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Mental rotation and working memory in musicians' dystonia

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ABSTRACT

Background: Mental rotation of body parts engages cortical-subcortical areas that are actually involved in the execution of a movement. Musicians' dystonia is a type of focal hand dystonia that is grouped together with writer's cramp under the rubric of "occupational dystonia", but it is unclear to which extent these two disorders share common pathophysiological mechanisms. Previous research has demonstrated patients with writer's cramp to have deficits in mental rotation of body parts. It is unknown whether patients with musicians' dystonia would display similar deficits, reinforcing the concept of shared pathophysiology.
Methods: Eight patients with musicians' dystonia and eight healthy musicians matched for age, gender and musical education, performed a number of tasks assessing mental rotation of body parts and objects as well as verbal and spatial working memories abilities.
Results: There were no differences between patients and healthy musicians as to accuracy and reaction times in any of the tasks.
Conclusions: Patients with musicians' dystonia have intact abilities in mentally rotating body parts, suggesting that this disorder relies on a highly selective disruption of movement planning and execution that manifests only upon playing a specific instrument. We further demonstrated that mental rotation of body parts and objects engages, at least partially, different cognitive networks.

1. Introduction

Motor imagery is defined as the mental process by which an individual rehearses or simulates a given action (Thayer, Johnson, Corballis, & Hamm, 2001). Motor imagery engages brain areas that are also active during the observation and/or execution of actions such as the sensorimotor cortices and basal ganglia (Alivisatos & Petrides, 1997; de Lange, Hagoort, & Toni, 2005; Vingerhoets, de Lange, Vandemaele, Deblaere, & Achten, 2002). One paradigm to evaluate motor imagery is the mental rotation of body parts (BMR). Namely, subjects have to imagine how a body part would look if rotated away from the orientation in which it actually appears (Thayer et al., 2001). This likely occurs via the integration of visual, proprioceptive and motor information and BMR can be deemed a cognitive analogue of an actual action (Parsons, 1994), as also supported by the fact that longer rotation times are usually observed for stimuli orientations that would actually be difficult to maintain (Ionta, Fourkas, Fiorio, & Aglioti, 2007). However, it is conceivable that BMR engages a wider cognitive network, which also deals with problem solving and decision-making. In fact, to mentally rotate a body part, one most likely creates a mental representation that is continuously updated as it rotates (Shepard & Metzler, 1971; Vandenberg & Kuse, 1978). This process is consistent with current models of working memory (WM) Miyake & Shah, 1999, in which a central executive can access and manipulate information retained in dissociable buffers for visuospatial and sensori-motor information and determine, for instance, if the body part will be rotated clockwise or not. One study supporting this notion found a significant association between higher rotational ability for objects and lower reaction times (RT) in a task of spatial WM (SWM) Christie et al., 2013. Yet, it is not entirely clear to which extent BMR, object MR (OMR), and scene MR, share common cognitive mechanisms (Dalecki, Hoffmann, & Bock, 2012).

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Musicians' dystonia (MD) is a type of focal, task-specific, hand dystonia affecting as many as 1 in 200 musicians during their career and often resulting in the termination of professional performance (Altenmüller, Ioannou, & Lee, 2015). The pathophysiology of MD is not entirely clear (Altenmüller et al., 2015). There are many clinical and pathophysiological similarities between MD and other types of task-specific, focal dystonia such as writer's cramp (WC), so that MD and WC are usually grouped together under the umbrella of "occupational dystonia", based on the suggestion that over-training can induce maladaptive plasticity and results in dystonia (Altenmüller et al., 2015; Torres-Russotto & Perlmutter, 2008). In this context, previous research using MR paradigms has shown that patients with WC have deficits in BMR, which are selective to the hands, as compared to healthy controls, suggesting a close link between the impairment of motor planning/execution (at least as assessed by MR) and the manifestation of dystonia (Fiorio, Tinazzi, & Aglioti, 2006). It is, however, unknown whether subjects with MD would display similar deficits with this paradigm, reinforcing the concept of shared pathophysiology between these two disorders.

In the current study we therefore aimed to explore this topic using the MR paradigm in MD. Specifically we assessed BMR for hands, feet and hemi-faces. As a control task, we used a task of OMR, in which a letter was presented in its canonical or mirror-reversed form. Moreover, we further evaluated WM abilities in MD to explore if they are indeed associated with MR performances for body parts and/or objects.

2. Methods

2.1. Subjects

Eight patients with MD and eight healthy professional musicians with similar age (53.5 ± 8.3 vs 54.5 ± 12.8, p > 0.05), gender (6 M/2F vs 5 M/3F, p > 0.05) and musical education (40.9 ± 13.1 vs 42.8 ± 8.9, p > 0.05) were enrolled in the current study. All subjects but 3 (2 among patients and 1 among healthy musicians) were right-handed, (p > 0.05). MD patients were either not receiving any treatment (n = 3) or were assessed at least four months after the last set of botulinum toxin (n = 5). The study was approved by the Local Ethics Committee and all subjects gave their written informed consent.

2.2. Procedure

The test was carried out in a quiet room. Subjects were seated in front of a computer screen (15 in.) with their non-dominant hand out of sight on their laps. The dominant hand was used to press the answer key (right/left arrow keys for right-handed subjects and z/c keys for left-handed subjects) on an international US-keyboard, as described below. All tasks were programmed using MatLab 2013b.

2.2.1. Mental rotation paradigm

The mental rotation paradigm was adapted from previous studies in focal dystonia (Fiorio et al., 2006, 2007). Specifically, subjects were presented with realistic photos of left or right hands, feet and hemi-faces. The three different types of stimuli were chosen to explore whether abnormalities were present only in the affected (dystonic) body regions (e.g., hands) compared to non-affected ones (e.g., feet and hemi-faces). All three stimuli were presented in eight angular orientations (AO; e.g., 0°, 45°, 90°, 135°, 180°, 225°, 270° and 315°) and subjects had to report the laterality of the presented stimuli (e.g., right or left) by pressing the corresponding key on a keyboard.

Subjects were instructed to respond to each stimulus accurately and as quickly as possible. Response accuracy (RA) and reaction time (RT) were recorded. Each stimulus was presented until subjects responded (for a maximum of 5 s, after which the

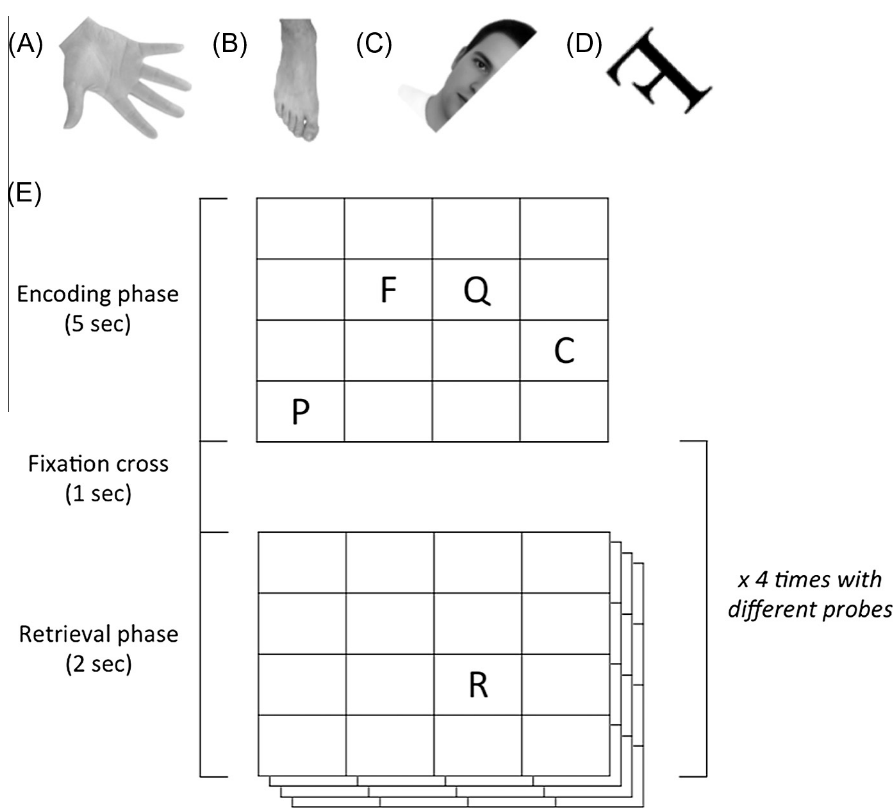

Fig. 1. A–D: Examples of different probes used in the mental rotation tasks. E: Graphical description of the spatial working memory task.