International Journal of Psychophysiology xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

International Journal of Psychophysiology

journal homepage: www.elsevier.com/locate/ijpsycho

Registered Reports

Resting state connectivity mediates the relationship between collectivism and social cognition

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A R T I C L E I N F O

Keywords:
Collectivism
Social cognition
Medial prefrontal cortex
Connectivity
Mediation analysis

A B S T R A C T

Humans are intrinsically social beings and it is natural that self-processing is associated with social cognition. The degree to which the self is perceived as a part of social environment is modulated by cultural stereotypes, such as collectivism and individualism. Here, we tested the hypothesis that individuals who endorse collectivist values would spontaneously think more about their relationships with other people and this association would be mediated by connectivity between the medial prefrontal cortex (MPFC) and the rest of the brain. Connectivity was evaluated based on resting state EEG data using the recently developed methods, which combine beamformer spatial filtering with seed based connectivity estimation. The formal mediation analysis revealed that collectivism is associated with an enhanced connectivity of MPFC with a set of cortical regions that are frequently co-activated in moral reasoning, empathy, and theory of mind tasks and with diminished connectivity with the precuneus\posterior cingulate cortex, which is involved in self-centered cognition. The relationship between collectivism and social cognition was mediated by MPFC connectivity with the left middle temporal gyrus implying that in participants with collectivistic attitude, thinking about relationships with other people may be associated with semantic memory retrieval and reasoning on moral issues and others' intentions.

1. Introduction

Humans are intrinsically social beings. Sociality is not just a component of human behavior and mind, but also the very thing that shaped the human brain (Dunbar and Shultz, 2007). It is only natural then that self-processing is inextricably linked with social cognition. This link has been noted both in social psychological research, e.g., in the concepts of relational and interdependent self-construal (Markus and Kitayama, 1991), and in neuroscience, whereby self-processing and social processing are largely ascribed to the same brain regions (e.g., Buckner et al., 2008; Spreng et al., 2008). However, the degree to which the self is perceived as a part of social environment is modulated by cultural stereotypes. (Markus and Kitayama, 1991) coined the term self-construal in describing the ways in which representatives of different cultural groups define and make meaning of the self. Particularly, they identified independent and interdependent self-construals and proposed that Europeans and Americans construe the self as fundamentally individual and separate from others, whereas East Asians tend to construe the self as fundamentally connected to others. However, cultures do not reside exclusively within respective countries and people within a country may differ in the degree to which they adopt individualist and collectivist attitudes (Triandis, 1995). This is particularly true in cultures, which combine Western and Eastern values. Hence, individualism and collectivism could be investigated both at the cultural level and at the individual level. For instance, they are considered opposite sides of a single dimension at the cultural level, but are frequently treated as orthogonal dimensions at the individual level (Triandis and Gelfand, 1998).

With the advent of brain imaging, it has become possible to study the representation of social cognition in the human brain. Interdisciplinary fields, such as social neuroscience (Cacioppo et al., 2011) and cultural neuroscience (Chiao, 2009), which aim to explain social and cultural mental phenomena in terms of a synergistic product of mental and neural events, are rapidly developing. These fields primarily adopt the experimental methods of social and cultural psychology as the means to uncover the brain underpinning of the processing of social cues in representatives of different cultures (Han and Northoff, 2008). There is reason to believe, however, that the processing of external cues is only the tip of the iceberg in the mental life of a human being, most part of which proceeds in the so-called resting state.

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https://doi.org/10.1016/j.ijpsycho.2017.12.002
Received 23 September 2017; Received in revised form 13 November 2017; Accepted 2 December 2017
0167-8760/

This could be deduced indirectly from the fact that relative to the high rate of ongoing energy consumption by the brain (which is 20% of the body's energy budget, (Clarke and Sokoloff, 1999)), the additional energy consumption associated with task-evoked changes is < 5% (Raichle, 2015; Raichle and Mintun, 2006). Spontaneous cognition, which is differentially called daydreaming, mind wandering, or stimulus-independent thoughts (Andrews-Hanna et al., 2010), routinely involves thoughts about one's personal past and future as well as thoughts about relationships with others. Functional magnetic resonance imaging (fMRI) and positron emission tomography studies of brain activity in the resting state and during transition from rest to task processing allowed discovering the so-called default mode network (DMN), which is active in the resting brain and deactivates during the initiation of task-related activity (Raichle et al., 2001). The DMN includes the precuneus/posterior cingulate cortex (PCC), the medial prefrontal cortex (MPFC), and medial, lateral, and inferior parietal cortex, which show a high degree of functional interconnectivity in the resting state (Greicius et al., 2003). An exception to the general pattern of deactivation of the DMN during goal-directed activity is observed in tasks, which include self-referential thoughts and social cognition (e.g., Gobbini et al., 2007), raising the possibility that the DMN supports these mental processes (Gusnard et al., 2001; Mitchell, 2006).

The overwhelming majority of studies in this field has been conducted using fMRI. Recently, it has been shown that the DMN also emerges from source-level connectivity patterns derived from magnetoencephalographic and electroencephalographic (EEG) data (Brookes et al., 2011a, 2011b; de Pasquale et al., 2010; Hipp et al., 2012; Knyazev et al., 2011, 2016, 2017; Siems et al., 2016). These findings are important, because they confirm the neural basis of the DMN.

In this study, we proceeded from an assumption that individuals who endorse collectivist values would spontaneously think more about their relationships with others and this association would be mediated by connectivity between the MPFC and the rest of the brain. MPFC, the pivotal DMN hub, has been chosen because among other DMN hubs, it is most strongly associated with both self-referential and social cognition (Gusnard et al., 2001; Schmitz et al., 2004; Seger et al., 2004; Han and Northoff, 2009). We hypothesized that connectivity between MPFC and emotional brain circuits would be particularly engaged. Connectivity was evaluated based on resting state EEG data using the recently developed methods, which combine beamformer spatial filtering with seed based connectivity estimation.

2. Methods

2.1. Participants

The sample included 85 Caucasians (mean age = 22.7, SD = 4.9, 68% females). Undergraduate and graduate students made up the majority of the sample (75%). The majority of nonstudents had university diploma and were schoolteachers, physicians, and University staff members. Participants were included in the study if they had no history of neurological or psychiatric disorders, no alcohol or drug dependence, and no current treatment with vasoactive or psychotropic drugs. All subject protection guidelines were followed in accordance with the Declaration of Helsinki. Each participant signed an informed consent. Participation was rewarded with a sum equivalent to about 5% of the monthly living wage. The study was approved by the Institute of Physiology and Fundamental Medicine ethical committee.

2.2. Procedure

During EEG recording, participants sat in a soundproof dimly illuminated room and were asked to minimize movement and blinking. The procedure consisted of ten one-minute recordings (5 with eyes closed and 5 with eyes open) alternating sequentially. During the eyes open condition, participants were asked to look at an empty computer screen, which was situated at a distance of 120 cm from the participant. Only the latter condition was used in the analysis based on the observation that resting-state connectivity diminishes in the eyes closed, compared to the eyes open condition (Van Dijk et al., 2009). Just after the spontaneous EEG registration, participants were asked to fill out the Spontaneous Thoughts Questionnaire (STQ, Knyazev et al., 2012). After that, they participated in other experiments that are not reported here. Eventually they filled in a set of questionnaires and were debriefed.

2.3. Measures

The STQ (Knyazev et al., 2012) was designed to measure different aspects of subject's state, thoughts, and feelings during spontaneous EEG registration (see Appendix for the current version). All items were measured on a five-point Likert scale. Principal components factor analysis with varimax rotation was conducted in the total sample of subjects (N = 85). Examination of the eigenvalues and scree plot for a principal component analysis revealed that a four-factor solution best fitted the data. Accordingly, four scales were created that described nervousness/negative emotion (example item: “felt nervous”); self-referential thought (example item: “recollected episodes from my own life”); social cognition (example item: “thought how my close relatives feel about me”); arousal level (example item: “was almost asleep”).

The Self-Construal Scale (SCS, Singelis, 1994) contains two 12-item subscales assessing on a 7-point Likert scale the interdependent and independent self-construals and has shown good reliability in Russia (Dorosheva et al., 2016). Since we were interested in collectivism vs. individualism effect, the independent self-construal scale was reversely coded and summed with the interdependent self-construal scale, thus forming a combined collectivism-individualism scale (here after ‘collectivism’), Cronbach's alpha = 0.70.

2.4. EEG recording

118 electrodes mounted in the Quik-Cap128 NSL according to the extended International 10–10 system were used for EEG acquisition. The electrooculogram was recorded simultaneously. ‘Neuroscan (USA)’ amplifiers with a 0.1–100 Hz analog bandpass filter were used for signal amplification. The sampling rate was 1000 Hz. FASTRAK digitizer (Polhemus) was used to measure the position of each electrode and the three fiduciary points (nasion and two preauricular points). Frontocentral electrode was used as the ground and Cz as the reference. Electrode impedances were kept at or below 5 kilo-ohms. EEG data were recomputed to the average reference offline and artifacts were corrected using independent component analysis (ICA) via the EEGlab toolbox (http://www.sccn.ucsd.edu/eeglab/).

2.4.1. Filtering the data to the frequency band of interest

Fig. 1 presents a flowchart of EEG data analysis. In most published studies, most reliable DMN signatures were revealed in the alpha frequency band (Ben-Simon et al., 2008; Brookes et al., 2011b, 2012; Chen et al., 2012; de Pasquale and Marzetti, 2014; Knyazev et al., 2011; Luckhoo et al., 2012; Sadaghiani et al., 2010, 2012; Wens et al., 2014). Therefore, only this band was investigated in this study. The alpha band boundaries were determined for each participant separately using individual alpha peak frequency (IAF) as the anchor point (Doppelmayr et al., 1998) and the methodology described in Lansbergen et al. (2011). First, in the eyes closed condition, the frequency of maximal alpha power at the parietal and occipital electrodes within 5–15 Hz was determined. Next, EEG spectrum data in the eyes open condition were subtracted from the EEG spectrum data in the eyes closed condition to determine the frequency at which alpha power was most attenuated by opening of the eyes. If results of the two methods differed > 0.5 Hz, the IAF was determined by visual inspection of the EEG spectrum. The bandwidth for the alpha frequency band was defined as 0.8*IAF–1.2*IAF. EEG data were frequency filtered into these boundaries