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Self-referential reflective activity and its relationship with rest: a PET study

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This study used positron emission tomography (PET) to identify the brain substrate of self-referential reflective activity and to investigate its relationship with brain areas that are active during the resting state. Thirteen healthy volunteers performed reflective tasks pertaining to three different matters (the self, another person, and social issues) while they were scanned. Rest scans were also acquired, in which subjects were asked to simply relax and not think in a systematic way. The mental activity experienced during each scan was assessed with rating scales. The results showed that, although self-referential thoughts were most frequent during the self-referential task, some self-referential reflective activity also occurred during rest. Compared to rest, performing the reflective tasks was associated with increased blood flow in the dorsomedial prefrontal cortex, the left anterior middle temporal gyrus, the temporal pole bilaterally, and the right cerebellum; there was a decrease of blood flow in right prefrontal regions and in medial and right lateral parietal regions. In addition, the ventromedial prefrontal cortex (VMPFC) (1) was more active during the self-referential reflective task than during the other two reflective tasks, (2) showed common activation during rest and the self-referential task, and (3) showed a correlation between cerebral metabolism and the amount of self-referential processing. It is suggested that the VMPFC is crucial for representing knowledge pertaining to the self and that this is an important function of the resting state.

Keywords: Medial prefrontal cortex; Self-referential processing; Rest; Neuroimaging; PET

Introduction

Recent neuroimaging studies have begun to unravel the neural basis of various aspects of self-referential processing, such as recognizing one's own face (Keenan et al., 2000; Kircher et al., 2001), detecting one's own first name (Perrin et al., 2005), attributing actions to oneself (Farrer et al., 2003; Ruby and Decety, 2001), reflecting on one's own abilities, personality traits or attitudes (Fossati et al., 2003; Johnson et al., 2002; Kelley et al., 2002; Kjaer et al., 2002; Schmitz et al., 2004), and remembering previous judgements about oneself (Lou et al., 2004). Many of these studies point to cortical midline structures as brain regions essential for representing, monitoring, evaluating, and integrating self-referential stimuli (Northoff and Bermpohl, 2004). In particular, the medial prefrontal cortex (MPFC) seems to be important for reflecting on knowledge about the self. For instance, the MPFC has repeatedly been found to be activated when people reflect on their own personality traits as compared to when they reflect on the traits of another person or when they perform other kinds of semantic processing (Fossati et al., 2003; Johnson et al., 2002; Kelley et al., 2002; Kjaer et al., 2002; Schmitz et al., 2004).

Several studies and meta-analyses have revealed that levels of blood flow in medial prefrontal and parietal cortices decrease when people perform various cognitive tasks compared to a resting baseline (Binder et al., 1999; Mazoyer et al., 2001; McKiernan et al., 2003; Shulman et al., 1997; Wicker et al., 2003). The consistency with which these task-induced deactivations are observed across a wide variety of studies suggests that these decreases in cerebral blood flow are caused by interruption of processes that usually occur in the resting state (Gusnard and Raichle, 2001). According to this view, "rest" is not at all restful but is a state of organized, functional brain activity that is suspended or interrupted during various goal-directed behaviors. The mental activity that occurs during "rest" could involve many processes, including monitoring of external environment and body state (Gusnard and Raichle, 2001); attention to self-referential information (Wicker et al., 2003); stimulus-independent thought (McGuire et al., 1996); planning and problem-solving (Binder et al., 1999). These processes are in no way mutually exclusive, and it seems quite likely that different brain areas that are active during the resting state are involved to different degrees in these and other processes. With regard to the MPFC, Wicker et al. (2003) proposed

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that this structure is involved when subjects are engaged in tasks that refer to internally triggered processes versus tasks that refer to external percepts (internally versus externally directed attention), and that both self-referential reflective tasks and the resting state involve some amount of internally directed attention in order to retrieve and inspect information about the self. Gusnard and Raichle (2001) further suggested that the ventral and dorsal parts of the MPFC may serve different functions, with the ventromedial prefrontal cortex (VMPFC) being involved in the integration of cognitive and emotional processes while the dorsomedial prefrontal cortex (DMPFC) is involved in self-referential mental activity. However, a substantial number of recent neuroimaging studies have reported activation of the VMPFC during self-referential reflective tasks (Johnson et al., 2002; Kelley et al., 2002; Schmitz et al., 2004). Northoff and Bermpohl (2004) recently proposed that the VMPFC is involved in the continuous representation of self-referential stimuli, whereas the DMPFC is involved in the evaluation of these stimuli. However, the precise relationship between these processes and the resting state is not yet well understood.

The purpose of the present study was precisely to further examine brain regions that are active during the resting state and to better investigate their relationship with brain regions that support self-referential reflective activity. More specifically, given that previous studies comparing the resting state with goal-directed cognitive processing used tasks in which subjects' attention was directed towards externally presented stimuli (Binder et al., 1999; Mazoyer et al., 2001; McKiernan et al., 2003; Shulman et al., 1997; Wicker et al., 2003), the first aim of this study was to examine whether the increases and decreases in brain activity that occur when performing these tasks are also found when rest is compared to tasks involving internally instead of externally directed attention (i.e., tasks that do not require processing of external stimuli). To this end, rest was compared to reflective tasks in which subjects' mental activity was exclusively internal (i.e., no stimuli were presented during the scans and no responses were required), so that these tasks were closely matched to the resting state in this respect. Our second purpose was to identify the brain regions that are specifically involved in self-referential reflective activity and to determine whether these regions are also active during the resting state. Accordingly, three reflective conditions were used in which participants had to focus their mental activity on specific topics pertaining either to the self or to other matters (i.e., another person or social issues). The brain substrate of self-referential reflective activity was identified, firstly, by comparing the self-referential reflective task to reflective tasks pertaining to other matters and, secondly, by correlating cerebral metabolism with the percentages of self-referential thought (as assessed by rating scales) across all conditions. Finally, the cerebral areas that are commonly activated by rest and by the self-referential reflective task were determined by means of a conjunction analysis.

Methods

Subjects

Thirteen right-handed volunteers from the University of Liège (7 women, 6 men; age range, 21 to 28 years) participated in the study. None had any significant history of neurological or psychiatric problems nor did they use any medication. The study was approved by the Ethics Committee of the Faculty of Medicine of the University of Liège. After the study was described in detail for the subjects, they gave their informed consent in writing. Data from one male participant were discarded because he did not follow the experimental instructions properly.

Reflective tasks

Three reflective conditions were used: reflection on one's own personality traits ("self" condition); reflection on the personality traits of another person ("other" condition); reflection on social issues ("society" condition). Subjects were scanned three times for each condition, the topics being slightly different for each scan: for the "self" condition, subjects were asked to think of their own personality traits in three different contexts (profession, family, and social relations); for the "other" condition, they were asked to think of the personality traits of three different persons (the French president Jacques Chirac, the French singer Johnny Hallyday, and the Belgian princess Mathilde); for the "society" condition, they were asked to think about three different social issues (social security, the right to vote, and globalization of trade). A fourth condition was also included, which corresponded to rest. In this condition, subjects were asked to simply relax and not think in a systematic way but to open themselves to any images, thoughts or memories that appeared spontaneously. Three rest scans were administered randomly.

For each scan, the procedure was as follows: 45 s before the beginning of the scan, the experimenter asked subjects to close their eyes and relax; 15 s later (i.e., 30 s before the scan), the experimenter read the instructions pertaining to the reflective task or the rest period (e.g., "Now you will be asked to think about yourself for about 2 min. More specifically, I would like you to consider the traits and attitudes you have in the context of social relations. Try to think about your traits and attitudes, about your personality, in your relationship with others."). The length of the instructions was similar for the four conditions (mean number of words was 49 for the "self" condition, 49 for the "other" condition, 48 for the "society" condition, and 46 for the "rest" condition). Following the experimenter's instructions, subjects began reflecting on the topic 5 s before the scan and ended their reflection 5 s after the scan, thereby thinking about each topic for 100 s. Subjects kept their eyes closed for the entire scan; no stimuli were presented and no motor responses were required. Thus, unlike earlier studies that compared rest to goal-directed cognitive tasks, subjects' activity during the reflective tasks was exclusively internal (i.e., the tasks did not require the processing of external stimuli) so that the reflective conditions and rest were closely matched in this respect. Immediately after each scan, subjects were asked to verbally report the thoughts, images, and/or memories they had had while they were reflecting on the topic. Then they rated several aspects of the mental activity they had experienced during the scan, including amount of visual images; thoughts (i.e., total amount of thoughts experienced, whatever their content); relative amount of thoughts about the self; thoughts about other persons; memories; physical sensations. Ratings were made on 10-point scales (e.g., *I experienced visual images*: 1, not at all; 10, all the time). Subjects also evaluated the amount of time they had thoughts, images, and/or memories that were directly related to the topic they were asked to think about (in percentage of total scan time). Verbal reports and ratings were made without time constraints.