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Common and distinct neural mechanisms of the fundamental dimensions of social cognition

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In the present study, we used a valence classification task to investigate the common and distinct neural basis of the two fundamental dimensions of social cognition (agency and communion) using functional magnetic resonance imaging (fMRI). The results showed that several brain areas associated with mentalizing, along with the inferior parietal gyrus in the mirror system, showed overlap in response to both agentic and communal words. These findings suggest that both content categories are related to the neural basis of social cognition; further, several areas in the default mode network (DMN) showed similar deactivations between agency and communion, reflecting task-induced deactivation (TID). In terms of distinct activations, the findings indicated greater deactivations for communal than agentic content in the ventral anterior cingulate (vACC) and medial orbitofrontal cortex (mOFC). Communion also showed greater activation in some visual areas compared to agentic content, including occipital gyrus, lingual gyrus, and fusiform gyrus. These activations may reflect greater allocation of attentional resources to visual areas when processing communal content, or inhibition of cognitive activity irrelevant to task performance. If so, this suggests greater attention and engagement with communion-related content. The present research thus suggests common and differential activations for agency- versus communion-related content.

Keywords: Fundamental dimensions; Social cognition; Communion; Agency; Mentalizing.

In order to adapt to the social world, individuals need to attend to, make inferences, and store information about their own and other people's traits, motives, values, and goals (Van Overwalle, 2009). Although numerous inferences can occur, researchers in social cognition have shown that many of the inferences we make about others and also ourselves abide by two general categories of content or fundamental dimensions of social cognition (e.g., Bakan, 1966; Chance, 1988; Hogan, 1983; Wiggins, 1991; Ybarra et al., 2008). The fundamental dimensions go by different labels, such as agency, competence, or ability versus

communion, warmth, and morality (e.g., Abele & Wojciszke, 2007; Fiske, Cuddy, & Glick, 2007). Here, we use agency and communion, although we are not married to a particular set of labels.

The fundamental dimensions appear central to organizing how people think about their social worlds. Further, their presence in diverse research findings also makes sense because their content reflects two recurring challenges in people's lives, not only building social connections and gaining and maintaining social acceptance (communion), but also striving for personal goals, status, and developing competencies

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(agency) (Hogan, 1983; Humphrey, 1976; Wilson, 2012; Ybarra et al., 2008). Hence, the fundamental dimensions have the potential to inform researches on social neuroscience by highlighting the role of content.

Despite this potential, most of the available research documenting the role of the fundamental dimensions in social cognition has focused on behavioral outcomes. Only a modicum of neuroscientific studies has considered social cognitive content (e.g., Mende-Siedlecki, Baron, & Todorov, 2013; Swencionis & Fiske, 2014). A focus on content matters because content has been shown to affect information processing and likely underlying neural activations, but content is confounded many times with the tasks participants are asked to perform. For example, an important demarcation in social cognition is that between self and other (e.g., Ng, Han, Mao, & Lai, 2010; Zhu & Zhang, 2002). Research on the fundamental dimensions indicates a tendency at times for perceivers to focus on communion when judging others but on agency when thinking about the self (Abele & Wojciszke, 2007). So, to really assess the effect of content, it is important to dissociate content from perspective (self vs. other). In the present research, we dealt with this issue by keeping the task constant (classify the favorability of trait words) while varying the content (agency vs. communion) of the trait words.

Processing words with the goal of categorizing their favorability is likely to activate specific neural areas. Several imaging studies have found that the ventral anterior cingulate cortex (vACC), orbitofrontal regions, and amygdale are activated when distinguishing positive from negative words (Fossati et al., 2003; Hughes & Beer, 2012; Straube, Sauer, & Miltner, 2011). Thus, due to the nature of the task and stimuli that vary in valence (although of equivalence within dimension), we expected activations in these areas.

Although communion is related to being accepted and forming social connections, whereas agency is related more to status, achievement, and gaining distinction, at a more general level, both dimensions tell us that an actor has decided on an action to undertake and a social goal to pursue (to try to get along or try to get ahead). Such inferences that an actor is directing their behavior or pursuing a goal is likely to implicate various neural processes involved in mentalizing.

The neural structures consistently involved in mentalizing—inferring others' intentions, goals, preferences, and characteristics—make up a critical network that underlies social cognition (Van Overwalle & Baetens, 2009). Social cognitive tasks that involve mentalizing typically involve the medial

prefrontal cortex (mPFC), temporal-parietal junction (TPJ), posterior cingulate cortex (PCC)/precuneus, and medial orbital frontal cortex (mOFC; Eddy, Beck, Mitchell, Praamstra, & Pall, 2013; Howard-Snyder, 2005). For example, growing evidence indicates that drawing inferences about others' traits and characteristics is mediated by the mPFC (Mitchell, Cloutier, Banaji, & Macrae, 2006). PCC and its neighbor, precuneus, are responsible for integrating various informational inputs from other brain regions, for example, memory input from the hippocampus, and then using this information to infer the mental states of others (Mar, 2011). The mOFC has been shown to play an important role in a diversity of learning tasks that involve rewards related to understanding personal interactions in social domains (Elliott, Friston, & Dolan, 2000; Nestor et al., 2013). The TPJ is engaged in encoding temporary states, especially the current thoughts or beliefs of others, not the appearance or personality implications of social information (Sax & Powell, 2006; Van Overwalle, 2009). In addition to the structures described above, a recent meta-analysis indicated that the cerebellum is consistently engaged in tasks that involve some aspects of mentalizing versus no mentalizing (Van Overwalle, Baetens, Mariën, & Vandekerckhove, 2014). Thus, we expected that when presented with trait information to process, participants would consistently show activations in these brain regions regardless of the dimension (agency or communion) the stimuli were related to.

In terms of potential differences, the fundamental dimensions have been shown to impact information processing. Many studies have found that communion-related information is weighted more than agency-related information in judging others. When asked what information they would want to know about an unknown other, individuals were more likely to initially request communal than agentic information (Wojciszke, Bazinska, & Jaworski, 1998). Communion-related traits are also perceived to be more stable over time; thus, perceivers may use them more consistently to describe and think about others (Kenworthy & Tausch, 2008). There is also greater agreement in people's judgments of others' communion-related than agency-related attributes (Ybarra et al., 2008). Further, in terms of basic metrics such as speed of processing, research indicates that communal information is processed more rapidly than agentic information (Abele & Bruckmüller, 2011; Ybarra, Chan, & Park, 2001).

Although little research has directly examined the differences in the neural correlates involved in

processing communal and agentic information (for recent exceptions, see Mende-Siedlecki et al., 2013; Swencionis & Fiske, 2014), there are studies involving content related to communion and agency that can be used to suggest areas of interest. In terms of communion-related content, research has shown that the putamen and globus pallidum are related to affiliation motivation (Quirin et al., 2013). In addition, several fMRI studies dealing with morality, which can be considered a specific component of communion, have shown activations in the ventromedial prefrontal cortex (vmPFC; Shenhav & Greene, 2010; Young & Dungan, 2012) and some temporal regions, including the TPJ (Young & Saxe, 2009) and the superior temporal sulcus (STS; Eslinger, Moll, & Oliveira-Souza, 2002; Harenski & Hamann, 2006). The insular cortex is also implicated in studies of morality, in particular processing information related to rule and regulation violations (Fumagalli & Priori, 2012; Huebner, Dwyer, & Hauser, 2009). Further, other research has shown that the insular cortex plays an important role in processing social warmth information (Inagaki & Eisenberger, 2013), which is also related to the communal dimension (e.g., Wojciszke, Baryla, Parzuchowski, Szymkow, & Abele, 2011).

Agentic goals can usually be represented as power, achievement, and self-mastery (Reisz, Boudreaux, & Ozer, 2013). There are few studies examining tasks that involve agency-related content, but researchers have suggested that the mPFC plays a vital role in behavior related to achievement goals (Matsumoto & Tanaka, 2004). In addition, an fMRI study using anger and surprise faces as stimuli in the study of power motivation showed that participants with high power had stronger activations in the lateral OFC, dorsal striatum, and insula when watching these faces (Schultheiss et al., 2008). Another study on power revealed mPFC activations while participants were watching movie clips related to power, such as scenes depicting a dominant boss talking to his subordinate in the “The Godfather” (Quirin et al., 2013).

In conclusion, although there is little research focusing on the differences in the neuromechanisms associated with communal and agentic information, available studies suggest some potential differences, for example, TPJ, OFC, and putamen. But we advance this proposal cautiously, given that few comparisons exist in terms of the content dimensions and the studied tasks. Further, the content that has been part of the studied tasks has not been selected to specifically target the communal and agentic aspects of social cognition.

As little research has directly examined the neural correlates of agency and communion, the purpose of the present research was to use a valence classification task and fMRI to demonstrate both the common as well as distinct brain bases of the two content domains. We hypothesized that both the communal and agentic words would predict activity in areas related to mentalizing. However, we also expected distinct activations as a function of content dimension given previous social cognition research on processing differences and neuroscientific research suggesting potential differences involving the frontal cortex, temporal cortex, and subcortical structures. In addition, categorizing the stimulus words—due to their emotional content—may evoke activations in vACC, orbitofrontal regions, and amygdale. To make sure that such emotion-related processing did not influence the processing of communal and agentic contents, we also examined the interaction between contents and valence.

MATERIALS AND METHODS

Participants

Forty-two Chinese university undergraduates (mean age 21.05 years, age range 18–25 years; 22 females) were recruited to participate in a study on trait word recognition. All participants were right-handed, native speakers, had normal or corrected to normal vision, and had no psychiatric history. Due to large head motions (>3 mm and/or >3°) or high error rates in judging the stimuli (>25%), two subjects' fMRI data were excluded for the first run, one for the second run, and four for the third run. All subjects received ¥60 (about \$9.8) for participation and gave written, informed consent in accordance with procedures and protocols approved by the Review Board of the SWU MRI Center for Brain Research.

Materials

The stimuli consisted of a total of 160 trait words that depicted personality characteristics, 80 for each category (communal words and agentic words). The stimulus words were selected from established personality trait adjective pools (Huang & Zhang, 1992; Wang & Cui, 2005; Wang, Zhou, & Lou, 2008). In a pilot study, 49 participants rated the stimulus words with regard to how representative they were of the agentic and communal dimensions based on given definitions (the scale ranged from $-3 =$ a great amount

of communion (agency) but negative, to 0 = little to no communion (agency), and to 3 = a great amount of communion (agency) but positive; Abele & Bruckmüller, 2011). Higher scores represent a higher degree of agency or communion for each word. To isolate the effects of stimulus valence, we also asked participants to separately rate the favorability of each word using 7-point scales as well as their familiarity, -3 = very negative (very unfamiliar), 0 = neither positive nor negative (neither unfamiliar nor familiar), 3 = very positive (very familiar).

The results indicated that the agentic words were rated as higher in agentic content ($M = 2.20$, $SD = .37$) than communal words ($M = 1.68$, $SD = .31$), $t(158) = 9.76$, $p < .001$; Communal words were rated as higher in communal content ($M = 2.18$, $SD = .27$) than agentic words ($M = 1.75$, $SD = .27$), $t(158) = 9.29$, $p < .001$. Agentic words (positive: $M = 2.46$, $SD = .21$, negative: $M = -1.90$, $SD = .37$) and communal words (positive: $M = 2.49$, $SD = .22$, negative: $M = -2.04$, $SD = .32$) were rated on a separate scale as equally favorable, both $t_s < 1.88$, $p_s > .5$. In addition, the number of written strokes, frequency rank (Research Group, 2008), and familiarity were balanced between communion (strokes: $M = 17.54$, $SD = .32$, frequency rank: $M = 12894.81$, $SD = 8212.95$, familiarity: $M = 2.50$, $SD = .27$) and agency (strokes: $M = 18.54$, $SD = 4.96$, frequency rank: $M = 13279.78$, $SD = 8364.18$, familiarity: $M = 2.47$, $SD = .24$), $t_s(158) < 1.22$; $p_s > .05$ (Han, Ybarra, & Bi, 2015).

Procedure

We used a block design in the current study. There were three different kinds of blocks depending on the stimuli: the valence classification task for agentic words (agentic condition), the valence classification task for communal words (communal condition), and a fixation task as the baseline task (Kuo et al., 2004).

Upon arrival at the lab, the experimenter asked participants to practice to confirm their understanding of the instructions and materials. For this, they completed a valence classification task (words used were different from the ones used in the final experiment) and a fixation task. After participants were familiarized with the experimental procedure, they were taken to the fMRI scanner to complete the experimental tasks in the scanner. A total of 19 blocks (five valence classification blocks each for agentic words and communal words, and nine fixation blocks) were distributed into three runs pseudo-randomly. Each participant completed all of the three runs in the experiment. Functional images

were collected during the intervals corresponding to the second and third runs.

After performing the tasks, participants completed the Chinese version of the Positive Affect and Negative Affect Scale (PANAS; Huang, Yang, & Ji, 2003), and they provided information on their age, gender, and handedness before they were thanked and debriefed.

Behavioral tasks

During the scanning, each participant needed to complete two kinds of tasks: the valence classification task and the fixation task. In the valence classification task, participants were asked to decide as quickly as possible whether the word that appeared on the screen was positive or negative by pressing one of two keys on the keyboard. The mapping of keys corresponded to response type and was counterbalanced across participants. At the beginning of each block, instructions appeared for 3 s, which defined the task (e.g., judge whether the word is positive or negative) for each block of trials. Then, the stimulus word appeared on the screen for 2000 ms, during which participants responded to the stimulus. Following this was a fixation task lasting 1000 ms. Each block contained 16 trials. In the agentic block, the stimuli were all agentic words, while in the communal block, they were all communal words. For the fixation task, a crosshair was presented in the center of the screen for 16 s; participants were asked to fixate on the crosshairs without any response.

fMRI data acquisition

Images were acquired with a Siemens 3T scanner (Siemens Magnetom Trio TIM, Erlangen, Germany). Functional data were collected by a T2-weighted gradient Echo-Planar imaging (EPI) sequence with time of repetition (TR) = 2000 ms; echo time (TE) = 30 ms; flip angle = 90° ; field of view = $192 \times 192 \text{ mm}^2$; matrix size = 64×64 ; voxel size = $3 \times 3 \times 3 \text{ mm}^3$; interslice skip = 0.99 mm; slices = 32. T1-weighted high-resolution anatomical images were acquired with TR = 1900 ms, TE = 2.52 ms, slice thickness = 1 mm, flip angle = 9° , matrix size = 256×256 .

fMRI data analysis

We used SPM8 (statistical parametric mapping; Institute of Neurology, London, England) to analyze the functional data (Friston et al., 1994). For T2*-weighted

images, slice order was corrected through slice timing, and six parameters of head movement were estimated and removed using the realign option, and the first five images were discarded to achieve a steady magnet state. Then the anatomical images were co-registered with the functional images for each participant. The anatomical and functional images were spatially normalized to an EPI template provided in SPM8. Finally, the images were smoothed by a Gaussian kernel with 8-mm full width at half maximum. The resulting images had cubic voxels of $3 \times 3 \times 3 \text{ mm}^3$.

We analyzed the fMRI using the first level of the general linear model (GLM) framework (Lidzba, Ebner, Hauser, & Wilke, 2013). The data were defined into three types: communal condition, agentic condition, and fixation task. For each participant, there were contrast images created for each comparison. First, we separately evaluated the agentic words and the communal words, contrasted with fixation trials. Second, we used a conjunction analysis between the contrast of communion vs. fixation and agency vs. fixation, to explore the regions activated by both communion and agency. Finally, we used pair-sampled *t*-tests to compare communal with agentic trials. The data obtained on the PANAS were used as a covariate to control for participants' affective state. Results were corrected with AlphaSim error correction at the .01 level (voxel threshold $p < .005$; cluster size > 105 voxels; Hamberger, Habeck, Pantazatos, Williams, & Hirsch, 2013). This correction was confined within the group gray matter mask (size: 67855) and determined by Monte Carlo simulations (Ledberg, Åkerman, & Roland, 1998) using the REST AlphaSim program (www.restfmri.net).

In addition, because the processing of communal and agentic words during the classification task involved emotional information, we used a repeated measures ANOVA with dimension (communion vs. agency) and valence (positive vs. negative) as the two factors to determine whether there was a valence main effect during word classification.

Although during the fixation task participants were asked to attend to the crosshairs at the center of the screen, it is difficult to ensure that participants did not engage in unconstrained thought or other self-referential aspects of consciousness. So, the fixation task could be associated with significant cognitive activity (Stark & Squire, 2001). Hence, we also used the implicit baseline as a control, which is the average intensity across all trials calculated by SPM (Adcock, Thangavel, Whitfield-Gabrieli, Knutson, & Gabrieli, 2006). We separately evaluated the agentic words and the communal words, compared with implicit baseline, and we used a conjunction analysis between these two contrasts.

RESULTS

Behavioral results

We conducted a two-way analysis of variance on mean reaction times with word content dimension (agency/communion) and valence (negative/positive) as within-participants' factors. The main effect of word content dimension was significant, $F(1, 41) = 4.32$, Mean Square Error (*MSE*) = 1263.52, $p = .044$; mean reaction times were shorter for communal words ($M = 776.02$, $SD = 96.90$) than agentic words ($M = 787.65$, $SD = 96.75$). Participants also were faster responding to positive ($M = 759.63$, $SD = 94.88$) than negative words ($M = 804.90$, $SD = 102.79$), $F(1, 41) = 32.81$, $MSE = 2623.54$, $p < .001$. The interaction of the two factors was not reliable, $F(1, 41) = 0.10$, $MSE = 848.27$, $p = .754$ (see Table 1), which indicated that content dimension was independent of valence, at least with regard to the behavioral aspects.

fMRI results

In order to explore brain region activations as a function of processing the communal and agentic words, we focused on agentic and communal trials contrasted with baselines without regard to word valence (see Figure 1).

Based on the conjunction analysis, a number of brain areas revealed significant increased activations for both agentic and communal contents. These similar activations have been associated with social cognitive processing and included the cerebellum, superior frontal gyrus, inferior parietal gyrus (IPL), insula, and putamen. The similar brain responses between agency and communion also included some deactivations, such as mOFC, vACC, the middle temporal gyrus, the posterior superior temporal gyrus, and precuneus (see Table 2, Figure 2). Using the implicit baseline, we found that the results for agency, communion and the conjunction analysis were similar to the results using the fixation baseline (see Table 2, Figures 1, 2).

TABLE 1
Response latencies for the word judgment task (ms)

<i>Traits</i>	<i>Mean</i>	<i>Std. deviation</i>
Agency positive	766.04	99.44
Agency negative	809.89	103.04
Communion positive	753.22	94.97
Communion negative	799.91	108.28

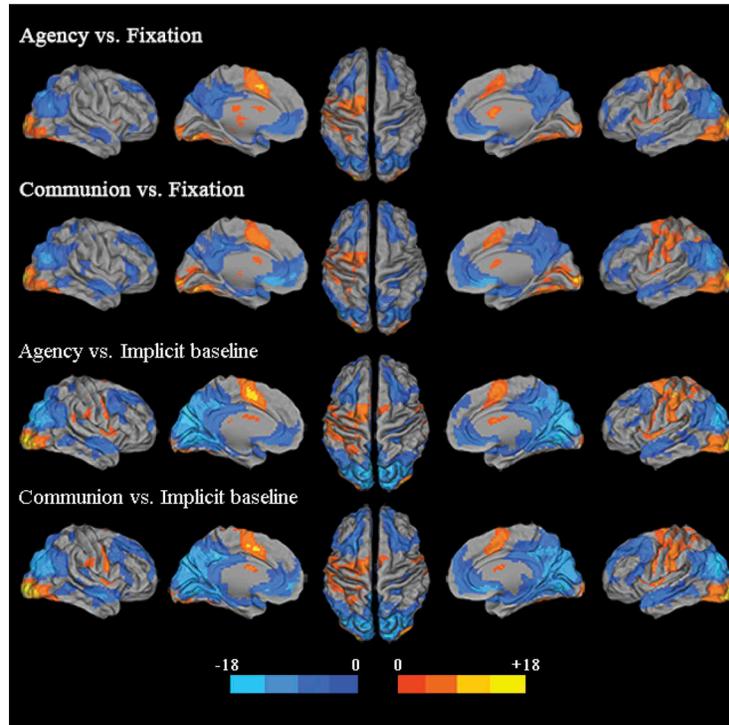


Figure 1. Regions showing significant increased (red) and decreased (blue) activation in the contrast of Agency vs. Fixation, Communion vs. Fixation, Agency vs. Implicit baseline, and Communion vs. Implicit baseline. The activations were reported with AlphaSim correction of $p < .01$.

To investigate brain activation differences between agentic and communal contents, we contrasted responses to the communal trials with agentic trials without the baseline (fixation task or implicit baseline). Agency showed greater activation in vACC and mOFC than communal content, whereas communal content resulted in greater activation for several visual areas, including occipital gyrus, lingual gyrus, and fusiform gyrus (see Table 3, Figure 3).

When contrasted with the baselines, however, both agency and communion showed reduced activation in vACC and mOFC (see Figure 1), which was even lower for communion than agency. That is, communal content appears to involve greater deactivation during the word classification task.

To identify whether or not there was an effect of valence on word categorization, we computed the main effect of valence and the interaction of content dimension (agency/communion) and valence (negative/positive). Our primary interest areas, vACC, mOFC, and other brain regions discussed above, showed no significant differences ($-2.31 < ts < 2.44$) in activation as a function of word valence or the interaction of word valence and content dimension

(AlphaSim-corrected, $p < .01$). Hence, the effects obtained as a function of content dimension were independent of valence.

DISCUSSION

The current research explored brain activations related to the processing of communal and agentic content using a valence classification task. Regions related to mentalizing, including the cerebellum, superior frontal gyrus, insula, putamen, along with the IPL related to the mirror system, were activated. The mOFC, vACC, middle temporal gyrus, superior temporal gyrus, and precuneus were deactivated by both communal and agentic words. The results further indicated that when comparing content dimension, communal words led to more deactivation in vACC and mOFC than agentic words, and communal content compared to agentic content led to increased activations in certain visual areas (e.g., middle occipital gyrus, fusiform gyrus). These activation patterns were present regardless of the emotional valence of the communal and agentic words.

TABLE 2
Conjunction of BOLD Signal for agentic and communal words

Anatomical region	Compared to implicit baseline			Compared to fixation task						
	MNI coordinates (X, Y, Z)	<i>t</i> -value	Cluster size	MNI coordinates (X, Y, Z)	<i>t</i> -value	Cluster size				
Activation										
Cerebellum										
L cerebellum VI				-42	-57	-24	6.87	313		
R cerebellum VI	26	-54	-24	7.50	353	30	-54	-24	9.48	483
R cerebellum IV-V	22	-50	-24	6.71	148					
Frontal gyrus										
L superior frontal gyrus	-14	-8	74	6.18	203	-30	-9	69	6.45	161
L supplement motor area	-4	6	52	10.38	911	-3	9	51	9.42	382
R supplement motor area	2	6	54	8.67	616	3	6	54	6.28	188
L precentral gyrus	-32	-14	68	6.63	793	-36	-12	66	7.49	611
Occipital gyrus										
L middle occipital gyrus	-24	-98	-2	15.13	647	-15	-90	-6	14.55	452
R middle occipital gyrus	28	-94	0	14.36	188	24	-96	6	11.51	140
L inferior occipital gyrus	-26	-96	-6	14.69	620	-18	-93	-9	13.84	292
R inferior occipital gyrus	28	-94	-2	14.75	521	24	-93	-3	9.20	230
L fusiform gyrus	-36	-86	-14	8.87	378	-30	-78	-12	10.00	395
R fusiform gyrus	40	-52	-24	4.35	74	27	-81	-9	9.86	365
Temporal gyrus										
R inferior temporal gyrus	44	-74	-8	5.29	96					
L lingual gyrus						-18	-90	-12	12.79	171
R lingual gyrus	24	-90	-2	12.93	93	21	-87	-3	11.26	279
Parietal gyrus										
L inferior parietal gyrus	-56	-24	50	7.09	346	-27	-57	42	6.54	227
L postcentral gyrus	-60	-18	26	6.78	743	-57	-18	48	6.76	480
Insula										
L insula	-44	0	6	7.80	646	-33	18	12	5.50	244
Subcortical structures										
L putamen	-24	-6	14	6.29	386	-24	12	12	5.38	204
Deactivation										
Frontal gyrus										
L middle frontal gyrus	-21	21	48	-6.47	501	-21	24	48	-5.72	216
R middle frontal gyrus	24	33	42	-6.09	399	24	30	42	-4.89	142
L superior frontal gyrus	-21	27	42	-6.27	190	-18	24	48	-5.37	221
R superior frontal gyrus	24	36	42	-5.75	381	21	54	39	-4.60	242
R medial orbitofrontal gyrus	3	54	-9	-7.10	204	0	24	-12	-6.30	202
L medial orbitofrontal gyrus	0	54	-12	-6.90	167	-9	51	-9	-6.47	167
L ventral anterior cingulate	-9	45	-3	-5.62	190	-6	27	-9	-5.79	180
L middle cingulate	-9	-42	42	-11.69	397	-9	-42	42	-6.44	293
R middle cingulate	3	-42	42	-8.93	384	3	-39	45	-5.28	234
Occipital gyrus										
L calcarine fissure	-15	-63	18	-9.87	675					
R calcarine fissure	6	-84	3	-9.60	536					
L middle occipital gyrus	-27	-78	39	-12.25	575	-42	-81	30	-8.13	340
R middle occipital gyrus	42	-78	21	-11.71	452	42	-69	27	-8.18	291
L superior occipital gyrus	-18	-81	39	-13.72	441	-18	-81	42	-7.98	145
R superior occipital gyrus	24	-75	45	-11.74	416					
Temporal gyrus										
R middle temporal gyrus	45	-72	21	-10.74	620	48	-66	21	-7.68	437
L middle temporal gyrus	-57	6	-18	-6.58	699	-48	-75	18	-6.47	286
R superior temporal gyrus	54	-3	-12	-6.52	222	60	-6	-12	-4.32	121
L lingual gyrus	-21	-45	-9	-10.61	580					
R lingual gyrus	24	-60	-3	-9.81	596					
Parietal gyrus										
R superior parietal gyrus	18	-75	51	-13.25	261					
R precuneus	18	-75	48	-11.48	981	15	-78	48	-6.20	603
L precuneus	-9	-45	45	-11.13	918	-3	-48	45	-7.01	460
R angular gyrus	36	-78	42	-9.89	497	45	-69	30	-7.53	361

Notes: A correct voxel-wise threshold of $p < .01$ (AlphaSim-corrected) was used, and the coordinates, cluster size, and *t*-values relate to activations of the single brain region listed in the table. MNI, Montreal Neurological Institute.

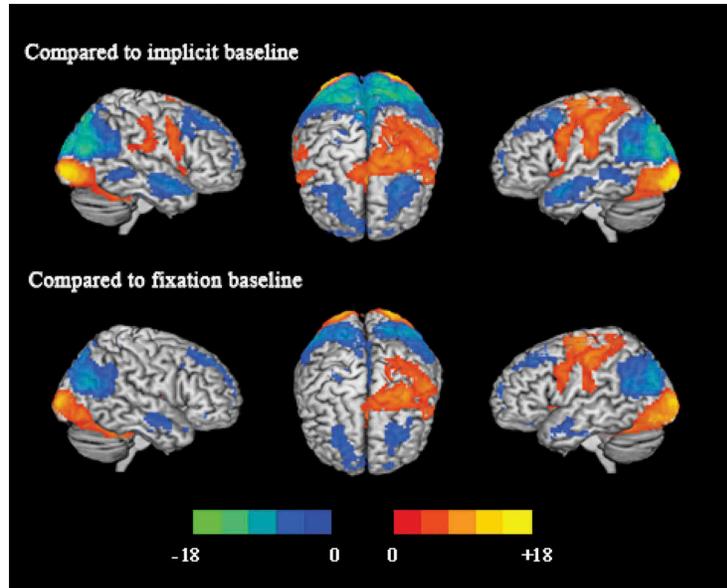


Figure 2. Results of conjunction analysis (AlphaSim correction of $p < .01$).

TABLE 3
Identification of BOLD signal for agentic and communal words

Region	MNI coordinates			<i>t</i> -value	Cluster Size
	<i>x</i>	<i>y</i>	<i>z</i>		
Agency vs. Communion					
Frontal gyrus					
R medial orbitofrontal gyrus	0	24	-10	4.04	110
L ventral anterior cingulate	0	24	-6	4.60	94
R ventral anterior cingulate	2	24	-6	4.62	86
L caudate	-4	18	-6	3.80	133
Communion vs. Agency					
Occipital gyrus					
R middle occipital gyrus	30	-86	8	4.19	196
Temporal gyrus					
R fusiform gyrus	26	-66	-12	3.63	222

Notes: A correct voxel-wise threshold of $p < .01$ (AlphaSim-corrected) was used, and the coordinates, cluster size, and *t*-values relate to activations of the single brain region listed in the table.

The common neural mechanisms of agency and communion

The role of mentalizing in categorizing the favorability of agentic and communal words

Among the similarities in activation patterns, the cerebellum's role was highlighted. The cerebellum is known as a sensorimotor area; however, it also involves higher-order cognitive, affective, and personality-related processing, especially cerebellum lobule VI (Picerni et al., 2013; Stoodley, Valera, & Schmahmann, 2012). The activations of cerebellum

lobule VI in the present study suggest it may play a role in processing social cognitive information (Garrard, Martin, Giunti, & Cipolotti, 2008; Van Overwalle et al., 2014).

Another area activated in response to both agentic and communal information was the insula. Activations of the insular cortex have been associated with the motivation to approach others, such as cooperation, compassion, admiration, and romantic or maternal love (Lamm & Singer, 2010). These responses fit under the communion category. On the other hand, recent evidence points to the insula as important for the sense of agency and attribution of

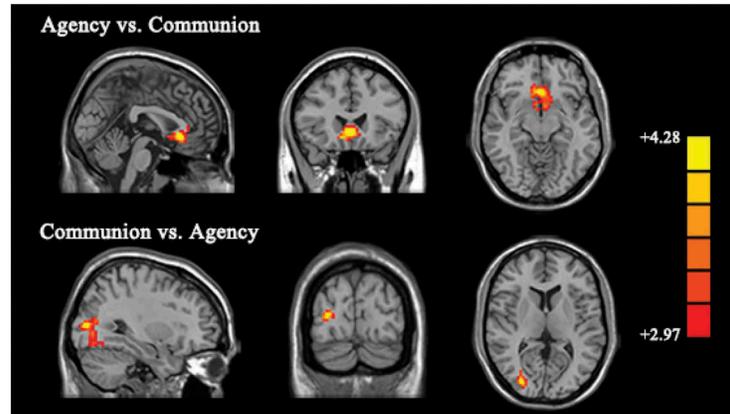


Figure 3. Statistical activation maps comparing agentic to communal trials demonstrate greater activity in the ACC (6, 24, -3) and mOFC (0, 24, -6). The activations were reported with AlphaSim correction of $p < .01$.

actions to the self (Craig, 2009; Farrer & Frith, 2002). In other words, the insula has been identified as participating in the experience of self, suggesting that insular activations are also related to agentic content.

The superior frontal gyrus is activated when perceivers are trying to predict others' behaviors, for example, engaging theory of mind (Cui, Bryant, & Reiss, 2012). In the current task, activations in the superior frontal gyrus also contained parts of dorsal ACC/posterior mPFC (see Figure 2), which play an important role in modulation of attention and executive functioning (Bush, Luu, & Posner, 2000; Bush et al., 2000). Hence, it makes sense that activations of the superior frontal gyrus could be related to the agency and communion content, or the cognitive processing during the whole task.

The putamen also showed activation for both agency- and communion-related contents.

This finding is concordant with reports in recent neuroimaging research indicating that the putamen is engaged in inferring and comprehending others' mental states (Abu-Akel & Shamay-Tsoory, 2011; Herve', Razafimandimby, Jobard, & Tzourio-Mazoyer, 2013). In addition to mentalizing processes, both communion-related stimuli (Maternal and romantic love) and agency-related stimuli (goal accomplishment) have been implicated in recruitment of the putamen (Balleine, Delgado, & Hikosaka, 2007; Bartels & Zeki, 2004).

Finally, the IPL, which is related to social cognitive processing in the mirror system, is also activated in response to both agentic and communal contents (Van Overwalle, 2009). The IPL is involved in imitating social behaviors and encoding intentions behind others' actions (Koenigs, Barbey, Postle, & Grafman,

2009). Moreover, even imagining actions can influence IPL activation (Gerardin et al., 2000). Thus, IPL activation may not only have occurred because agentic and communal traits can be used to describe others' behaviors, but also because they can convey motivation (Trapnell & Paulhus, 2012), which may have prompted people to imagine the related behaviors.

In summary, various neural activation similarities exist when processing both communal and agentic contents, despite dissociating content from perspective (self vs. other) in the present study. Many of these similarities may have their basis in the recruitment of shared social cognitive processes to simulate and infer meaning about others and their behavior.

The role of default mode network in categorizing the favorability of agentic and communal words

In addition, the similar brain responses between agency and communion also included some deactivations, such as mOFC, vACC, the middle temporal gyrus, the posterior superior temporal gyrus, and precuneus. All these areas play core roles in mentalizing. Specifically, the vACC and mOFC are part of the mPFC, which is not only subserves executive functioning (Gazzaniga, Ivry, & Mangun, 2008), but also is typically associated with inferring enduring dispositions of others and the self (Van Overwalle, 2009). In the present study, deactivations were also present for parts of TPJ (e.g., the posterior superior temporal gyrus, see Figure 2; cf. Michael et al., 2014), which have been implicated in diverse social cognitive experimental paradigms that manipulate decision-making or making inferences of others' goals and desires (Carter & Huettel, 2013; Van Overwalle,

2009). Complex social processes, such as mental state inference, impression formation, spontaneous trait inferences, and behavioral predictions, also rely on the precuneus (Lee & Harris, 2013). In the present study, these core mentalizing areas showed deactivations. Such deactivations may be implicated in task processing.

The mPFC, precuneus, and lateral temporal cortex can be regarded as part of the default mode network (DMN; Gazzaniga et al., 2008; Mannell et al., 2010). When people are in the resting state, DMN activation relates to explicit, conscious representations of the self (Gusnard & Raichle, 2001). The present tasks, including valence classification and the fixation baseline, did not ask participants to contemplate the self. Thus, high neuronal activity in DMN during the resting state was inhibited in the present tasks, which required participants to attend to complex external stimuli that did not refer to the self (Grimm et al., 2008; Mannell et al., 2010). This appears to reflect task-induced deactivation (TID) in DMN. Previous studies have argued that the magnitude of TID reflects the reallocation of attention from rest state to task state or from task-irrelevant regions to task-relevant regions (Takeuchi et al., 2011). The fixation baseline task is easier to perform than the valence classification task, so fewer resources in mPFC, precuneus, and lateral temporal cortex during baseline will be reallocated compared to performing the valence classification task. So, communion and agency appear to represent deactivations when contrasted separately with the baseline. Such deactivations may play a role in preparing for deeper social-cognitive processing.

The distinct neural mechanisms of agency and communion

Apart from these similar brain responses, the main differences between the processing of agentic and communal information were restricted to vACC and mOFC. The results indicated that vACC and mOFC showed greater deactivations in the communal condition than agentic condition.

The role of vACC in categorizing the favorability of agentic and communal words

The different activations between agency and communion are unlikely to result from differences in emotional information. The vACC is usually activated during emotional and motivational information processing (Bush et al., 2000), but it also can be characterized by deactivation in various emotional-

cognitive tasks (Grimm et al., 2006). However, the emotional valence of the stimulus words in the present study was balanced between communion and agency, so the distinct activations may be due to people having different understandings and consequent cognitive activity for communion compared to agency, rather than emotional information differences. Therefore, deactivation in vACC in the present study can be viewed as a part of TID. Communion showed greater deactivation in vACC than agency in the present study, which could be due to larger allocation of attentional resources to posterior visual areas, including the occipital gyrus and fusiform gyrus (Koshino et al., 2011). Consistent with this view, various visual areas evinced greater activation in response to communal information, suggesting that participants needed more processing resources to judge communal words, and these resources likely came from vACC. In addition, the increased activation of visual areas in response to communal content, which is also associated with spatial attention (Mangun, Buonocore, Girelli, & Jha, 1998), has been shown to enhance the visual representation of stimuli (Fan et al., 2007; Prinzmetal, McCool, & Park, 2005). These results suggest that compared to agentic information, communal information is more likely to capture visual attention, which can be taken as an indication that participants cared more about communal information.

There is another potential explanation for the distinct deactivations in vACC, which speak more broadly about cognitive activity and not allocation of attentional resources. The observed deactivations may represent attempts to inhibit cognitive activity irrelevant to task performance (Takeuchi et al., 2011). Combining the behavior and fMRI results, deactivation in vACC may represent greater suppression of distributed cognitive processing, which may facilitate behavior performance. This is consistent with the previous research findings indicating a positive relationship between the magnitude of TID and task performance (Sambataro et al., 2010).

In addition, these different activations also accord with previous research on the two fundamental dimensions showing that communion information is preferentially processed (Wojciszke et al., 1998; Ybarra et al., 2001). Although whether another person can act in ways that benefit or harm the self depends on their capacity to carry out different behaviors (e.g., to lie, to help) (cf. Abele & Wojciszke, 2007; Fiske et al., 2007), a perceiver's assessments of another's capabilities to

enact actions (i.e., be agentic) has limited meaning if others' intentions and interpersonal purposes (to help or harm) are not known. Thus, it makes sense that communal information is preferentially processed, as it is relatively more important for social navigation. It is possible that the greater deactivations of vACC may serve to inhibit irrelevant cognitive processing to provide more processing resources to visual areas, ensuring people pay more attention to communion-related information. Put differently, the processing of communal information may induce more concentrated effort.

The role of mOFC in categorizing the favorability of agentic and communal words

The other unique activations between communion and agency involved mOFC, which is implicated in higher-order cognition, including social decision-making and monitoring reward- and punishment-related learning (Powell, Lewis, Dunbar, García-Fiñana, & Roberts, 2010; Rolls, Everitt, & Roberts, 1996). Deactivation in the mOFC can also be regarded as potentially reflecting a reallocation of attention, or inhibition of irrelevant cognitive activity similar to the vACC (Powell et al., 2010).

It is important to note that the differences in neural activations in response to the agentic and communal contents were small. The size of the observed effects may be limited by the nature of the present task (classification of a word's valence) and the degree of processing and elaboration the task elicits. It may be that tasks that induce deeper social cognitive processing or differing perspectives (other vs. self) may elicit greater differences in the neural correlates of the fundamental dimensions.

Related to the issue of the task used in this study, we hypothesized that some brain regions in the frontal and temporal lobes would activate, such as the PFC and TPJ. In contrast, these hypothesized areas showed deactivations. These brain regions are usually implicated in tasks that induce deeper social-cognitive processing, such as making trait-inferences and identifying intentions (Mitchell et al., 2006; Van Overwalle, 2009). It may be that the simpler word valence classification task used in the present study, without instruction to make sense of others or the self, did not induce this deeper kind of social cognitive processing. Nevertheless, the simple nature of the task provided a context for isolating the effects of communion- and agency-related contents. In addition, although we expected that the amygdala would be activated when

classifying the valence of the words, the absence of amygdala activation in the present study may be due to the stimulus words not arousing strong enough emotional responses.

It is necessary to repeat and extend our experiment in future research. First, the magnitude of the activations for agentic and communal words was lower than the baseline. This may be due to the nature of the implicit baseline or fixation task. For example, the fixation task may be associated with unconstrained thought, and the implicit baseline averages over several variables, some of which may be difficult to control. Thus, in future research, a baseline task that can control for muscle recruitment or eye movement unrelated to the studied tasks will be useful to implement, such as a font judgment task. Second, the current research focused mainly on the brain regions relevant for mentalizing. However, apart from mentalizing, the mirror system is implicated in the understanding of others' nonverbal behaviors and movements (Van Overwalle et al., 2014). Although the current study did not require participants to infer the purpose of others' actions, an area of the mirror system was activated nevertheless. Many other studies of social cognition have also relied on nonaction-based stimuli for processing. Thus, it would be interesting to assess the neuromechanisms implicated when people process communion- and agency-related actions and not personality adjectives that represent more generalized or abstract behavioral tendencies and even mental states.

CONCLUSIONS

The present research is one of the first to directly explore the neural representation of the two fundamental dimensions of social cognition. Our findings suggest that some areas such as the cerebellum, insula, and superior frontal gyrus—areas closely related to mentalizing, and the IPL—related to the mirror system, were activated by both communal and agentic words. Because the current task did not ask participants to contemplate the self, some areas of the DMN, such as mOFC, vACC, and TPJ, showed deactivations in both the agentic and communal conditions, reflecting TID. Furthermore, vACC and mOFC were marked by greater deactivations when categorizing communal words than agentic words, which may reflect greater attention and engagement with communion-related content. The findings indicate not only similarities but also differences when individuals process information

from the fundamental dimensions. Such differences have potential implications for the many studies that examine social cognitive processing, as it may be less than clear the degree to which the task or the content of the information to be processed plays a role in the observed activations.

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