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Ego-rotation and object-rotation in major depressive disorder

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ABSTRACT

Mental rotation (MR) performance provides a direct insight into a prototypical higher-level visuo-spatial cognitive operation. Previous studies suggest that progressive slowing with an increasing angle of orientation indicates a specific wing of object-based mental transformations in the psychomotor retardation that occurs in major depressive disorder (MDD). It is still not known, however, whether the ability of object-rotation is associated with the ability of ego-rotation in MDD. The present study was designed to investigate the level of impairment of mental transformation abilities in MDD. For this purpose we tested 33 MDD (aged 18–52 years, 16 women) and 30 healthy control subjects (15 women, age and education matched) by evaluating the performance of MDD subjects with regard to ego-rotation and object-rotation tasks. First, MDD subjects were significantly slower and made more errors than controls in mentally rotating hands and letters. Second, MDD and control subjects displayed the same pattern of response times to stimuli at various orientations in the letter task but not the hand task. Third, in particular, MDD subjects were significantly slower and made more errors during the mental transformation of hands than letters relative to control subjects and were significantly slower and made more errors in physiologically impossible angles than physiologically possible angles in the mental rotation hand task. In conclusion, MDD subjects present with more serious mental rotation deficits specific to the hand than the letter task. Importantly, deficits were more present during the mental transformation in outward rotation angles, thus suggesting that the mental imagery for hands and letters relies on different processing mechanisms which suggest a module that is more complex for the processing of human hands than for letters during mental rotation tasks. Our study emphasises the necessity of distinguishing different levels of impairment of action in MDD subjects.

1. Introduction

Mental rotation (MR) is the ability to rotate mental representations of two- and three-dimensional objects, and usually involves the creation of a mental image of an object and its subsequent rotation. It is often cited as a prototypical higher-level visuo-spatial cognitive operation. At least two types of mental transformation can be distinguished: object-based mental transformations (object-rotation) and egocentric mental transformations (ego-rotation). Object-rotation concerns the representation of an external object, which is mentally transformed (i.e., rotated or translated) in space. Ego-rotation concerns the mental representation of one's own body or body part, which is imagined to be moving relative to the environment (Parsons, 1987). This increase in reaction time (RT) that is proportional to the orientation of the stimulus has been demonstrated for many different types of external objects, such as three-dimensional shapes (Shepard and Metzler, 1971), alphanumeric characters (Cooper and Shepard, 1973), and novel pictures of common objects (Jolicoeur, 1985). However, stimuli pertaining to the human body might lead to different patterns of results. The mental imagery of body parts has generally been investigated by using a laterality or handedness judgement task. Numerous authors (e.g., Sekiyama, 1982; Parsons, 1987; Zacks et al., 1999) have administered tasks in which subjects are presented with pictures of body parts in different postures and rotated angles and are asked to determine whether it is a body part that belongs to the right or left side of the body. These authors reported that in this particular situation subjects tend to spontaneously imagine their own body part in the orientation of the stimulus. During that procedure they seem to mentally simulate the kinematic properties of the physical action of their body part moving from its resting posture to that of the stimulus.

Clinical studies have revealed those with major depressive disorder (MDD) were impaired significantly in attention and executive function and visuo-spatial learning and memory,

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compared with controls (Asthana et al., 1998; Porter et al., 2003). Psychomotor disturbances in MDD might not be simply a secondary reaction to impaired mood and motivation, but rather a reflection of an underlying neurophysiological deficit (Rogers, 1986). This type of impairment might also be an important and possibly defining marker of MDD in particular (Nelson and Charney, 1981). Any motor slowing in MDD, however, has been thought to stem from a functional, rather than a structural deficit, given the typically good response to somatic treatment. Indeed, psychomotor signs might be among the first to remit (Sobin and Sackheim, 1997). MDD subjects exhibited a cognitive component (slowing) on a motor task. Bradyphrenia may play a role in psychomotor retardation, specifically in terms of slowed motor preparation (Rogers et al., 2002).

Mental rotation may be useful for assessing the potential role of bradyphrenia in the slowed motor preparation that occurs during psychomotor retardation. Mental rotation requires the integrity of specific cortical–subcortical motor structures (motor and premotor areas and basal ganglia) and sensory systems (somatosensory and visual) (de Lange et al., 2006). Mental rotation engages an anatomically interconnected system implicated in the integration of sensory information with motor actions. The mental simulation of real perceptual–motor behaviours could be considered a sort of internal or cognitive analogue of actual movements (Duncombe et al., 1994). This stimulation likely taps the cortical regions and mechanisms involved in motor preparation, particularly motor anticipation, that is, the anticipation of the likely consequences of a motor action (Rogers et al., 2002). As such, mental rotation may be considered a mental analogue of bradykinesia rather than as a measure of global bradyphrenia.

However, relatively recent studies in healthy participants have suggested that object-rotation and ego-rotation rely on different cognitive and neural mechanisms (Kosslyn et al., 1998; Vingerhoets et al., 2001; Wraga et al., 2005; Buxbaum et al., 2005; Lenggenhager et al., 2008; Grabherr et al., 2011). Moreover, Harris and Miniussi (2003) and Overney et al. (2005) found evidence of the exclusive right hemisphere involvement in the mental transformation of alphanumeric characters. Using fMRI, Wraga et al. (2005) showed that this process relies on both hemispheres for the mental transformation of stimuli depicting the entire body but predominantly relies on the left hemisphere at the junction of the temporal, occipital, and parietal lobes. In contrast, using a similar task, Arzy et al. (2006) used ERP mapping and found that the mental transformation of entire bodies activated the temporo-parietal junction bilaterally with a right hemispheric predominance. In addition, the temporo-parietal junction was also found to be involved in the integration of multisensory body-related information (Wraga et al., 2005; Blanke and Arzy, 2005). A number of clinical studies have investigated the influence of vestibular information on object rotation and ego rotation. Performance was impaired during right anodal stimulation but, interestingly, only when participants were engaged in an egocentric mental transformation strategy (Lenggenhager et al., 2008). Body parts were more difficult to mentally rotate than objects (Rumiati et al., 2001; Tomasino et al., 2003; de Vignemont et al., 2006; Overney and Blanke, 2009). However, these cognitive tasks have not yet been simultaneously tested in MDD subjects. In the present study, we wanted to determine whether MDD patients would be more impaired in rotating the representation of their hands than letters.

The aim of this study was to evaluate whether MDD can result in different degrees of deficit in object-based and egocentric mental transformation abilities. Based on the previous literature (Rogers et al., 2002; Kosslyn et al., 1998; Asthana et al., 1998; Molloy et al., 2003; Fiorio et al., 2003), we expect that MDD patients will have difficulty performing the tasks. We also hypothesise that if MDD patients are impaired at motor imagery, they are also slower and make more errors than controls while mentally rotating hands and letters. Moreover, we predicted that the patterns of RTs and ERs would result from the absence of a typical mental rotation function and different processing mechanisms would be found between object-rotation and ego-rotation in MDD. The study on motor imagery is particularly relevant for investigating the degree of impairment of visuo-spatial cognition and provides further evidence for the processing mechanism in spatial cognition in MDD. Our patients' impaired performances may also be due to the dysfunction of the primary somatosensory area and higher order parietal areas. Such impairment may also be an important and possibly defining marker of MDD. Knowing more about the cognitive consequences of the processing mechanisms of mental rotation will provide a more profound understanding of such patients and may help to establish rehabilitation procedures along those lines.

2. Materials and methods

2.1. Participants

Patient group: A total of 33 MDD outpatients and inpatients (17 males and 16 females; mean age 27.0 ± 6.0 years) were recruited for this study from the *Center for Mental Disease Control and Prevention, Third Hospital of the People's Liberation Army, Baoji, China,* from October 2010 to November 2011. They were diagnosed by two experienced psychiatric doctors. The mean average illness duration was 11.8 ± 2.4 months. Inclusion criteria: depressive outpatients and inpatients whose symptoms met the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition Text Revision, formulated by American Psychiatric Association (DSM-IV-TR). Clinical symptoms of MDD were evaluated by 17-Item Hamilton Depression Rating Scale ($HDRS_{17}$) (Zheng et al., 1988) with a minimum score of 24 needed to participate. Patients were right-handed (laterality index range: +80 to +100) and had normal or corrected-to-normal vision. Patients with a personal history of psychotic or neurological illness, other brain disorders, severe physical disease, and dementia were excluded. All patients were taking standard antidepressant medications and were clinically stable at the time of testing.

Control group: A total of 30 non-depressed, healthy control participants (15 males and 15 females; mean age 26.8 ± 4.9 years) from the trainees, interns and hospital staffs at the Baoji Third Hospital of the People's Liberation Army of China were recruited. These individuals were matched with patients on demographic factors (handedness, age, education, and gender). None of these control participants had a history of alcoholism or drug abuse or family history of psychiatric illness. Table 1 provided group information about age, gender, and education. All participants were paid for participating and gave written informed consent in line with procedures approved by the Human Participants Ethics Committee of the Baoji Third Hospital of the People's Liberation Army. Protocols were performed in accordance with the Administrative Regulations on *Medical Institution*, formulated by State Council of the People's Republic of China.

2.2. Apparatus

2.2.1. Hand task

The hand task stimuli consisted of one photograph of a female hand (height: 11.7° visual angle, width: 8.0° visual angle). The hand was always shown with the palm pointing downwards. This photograph was edited with Photoshop CS3 Extended software (version 10.0.1, 2007) to create identical pictures of a right

Table 1
Group characteristics comparison of baseline data between major depressive disorder (MDD) and control group (CG).

Item	MDD	CG	χ^2	t
Participants (n)	33	30		
Age [mean (S.D.)]	27.0 (6.0)	26.8 (4.9)		0.141
Education [mean(S.D.)]	14.3 (2.1)	14.4 (3.6)		0.122
Gender (male/female, n)	17m/16f	15m/15f	0.026	
$HDRS_{17}$ total score [mean(S.D.)]	29 (5)	–		

$HDRS_{17}$: 17 items in the Chinese Hamilton Depression Rating Scale; S.D.: standard deviation.

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