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Research article

Motor Imagery and Tennis Serve Performance: The External Focus Efficacy

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Abstract
There is now ample evidence that motor imagery (MI) contributes to enhance motor performance. Previous research also demonstrated that directing athletes' attention to the effects of their movements on the environment is more effective than focusing on the action per se. The present study aimed therefore at evaluating whether adopting an external focus during MI contributes to enhance tennis serve performance. Twelve high-level young tennis players were included in a test-retest procedure. The effects of regular training were first evaluated. Then, players were subjected to a MI intervention during which they mentally focused on ball trajectory and specifically visualized the space above the net where the serve can be successfully hit. Serve performance was evaluated during both a validated serve test and a real match. The main results showed a significant increase in accuracy and velocity during the ecological serve test after MI practice, as well as a significant improvement in successful first serves and won points during the match. Present data therefore confirmed the efficacy of MI in combination of physical practice to improve tennis serve performance, and further provided evidence that it is feasible to adopt external attentional focus during MI. Practical applications are discussed.

Key words: Movement imagery, motor performance, focus of attention, safety window.

Introduction

Determining the optimal prerequisites to achieve peak performance is the primary goal of most athletes and coaches. Among them, previous research consistently demonstrated that inducing an *external* focus of attention by directing athletes' attention to the effects of their movements on the environment is more effective that providing instructions on the movement per se, which rather induces an internal attentional focus (Porter et al., 2010; Wulf and Prinz, 2001; Wulf et al., 1998). Such beneficial effects were reported in various motor skills, including those requiring movement precision such as basketball shot and volley-ball serve accuracy, as well as soccer shot precision (Al-Abood et al., 2002; Wulf et al., 2002). The external focus advantage was mainly explained in reference to the common-coding theory (Prinz, 1990), stating that actions are more effective when they are planned in terms of intended movements effects, as well as the constraint action hypothesis (Wulf et al., 2001) supporting that the external focus promotes an automatic mode of movement control. Interestingly, Wulf (2007, p. 12) argued that "*not only is a higher level of performance achieved faster with an external relative to an internal focus, but the skill is retained more effectively*".

Surprisingly, looking at the effects of directing attention externally or internally during mental practice has not yet been fully explored. One of the most remarkable capacities of the mind is its ability to simulate sensations, movements and other types of experience. Accordingly, motor imagery (MI) refers to the mental representation of an action without engaging in its actual execution. There is now ample evidence that MI substantially contributes to improve motor performance and facilitate motor recovery (e.g., Driskell et al., 1994; Guillot and Collet, 2008; Sharma et al., 2006; de Vries and Mulder, 2007). Practically, MI is a multi-sensory construct based on different sensory modalities. While visual imagery refers as to the visualization of an action, kinesthetic imagery rather involves the sensations of how it feels to perform, including the force and effort perceived during movement and balance (Callow and Waters, 2005). Other researchers introduced the concept of imagery perspectives. During internal (first-person) perspective, performers visualize the action as how would happen in the real-life situation and see images as if through their own eyes, while in the external (third-person) perspective they imagine, as spectators, the action that somebody is performing, regardless of the agency of the movement (i.e., whether they 'see' themselves or others). While imagery research generally demonstrated that all imagery modalities and perspectives can serve different purposes, and that their respective effectiveness may depend on the nature of the task being imagined, some authors specifically compared the efficacy of each imagery perspective. External visual imagery was found to be effective for form-based tasks as athletes could easily visualize the global positions and movements that are required for successful performance (Hardy and Callow, 1999; White and Hardy, 1995). Conversely, internal visual imagery would be superior in goal-directed tasks or motor skills that incorporate changes in the visual field (Callow and Roberts, 2012; White and Hardy, 1995). More recently, some authors further underlined the influence of individual sport experience (Morris and Spittle, 2012) and task requirements (Collet and Guillot, 2012) on respective visual imagery perspective efficacy, while others highlighted the distinction between imagery perspective use and imagery perspective preference (Callow and Roberts, 2012).

Basically, adopting an external focus of attention during MI might promote associations between movements and their exteroceptive effects, whereas using an internal focus would support the link between movementand both tactile and kinesthetic sensations. In other words, providing specific imagery instructions on the

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effects of the movement might result in using an external visual imagery perspective, whereas prioritizing tactile and kinesthetic sensations would mean combining internal visual imagery perspective and kinesthetic imagery. In tennis, for example, athletes would adopt an internal focus during MI while feeling arm movements and effort needed for serving, as well as seeing the ball throw and the hitting phase. In contrast, an external focus would require imagining the ball trajectory and its rebound after serve.

The tennis serve is certainly one of the most difficult tennis shot to learn, but it can substantially contribute to win or gain advantage in the point. When considering tennis serve performance, the relation between speed and accuracy is critical (Brody, 2003). First serves have usually greater velocity, players being successful in hitting the ball in the proper serve area about 40% to 70% of the time (Davids et al., 2006). In contrast, second serves have a slower velocity ball and a much higher probability of landing in the proper court (near 90%). Hence, players adjust the speed of the serve and these two factors must be considered to evaluate serve performance (Davids et al., 2006). In addition, regularity of the performance, i.e. low performance variability, as well as percentage of successful serves and percentage of points won after first serve during tennis matches, are three complementary relevant indicators of serve performance (Brody, 2003). Practically, during the classical course of motor learning, coaches often provide instructions related to the movement. As well, athletes spontaneously focus on the key-components of the correct movement to be performed, for instance to fit a model or template performance. Previous research showed that MI is a reliable technique to improve the effectiveness of the tennis serve (e.g., Coelho et al., 2007; Guillot et al., 2012; Mamassis, 2005). In most of these MI interventions, athletes are requested to successively rehearse each stage of the movement mentally. Unfortunately, few details are usually provided with regards to the specific content of the imagery experience. Based on the literature highlighting the advantage of the external focus of attention in motor skills requiring precision, the present study aimed at evaluating whether specifically adopting an external focus during MI might contribute to enhance tennis serve performance. Practically, players were instructed to mentally focus on ball trajectory and visualize the space above the net where the serve can be successfully hit. This has been defined as the 'safety window' (Brechbuhl et al., 2001), which is individually calculated to determine the adequate safety ranges for the serve. Through a within-subjects design including a sample of young elite tennis players, we postulated that using MI with an external focus of attention might positively impact subsequent motor performance.

Methods

Participants

Five girl and seven boy elite tennis players (age: 11 yrs; height: 1.45 ± 0.04 m; mass: 34 ± 4 kg; tennis practice: 4 ± 2 yrs; weekly tennis training: 7 ± 1 h; weekly conditioning training: 2 h) volunteered to participate in this study, which was approved by the ethics committee Sud-Est II. All participants had successfully passed the detection program organized by the regional committee of tennis in Lyon, France. As a consequence, they were considered national-level tennis players and were therefore the best players for their age category. Written informed parental and player's consents were obtained from all participants before data collection.

Experimental design

A test-retest procedure was used to design this study, which spanned over 16 weeks. The choice of a within subjects test-retest experimental design was justified by the difficulty to find a control group of age-matched players with a similar level of expertise, where participants would not have been subjected to MI training. During the first eight weeks, all players performed their regular training five times per week (RT; tennis and conditioning training). RT training sessions lasted 90 min, with two to four players per court. Each session was conducted by the same experimenter. After a general and specific warm-up (10 min), exercises to control ball direction and depth in basic strokes (20 min) were proposed. Specific exercises for the transition to the net and volley (25 min), as well as tactical games (20 min), were then scheduled. Finally, sessions included training matches (15 min). Conditioning was made of coordination exercises and core training. Then, during the last eight weeks, specific motor-imagery (MI) was implemented into the two conditioning sessions including mental practice. Before (T_0), as well as after 7 weeks (T_{RT}) and 16 weeks (T_{MI}), serve performance was measured using a standard serve test (Desliens et al., 2011; Guillot et al., 2012). The efficacy of the serve during a real set match performance was also evaluated. All players were assessed during the same week. Before evaluation, a systematic 15-min standard warm up was performed including running, specific displacements, serve-line and baseline ground strokes, and serve drills. The effects of regular training were evaluated by the comparison between performances at T_0 and T_{RT}, and the effects of MI practice were obtained by the comparison at T_{RT} and T_{MI}.

Testing procedures

Tennis performance was evaluated under two ecological field conditions. First, serve performance was evaluated under serve test condition consisting in performing 16 successive serves (eight per diagonal). Players were instructed to hit first serves as fast as possible with their own racket in a predetermined target, while looking for aces. The experiment was conducted in an indoor tennis court, as previously described in Desliens et al. (2011) and Guillot et al. (2012). The velocity of the serve was evaluated by the post-impact ball velocity, measured using a radar gun (error margin = 0.28 $m \cdot s^{-1}$, SR3600, Sports-radar, Homosassa, FL, USA) located behind the player. The target was defined from the 'T' of the court (intersection of the service-box and center lines) inside the serve boxes, and divided into three areas. A ball rebound in the small area (0.5 x 0.5 m) accounted for five points, in the medium area (1 x 1 m) for three points, and in the service box for one point. Another location of the ball rebound resulted in zero point. Serve accuracy was estimated through five outcomes including the percentage of successful serves (ball rebound in the service box), the accuracy score (sum of the won points for the 16 serves), the coefficient of variation of the score, the mean velocity of successful serves, and the coefficient of variation of this mean velocity. Then, the match performance was evaluated by collecting the percentages of successful serves after a first ball, of won points after a serve first-ball, and of aces and double faults, during a complete set, applying the rules of French Tennis Federation for 11-yrs old players (i.e., five games per set with decisive point at 40/40).

Motor imagery training sessions

Before the experiment, all players completed the French version of the Revised Movement Imagery Questionnaire (MIQ-R; Hall and Martin, 1997; Lorant and Nicolas, 2004). During the last eight weeks of the protocol, specific training sessions including MI exercises were added twice per week. Practically, players mentally rehearsed the serve once before each subsequent physical practice trial. In each MI session, 20 tennis serves were performed (both diagonals per session), with the same instructions than during the testing protocol in terms of serve velocity and accuracy. A total of 20 imagined and 20 actual trials were thus performed during each session.

An imagery script was read to the participants at the beginning of each MI session to ensure that they received similar imagery instructions[1]. MI guidelines included a brief description of the course of the tennis serve, but with predominant instructions being related to the ball trajectory, the "safety window" in terms of height, and the ball rebound in the serve box, in order to emphasize players' external focus of attention. The "safety window" is defined as the space above the net where the serve can be successfully hit, i.e. the adequate safety range for the serve (Brechbuhl et al., 2001). Its computation is based on the individual maximal ball velocity after impact and the height of the contact point between ball and stringbed at serve impact. All these measurements were made at T_{RT} in order to define the individual "safety window" height. The difficulty of the MI task, i.e. the materialization of the "safety window" height, evolved along the 16 MI sessions. During the first four sessions, the "safety window" was marked by a carton framework, fixed on the upper border of the net. During the next four sessions, the 'safety window' was materialized by balloons, attached to the upper border of the net. For sessions nine to 12, the "safety window" was marked by a green elastic wire spread hold horizontally up the upper border of the net. Finally, during the last four sessions, the "safety window" was no more materialized.

Every three sessions, individual debriefings were scheduled to investigate adherence of the participants to the MI instructions, and to determine whether they encountered difficulty in forming mental images. Participants were also asked to rate the quality of MI using a Likert-type scale (from 1 = poor mental representation to 6 = extremely vivid mental representation).

Statistical analysis

Data are presented as Mean ± Standard Deviations. Data of the MIQ-R allowed the comparison between visual and kinesthetic MI using a Student's t-test for paired samples. We first checked the normality of the data as well as the homoscedasticity. The sphericity assumption was also tested using the Mauchly's sphericity test. Data showed that the normality and sphericity were not violated and thus that parametrical statistical tests could be used despite the small sample size. ANalyses Of VAriance (ANOVAs) for repeated measures were thus performed to compare the effects of training and test differences between regular training and MI practice. When ANOVAs revealed a significant difference, F- and p-values, as well as partial effect sizes (η^2), and effect sizes (ES) and their interpretation according to Cohen's scale (Cohen, 1988), were reported. T_0/T_{RT} and T_{RT}/T_{MI} comparisons were made using post-hoc tests with Bonferroni's corrections. The level of significance was set at $p \leq 0.05$. All analyses were performed on SPSS 11.0 (SPSS, Inc., Chicago, IL.).

Results

For the serve test, ANOVA revealed significant differences in the percentage of successful serves ($F(2,22) = 7.948$; $p = 0.003$; $\eta^2 = 0.42$), as well as the accuracy score ($F(2,22) = 4.304$; $p = 0.026$; $\eta^2 = 0.28$) and its coefficient of variation ($F(2,22) = 4.304$; $p = 0.026$; $\eta^2 = 0.28$). The percentage of successful serves was 37 ± 10 % before the protocol, increased significantly by 8 % after regular training (ES = 0.79; $p = 0.009$), and increased again by 4% after MI training (ES = 0.34; p = NS) (Figure 1A). The accuracy score was 13.6 ± 4.8 before the protocol, and remained constant after regular training (ES = 0.10; p = NS), while a significant increase was observed after MI training (ES = 0.59; $p = 0.033$) (Figure 1B). Similar results were obtained for the coefficient of variation of accuracy score, which was comparable before and after regular training (ES = 0.14; p = NS), but decreased significantly after MI training (ES = 0.57; $p = 0.037$) (Figure 1C).

ANOVA showed significant differences in the serve velocity during serve test ($F(2,22) = 7.742$; $p = 0.003$; $\eta^2 = 0.41$), while no difference was reported for the coefficient of variation of the serve velocity ($F(2,22) = 0.631$; p = NS; $\eta^2 = 0.08$). Before the protocol, the mean velocity was 29.5 ± 1.6 $m \cdot s^{-1}$. This velocity decreased significantly by 3.5 % after regular training (ES = 0.64; $p = 0.023$), and increased significantly by 6.2 % after MI training (ES = 1.29; $p < 0.001$) (Figure 2A). The coefficient of variation remained low along the protocol (Figure 2B).

For simulated match, ANOVA displayed significant differences either for the percentage of successful first-ball serve ($F(2,22) = 6.46$; $p = 0.006$; $\eta^2 = 0.37$), or for the percentage of points won after a successful first-ball serve ($F(2,22) = 121.94$; $p < 0.001$; $\eta^2 = 0.92$). Before protocol, the percentage of successful first-ball serve was 50 ± 8 %; it increased significantly by 4 % after regular training (ES = 0.99; $p = 0.003$), and increased again by

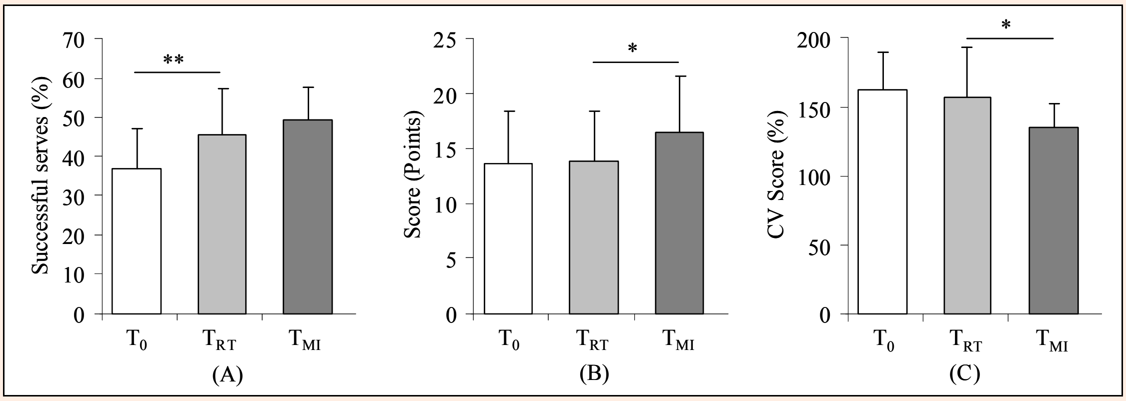

Figure 1. Mean ± Standard Deviation for the accuracy outcomes during serve test before (T_0), after regular training (T_{RT}) and after Motor Imagery training (T_{MI}). (A) The percentage of successful serves, (B) the accuracy score and (C) the coefficient of variation (CV) of the accuracy score, with * for $p \leq 0.05$ and ** for ≤ 0.01.

6% after MI training (ES = 0.59; p = 0.033) (Figure 3A). Initially, the percentage of points won after a first-ball serve was 33 ± 7 %; this ratio increased significantly by 10 % after regular training (ES = 2.53; p < 0.001), and then increased again by about 30 % after MI training (ES = 2.66; p < 0.001) (Figure 3B). The numbers of aces and double faults were marginal during simulated sets among all players and all test sessions (0 ace and 1.7 to 2 double faults in average). These percentages were therefore not statistically analyzed.

The score of the MIQ-R indicated that all players showed a higher visual MI ability than kinesthetic one (24.4 ± 2.3 pt *vs*. 16.6 ± 8.4 pt, respectively; ES = 0.89; p = 0.005). In addition, significant differences were reported for the auto-evaluation of MI quality according to the four periods of training ($F(3,33) = 18.85$; $p < 0.001$; $\eta^2 = 0.71$). During the first period, the MI quality was 4.7 ± 0.6 points (on a maximal of 6 points). This evaluation remained similar during the second period (4.4 ± 0.8 points; ES = 0.36; p = NS), then decreased significantly during the third period (3.6 ± 0.9 points; ES = 1.39; p < 0.001), and decreased slightly during the last period of training (3.4 ± 0.7 points; ES = 0.39; p = NS).

Discussion

This study first aimed at evaluating the efficacy of MI in combination of physical practice to improve tennis serve performance in high-level young tennis players. The main results showed that adopting an external focus during MI resulted in a significant increase in accuracy and velocity during an ecological serve test, as well as a significant improvement in successful first serves and won points during a real match.

Although no comparable data is available in the literature for similar age, the 11 years old players involved in the present study displayed high serve performance. They achieved similar mean velocity (Figure 2A) and higher accuracy (Figures 1A and 1B) than 14 to 16 years-old recreational tennis players (Guillot et al., 2012). Practically, they were the best tennis players of their category, as revealed by a thorough evaluation procedure conducted by the tennis league. Despite this, the effects of regular training (T_{RT}/T_0) were contrasted, as during the ecological serve test, we observed an increase in serve accuracy along with a decrease in shot velocity, hence indicating variability in serve performance. Furthermore, during the

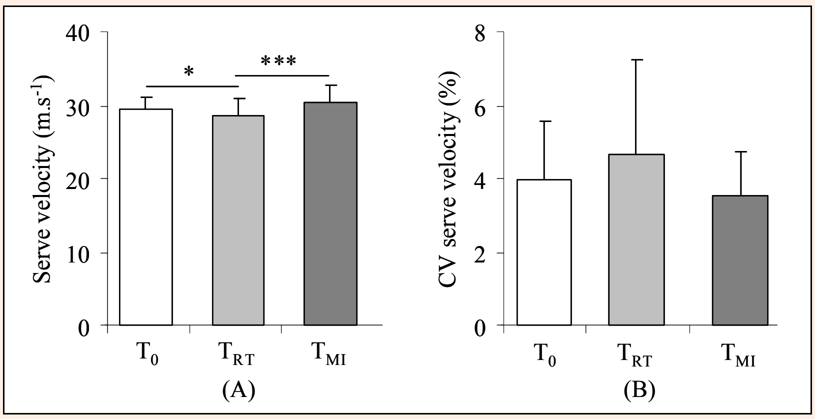

Figure 2. Mean ± Standard Deviation for the velocity outcomes during serve test before (T_0), after regular training (T_{RT}) and after Motor Imagery training (T_{MI}). (A) The serve velocity of successful serves, (B) the coefficient of variation (CV) of the serve velocity, with * for $p \leq 0.05$ and * for ≤ 0.001.**

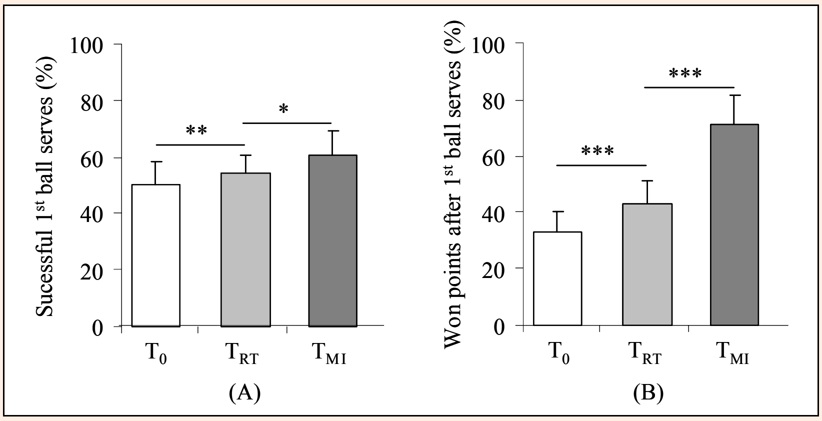

Figure 3. Mean ± Standard Deviation for the velocity outcomes during serve test before (T_0), after regular training (T_{RT}) and after Motor Imagery training (T_{MI}). (A) The serve velocity of successful serves, (B) the coefficient of variation (CV) of the serve velocity, with * for p ≤ 0.05, ** for p ≤ 0.01 and * for ≤ 0.001.**

real match, baseline ratios for successful first serves and won points after first serve were low (Figure 3), such ratios being considered "acceptable" when up to 60 % (Brody, 2004). Although an increase in successful first serves (Figure 3A) and won points after first serves (Figure 3B) was observed, the number of won points after serve remain a better indicator as it is strongly related to the opportunities to win a game (Brody, 2004). This latter ratio slightly increased from 30 to 40% but remained quite low before MI practice, hence suggesting that players had a range of progress to improve their serve performance, in terms of velocity and accuracy consistency, as well as in terms of probability to win game.

Results clearly demonstrated that MI practice (T_{MI}/T_{RT}) in combination of physical practice contributed to substantially improve tennis serve performance, hence supporting previous data reported in a similar sport setting (Coelho et al., 2007; Guillot et al., 2012). Accordingly, mental practice resulted in an increased accuracy score combined with decreased performance variability. Players also increased the speed of their serve (Mamassis, 2005), so that they finally served faster, more accurately, and with more consistency during the ecological serve test. Interestingly, data provided further evidence of the efficacy of MI on serve performance in a real tennis match situation, as both the percentage and the number of won points after first-ball serves significantly increased. Notwithstanding the slight effect of regular training on these variables mentioned above, data tend thus to suggest that MI substantially improve the probability to win game. From a more theoretically viewpoint, these findings not only support the effectiveness of MI on subsequent motor performance (Driskell et al., 1994; Guillot and Collet, 2008), but also promote the efficacy of adopting an external focus of attention (Porter et al., 2010; Wulf et al., 1998; 2002) by directing tennis players' attention to the effects of their serve on the environment during MI. Finally, these results bring experimental evidence of the usefulness of considering the "safety window" as a reliable individual parameter and a kind of predictor of tennis serve performance (Brechbuhl et al., 2001).

In order to promote the best rules for MI practice, present work sketches potentially fruitful practical applications for tennis coaches and athletes. Firstly, tennis players should consider the use of an external focus of attention during MI by focusing on ball trajectory and visualizing the space above the net where the serve can be successfully hit. Practically, present data do not support that adopting an external focus of attention during MI contributes to improve serve performance in a greater extent than using an internal focus of attention. Such conclusion could be reached only by comparing each experimental situation including two groups of players or two types of MI practice. We rather suggest that providing instructions inducing an external focus of attention during MI of tennis serve might be a reliable way to improve serve performance. Furthermore, as pointed out by Maurer and Zentgraf (2007), we agree that a possible external focus advantage would not be systematic. Indeed, it may depend on the characteristics of the task. Put simply, an external focus might be used for tennis serve performance, like in the present study, but not necessarily for learning other basic strokes such as the backhand slice. Accordingly, different MI modalities and perspectives can be used, and athletes may have developed a preference for either an internal or an external visual imagery perspective (Callow et al., 2013; Hall, 1997). In such case, this would influence the ease of using either the external or the internal focus of attention. We also support Maurer and Zentgraf's view (2007) that athletes might selectively adopt either an external or internal focus of attention according to their level of expertise or the different stages in the course of learning. A second practical perspective emerging from this work is that engaging in MI requires explicit knowledge of the main imagery guidelines that need to be considered. MI use is very popular, but in many occasions, athletes do not use it adequately. The content of the imagery experience must be fully controlled to optimize the efficacy of MI interventions (for reviews, see Guillot and Collet, 2008; Holmes and Collins, 2001). Orienting attention of tennis players on the safety 'window' during MI of their serve routine, in order to promote a more automatic control of the movement (Wulf et al., 2001), is a good example. Finally, one should keep in mind that the "safety window" is an individual parameter based on the maximal ball velocity after impact and the height of the contact point between ball and stringbed at the serve impact (Brechbuhl et al., 2001). Consequently, such variable is likely to change across time, and must be regularly actualized, especially in children.

As with all research, this study has some limitations that should be considered before drawing general conclusions. As mentioned above, we did not include a control group with a significantly lower level of expertise where participants would not have been subjected to MI training, as it may have considerably biased our data. Although this may prevent from generalization, we thus chose to conduct a within-subjects design. Recruiting another group of participants subjected to regular training but where players would not engage into MI practice would contribute to improve the imagery-related effects on serve performance. As well, we cannot totally rule out that both regular training and conditioning may have slightly contributed to the enhancement of serve performance, although data confirm previous findings supporting the additional beneficial effects of MI. Another limitation is related to the age of the participants, which also precludes from drawing definitive conclusions in regards to MI use. Futures studies looking at the external focus efficacy during MI should thus ideally include larger sample sizes with participants of different levels of expertise, as well as a control group or a control condition. Finally, experimental work focusing on MI should compare the efficacy of the external focus to the internal focus of attention, before concluding about the benefits of the external focus.

Conclusion

Present preliminary data confirmed the efficacy of MI practice in combination of physical practice to improve tennis serve performance, and further provided evidence that it is feasible to adopt external attentional focus during MI. The "safety window", as proposed by Brechbuhl et al. (2001), thus appears as a reliable individual parameter that should be considered during both actual and MI training in tennis. This study further points some interesting perspectives. Among them, the use of video recordings, as a possible priming of MI use, might be very useful for practitioners, most especially in children, or players with low imagery ability. For instance, Atienza et al. (1998) showed that the combination of physical training with MI using video-model observation significantly improved the quality of the serve in 9- to 12-year old children, compared to physical training only. The use of video might also contribute to limit the possible alterations of MI quality along the course of the successive training sessions, as some visual feedback of the correct movement to be performed can be easily delivered and restored in working memory.

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Key points

- Motor imagery contributes to enhance tennis serve performance.
- Data provided evidence of the benefits of adopting an external focus of attention during imagery.
- Results showed significant improvement in successful first serves and won points during a real match.

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