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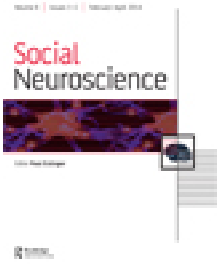

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The correlation between gray matter volume and perceived social support: A voxel-based morphometry study

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The correlation between gray matter volume and perceived social support: A voxel-based morphometry study

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Social support refers to interpersonal exchanges that include the combinations of aid, affirmation and affection. Perceived social support is a kind of subjective judgment of one's availability of social support. In spite of the importance of perceived social support to health, however, its neural substrate remains unknown. To address this question, voxel-based morphometry was employed to investigate the neural bases of individual differences in responses to the Perceived Social Support Scale (PSSS) in healthy volunteers (144 men and 203 women; mean age = 19.9; SD = 1.33, age range : 17–27). As a result, multiple regression analysis revealed that the PSSS scores were significantly and positively correlated with gray matter volume in a cluster that mainly included areas in posterior parts of posterior cingulate cortex, bilateral lingual cortex, left occipital lobe and cuneus. Highly-supported individuals had larger gray matter volume in these brain regions, implying a relatively high level of ability to engage in self-referential processes and social cognition. Our results provide a biological basis for exploring perceived social support particularly in relationship to various health parameters and outcomes.

Keywords: Perceived social support; Voxel-based morphometry; Gray matter volume.

Humans live in complicated societies in which they are not alone, but rather connected with each other tightly. Without any exaggeration, social support is one of the reasons why we would feel we aren't separated from others. Social support is a complex conception and social phenomenon. At the simplistic level, it refers to interpersonal exchanges that include combinations of aid, affirmation and affection (Williams et al., 2004). Generally speaking, social support is defined as living in a social network that is defined by size, duration of membership, percentage of relationships that are both help giving and help receiving, and the proportion of members who are familiar with each other (Gulick, 1994). Furthermore, perceived social support emphasizes the subjective feeling of help and care offered by the community, social networks, and confiding partners (Lin, 1986). Perceived availability of social support appears to differ among individual despite access to similar resources.

Clearly, perceived social support can be beneficial to health outcomes both physically and mentally. Specifically, two distinct models have been proposed with regard to the benefits of social support to health outcomes. One claimed that social support could produce helpful effects on a person's life ~~directly~~, regardless of the level of stress or disruption (Broadhead et al., 1983); on the contrary, the other treated social

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support as ~~a buffer~~, which protected individuals from the harmful effects of stress (Blumenthal et al., 1987; Cohen & McKay, 1984; Dalgard & Tambs, 1995; Feldman, Downey, & Schaffer-Neitz, 1999; Gore, 1981; Helgeson & Cohen, 1996; House, 1981; Peirce, Frone, Russell, Cooper, & Mudar, 2000). Furthermore, multiple mechanisms were proposed regarding how social support buffered stress (and, hence, improved clinical outcomes), which included improved therapeutic compliance and accessibility to medical emergency care and treatment, health-promoting behavior change and direct neuroendocrine effects (Ikeda et al., 2008). Despite controversy about the specific pathways, it is considered likely that social support can have a positive effect on health outcomes.

In spite of the importance of perceived social support to health, however, its neural bases remain unknown. In this study, we propose to experimentally measure perceived social support and examine its relationship to brain anatomy. The Multidimensional Scale of Perceived Social Support (MSPSS) has been developed as a self-report measure of subjectively assessed social support, encompassing individuals' self-reflection on the availability of social support (Zimet, Dahlem, Zimet, & Farley, 1988). When it comes to the processes of self-reflection and self-related materials, a refined anatomical brain network, namely the “default mode network” (DMN), is generally recruited (Raichle et al., 2001). The DMN consists of dorsal and ventral medial prefrontal cortex (mPFC), posterior cingulate cortex (PCC), precuneus (PREC), posterior inferior parietal regions, lateral temporal cortex, and the hippocampal formation including parahippocampus (Buckner et al., 2008). The DMN is further engaged in the maintenance of baseline brain activities including self-awareness, episodic memory and information exchange between the internal mind and external world (Buckner, 2008; Fox et al., 2005; Raichle et al., 2001).

Perceived social support also can be conceptualized as a specific kind of social cognition that may invoke abilities such as remembering the past (autobiographical memory), thinking about the future (envisioning) and understanding other minds (mentalizing) (Buckner & Carroll, 2007). Several of these abilities have been associated with structures comprising the DMN. Specifically, a common pattern of neural activation in DMN was demonstrated underlying processes of autobiographical remembering, prospection, and mentalizing (Spreng & Grady, 2010). Episodic memory and envisioning the future were demonstrated to share a common neural network including PCC/PREC and medial prefrontal cortex (mPFC) (Addis, Wong, & Schacter, 2007). In addition, identical functional connectivity patterns were detected among ventromedial prefrontal cortex (vmPFC), PCC/PREC and temporoparietal junction (TPJ) regions during mentalizing of both self and other (Lombardo, Chakrabarti, Bullmore, Wheelwright, & Sadek, 2010). In summary, there is strong evidence that neural signatures underpinning social cognition extensively match with DMN (Amodio & Frith, 2006; Cavanna & Trimble, 2006; Saxe, 2006), supporting the hypothesis that human beings may have a predisposition for social cognition when not faced with an environmental demand (Schilbach, Eickhoff, Rotarska-Jagiela, Fink, & Vogeley, 2008). Given these findings, an intriguing question can be raised whether individuals will be engaged in assessing the availability of social support when left alone.

To answer the question, voxel-based morphometry (VBM) was employed to probe the neural bases of individual differences in perceived social support. VBM is a fast, straightforward method to quantify the amount of gray matter existing in a voxel (Ashburner & Friston, 2000; Bullmore et al., 1999; Good et al., 2001; Wright et al., 1995). Gray matter volume is conceptualized as the amount of gray matter lying between the gray–white interface and the pia mater (Winkler et al., 2010). Compared to functional imaging, structural imaging studies are particularly suitable for investigating the anatomical correlates of personal characteristics including a series of behaviors and ideas occurring outside the laboratory (Takeuchi et al., 2012). Therefore, we propose to test the hypothesis that individual differences in perceived social support will be associated with differences in the volume of DMN structures, especially parts of its core hubs- the PCC and mPFC.

MATERIALS AND METHODS

Subjects

A total of 347 right-handed, healthy volunteers (144 men and 203 women; mean age = 19.9; SD = 1.33, age range: 17–27) participated in this study, which was a part of our ongoing project aimed at examining the associations among brain imaging, creativity and mental health. All of the participants were undergraduate students from a local university in southwest China. All participants were directed to complete the Perceived Social Support Scale (PSSS) (Jiang, 2001). None had a history of neurological or psychiatric illness. The study was approved by the Southwest University Brain Imaging Center Institutional

Review Board at its beginning. According to the Declaration of Helsinki, all participants signed a written informed consent.

Assessment of perceived social support

The perceived Social Support Scale (PSSS) is a revised version of the Multidimensional Scale of Perceived Social Support (MSPSS) (Zimet et al., 1988), which was developed to measure the level of subjectively assessed social support. The PSSS contains 12 items ranging from family to friend and to significant other support. Participants answered the questions using a 7-point scale from "strongly disapproval" to "strongly approval". The PSSS has been found to be a sensitive and ecologically valid self-report measure of social support (Zimet et al., 1988; Zimet, Powell, Farley, Werkman, & Berkoff, 1990). Examples of PSSS items are as follows: "My family really tries to help me." (*Family support*); "I have friends with whom I can share my joys and sorrows." (*Friend support*); "There is a special person who is around when I am in need" (*Significant others support*) (Zimet et al., 1988).

MRI data acquisition

A 3.0-T Siemens Trio MRI scanner (Siemens Medical, Erlangen, Germany) was employed to acquire MR images. High-resolution T1-weighted anatomical images were obtained with the application of a magnetization-prepared rapid gradient echo (MPRAGE) sequence (repetition time (TR) = 1900 ms; echo time (TE) = 2.52 ms; inversion time (TI) = 900 ms; flip angle = 9 degrees; resolution matrix = 256 × 256; slices = 176; thickness = 1.0 mm; voxle size = 1 × 1 × 1 mm).

Voxel-based morphometry

To process the MR images SPM8 (Wellcome Department of Cognitive Neurology, London, UK; www.fil.ion.ucl.ac.uk/spm) was implemented in Matlab 7.8 (MathWorks Inc., Natick, MA, USA). In order to screen for artifacts or gross anatomical abnormalities, each MR image was first displayed in SPM8. The reorientation of the images was manually set to the anterior commissure for better registration. The New segmentation in SPM8 was applied for segmenting the images into gray matter (GM) and white matter (WM). Then, Diffeomorphic Anatomical Registration through Exponentiated Lie (DARTEL) algebra in SPM8 was manipulated for registration, normalization, and modulation (Ashburner, 2007). To ensure that regional differences in the absolute amount of GM were conserved, we modulated the image intensity of each voxel by the Jacobian determinants and then transformed registered images to Montreal Neurological Institute (MNI) space. Finally, in order to increase signal to noise ratio, the normalized modulated images were smoothed with a 10-mm full-width at half-maximum Gaussian kernel.

Statistical analysis

SPM8 was applied for statistical analyses of gray matter volume (GMV) data. To identify brain regions where regional GMV was statistically related to individual differences in perceived social support, a multiple linear regression was employed in the whole-brain analyses. Specifically, in the multiple linear regression model, the scores of the PSSS served as the variable of interest, while age, gender and global volumes of gray matter were entered as covariates to control possible confounds. Absolute threshold masking of 0.2 was set so as to refrain from the edge effects around the boundary between GM and WM. Hence, voxels were excluded from the analyses if its gray matter values were lower than 0.2. For all analyses, we set the cluster-level statistical threshold at $p < .05$ and corrected with underlying voxel level of $p < .001$ at the non-stationary cluster correction (Hayasaka, Phan, Liberzon, Worsley, & Nichols, 2004).

RESULTS

Basic data

Table 1 showed the average and standard deviation (SD) for PSSS scale scores as well as for age. It also showed the distribution of PSSS scale scores. The

TABLE 1
Demographic variable and distribution of PSSS scale scores of the study subjects (*N* = 347; men = 144, women = 203)

Measure	*Mean*	*SD*	*Range*				
Age	19.9	1.33	17–27				
PSSS	64.7	7	40–49	50–59	60–69	70–79	80–84
			5	76	171	94	1

PSSS scale scores did not significantly correlate with age ($r = 0.015$, $p = .783$), gender ($r = 0.06$, $p = .262$) and whole brain volume ($r = -0.06$, $p = .261$).

Correlation between GMV and PSSS scale scores

We tested the association between GMV and individual differences in PSSS scores. After controlling for age, gender and total gray matter volume using multiple regression analysis, results revealed that the PSSS scores were significantly and positively correlated with GMV in a cluster that mainly included areas in the posterior portion of bilateral posterior cingulate cortex, extending to bilateral lingual cortex, left occipital lobe and cuneus (MNI coordinates, 1.5, –60, 4.5, cluster size = 181, $t = 4.71$, $p[\text{corr}] < .05$ nonstationary) (Figure 1 and Table 2). Highly-supported individuals had relatively larger gray matter volume in this cluster. Figure 2 depicted the significant linear relationship between PSSS and gray matter volume in posterior PCC.

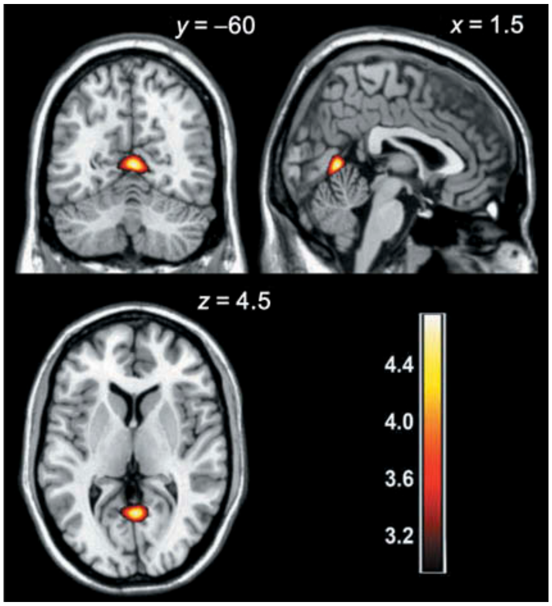

Figure 1. Anatomical correlates of PSSS. The regions of significant correlation are overlaid on SPM8's "single subject" T1 image. GMV was positively correlated with individual PSSS in a cluster that mainly included areas in the posterior cingulate cortex, extending to cuneus and lingual cortex. Results are $p < .05$, corrected for multiple comparisons at a cluster level with nonstationary correction, with an underlying voxel level of $p < .001$, uncorrected.

TABLE 2
Brain regions with significant correlations between GMV and PSSS scale scores

		MNI coordinates (mm)				*Cluster size*
Region	*Side*	*x*	*y*	*z*	*T-score*	*(voxels)*
Posterior cingulate cortex	R/L	1.5	–60	4.5	4.71	181

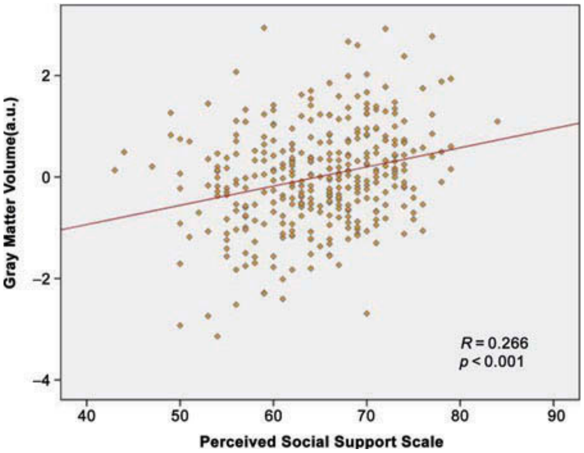

Figure 2. Significant correlation between VBM response in PCC peak voxel (controlling for effects of age, gender, and total gray matter volume) and PSSS.

DISCUSSION

To the best of our knowledge, this is the first study to investigate the neural substrates of perceived social support by means of voxel-based morphometry. Increased gray matter volume in the posterior parts of posterior cingulate cortex, the bilateral lingual cortex, the left occipital lobe and the cuneus was associated with individual differences in perceived social support. Specifically, individuals reporting high levels of perceived social support had larger gray matter volume in these brain regions, implying a relatively high level of ability to engage in self-referential processes and social cognition.

Lower regional gray matter volume in the posterior portion of PCC and cuneus may be associated with reduced abilities of self-reflection and self-referential processes, leading to decreased perceived social support. The posterior cingulate cortex has been regarded as one of the key hubs in the default mode network involved in self-awareness and self-referential processes (Buckner, 2008; Fransson & Marrelec, 2008; Greicius, Krasnow, Reiss, & Menon, 2003). The cuneus also has been treated as a component of DMN in a few studies (Buckner, 2008; Sreenivas, Boehm, & Linden, 2012; Zhang et al., 2010), although with less certainty. A number of studies have confirmed a critical role for posterior parts of PCC in self-reflection and self-referential processes, including integrating self-referential stimuli (Northoff & Bermpohl, 2004), self-referential mental activity (Menon, 2011), and, along with mPFC, self-reflective thought in individual analyses (Johnson et al., 2002). Therefore, variability in individual differences in posterior PCC and cuneus volumes may result in differences in self-reflection and self-referential processes. Because of the fact that self-report of social support relies on such self-referential processes, it's reasonable to speculate that different levels of perceived social support will result from individual differences in posterior PCC and cuneus volumes. Specifically, for those with relatively larger GMV in posterior PCC and cuneus, increased abilities of self-reflection and self-referential processes may facilitate social insight and awareness and lead to report of higher levels of social support. A connection between perceived social support and GMV in posterior PCC and occipital lobe may also stem from the role of these brain areas in visual imagery processes (Mantani, Okamoto, Shirao, Okada, & Yamawaki, 2005). For example, the posterior PCC has been proposed to have a crucial role in alexithymia-related imagery disturbance (Mantani et al., 2005). What's more, medial parieto-occipital area (MPOA) was recruited in imagery domain studies (Ghaem et al., 1997; Kosslyn et al., 1993; Mantani et al., 2005; Mellet, Tzourio, Denis, & Mazoyer, 1995; Roland & Gulyás, 1995). Moreover, larger GMV in the posterior PCC and occipital lobe have been associated with increased ability in visioning or visual imagery processes which may play a major role in imagining scenes relevant to social support. In this way, higher levels of perceived social support may come to mind more easily to those with larger GMV in posterior PCC and occipital lobe when left to assess the availability of social support.

Commonly, it's desirable to explore the neural bases of social cognition from non-human primates when questioning the "social brain" in human beings. Interestingly, a DMN similar to that in the human brain has been detected in non-human primates (Kojima et al., 2009; Vincent et al., 2007). Furthermore, Mars et al. (2012) suggested an overlap between the DMN and brain areas underpinning social cognition in macaque, of which the posterior PCC is a core component. In consideration of the critical role for the posterior portion of PCC in social cognition among human participants (Addis et al., 2007; Spreng, Mar, & Kim, 2009), it's easy to propose that increased GMV in the posterior PCC provides a neural substrate for relatively higher ability to engage in social cognition. Accordingly, this increased ability of social cognition can pave a way for better performance in autobiographical memory and envisioning the future when individuals are directed to estimate the level of social support.

The observed association between perceived social support and volume of posterior PCC and occipital lobe can also be interpreted from this region's role in anxiety and risk mental state. For one thing, a negative correlation was detected between gray matter volume in posterior PCC and anxiety scores (Spampinato, Wood, De Simone, & Grafman, 2009). Conceptualizing this result into a neural network of anxiety, some aspects of cognitive profiles, such as negative memory bias or perceptual biases in the comprehension of environment, were observed in trait and clinical anxiety due to dysfunction of the posterior portion of PCC (Spampinato et al., 2009). Moreover, occipital areas were found to be engaged in detecting external threatening signals in subjects with increased anxiety (Wu, Andreescu, Figurski, Tanase, & Aizenstein, 2009). Smaller GMV in posterior PCC was reported in individuals with an "At Risk Mental State" (ARMS) compared to healthy volunteers (Borgwardt et al., 2007). These studies suggest that decreased GMV in occipital lobe and posterior PCC might lead to negative, even false observation and interpretation of emotional events and experiences resulting in reduced perceived social support.

The main strength of present study was the application of an automated volumetric technique probing associations between brain morphometry and perceived social support. However, our study has several limitations. First, because of the fact that experiences of social connection and detection of safety rely on basic reward-related circuitry (Eisenberger & Cole, 2012), it's reasonable to speculate that perceived social support would be associated with reward-related regions including vmPFC, ventral striatum (VS) and septal area (SA) (Eisenberger & Cole, 2012; Moll et al., 2012). However, significant correlation between perceived social support and GMV in reward-related regions wasn't observed in present study. There is evidence suggesting that the PCC plays a critical role in responding to safety cues that could be experienced as rewarding or reinforcing, in addition to reward-related regions mentioned above (Atlas, Bolger, Lindquist, & Wager, 2010; Delgado, Olsson, & Phelps, 2006; Phelps, Delgado, Nearing, &

LeDoux, 2004; Wager et al., 2009). Among those in social exclusion, providing them socially supportive information increased activity in PCC (Onoda et al., 2009). Hence, future researchers need to investigate how to discriminate PCC from reward-related regions during responses to safety cues. Secondly, "affiliation" related regions were not correlated with perceived social support. It may be the case that "affiliations" lay stress on intimate relations, especially on relatives (Moll et al., 2012); however, the PSSS extends it also to friends and significant others. These tiny distinctions may contribute to the failure in observing significant association between the PSSS and "affiliation" related regions. Interestingly, the precuneus activation in the affiliative versus nonaffiliative contrast occurred in close proximity to the brain areas observed in present study (Moll et al., 2012). Another concern is the assessment of perceived social support which often has been divided into three types of support, namely emotional, instrumental, and informational support (House & Kahn, 1985; House, 1981; Kahn & Antonucci, 1980; Thoits, 1985). Since the PSSS surveys subjectively assessed social support (Zimet et al., 1988), it will be tightly associated with emotional support even though several items (items 1, 3, 6, 7, 8, 11, 12, Table 3) will guide participants to the thought of vivid scenes relevant to instrumental and informational support. In effect, no studies to date have been reviewed to divide PSSS into these three subscales accurately. Moreover, a review of studies confirmed that caudal part of the PCC was the cortical region activated by emotional stimuli (Maddock, 1999), in addition to the "affective" regions such as VS, SA, vmPFC and insula. Also, the PCC was shown to be connected with regions engaged in emotional processing (Goldman-Rakic, Selemon, & Schwartz, 1984; Musil & Olson, 1993; Van Hoesen, Morecraft, & Vogt, 1993). Reasons why the "affective" regions were not correlated significantly with PSSS in present study may lie in the fact that PSSS is a complicated instrument that includes emotional, instrumental, and informational support. Besides, it was a pity that mental health outcome wasn't acquired in this analysis which could made the results stronger. In future studies, we will try to screen for psychiatric disorders in participants and to clarify the relationship among perceived social support, brain data and mental health outcome clearly.

TABLE 3
Items of the PSSS

Number	*Item*
1	There is a special person who is around when I am in need.
2	There is a special person with whom I can share my joys and sorrows.
3	My family really tries to help me.
4	I get the emotional help and support I need from my family.
5	I have a special person who is a real source of comfort to me.
6	My friends really try to help me.
7	I can count on my friends when things go wrong.
8	I can talk about my problems with my family.
9	I have friends with whom I can share my joys and sorrows.
10	There is a special persons in my life who cares about my feelings.
11	My family is willing to help me make decisions.
12	I can talk about my problems with my friends.

To the best of our knowledge, this is the first study to investigate the associations between gray matter structures and perceived social support. Results supported our hypothesis that parts of DMN, specifically posterior portion of PCC, occipital lobe and cuneus, were associated with perceived social support. It's suggested that individual differences in perceived social support can reflect the gray matter structures of focal regions. Our results provide a biological basis for exploring perceived social support. Future researchers should focus on investigations of the neural substrates of perceived social support and its applications to physical, social and emotional health.

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