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Mental rotation of body parts and non-corporeal objects in patients with idiopathic cervical dystonia

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Abstract

Mental rotation of body parts is performed through inner simulation of actual movements, and is likely to rely upon cortical and subcortical systems (e.g. motor and premotor areas and basal ganglia) involved in motor planning and execution. Studies indicate that sensory and motor deficits, such as for example pain, limb amputation or focal hand dystonia, bring about a specific impairment in mental rotation of the affected body parts. Here we explored the ability of patients affected by idiopathic cervical dystonia (CD) to mentally rotate affected (neck) and unaffected (hands and feet) body districts. The experimental stimuli consisted of realistic photos of left or right hands or feet and the head of a young men with a black patch on the left or the right eye. As non-corporeal stimulus the front view of a car with a black patch on the left or the right headlight was used. The stimuli were presented at six different degrees of orientations. Twelve CD patients and 12 healthy participants were asked to verbally report whether the hands or feet were left or right, or whether the patch was on the left or the right eye or headlight. Reaction times and accuracy in performing the laterality tasks on the four stimuli were collected. Results showed that CD patients are slow in mental rotation of stimuli representing body parts, namely hand, foot and head. This abnormality was not due to a general impairment in mental rotation per se, since patients' ability to rotate a non-corporeal object (a car) was not significantly different from that of healthy participants. We posit that the deficit in mental rotation of body parts in CD patients may derive from a defective integration of body- and world-related knowledge, a process that is likely to allow a general representation of "me in the external world".

Keywords: Motor imagery; Body schema; Torticollis; Basal ganglia; Egocentric space

1. Introduction

Goal-directed actions are accomplished not only by regularly monitoring the position of our body in space but also by predicting the correct sequence of movements to be executed and the final position of our body parts. Mental rotation of corporeal objects, i.e. the ability to imagine how a body part would look if rotated away from its prototypical orientation (Thayer, Johnson, Corballis, & Hamm, 2001), is likely to contribute to the prediction process. Indeed, mental rotation of body parts seems to be carried out by simulating the actual movement of the very same body part (Parsons, 1994). The mental simulation of real perceptual-motor behaviours could be considered a sort of internal or cognitive analogue of actual movements (Duncombe, Bradshaw, Iansek, & Phillips, 1994), useful for movement planning and prediction. The important role of the parietal cortex in this task has been highlighted by

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lesion studies in patients (Sirigu et al., 1995, 1996; Sirigu & Duhamel, 2001). In particular, Sirigu and Duhamel (2001) found a functional dissociation between visual and motor imagery in two patients with lesions located in different brain regions. A patient with a left parietal lobe tumour was impaired in tasks requiring mental motor imagery; on the contrary a patient with bilateral inferotemporal damage was impaired in mental visual imagery (Sirigu & Duhamel, 2001). Moreover, cortical neural networks including posterior parietal (Brodmann areas 5 and 7) and visual cortex, premotor and supplementary motor areas and primary motor cortex are activated during mental rotation of objects and body parts (Bonda, Petrides, Frey, & Evans, 1995; Ganis, Keenan, Kosslyn, & Pascual-Leone, 2000; Kosslyn, DiGirolamo, Thompson, & Alpert, 1998; Parsons et al., 1995). Further research has demonstrated that during mental rotation tasks sub-cortical structures, such as the basal ganglia, are also activated (Alivisatos & Petrides, 1997). Since basal ganglia and motor cortices are known to be involved in motor planning and execution, their activation during mental rotation suggests that actual and mentally simulated movements share largely overlapping cerebral structures.

The ability to perform mental rotation of body parts is strictly linked to the concept of “body schema”, a term that alludes to the complex of sensations, perception, memories and ideas about one’s own and others’ anatomy (Berlucchi & Aglioti, 1997). This mental construct about the body allows people to evaluate active and passive postural changes and movements, to localize tactile stimuli, to move, name, and point to specified body parts, and in general to map sensory inputs and motor outputs onto an orderly topographical model of the external anatomy of the human body. Some pathological conditions can cause changes in the mental representation of the body, thus influencing the ability to mentally rotate body parts. Recent studies have shown that brain representation of the body is modulated by peripheral alterations, such as pain (Moseley, 2004; Schwoebel, Friedman, Duda, & Coslett, 2001) and limb amputation (Nico, Daprati, Rigal, Parsons, & Sirigu, 2004). In a similar vein, we have reported in patients with focal hand dystonia with sustained muscular contractions localized to the dominant hand, an impairment of mental motor rotation of the affected body part (Fiorio, Tinazzi, & Aglioti, 2006). More specifically, patients were slower than control subjects in mentally rotating pictures of a hand (the affected body part) but not of another body segment, such as the foot. Here we sought to determine the specificity of the influence of actual motor disorders on mental rotation of body parts by testing patients affected by idiopathic cervical dystonia (CD), the most common adult-onset form of focal dystonia that is characterised by involuntary neck muscles contraction that induce abnormal head rotations and neck postures (Jankovic, Leder, Warner, & Schwartz, 1991; Nutt, Muenter, Aronson, Kurland, & Melton, 1988). We used laterality tasks, similar to that used in our study with focal hand dystonia patients (Fiorio et al., 2006), to assess the ability of patients with CD and healthy controls in mentally rotating different body parts (hands, feet, head, Experiment 1). Moreover, we further assessed the specificity of body representation by testing CD patients in a mental rotation task of non-corporeal objects (car, Experiment 2).

Table 1
Patients’ demographic and clinical information

Patient	Gender	Age (years)	Education (years)	Torticollis[a]	Severity score[b]
1	F	60	18	Left	3
2	M	63	18	Right	4
3	F	59	13	Right	9
4	F	59	5	Right	2.5
5	M	54	18	Left	7
6	F	44	14	Left	3
7	M	59	13	Left	2.5
8	F	68	5	Left	5
9	F	33	11	Right	9
10	M	67	8	Left	6
11	M	69	5	Right	5
12	F	71	8	Left	3

[a] Side of rotation of the neck.
[b] Burke–Fahn–Marsden movement and disability scale.

2. Methods

2.1. Subjects

We tested 12 right-handed patients affected by idiopathic cervical dystonia (7 women) and 12 right-handed healthy subjects (7 women) matched for age (mean 52.7 years, range 32–70) and education (mean 10.8 years of schooling, range 5–18). Duration of patients’ disease ranged from 4 to 11 years. Severity of motor impairment was evaluated by using the Burke–Fahn–Marsden movement and disability scale (Burke et al., 1985). Biochemical, computed tomography and magnetic resonance imaging examinations were normal, thus suggesting that dystonia was idiopathic. Four patients were untreated; the remaining eight patients had received treatment with botulinum toxin until 6 months before the study. Additional demographic and clinical information on the patient group is provided in Table 1.

All subjects gave their written informed consent after the non-therapeutic nature of the experimental tests was explained to them. Before testing, all subjects were naive about the aims of the experiments. The procedures were approved by the Local Ethics Committee of the University of Verona. All subjects were tested in the laterality judgements of body parts (hands, feet, head, Experiment 1). In addition, in order to assess the specificity of body representation, we added a further control task by testing subjects in a laterality judgement of a non-corporeal object, such as a car (Experiment 2). The order of the two experiments was counterbalanced across subjects; in view of this, the task with the non-corporeal object could be performed at the beginning as well as at the end of the whole experimental procedure.

2.2. Experiment 1

Subjects sat in front of a computer screen with their hands out of sight on their laps. The experiment was programmed using E-Prime, Beta software running on a PC. Stimuli consisted of realistic photos of a hand, a foot, and the head of a young men (Fig. 1). On each trial, subjects were asked to look at a computer screen and to maintain eyes steady on the screen throughout the entire perception-verbal report cycle. Patients’ head was kept straight by an examiner during stimuli delivery. Stimuli were large approximately 9.3 cm along the widest axis, which corresponded to about 10.65° of horizontal visual angle with participants’ viewing distance of 50 cm. Left and right hands (and feet) were mirror images of each other and could be presented in four views (back in picture plane, palm in picture plane, side from little finger and side from thumb). The head was presented only in the front side and had a black patch on either the left or the right eye. All stimuli were presented in six orientations (0°, 60°, 120°, 180°, 240° and 300°).

A total of 144 stimuli was delivered: 48 in the ‘hand block’, 48 in the ‘foot block’ and 48 in the ‘head block’. The three sessions were presented in counterbalanced order between the subjects. After each stimulus presentation, subjects