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# Synchronous activation within the default mode network correlates with perceived social support

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ABSTRACT

Perceived social support emphasizes subjective feeling of provisions offered by family, friends and significant others. In consideration of the great significance of perceived social support to health outcomes, attempt to reveal the neural substrates of perceived social support will facilitate its application in a series of mental disorders. Perceived social support potentially relies on healthy interpersonal relationships calling for cognitive processes like perspective taking, empathy and theory of mind. Interestingly, functional activations and connectivity within the default mode network (DMN) are extensively involved in these interpersonal skills. As a result, it is proposed that synchronous activities among brain regions within the DMN will correlate with self-report of perceived social support. In the present study, we tried to investigate the associations between coherence among the DMN regions and perceived social support at resting state. A total of 333 (145 men) participants were directed to fulfill the Multidimensional Scale of Perceived Social Support (MSPSS) after a 484-s functional magnetic resonance imaging (fMRI) scanning without any task. As a result, seed-based functional connectivity and power spectrum analyses revealed that heightened synchronicity among the DMN regions was associated with better performance on perceived social support. Moreover, results in the present study were independent of different methods, structural changes, and general cognitive performance.



## 1. Introduction

Across the long history of human development, human beings benefit to survive in complex social environments from broad social interactions (De Waal, 1982; Cheney & Seyfarth, 2007). Specifically, perceived social support from others can be regarded to reflect the social relations between self and others. Perceived social support puts emphasis on individuals' self-judgment on available social support (Zimet, Dahlem, Zimet, & Farley, 1988; Zimet, Powell, Farley, Werkman, & Berkoff, 1990). As a kind of social connections, perceived social support is proved to contribute to human health outcomes (Gulick, 1994; Helgeson & Cohen, 1996; Feldman, Downey, & Schaffer-Neitz, 1999; Peirce, Frone, Russell, Cooper, & Mudar, 2000). Moreover, relatively low level of perceived social support is associated with multiple mental disorders like loneliness (Solomon, Mikulincer, & Hobfoll, 1986; Jones & Moore, 1987; Cacioppo et al., 2006), anxiety and depression (Cohen & Wills, 1985; Zimet et al., 1988; Peirce et al., 2000; Mustafa, Nasir, & Yusooff, 2010; Hyde, Gorka, Manuck, & Hariri, 2011; Stice, Rohde, Gau, & Ochner, 2011).

As mentioned, the level of perceived social support depends on to what extent individuals are socially connected with others. Generally speaking, healthy social relations call for complex interpersonal skills like perspective taking, empathy and theory of mind. Interestingly, all the mentioned social skills rely on a robust pattern of intrinsic brain activity known as the default mode network (DMN) (for reviews see Schilbach, Eickhoff, Rotarska-Jagiela, Fink, & Vogeley (2008); Mars et al. (2012)). The default mode network, which is more activated during resting state than during goal-directed analyses of environmental stimuli (Shulman et al., 1997; Raichle et al., 2001), is demonstrated to be composed of regions along the anterior and posterior midline, the lateral parietal cortex (LP), prefrontal cortex (PFC), and the medial temporal lobe (Buckner, Andrews-Hanna, and Schacter, 2008). Generally speaking, regions within the default network tend to be activated in multiple cognitive processes like autobiographical memory, thinking about one's future, theory of mind and affective decision making (Ochsner et al., 2004; Buckner et al., 2008; Spreng, Mar, & Kim, 2009).

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In fact, numerous imaging studies confirm the critical role for the DMN in interpersonal skills of perspective taking, empathy and theory of mind. For example, brain regions recruited in adopting the perspective of others versus self-perspective are located at core regions of the DMN in medial prefrontal cortex (PFC) and posterior cingulate cortex (PCC) (Ruby & Decety, 2001, 2003, 2004). Moreover, imaging others in painful situation versus self in painful situation recruits most parts of the default network in PCC/precuneus and the right temporo-parietal junction (TPJ) as well as a cluster in the middle frontal gyrus (Jackson, Brunet, Meltzoff, & Decety, 2006). And empathy elicited by abstract visual information on the other's affective state engages brain areas strongly in precuneus, ventral medial prefrontal cortex (vmPFC), superior temporal cortex, and TPJ, which is suggested to infer and represent mental states of self and other (Lamm, Decety, & Singer, 2011). Besides, theory of mind can be regarded as the cognitive and regulatory component of empathy (Walter, 2012) generating activations in a large network including ventral- and dorsal medial prefrontal cortex (vmPFC and dmPFC), precuneus, TPJ, temporal poles (TP) and superior temporal sulcus (STS) (Frith & Frith, 2003; Gallagher & Frith, 2003; Walter et al., 2004; Frith & Frith, 2006a, 2006b; Carrington & Bailey, 2009). As a whole, extensive involvement of the DMN is revealed in interpersonal skills that are necessary to facilitate healthy social connections.

Generally speaking, recent years witness a rapid increase in studies revealing the critical role of resting-state functional connectivity (RSFC) within the DMN regions in social cognitions like autobiographical memory, empathy and theory of mind (Schilbach et al., 2008; Mars et al., 2012). Higher integration of the orbitofrontal cortex into the anterior DMN at rest is proved to correlate with higher pain ratings of visual stimuli depicting individuals in painful and non-painful situations (Otti et al., 2010). Moreover, functional connections between the TPJ and dmPFC are commonly detected in theory of mind and morality studies (for a review see Li, Mai, & Liu (2014)). In consideration of the extensive activations and connections of the DMN regions in these complex skills for social interactions, it is proposed that RSFC within the DMN regions will correlate with healthy social relations reflected possibly by high level of perceived social support. Moreover, because low-frequency oscillations are believed to contribute to functional connectivity (Cordes et al., 2001) and altered low-frequency oscillations in the DMN are revealed in mental disorders (Garrity et al., 2007), it's interesting to investigate whether low-frequency oscillations in the DMN correlate with self-report of perceived social support. Given the great significance of perceived social support to health outcomes (Gulick, 1994; Helgeson & Cohen, 1996; Feldman et al., 1999; Peirce et al., 2000), attempt to reveal the neural substrates of perceived social support will gain an understanding of these symptoms and may suggest new therapies for these disorders.

In the present study, synchronous activities within the DMN regions were investigated at rest to correlate with perceived social support. Seed-based functional connectivity was analyzed to inspect the synchronicity within the DMN regions. Moreover, synchronous activities within the default network were also assessed with the application of independent component analysis (ICA) to increase the robustness against method impact, followed by correlation analyses between self-report of social support and spectral power of the default component in different frequency bands. ICA was a model free data-driven approach which decomposed the data into independent component (Damaraju et al., 2010). The advantage of ICA over seed-based functional connectivity was that ICA did not require a predefined region of interest (McKeown et al., 1998; Damoiseaux et al., 2006; Kasparek et al., 2013). Besides, self-report of loneliness, general cognitive ability and DMN structure variances (Che et al., 2014) with regard to perceived social support were controlled as of the extensive involvement of the DMN regions in them (Damoiseaux et al., 2008; Cacioppo, Norris, Decety, Monteleone, & Nusbaum, 2009; Kanai, Bahrami, Roylance, & Rees, 2011; Powers, Wagner, Norris, & Heatherton, 2011; Cole, Yarkoni, Repovš, Anticevic, & Braver, 2012; Che et al., 2014Kanai et al., 2012). Taken together, we aimed at testing the hypothesis that coherence among the DMN regions was closely associated with perceived social support.

## 2. Methods

### 2.1. Subjects

Totally 350 right-handed, healthy volunteers participated in this study, of which 11 subjects were excluded for missing any question of the behavioral measures used and six participants were discarded owing to excessive head motions in the scanner. Finally, a total of 333 (145 men) subjects were included to the subsequent analyses. All the participants were undergraduate students of Southwest University. None had a history of neurological or psychiatric illness. The study was approved by Southwest University Brain Imaging Center Institutional Review Board at initial stage. According to the Declaration of Helsinki, all participants signed a written informed consent.

### 2.2. Assessment of perceived social support

The Multidimensional Scale of Perceived Social Support (MSPSS) was built to measure the level of subjective feeling of social support; it was tested to be a psychometrically sound measure of perceived social support (Zimet et al., 1988; Zimet et al., 1990). The MSPSS scale contained 12 items ranging from family, friend to significant other's support. Participants answered questions using a 7-point scale from "strongly disapproval" to "strongly approval". Examples of the MSPSS items were 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).

### 2.3. Assessment of general intelligence

The Raven's Progressive Matrices test was a good measure of the general factor of fluid intelligence (Raven, 1938). In previous studies, the Chinese version of the combined Raven's Progressive Matrices test (CCRPM) was testified to be a psychometrically sound measure of fluid intelligence (Li, Hu, Cheng & Jin, 1988; Wang & Qian, 1989; Wang, Di, & Qian, 2007). The CCRPM was composed of the Colored Progressive Matrices (A, B, and AB sets) and the last three parts of the Standard Progressive Matrices (C, D, and E sets), of which each set included five items with increasing difficulty. Numbers of corrected answers given in 40 min were counted as a measure of the CCRPM score.

### 2.4. Assessment of loneliness

The UCLA Loneliness Scale was a 20-items' questionnaire measuring one's general loneliness and degree of satisfaction with social relationships (Russell, 1996). Participants were instructed that each item described how people sometimes felt, and that they rated each item using a 4-point scale from "never" to "always". An example statement was "How often do you feel that there is no one you can turn to?" After reverse scoring appropriate items, loneliness score was counted by summing the scores of all items ($\alpha = 0.88$).

### 2.5. Imaging data acquisition

Functional images were acquired in a 3.0-T Siemens Trio MRI scanner (Siemens Medical, Erlangen, Germany). The whole-brain resting-state functional images were obtained with the application of gradient-echo echo planar imaging (EPI) sequences with following parameters: slices = 32, repetition time (TR) / echo time (TE) = 2000 / 30 ms, flip angle = 90°, field of view (FOV) = 220 mm × 220 mm, and thickness / slice gap = 3 / 4 mm.

### 2.6. Preprocessing

Preprocessing of the resting-state image data was performed with the application of the data processing assistant for resting state (DPARSF) software (http://www.restfmri.net/forum/DPARSF) (Yan et al., 2009). The toolbox worked on basis of SPM8 software package (Wellcome Trust Center for Neuroimaging, London, England). First 10 volumes of the functional images were discarded accounting