71°] with each volume consisting of 50 axial slices. Higher-order shimming was used to reduce susceptibility to artifacts. A high-resolution full-brain image using a magnetization prepared rapid gradient echo pulse sequence (TR = 1900 ms,

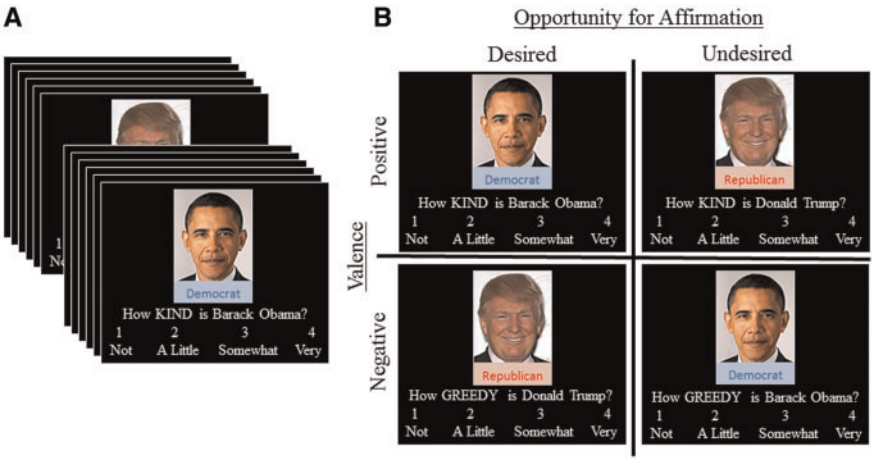

Fig. 1. Social evaluation task. (A) Participants (prescreened for political party affiliation) evaluated the positive and negative traits for three politicians from each of their in-group political party and out-group political party. Social evaluations were made in blocks that consisted of the same politician paired with six positive or six negative traits. (B) The social evaluation task crossed Valence (positive, negative) with Opportunity for Affirmation (desired, undesired).

inversion time (TI) = 900 ms, TE = 2.43 ms, flip angle = 9°, FOV = 256 mm) was acquired for image registration.

Behavioral analysis

Participants' ratings were analyzed in a 2 (Valence: Positive and Negative) by 2 (Politician: Democrat and Republican) within-subjects analysis of variance (ANOVA) to test whether participants showed behavioral evidence that they were more likely to affirm the positive traits of Democrats (i.e. their in-group political party) and more likely to affirm the negative traits of Republicans (i.e. the opposing political party).

Pre-processing and analysis

Pre-processing and statistical analyses were conducted using the FSL software toolbox [Oxford Center for Functional Magnetic Resonance Imaging (FMRIB); Smith *et al.*, 2004]. Functional image volumes were motion corrected using MCFLIRT (Jenkinson *et al.*, 2002) and non-brain structures were stripped from functional and structural volumes using the Brain Extraction Tool (Smith, 2002). Functional and structural data were coregistered and normalized into MNI-152 standard anatomical space (2 mm isotropic voxels) based on a T1 template (Montreal Neurological Institute). Images were smoothed with 8 mm FWHM Gaussian kernel. A high-pass filter with a cutoff period of 90 s was applied to remove within-session drifts and a fieldmap was used to correct EPI data to reduce spatial distortions.

A fixed-effects analysis modeled (i) Positive Valence and Democrat Politician, Positive Valence and Republican Politician, Negative Valence and Democrat Politician, Negative Valence and Republican Politician blocks using a canonical block hemodynamic response function and (ii) the inter-block intervals as a regressor of no interest. Contrasts from each run of each participant were used in a second-level analysis treating runs as a fixed effect. FEAT's FLAME module (FMRIB's Local Analysis of Mixed Effects; Smith *et al.*, 2004) was used to conduct a third-level analysis treating participants as a random effect. The group average maps were small volume corrected with a bilateral region of interest (ROI) in the posterior portion of the vACC (see Figure 3A, voxel corrected at $P < 0.05$; ROI includes 870 voxels, reported k values range from 21 to 105). More specifically, the ROI was derived from activation patterns reported in previous research on the role of vACC in social evaluation of personal characteristics [Beer and Hughes, 2010 (peak 14, 38, −4); Hughes and Beer, 2012 (peak 12, 40, −6); Moran *et al.*, 2006 (peak 9, 23, −9); Sharot *et al.*, 2007 (peak −11, 42, −1); Kuzmanovic *et al.*, 2016 (peak 0, 34, −14)]. The previous studies suggested that social evaluation tends to be associated with the subgenual region of the anterior cingulate cortex and may extend down into the posterior orbitofrontal cortex (see Figure 3A). A general linear model tested the main effects of Valence, Politician and the Valence × Politician interaction.

Exploratory analyses

Controlling for reaction time in Valence × Politician ANOVA of fMRI data. One of the ways in which the affirmation of desired attributes has differed from the denial of undesired attributes in previous behavioral research is that affirmation of desired attributes tends to require less cognitive effort (e.g. Ditto and Lopez, 1992; Ditto *et al.*, 1998). Therefore, in order to explore whether any significant activation in the planned Valence × Politician ANOVA was simply due to reaction time differences, we also conducted the ANOVA as described above but included trial reaction time as a parametric regressor.

Results

Pre-screening check: participants characterized themselves as sharing the values of the US Democratic political party

Self-reports from the day of the fMRI study were consistent with the earlier pre-screening for political party affiliation. Participants rated themselves as significantly more liberal than conservative in their political views [$t(35) = 14.74$, $P < 0.001$, $d = 2.46$], significantly more liberal than the centerpoint of the seven-point scale [$M = 5.97$, s.d. = 0.84; $t(35) = 14.01$, $P < 0.001$, $d = 2.35$] and significantly less conservative than the centerpoint of the seven-point scale [$M = 1.89$, s.d. = 1.06; $t(35) = -11.92$, $P < 0.001$, $d = -1.99$]. Additionally, participants rated themselves as significantly more politically engaged than the centerpoint of the seven-point scale [$M = 4.69$, s.d. = 1.17; $t(35) = 3.57$, $P = 0.001$, $d = 0.59$) and more likely to vote than chance levels in the upcoming election [$M = 92.19\%$, s.d. = 20.56%; $t(35) = 12.32$, $P < 0.001$, $d = 2.05$].

Participant ratings were consistent with a desire to affirm positive traits to in-group politicians and a desire to affirm negative traits to out-group politicians

As hypothesized, trait ratings were characterized by a significant interaction between valence and politician (see Figure 2). The significant main effects of politician [$F(1, 35) = 7.13$, $P = .011$] and valence [$F(1, 35) = 19.65$, $P < 0.001$] were qualified by a significant interaction between politician and valence [$F(1, 35) = 529.44$, $P < .001$]. Participants were significantly more likely to rate Democratic politicians as having positive traits than Republican politicians [Democrat: $M = 3.496$, s.d. = 0.284; Republican: $M = 1.596$, s.d. = 0.335, $t(35) = 21.37$, $P < 0.001$, $d = 3.568$]. Similarly they were significantly more likely to rate Republicans as having negative traits than Democratic politicians [Republican: $M = 3.292$, s.d. = 0.442; Democrat: $M = 1.282$, s.d. = 0.210, $t(35) = 23.39$, $P < 0.001$, $d = 4.080$].

Response times were characterized by a significant main effect of politician condition [$F(1, 35) = 17.80$, $P < .001$] that was qualified by a significant interaction between politician and valence [$F(1, 35) = 23.78$, $P < .001$]. Participants' response times

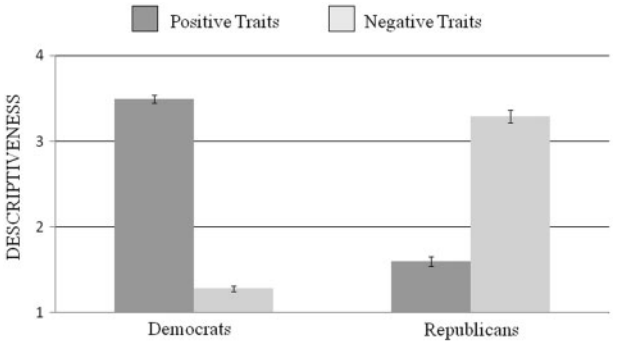

Fig. 2. Participants were significantly more likely to affirm positive personality traits as descriptive of Democratic politicians (in comparison to negative traits) and significantly more likely to affirm negative personality traits as descriptive of Republicans politicians (in comparison to positive traits).

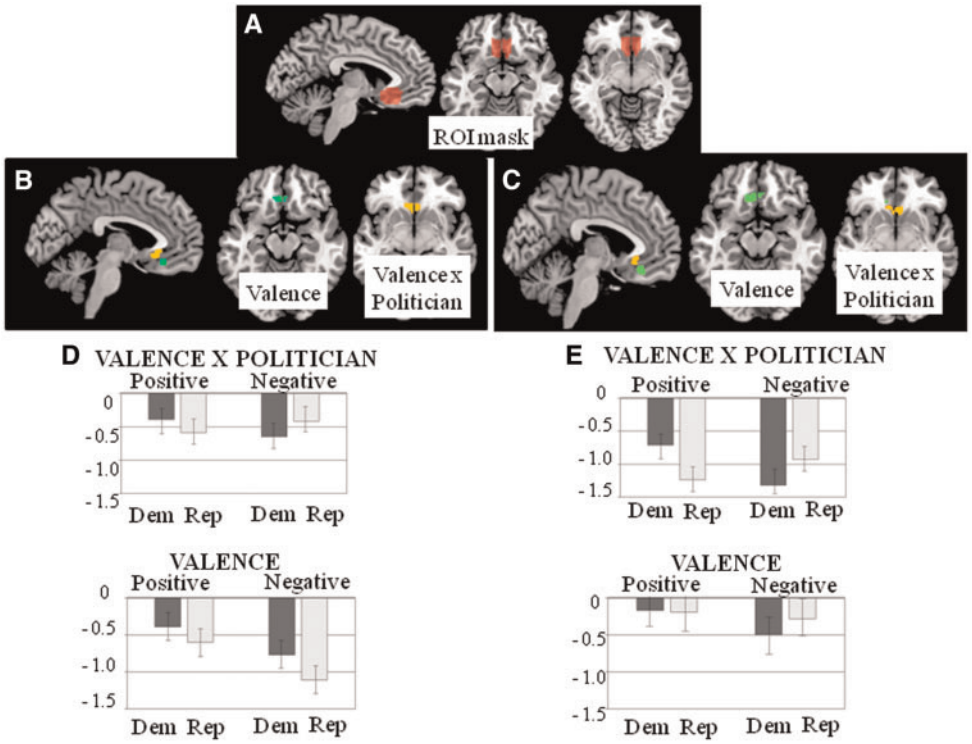

Fig. 3. Results from Valence × Politician ANOVA in vACC ROI. (A) vACC ROI based on previous research in social evaluation. (B + C) Main effects of Valence (green) and Politician × Valence interaction (orange) (B = without RT in model; C = with RT in model). (D + E) For each activation cluster, parameter estimates (*y*-axis) are plotted for all four block types (D = without RT in model; E = with RT in model).

were significantly different across all conditions with the exception that there were no significant difference between ratings of negative traits for Democratic politicians and negative traits for Republican politicians [$t(35) = -1.06$, $P = 0.29$, see Gaertner and McLaughlin, 1983, for similar results]. Participants responded most quickly when rating positive traits of Democratic politicians (Mean = 1224.01 ms, s.d. = 228.11 ms) compared to ratings of positive traits of Republican politicians [Mean = 1383.82 ms, s.d. = 221.33 ms; $t(35) = -8.36.71$, $P < 0.001$], negative traits of Democratic politicians [Mean = 1294.17 ms, s.d. = 235.45 ms, $t(35) = -4.18$, $P < 0.001$] and negative traits of Republican politicians [Mean = 1328.27 ms, s.d. = 189.08 ms; $t(35) = -3.44$, $P = 0.002$]. Ratings of positive traits of Republican politicians were significantly slower than negative trait ratings of Democratic politicians [$t(35) = 3.71$, $P = 0.001$] and negative traits of Republican politicians [$t(35) = 2.49$, $P = 0.018$].

Distinct subregions within the vACC ROI are modulated by positive valence and opportunity for desired affirmation

As hypothesized, the vACC ROI showed significant bilateral modulation in relation to the main effect of valence and an interaction between politician and valence (see Figure 3B and C, Table 1). One bilateral region of the vACC was modulated by Positive Valence and another more posterior bilateral region was modulated by the hypothesized Politician × Valence interaction. Furthermore, our exploratory analysis found that the pattern of activation was similar even when reaction time was considered in the model (see Table 1 and Figure 3). The activation clusters associated with Valence and the Politician × Valence interaction did not show any overlap regardless of whether reaction time was considered in the model or not.

Table 1. Activation within the vACC ROI associated with opportunity for affirmation and positive valence

Region of activation	Cluster size	*X*	*y*	*z*	*z stat*
Results without RT in the model					
Politician × Valence					
vACC	50	−4	26	−4	2.52
	34	2	24	−4	2.45
Positive > Negative					
vACC	77	−2	30	−14	2.86
	28	2	32	−14	2.47
Results with RT in the model					
Politician × Valence					
vACC	43	−6	26	−6	2.39
	36	2	22	−6	2.42
Positive > Negative					
vACC	65	−2	30	−14	2.67
	14	2	34	−14	2.32

Discussion

This study advances our understanding of the role of vACC in social evaluation by addressing a confound in earlier research that made it difficult to delineate whether vACC was modulated by the detection of positive valence, the detection of opportunities for subjective reward or both. The social evaluation task in this study made it possible to tease apart positive valence from subjective reward and found that vACC is associated with each of these two hypothesized functions in social evaluation. More specifically, positive valence modulated a subregion of vACC and a relatively more posterior and non-overlapping subregion of vACC was modulated by a specific component of subjective

reward, that is the opportunity to affirm desired traits about social targets (i.e. a chance to say positive things about in-group members and negative things about out-group members indicated by the interaction between the politician and valence conditions). The current findings suggest a revision to current neural models of social cognition and suggest new approaches for investigating the role of vACC in social evaluation and other domains.

The current findings underscore the importance of updating models of social cognition to include vACC function. Current neural models of social cognition have made strides by drawing from the very narrow set of processes that have been studied at the neural level about self and other people (e.g. self-representation and self-control; representation, theory of mind and cognitive control over thoughts about other people). These models tend to focus mostly on medial prefrontal cortex (i.e. BA 8/9/10), the dorsal anterior cingulate cortex, right temporoparietal junction and the amygdala (Beer and Ochsner, 2006; Ito and Bartholow, 2009; Heatherton, 2011; Flagan and Beer, 2013; Amodio, 2014). However, numerous studies have found that vACC is involved in social evaluation (Moran *et al.*, 2006; Sharot *et al.*, 2007; Beer and Hughes, 2010; Hughes and Beer, 2012) and this study suggests that it may play two roles: detection of valence and detection of opportunities for subjectively rewarding affirmation.

In fact, this study raises the possibility that at least some previous studies on social evaluation may have mistaken a different process for the opportunity to affirm subjectively rewarding associations. For example, one study used the Implicit Association Task (IAT) to examine neural correlates of prejudiced social cognition and interpreted the results by drawing on vACC's role in emotional control in other domains (Beer *et al.*, 2008). In this study, participants had to categorize faces (African American or Caucasian American) and pictures (Positive or Negative). In the IAT, categorization is made using two response options and each option consists of two category labels. The pairing of category labels changes across blocks to examine whether participants are slower when using certain pairings. In the previous study, increased vACC activation was found when participants had to label the category of the picture using response options that paired their in-group with negative valence and their out-group with positivity: Caucasian American, Negative (response option 1) *vs* African American, Positive (response option 2) (in contrast to the opposite race–valence pairings: Beer *et al.*, 2008). Participants tend to be aware that their performance on the IAT reveals difficulties in associating positivity with faces from racial groups other than their own and negativity with their in-group which could be construed as indicating racist attitudes (Hahn *et al.*, 2014). Therefore, as previously suggested (Beer *et al.*, 2008), one interpretation of the vACC activation is that it indicates participants' control efforts to overcome any difficulty in expressing the positive association with a different race face or negativity with their in-group. However, the findings from this study raise another possible interpretation of this previous finding: vACC may have been modulated by the opportunity to display one's lack of prejudice by affirming positive associations with out-group race faces as well as affirming negative associations with in-group race faces. Future research should examine vACC activation and associated functional connectivity in paradigms that cross emotional control and detection of opportunities for subjectively rewarding affirmation in social evaluation.

The current findings also provide a foundation to more precisely characterize the psychological significance of vACC function in social evaluation. In this study, the opportunity to affirm desired traits was distinct from related constructs such as expectancy, congruency and approach. More specifically, participants learned in the practice trials that they would be rating both positive and negative traits for Democratic and Republican politicians so the significant interaction in responses did not reflect differences in the extent to which the conditions were surprising or unexpected. It was also not the case that the conditions differed in terms of congruency. The behavioral results showed that participants were differentially inclined to affirm and disaffirm across conditions yet the affirming and disaffirming response options on the 1–4 scale were equally accessible to them in all conditions. Finally, the conditions were not likely to elicit differential motivations to approach or avoid as previous research suggests that people are not differentially likely to approach or avoid situations which afford the opportunity to disaffirm *vs* affirm traits about political candidates (Munro *et al.*, 2002; Pew Research Center, 2016).

This study suggests that a deeper understanding of the psychological function of vACC in social evaluation may benefit from the consideration of psychological frameworks that characterize the processes which underlie the affirmation of desired attributes for a social target (*vs* the denial of undesired attributes: Ditto and Lopez, 1992; Ditto *et al.*, 1998; Alicke and Sedikides, 2009). More specifically, researchers have suggested that the affirmation of desired attributes may involve less sensitivity to whether information is diagnostic and also less cognitive effort (e.g. Ditto and Lopez, 1992; Ditto *et al.*, 1998). An integration of the current findings, previous neuroimaging results and psychological frameworks suggest fruitful avenues for future research. Previous studies suggest that vACC is not a region that tends to be sensitive to generalized cognitive effort (e.g. Yarkoni *et al.*, 2009) and controlling for reaction time did not affect the general pattern of vACC activation in this study. Therefore, a more promising next step may be to address the relation between vACC activation and lowered sensitivity to the quality of information. For example, is vACC activation modulated by processes that permit individuals to overlook or ignore the relevance of the information they are using to make an evaluation? Similarly, future research might investigate meaningful individual differences that may influence the extent to which people are motivated to ignore the relevance of available information such as the degree to which they feel strongly about their political values.

Furthermore, the current findings also suggest new interpretations and approaches for research in the general domains of affect and reward processing. For example, the current results raise additional interpretations of the psychological implication of the abnormally high vACC metabolism associated with clinical depression (Mayberg *et al.*, 1999; Brody *et al.*, 2001; Greicius *et al.*, 2007). Most often, the relationship between abnormally high vACC metabolism and clinical depression is characterized in terms of dysfunctional emotion processing because of studies associating this vACC subregion with reward processing (Greicius *et al.*, 2007; Hamilton *et al.*, 2011). While depression is associated with dysfunctional negative emotion, it is also associated with the motivation to affirm negativity about oneself and the world (e.g. Nolen-Hoeksema, 1991; Gotlib *et al.*, 2004; Korn *et al.*, 2014). More specifically, depressed individuals prefer social interactions with others who are likely to affirm their negative self-views and show an increased interest in negative feedback about themselves (e.g. Swann *et al.*, 1992; Joiner *et al.*, 1997). In other domains, researchers have speculated that fMRI results linking psychological function to changes in the BOLD

signal may shed light on the psychological implications of metabolism changes (e.g. Gusnard and Raichle, 2001). Following this rationale, the relation between vACC modulation and detecting opportunities to affirm negative qualities about outgroup politicians in the current research raises the possibility that the higher vACC metabolism associated with clinical depression may reflect an overactive monitoring of opportunities for affirming negative qualities about the self and the world. Future research is needed to understand the relation between baseline vACC metabolism and psychological function.

The current research points to the need to dissociate valence from subjective reward to better understand the role of vACC in reward processing outside of the social evaluation domain. Most current research on the role of vACC in reward processing does not separate the valence of incentives from their subjective desirability (for a review, see Levy and Glimcher, 2012). Some studies have asked participants to choose the least negative of two outcomes yet the least negative outcome is still technically more positive in valence when compared to the more negative outcome (e.g. Fitzgerald *et al.*, 2009). Therefore, a deeper understanding of the role of vACC in more general reward processing will benefit from paradigms in which option valence is crossed with subjectively desired opportunities. Furthermore, the previous research on vACC function outside the social evaluation domain has not focused on understanding whether valence detection is associated with a distinct or overlapping vACC subregion associated with detecting opportunities for subjective reward. This study suggests that it is possible that these processes draw on distinct subregions and future research that crosses valence with subjectively desired opportunities will have the ability to test whether this distinction holds outside the social evaluation domain.

In conclusion, this study's findings suggest that vACC plays at least two roles in social evaluation: detection of positive valence and a component of subjective reward, that is detection of opportunities to affirm subjective perceptions of social targets. Both roles had been previously theorized but it was difficult to make strong conclusions because past paradigms conflated positive valence with subjective reward. The current findings point to the importance of updating neural models of social cognition to take into account the role of vACC and suggest new approaches to investigating the role of vACC in related domains such as affect and reward processing.

Funding

This research was supported by National Science Foundation (NSF)-BCS-1460947 to J.S.B.

Supplementary data

Supplementary data are available at *SCAN* online.

Conflict of interest. None declared.

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