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THE TOOL AS THE LAST PIECE OF THE ATHLETE'S GESTURE IMAGERY PUZZLE

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Abstract—The present study tested whether and how motor experience with a specific tool affects motor representation of a specific movement. To this aim, we considered a group of expert tennis players and a control group of athletic individuals without tennis experience. Participants were asked to execute 20 single forehands into the wall with a tennis racket (movement execution – ME) and, afterward, to produce a kinesthetic image of themselves while executing the same movements (motor imagery – MI). During MI participants handled one of the following tools: a tennis racket, a tennis-like racket and an umbrella. Results showed that the duration of the real and the imagined movements were almost similar when participants of both groups held the tennis rackets. In contrast, when tennis players handled the tools not specific for tennis the duration of the imagined movements increased significantly compared to the MI duration with a tennis racket. On the opposite, the handled tool did not modulate MI performances of the control group. In conclusion, this study showed that motor representation of subjects who developed motor skills associated to tool-use is reliant on the object used to practice movements. This finding suggests that, although MI mainly relies on the activity of cortical motor regions, non-motor information – as the use of the tool to practice movement – strongly affects the MI performance.

Key words: motor imagery, tennis, tool-use, motor representation.

INTRODUCTION

Motor imagery (MI) is the process of imagining movements without an overt motor output (Jeannerod, 2001). Motor imagery has been associated with planning stages of motor production, and, in particular, with internal models that predict the sensory consequences of motor commands and specify the motor commands required to achieve a given outcome. These internal models are modified according to practice and experience, and are requisite for motor learning and for the generation of skilled actions (Rosenbaum et al., 1993; Wolpert, 1997; Wolpert et al., 2001). The application of motor imagery techniques is thus considered a valid approach for describing the content and the structure of motor representations. Indeed, a large body of evidence showed that there is a functional equivalence between MI and the real movement execution (ME) (Johnson, 1982). Neurophysiological studies showed that motor imagery consistently recruits a large fronto-parietal network, in addition to subcortical and cerebellar regions, known to be involved also during action execution (Jeannerod, 2001; Grezes and Decety, 2001). Furthermore, behavioral researchers demonstrated that the imagination of a motor act exhibits many of the properties of the actual represented action. Some of them have nicely demonstrated that movement execution and motor imagery obey the same laws of movement control, such as Fitts' law (Decety and Jeannerod, 1995; Cerritelli et al., 2000). Other experiments agreed that the durations of real and mentally performed actions are similar and are governed by central motor rules (Decety and Jeannerod, 1995; Papaxanthis et al., 2002a,b; Gentili et al., 2004; Personnier et al., 2010). Several factors are known to affect this temporal congruence and consequently MI effectiveness. One of these factors came out from studies on professional athletes, which have shown that the expertise level in a specific sport can modulate MI ability (Reed, 2002; Louis et al., 2011), the higher expertise corresponding to better MI performance.

It is worth to note that in those sports that require tool use, the level of expertise is based on an athletic gesture associated with a specific use of a tool and not only movement per se. Indeed, the use of simple tools to extend reaching space, induces changes in the humans' behavior and/or in the neural activity (Berlucchi and Aglioti, 1997; Holmes and Spence, 2004). Further, not only the reaching space enlarges with tool-use, but also body representation is subjected to modification. It was proposed that the extensive use of an object in order to perform a specific movement,

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Abbreviations: ANOVA, analysis of variance; LR, tennis-like racket; ME, movement execution; MI, motor imagery; MIQ-R, Movement Imagery Questionnaire; SD, standard deviation; SE, standard error; TR, tennis racket; UM, umbrella.

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provokes brain modification such that the tool becomes part of one's body representation (Maravita and Iriki, 2004). Fourkas et al. (2008) showed an increased corticospinal facilitation in expert tennis players during motor imagery of tennis but not of golf or table tennis, underlying the key role of long-term experience in modulating sensorimotor representation. Nevertheless, the authors stated that a limitation of their study was that the paradigm does not allow them to discern whether the observed neuroplastic changes in expert tennis players might be attributed to the extensive training in the sport and/or to the extensive use of the tool necessary for the training.

With the aim of exploring whether and how motor experience with a specific tool influences motor representation of a specific movement, we asked to a group of expert tennis players and a group of athletic individuals without tennis experience to execute 20 single forehands into the wall with a tennis racket and, afterward, to produce a kinesthetic image of themselves while executing the same movements. During MI participants held one of the following tools: a tennis racket, a tennis-like racket and an umbrella. A kinematics description of the motor performances of the two groups was assessed with the tennis racket during forehand execution. Then, to evaluate whether and how MI was affected by the handled tool the durations of the mental imaging of movement with the three tools were evaluated. Since this paradigm focused on a specific sport (i.e., tennis), but considered three different objects, the results could shed light on the role that extensive tool-use has in changing the sensorimotor representation of the athletic gesture in expert sport players.

EXPERIMENTAL PROCEDURES

Main experiment

Participants. A total of 20 participants, naïve to the purpose of the study, took part in the experiment. They were classified in two groups on the basis of their declared tennis expertise quantified in training hours per week. The group of tennis players (n = 10, 5 male and 5 female, mean age ± standard deviation (SD) = 24.9 ± 4.8) had various levels of expertise: from 5 to 15 years' experience, and in the previous 7 days played tennis from 4 to 20 h. Some of them participated to local and regional tournaments, but none of them competed at national level. The novices group (n = 10, 6 male and 4 female, mean age ± SD = 25.4 ± 4.9) were athletic regularly participating recreationally in aerobics, dance, volleyball, water polo, swimming, gymnastic, football, sailing and cycling. None of them had played tennis. All the participants were right-handed as determined by the Edinburgh Handedness Inventory (Oldfield, 1971). The study was conducted in accordance with the Declaration of Helsinki and approved by the local ethics committee.

Experimental protocol. All measurements took place in a large room illuminated with homogeneous white light, and in the afternoon (between 13:00 h and 18:00 h), because the temporal accuracy of the mental imaging of movements reaches an optimum during this time of day (Gueugneau et al., 2009).

Before starting the experimental procedure, all the participants completed the Italian version of the Movement Imagery Questionnaire (MIQ-R; Hall and Martin, 1997) to assess their ability to form kinesthetic and visual images. The MIQ-R is an 8-item self-report questionnaire, in which participants rated the vividness of their mental representations using two 7-point scales (associated to visual and kinesthetic imagery): 1 means "really easy to feel/see" whereas 7 corresponds to "really difficult to feel/see". All participants considered it fairly easy to form motor images and the scores indicated that they possessed good motor imagery abilities (mean ± SD: tennis players = 15.8 ± 5.9, novices = 18.7 ± 7.8, t-test: p = 0.4). The experiment consisted of two sessions: movement execution and motor imagery. In the same day, motor imagery was always performed 30 min after movement execution to avoid possible fatigue effects. The experiment lasted about one and a half hours.

Movement execution. This session was carried out to quantitatively evaluate the kinematics of the athletic gesture in the two groups. During ME participants were provided with a tennis racket (weight: 0.3 kg) and were asked to perform 20 single forehands into the wall. Participants positioned themselves upright five meters distant from a wall and handled a tennis racket with the right hand. The left hand held the ball. They were instructed (1) to let the ball fall on the floor, (2) after its bounce, to hit the ball in order to strike the front wall inside a square of 4 m^2 area delimited with a colored tape, and (3) finally, to come back to the starting position. After the verbal instructions, the experimenter showed the movement to the participant to avoid any misunderstandings. Movement velocity was not emphasized; in contrast participants had to be enough accurate to hit the wall inside the square.

The right arm movement kinematics was recorded by mean of an optoelectronic motion capture system (Qualisys) with six cameras, which acquired the position of an infrared reflective marker placed on the palm of the participants (sample frequency = 120 Hz). In each trial, when participants said "Start" and "Stop" – in correspondence of motion beginning and end, respectively – the experimenter launched and ended the acquisition. Data were low-pass filtered at 5 Hz using a 2nd-order Butterworth filter. To define the onset and offset of the movement, we chose a threshold corresponding to 5% of the maximum value of the movement velocity profile.

Motor imagery. During MI participants were requested to keep the initial position got in ME session while handling different tools randomly provided trial by trial by the experimenter. The tools were three: a tennis racket (TR), a tennis-like racket (LR) and an umbrella (UM). The three tools differed for dimensions, but not