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Effects of the axis of rotation and primordially solicited limb of high level athletes in a mental rotation task

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ABSTRACT

A recent set of studies has investigated the selective effects of particular physical activities that require full-body rotations, such as gymnastics and wrestling (Moreau, Clerc, Mansy-Dannay, & Guerrien, 2012; Steggemann, Engbert, & Weigelt, 2011), and demonstrated that practicing these activities imparts a clear advantage in in-plane body rotation performance. Other athletes, such as handball and soccer players, whose activities do require body rotations may have more experience with in-depth rotations. The present study examined the effect of two components that are differently solicited in sport practices on the mental rotation ability: the rotation axis (in-plane, in-depth) and the predominantly used limb (arms, legs). Handball players, soccer players, and gymnasts were asked to rotate handball and soccer strike images mentally, which were presented in different in-plane and in-depth orientations. The results revealed that handball and soccer players performed the in-depth rotations faster than in-plane rotations; however, the two rotation axes did not differ in gymnasts. In addition, soccer players performed the mental rotations of handball strike images slower. Our findings suggest that the development of mental rotation tasks that involve the major components of a physical activity allows and is necessary for specifying the links between this activity and the mental rotation performance.

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1. Introduction

Mental rotation is an important cognitive ability that permits the mental rotation of representations of two- or three-dimensional objects. In a well-known study, Shepard and Metzler (1971) asked participants to judge whether two rotated 3D cube figures depicted identical or different objects and observed that the response time (RT) was linearly proportional to the angle of rotation from the original position. This result suggested that participants mentally rotated one item in reference to the other and that the degree of rotation of an object from the original directly correlates with the length of time required for a participant to judge if the two items are identical or different. This mental rotation of abstract objects induces an object-based transformation, for which the relationship between the environment and the egocentric frame of the observer remains fixed, while each of their relations to the object reference frame are updated (Amorim, Isableu, & Jarraya, 2006; Steggemann et al., 2011). This type of mental transformation classically generates a linear increase in the RTs as the angular disparity increases (Cooper, 1975; Shepard & Metzler, 1971; Steggemann et al., 2011). Other mental rotation tasks require egocentric perspective transformations, for which the relationship between the environment and the object reference frames remains fixed, while each of their relations to the egocentric reference frame of the observer are updated (Amorim et al., 2006; Jola & Mast, 2005; Steggemann et al., 2011). In these mental body rotation tasks, participants are asked to judge the laterality of full human body postures with one arm outstretched. In contrast to the mental rotation of abstracts objects, RTs are generally independent of rotation angle (Wraga, 2003; Wraga, Creem, & Proffitt, 2000; Wraga, Creem-Regehr, & Proffitt, 2004; Zacks, Mires, Tversky, & Hazeltine, 2002). Some studies of mental body rotations showed constant RTs at low angles but a sudden increase with greater angles (Graf, 1994; Keehner, Guerin, Miller, Turk, & Hegarty, 2006; Kozhevnikov & Hegarty, 2001; Michelon & Zacks, 2006). These findings show that the classical linear increase in the RTs with increasing rotation angles is not inevitable in mental body rotation tasks; even if some studies showed a linear increase in the RTs with increasing rotation angles, the slopes were less steep than those reported for abstract objects rotation (Easton & Sholl, 1995; Parsons, 1987; Rieser, 1989).

The above-mentioned differences in RT patterns depend on the spatial frames of reference involved in the mental rotation processes, i.e., object-related vs. egocentric frames of reference (Preuss, Harris, & Mast, 2013; Zacks et al., 2002). Using human body postures, Parsons (1987) showed a correlation between the time required for participants to imagine themselves in the position of the human-body stimulus and the time required to make a handedness judgment of the same figure during a mental body rotation task. He proposed that the participants performed the task by imagining themselves in the position of the body figure (i.e., egocentric perspective transformation). Therefore, this egocentric mental transformation would require embodied transformations and more specifically, the mapping of body axes (head–feet, front–back, and left–right) onto the stimuli defined as a spatial embodiment prior to performing the mental perspective transformation, which is defined as motoric embodiment (Amorim et al., 2006; Jola & Mast, 2005; Parsons, 1987; Steggemann et al., 2011). Thus, this embodied process relies on one's long-term knowledge of body structure (Amorim et al., 2006) and can be modulated by the motor processes because mental rotation rates are slower for impossible body postures compared to possible ones (Petit & Harris, 2005).

The influence of motor processes on the mental rotation performance is another noteworthy issue. The first study to investigate the relationship between motor processes and mental rotation was proposed by Wexler, Kosslyn, and Berthoz (1998), who asked participants to simultaneously perform manual and mental rotations of a joystick and observed the slower rotation times when manual and mental rotations were performed in opposite directions compared to when the rotation directions were identical. In accordance with the authors' hypothesis, this result suggests that mental rotation processes represent covert motor rotation. Similarly, Wohlschläger and Wohlschläger's research (1998) demonstrated that concordant directions in simultaneous manual and mental rotations facilitated mental rotation; conversely, discordant rotation directions inhibited mental rotation. These results suggest a common process that controls both overt and covert object reorientation dynamics.