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Nicolas Robin, Laurent Dominique, Lucette Toussaint, Yannick Blandin ...+2 more authors

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Effects of motor imagery training on service return accuracy in tennis: the role of imagery ability

Nicolas Robin[1], Laurent Dominique[2], Lucette Toussaint[1]*, Yannick Blandin[1], Aymeric Guillot[3], and Michel le Her[2]

[1]*Laboratoire "Performance, Motricité & Cognition"* [2]*Laboratoire "Adaptation au Climat Tropical, Exercice & Société"* [3]*Centre de Recherche et d'innovation sur le Sport*

Abstract

This study examined how imagery ability could affect motor improvement following motor imagery training in tennis Skilled tennis players were divided into 3 groups with regard to their MIQ scores (good imager, poor imager and control group) During a pre-test, participants physically performed 15 service returns towards a target The motor imagery training period was included during physical training for 15 sessions and each session consisted of 2 series of 15 imagined trials and 15 physical trials Some of the participants were required to use internal visual imag- ery (good and poor imager groups) while others were given a reading task (control group) Finally, 48 hours after the last training session, participants were submitted to a post-test similar to the pre-test Results indicated that motor imagery improved service return, and that this improvement was better in good imagers than in poor imagers The impact of motor imagery practice on motor performance, for skilled tennis players, is discussed

Keywords: imagery ability, internal visual imagery, motor learning, tennis

In the context of motor action, motor imagery is a conscious process which requires that individuals mentally simulate an action without executing it According to Paivio (1985), imagery is a frequently used technique in sport that usually bene ts performance, al- though to a lesser extent than physical practice (see Feltz & Landers, 1983 for review) This improvement in performance has been reported in various motor skills sports such as basketball, table tennis, gymnastics and tennis (Féry, 2003; Li-Wei, Qi-Wei, Orlick & Zitzelsberger, 1992) Moreover, the combination of motor imagery and physical prac- tice is the most ef cient condition to improve performance compared to physical or motor imagery practice alone (Atienza, Balaguer & Garcia-Merita, 1998; Driskell, Cop- per & Moran, 1994) Furthermore, recent data showed that muscle fatigue induced by prolonged exercice, which can lead to performance impairment, did not alter motor imagery accuracy (Guillot, Haguenauer, Dittmar & Collet, 2005) These overall results underline the need to better understand the impact of mental practice on sport In the present experiment, we will focus our attention on the effects of motor imagery training on service return accuracy in tennis.

According to Jeannerod (1999), the performance improvement following either physical or motor imagery training suggests that both are functionally similar and share a common system of action representation Evidence supporting this issue comes from several studies relying on varied experimental paradigms such as chronometric analysis of mentally simulated actions (Decety & Michel, 1989; Papaxanthis, Schieppati, Gen- tili & Pozzo, 2002; Guillot & Collet, 2005 for a review), measurement of autonomic responses (Collet, Guillot, Bolliet, Delhomme & Dittmar, 2003) and measurement of ce- rebral blood ow during imagery (Gerardin et al , 2000; Ingvar & Philipson, 1977) Altogether, results of these experiments strongly suggest that the cognitive mechanisms underlying elaboration, programming, and control of movements were involved both during physical and motor imagery practice (Decety & Grezes, 1999; Gallese & Gold- man, 1998; Grezes & Decety, 2001; Jeannerod, 1999, for reviews) This close functional equivalence has been proposed as an important prerequisite for valid and effective men- tal practice, as well as for a better understanding of the mechanisms involved in motor imagery (see the PETTLEP model, Holmes & Collins, 2001)

However, it has been reported that the bene cial effects of motor imagery on motor performance are modulated by numerous factors (Hall, 2001; Martin, Moritz & Hall, 1999) Some of them will be taken into account in the present study to better understand the importance of motor imagery training on service return accuracy in tennis Many authors have demonstrated that having optimal motor imagery effects requires suf cient expertise with regard to the simulated task (Hardy & Callow, 1999; Pie et al , 1996) The importance of imagery instructions given to performers as a function of task require- ments for the enhancement of motor performance was also outlined by Callow and Hardy (2004) These instructions may encourage participants to use different sensory modalities, such as external/internal visual imagery or kinesthetic imagery External visual imagery has been found to be more effective than internal visual imagery in tasks that rely heavily on form for their successful execution, such as kata, gymnastics rou- tines, or drawing tasks (Féry, 2003; Hardy & Callow, 1999; White & Hardy, 1995) By contrast, some authors have demonstrated internal visual imagery's superiority in tasks relying heavily on perceptual information, such as slalom task or racquet sport situations (Callow & Hardy, 2004; Hardy & Callow, 1999; White & Hardy, 1995) Moreover, in- ternal visual imagery was supposed to facilitate the integration of temporal component of motor action (e g the rhythm of the motor execution) Finally, kinesthetic imagery has been found to favor the learning of tasks that emphasize inter-segmental coordination (Féry, 2003; Féry & Morizot, 2000, for the tennis serve) but was bene cial only with an adequate degree of expertise at a task (Hardy & Callow, 1999) It effectively appeared that non-expert athletes usually have greater dif culties in feeling the movement (Guillot, Collet & Dittmar, 2004).

Other researchers have investigated imagery ability as another moderating vari- able of the effectiveness of imagery practice By means of the Movement Imagery Ques- tionnaire (MIQ), (Hall & Pongrac, 1983), which allows differentiating good from poor imagers, they have demonstrated that good imagers improve at complex motor tasks more than poor imagers (Isaac, 1992), that good imagers acquire simple movements in less trials than poor imagers (Goss, Hall, Buckolz & Fishburne, 1986; Hall, Buckolz & Fishburne, 1989, 1992), and that good imagers are

able to reproduce more accurate movement patterns (Hall et al , 1989) The authors concluded that good imagery abil- ity facilitates the memory information encoded in the representation of actions that is used during motor imagery In the same line, by recording autonomic nervous response, Roure et al (1999) and Guillot et al (2004) reported that the physiological response recorded after each instruction in good imagers attested to mental work during each trial Conversely, in poor imagers, weaker physiological responses were recorded dur- ing initial trials, which then tended to disappear, attesting that subjects did not perform mental imagery or did not succeed in forming an accurate representation of movement These works suggest that because athletes are usually required to imagine their move- ment as accurately as possible, their ability to form accurate images should be taken into consideration when investigating the effect of mental practice on motor performance In the applied mental imagery model developed by Martin et al (1999) to guide imagery use in sport, imagery ability effectively appears as a variable moderating the effects of imagery use on sport outcomes In the present experiment, we tested the relationship between imagery ability and service return accuracy in tennis

Finally the effect of the environmental context in which motor imagery is carried out also appears to in uence the effectiveness of imagery on motor learning (Hall, 2001; Holmes & Collins, 2001) Guillot, Collet and Dittmar (2005), using a task of service return in table tennis, investigated the effectiveness of motor imagery when performed in a context close to actual practice situations rather than in a neutral environment They showed that environmental conditions, particularly tactile, proprioceptive and auditory information, helped athletes to visualize and feel sensations elicited by actual practice Consequently, they suggested that table-tennis players should perform motor imagery in a situation close to the competition context, *i.e.* while wearing sports clothes, handling their paddle while standing in front of the table and starting mental imagery after the bounce of the ball on the table, such as just before actual serve

To our knowledge, studies examining the importance of motor imagery in tennis have previously investigated the effects of imagery on the serve, during which the form is the principal component of the motor act (Atienza et al , 1998; Féry & Morizot, 2000) None of these studies investigated service return, during which the perception of the opponent's action remains the principal component of the task The goal of this study was then to evaluate whether imagery training could improve the accuracy of the service returns, and whether this improvement may be in uenced by athletes' imagery ability The use of an internal visual imagery perspective was preferred because of its stronger impact on tasks with high perceptual requirements (Hardy & Callow, 1999; White & Hardy, 1995) Good and poor imagers were distinguished according to the ease or dif culty with which they were able to imagine movements Tennis players were expected to enhance motor performance accuracy after a motor imagery training pro- cess and performance improvement was expected to be dependent upon athletes' im- agery abilities As previously illustrated for laboratory tasks, we expected that service return accuracy would be better after mental practice for good imagers than for poor imagers

Method

Participants

Eighty self-declared right-handed tennis players who played tennis with the right hand gave their informed consent to participate in the study All were recruited in the "Aca- démie Cédric Nouvel & Pascal Courtois, les Hauts de Nîmes," played tennis for more than 7 years, and trained about 15 hours a week (for more than 3 years), competing at a regional or national level

Material and task

The experiment was conducted in an indoor tennis court (Quick surface) On this ground, a 460 x 460 cm square was drawn with a white chalk (Figure 1) This square was divid- ed into 46 "sub squares" of 10 cm In the middle of the square, a target was indicated by a plastic red cone (diameter: 20 cm) Participants had to perform service return toward the target, as accurately as possible Only forehand shots were performed (in a context similar to the one illustrated in Figure 1) When the returns were out of the square, they were considered invalid The sub squares also allowed the experimenter to collect errors in amplitude (long/short) and direction (left/right) of each valid service return Each trial was recorded by a video-recorder (type SHARP VLZ800S) located approximately 3m behind the target These video-recordings allowed to accurately collect the zone of the ball bounce in the square

Serves were performed by 3 tennis monitors, who played toward the right serve box of the receiver The monitors always served to the same place in the service box (see Figure 1) The speed of the serves, recorded by a radar (type R1000, Cordless MPH Radar Gun # R1000), was comprised between 130 and 170 km/h (see Table 1 for more details) Below or above this speed interval, serves were not taken into consideration To avoid the risk of tiredness and lassitude, servers performed series of 10 serves and then took turns throughout the experimental sessions Furthermore, all tennis players were required to return the same number of serves of each tennis monitor.

Measures

Before the experiment, participants completed the Movement Imagery Questionnaire (MIQ, Hall & Pongrac, 1983) It consists of 18 items which assess individual visual and proprioceptive imagery abilities Each item corresponds to a separate movement, which was speci cally described so that every person completing the questionnaire mentally simulates the same movements.

Figure 1. Illustration of tennis court, position of the target, squaring, receiver and server.
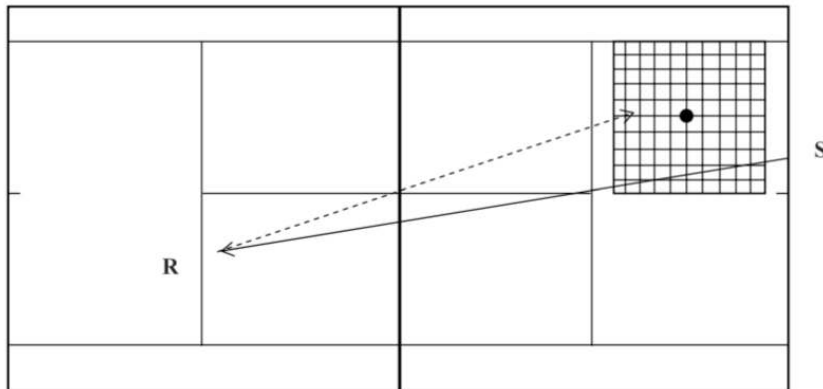
A variety of arm, leg, and whole body movements are incorporated in the MIQ and are relatively simple which ensures that most individuals are able to perform them Completing an item requires several steps First, the starting position for a movement is assumed Second, the participant produces the movement Third, the participant reassumes the starting position, and has to mentally simulate the movement (with either a visual or a proprioceptive imagery) Finally, the participant as- signs a value according to a 7-point rating scale regarding the ease/dif culty with which he mentally simulates the movement A low rating indicates that the movement is easy to imagine, while a high rating indicates a greater dif culty

Procedure

With regard to the MIQ scores, 30 participants were retained (mean age 19 years, SD = 2 5 years) All of them had similar scores with regard to proprioceptive imagery (scores > 26) and were divided into 3 groups as a function of their visual imagery scores: good imager (n = 10; scores < 11), poor imager (n = 10; scores > 26) and con- trol (n = 5 good imagers + n = 5 poor imagers) groups (see Goss et al , 1986 for similar participant selection)

Week 1 - Pre-test session: Participants physically performed 15 trials During a trial, a tennis monitor performed a serve in the right service box and participants had to per- form a service return as accurately as possible, in toward the target (Figure 1)

Week 2 to 9 - Mental and physical training: Participants were asked (during 15 sessions) to imagine 15 service returns as well as performing 15 actual trials The 15 imagery trials were always performed before the 15 actual trials This combination of mental and physical practice

was performed 2 times per session, in order to have a total of 60 trials (2*15 of imagined trials and 2*15 of actual trials) During motor imagery, performed on the tennis court in front of the experimenter, good and poor imagers were required to perform internal visual imagery (imagining being inside his/her body as if there were looking with their own eyes), by focusing their attention on the ball trajectory and on the target This consign was recalled by the experimenter before each imagery session After each session, athletes were required to describe the content of their mental representation, to check that they had followed the instructions None of them reported having performed something other than external visual imagery Imagery practice was performed in the receiver "ready position" (*i.e.* in a position similar to the one used when they physically wait for the serve), athletes wearing sport clothes and handling the tennis racket, as recommended by Guillot et al (2005) In the control group, the motor imagery task was replaced by a neutral task (reading a magazine) for a time equivalent to the duration of the 15 imagined trials (about 3 min)

Week 10 - Post-test: forty-eight hours after the end of the last training session, par- ticipants were submitted to a post-test, which was similar to the pre-test

Data analysis

For each service return, performed in the pre- and post-tests, the differences in ampli- tude (long and short) and direction (right and left) between the target and the rst ball bounce were measured The mean absolute error (AE) and variable error (VE) for both the amplitude and direction components were computed and retained as dependent variables The serve speed and the number of invalid service returns were also computed for both the pre- and post-test The dependent variables were submitted to a 3 Group (good/poor imagers and control) x 2 Test (pre- and post-test) ANOVA with repeated measures on the second factor All signi cant main effects and interactions were broken down using the Newman-Keuls technique.

Results

seRve speed And invAlid seRvice ReTuRns AnAlysis

As serve speed and accuracy of service returns are linked, a rst statistical analysis was conducted on the mean speed of the 15 services performed in the pre- and post-tests ANOVA did not reveal any signi cant main effect of group, $F(2,27) = 0\ 16$, $p > 0\ 05$, of test, $F(1,27) = 0\ 01$, $p > 0\ 05$, or group x test interaction, $F(2,27) = 0\ 16$, $p > 0\ 05$ The mean serve speed averaged was 145 km/h Detailed means are illustrated in Table 1.

A second analysis was performed on the mean number of invalid service returns (i e on returns that were out of the squaring) ANOVA did not reveal any signi cant main effect of group, $F(2,27) = 0\ 11$, $p > 0\ 05$, of test, $F(1,27) = 0\ 03$, $p > 0\ 05$, or an interaction between these two factors, $F(2,27) = 0\ 86$, $p > 0\ 05$ The number of invalid service returns averaged 3 5 Detailed means are reported in Table 2

Table 1. Mean serve speed (km/h) for all groups across pre-test and post-test (standard deviations).

	Pre-test	Post-test
Good Imagers	146.2 (5.5)	146.6 (6.7)
Poor Imagers	144.7 (5.7)	146.1 (6.4)
Control	145.1 (5.8)	144.4 (6.1)

Table 2. Number of invalid service returns for all groups across pre-test and post-test (standard deviations).

	Pre-test	Post-test
Good Imagers	3.8 (1.2)	3.4 (0.9)
Poor Imagers	3.5 (1.2)	3.6 (0.9)
Control	3.4 (1.1)	3.5 (1.0)

Absolute And variable errors analyses

AE and VE analyses for amplitude and direction were performed to examine the role played by imagery ability on improvement of service returns by comparing pre- and post-tests performance

The ANOVA computed on AE and on VE for *amplitude* revealed a signi cant main effect of group, $F(2,27) = 58\ 08$ and $17\ 25$, $p < 0\ 05$, and of test, $F(1,27) = 8\ 73$ and $17\ 81$, $p < 0\ 05$, as well as a signi cant group x test interaction, $F(2,27) = 6\ 31$ and $5\ 57$, $p < 0\ 05$ for AE and VE, resepctively The breakdown of the interaction for AE and VE revealed that the errors decreased from the pre-test to the post-test in good and poor imager groups (Newman-Keuls, $p < 05$), while no change was evident for the control group (Newman-Keuls, $p > 98$) (See Figure 2) Moreover, for VE, post-hoc analyses revealed that good imagers performed signi cantly better than poor imagers ($p < 05$, Figure 3), whereas there was no signi cant difference between the groups for AE and for VE at the pre-tests ($p > 75$)

The ANOVA on AE and VE for *direction* also revealed a signi cant main effect of group, $F(2,27) = 24\ 66$ and $13\ 47$, $p < 0\ 05$, and of test, $F(1,27) = 29\ 53$ and $30\ 02$, $p < 0\ 05$, as well as a signi cant interaction between these two factors, $F(2,27) = 10\ 95$ and $5\ 94$, $p < 0\ 05$ for AE and VE, respectively As illustrated by Figure 3, the errors de- creased from the pre- to the post-test in good and poor imager groups (Newman-Keuls, $p < 05$), while no change was observed in the control group ($p > 75$) Moreover, the post-hoc analyses revealed that good imagers were more accurate than poor imagers ($p < 05$, for AE), and that good imagers tended to be less variable than poor imagers ($p = 06$, for VE)
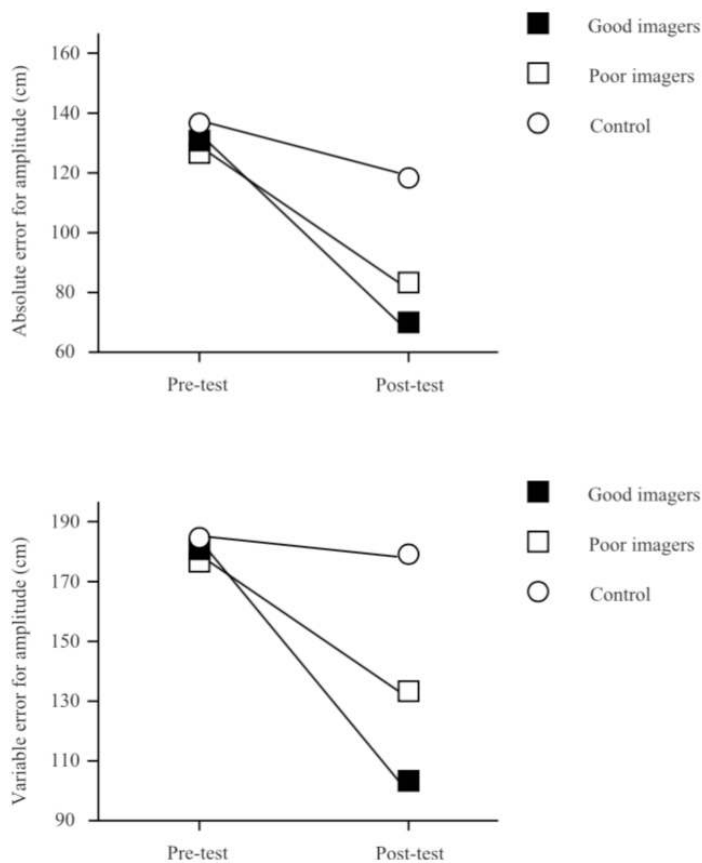
Figure 2. Absolute errors (top panel) and variable errors (lower panel) of amplitude of service returns as a function of test (pre- and post-test) and group (good/poor imagers and control).

Discussion

The aim of the study was to evaluate the effect of a motor imagery practice on motor performance of skilled tennis players, as well as the speci c in uence of participants' imagery abilities, when using an internal visual imagery perspective

Present results show that the combination of physical practice and motor imagery signi cantly improved the ac- curacy of the service returns in skilled performers This result is in agreement with Hardy and colleagues' viewpoint (Callow & Hardy, 2004; Hardy & Cal- low, 1999; White & Hardy, 1995), who suggested that an internal visual imagery has a positive effect on the acquisi- tion and the performance of tasks that mainly depend on perception for their accurate execution In such tasks, the mental rehearsal of actions is supposed to allow partici- pants to better anticipate the environmental changes and to envisage their own action in speci c conditions

Note that the previous suggestion does not invalidate the poten- tial effects of others imagery interventions (external visual imagery and/or kinaesthetic imagery) on service return improvement in tennis, the experimental protocol used in the present study being speci - cally focused on the effects of internal visual imagery practice compared to a no-imag- ery practice (control group).

More interestingly, the results of the present study indicate that imagery ability in u- ences the impact of motor imagery in enhancing the performance of the service returns Indeed, after 15 motor imagery sessions, good imagers signi cantly improved their accuracy for direction and were less variable when compared to poor imagers for am- plitude (tendency was observed for direction) Moreover, poor imagers took advantage of imagery practice (when compared to control), although to a lesser extent than good imagers Such ndings agreed with previous research showing that individual imagery ability differences may in uence the ease with which simple movement patterns can be learned (Goss et al , 1986), and improve the impact of motor imagery upon the accu- racy of complex motor actions (Isaac, 1992) It is therefore postulated that good imagers generate more easily a mental representation of action than poor imagers As suggested by Guillot et al (2004), poor imagers doubtlessly encountered greater dif culties to form vivid and accurate images of movement The results of the present study, showing that for direction accuracy, good imag- ers were more accurate than poor imagers, support this sug- gestion It may be possible that poor imagers had dif culties forming an accurate represen- tation of the localization of the target for the direction, whereas they would have had a correct representation of the amplitude (no difference between good and poor imagers was ob- served for AE) The latter result could be explained by the fact that skilled tennis players may pay more attention on the am- plitude than on the direction of the service return, particularly when the serve is quite fast

In spite of the limits linked to the use of questionnaires re- quiring athletes' self-estimation of imagery ability, this experi- ment con rmed that the MIQ is a reliable test to evaluate the success of imagery practice in sport situations, as it was previously con rmed in laboratory tasks (Atenzia et al , 1994; Hall, 2001; Hall et al , 1989) According to Paivio (1986), these inter-individual differences would be the product of the interaction between experience and genetic variables It is thus necessary to further consider the inter-individual differences in imag- ery ability, which appear to in uence the effects of imagery practice on the learning and the performance on sporting skills (Hall, 2001)
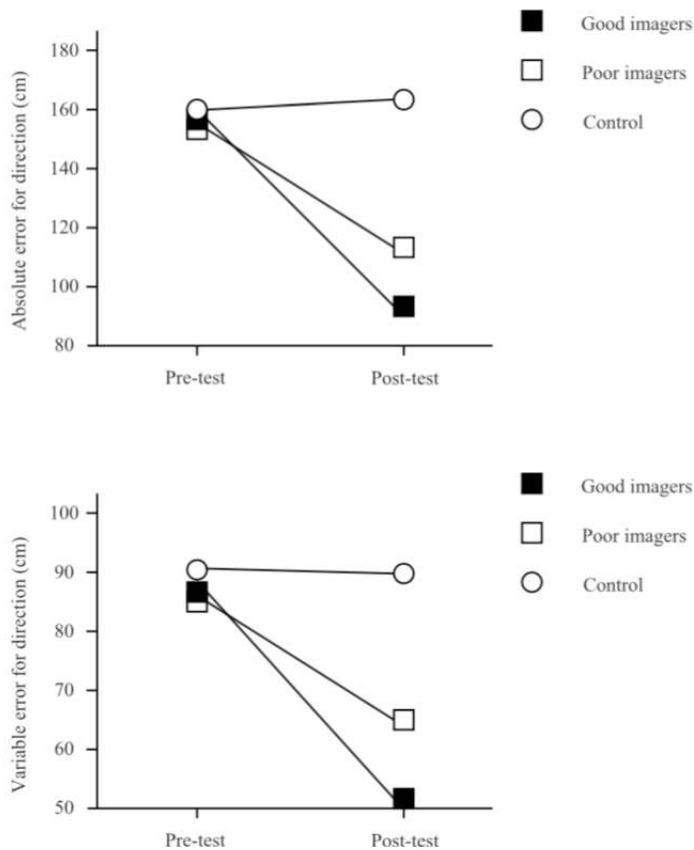
Figure 3. Absolute errors (top panel) and variable errors (lower panel) of direction of service returns as a function of test (pre- and post-test) and group (good/poor imagers and control).

The results obtained in this study indicated that the service return performances did not improve for the group who only had physical training (control group) The absence of any signi cant improvement for the control group may be explained by the fact that skilled players needed more than 15 sessions of 30 physical trials to increase the ac- curacy of the service returns The increase of performance should necessitate many thousands trials or more in order to re ne motor action carried out in an automatic way (Schmidt, 1993) or improve environmental information reading (ball trajectory of serve, angle of the elbow or the wrist of the server) In our minds, the improvement of motor performance of high sporting performers could require that practice partly occurs in a non-usual condition, as experimented when physical practice and motor imagery are combined This argument agrees with works that reported higher motor performance when physical training is combined with motor imagery than when it is not (Atenzia et al , 1998; Driskell et al , 1994)

The imagery ability effect observed in our experiment con rms the role played by motor imagery on the performance of skilled tennis players The bene cial effect of motor imagery could be due to either its motivational role (Paivio, 1985) or cognitive processes that supplement those induced

by physical practice As suggested by Hardy (1997), imagery practice is of interest if it generates images that give complementary information compared with information directly available during physical practice of the task In the present experiment, instructions given to the two imagery groups required participants to focus their attention on the trajectory of the ball and on the target How- ever, internal visual imagery perspective focusing participant's attention on the trajectory of the ball and on the target should be effective only for skilled tennis players, who high- ly automatized the knowledge of the service returns (Reed, 2002) By contrast, focusing attention on the racket movements should be more relevant for beginners Indeed, Wulf, McNevin, Fuchs, Ritter & Toole (2000) have shown that the improvement of the chip for golf beginners is better when participants focused their attention on the club (movement of pendulum, way and acceleration during impact) than on the trajectory of the ball Some experiments are actually undertaken in our laboratory in order to investigate the importance of an attentional adequ ate focus during motor imagery as a function of the level of expertise of participants

The imagery ability effect observed in our study could also be due to individual preferences with regard to the speci c imagery modality used The in uence of sensory dominance on motor control, which differs across individuals, was reported in various motor tasks (Boulinguez, Toussaint, Abed-Meraïm & Collignon, 2001; Coello, Milleville- Pennel & Orliaguet, 2004; Gullaud-Toussaint & Vinter 2003): some subjects favored visual control, while others favored proprioceptive control when producing accurate movements If functional equivalence between physical and imagery practice appears as an important prerequisite for valid and effective mental practice (Holmes & Collins, 2001; Jeannerod, 1999), then it may be possible that modifying the imagery script leads participants from the poor imager group to better improve their performance For this purpose, imagery script should require participants to image a motor action from their preferred sensory modality Further research will be conducted in our laboratory to iden- tify how imagery practice can be administered appropriately, with regard to sensory individual preferences, to maximize its potential effect

Conclusion

The results obtained in the present study highlight the effect of the internal visual imagery perspective on the service return accuracy in skilled tennis players, as well as the neces- sity to take into consideration athletes' imagery abilities to properly individualize motor imagery and motor learning Further research will be needed to investigate the effects of motor imagery in poor imagers in greater detail, and to test whether it may be individu- alized as a function of inter-individual differences and/or expertise level

References

Atienza, F L , Balaguer, I , & Garcia-Merita, M L (1998) Video modelling and imaging training on performance of tennis service of 9- to 12-year-old children *Perceptual and Motor Skills, 78,* 1323-1328

Boulinguez, P , Toussaint, L , Abed-Meraïm, B , & Collignon, F (2001) Nature of the perceptual encoding of hand positions according to subject's perceptuomotor expertise *Perceptual and Motor Skills, 93,* 24-30

Callow, N , & Hardy, L (2004) The relationship between the use of kinaesthetic imagery and different visual imagery perspectives *Journal of Sport Sciences, 22,* 167-177

Coello, Y , Milleville-Pennel, I , & Orliaguet, J P (2004) Weighted visuo-proprioceptive interaction in video-assisted pointing task explains spatial inaccuracy with rotated visual display *Neurosci- ence Letters, 369,* 214-218

Collet, C , Guillot, A , Bolliet, O , Delhomme, G , & Dittmar, A (2003) Corrélats neurophysi-ologiques des processus mentaux enregistrés en situation réelle par micro-capteurs non inva- sifs *Science et Sports, 18,* 74-85

Decety, J , & Grezes, J (1999) Neural mechanisms subserving the perception of human actions *Trends in Cognitive Sciences, 3,* 172-178

Decety, J , & Michel, F (1989) Comparative analysis of actual and mental movement times in two graphics tasks *Brain and Cognition, 11,* 87-97

Driskell, J E , Copper, C , & Moran, A (1994) Does mental practice enhance performance? *Journal of Applied Psychology, 79,* 481-491

Feltz, D L , & Landers, D M (1983) The effects of mental practice on motor skill learning and performance: A meta-analysis *Journal of Sport Psychology, 5,* 25-57

Féry, Y A (2003) Differentiating visual and kinesthetic imagery in mental practice *Canadian Journal of Experimental Psychology, 57,* 1-10

Féry, Y A , & Morizot, P (2000) Kinesthetic and visual images in modelling closed motor skills: the example of the tennis serve *Perceptual and Motor Skills, 90,* 707-722

Gallese, V , & Goldman, A (1998) Mirror neurons and the simulation theory of mind-reading *Trends in Cognitive Sciences, 12,* 493-501

Gerardin, E , Sirigu, A , Lehericy, S , Poline, J , Gaymard, B , Marsault, C , Agid, Y , & Le Bihan, D (2000) Partially overlapping neural networks for real and imagined hand movements *Ce- rebral Cortex, 10,* 1093-1104

Goss, S , Hall, C , Buckolz, E , & Fishburne, G (1986) Imagery ability and the acquisition and retention of movements *Memory & Cognition, 14,* 469-477

Grezes, J , & Decety, J (2001) Functional anatomy of execution, mental simulation, observation and verb generation of action: a meta-analysis *Human Brain Mapping, 12,* 1-19

Guillot, A , & Collet, C (2005) Duration of mentally simulated movement: A review *Journal of Motor Behavior, 37,* 10-20

Guillot, A , Collet, C , & Dittmar, A (2004) Relationship between visual vs kinesthetic imagery, eld dependence-independence and complex motor skills *Journal of Psychophysiology, 18,* 19 0 - 19 9

Guillot, A , Collet, C , & Dittmar, A (2005) In uence of environmental context on motor imagery quality *Biology of sport, 22,* 215-226

Guillot, A , Haguenauer, M , Dittmar A , & Collet C (2005) Effect of a fatiguing protocol on motor imagery accuracy European *Journal of Applied Physiology, 95,* 186-190

Gullaud-Toussaint, L , & Vinter, A (2003) The effect of discordant sensory information in graphic production: two distinct subject groups *Psychological Research, 67,* 291-302

Hall, C (2001) Measurement imagery abilities and imagery use Advances in sport and exercise psychology measurement *Purdue University Editor, 9,* 165-172

Hall, C , & Pongrac, J (1983) *Movement Imagery Questionnaire* London, Ontario: University of Western Ontario

Hall, C , Buckolz, E , & Fishburne, G (1989) Searching for a relationship between imagery ability and memory of movements *Journal of Human Movement Studies, 17,* 89-100

Hall, C , Buckolz, E , & Fishburne, G (1992) Imagery and the acquisition of motor skills *Canadian Journal of Sport Science, 17,* 19-27

Hardy, L (1997) Three myths about applied consultancy work *Journal of Applied Sport Psychology, 9,* 277-294

Hardy, L , & Callow, N (1999) Ef cacy of external and internal visual imagery perspectives for the enhancement of performance on tasks in which form is important *Journal of Sport and Exercise Psychology, 21,* 95-112

Holmes, P S , & Collins, D J (2001) The PETTLEP approach to motor imagery: a functional equiva- lence model for sport psychologists *Journal of Applied Sport psychology, 13,* 60-83

Ingvar, D H , & Philipson, L (1977) Distribution of cerebral blood ow in the dominant hemisphere during motor ideation and motor performance *Annals of Neurology, 2,* 230-237

Isaac, A (1992) Mental practice- does it work in the eld? *The Sport Psychologist, 6,* 192-198 Jeannerod, M (1999) The 25th Bartlett Lecture To act or not to act: Perspectives on the representation of actions *Quarterly Journal of Experimental Psychology, 52A,* 1-29

Li-Wei, Z , Qi-Wei, M , Orlick, T , & Zitzelsberger, L (1992) The effect of mental-imagery training on performance enhancement with 7-10 year-old children *The Sport Psychologist, 6,*

Martin, K A , Moritz, S E , & Hall, C R (1999) Imagery use in sport: A literature review and applied model *The Sport Psychologist, 13,* 245-268

Paivio, A (1985) Cognitive and motivational functions of imagery in human performance *Canadian Journal of Applied Sport Sciences, 10,* 22-28 Paivio, A (1986) *Mental representations: A dual coding approach* New York: Oxford University

Press Papaxanthis, C , Schieppati, M , Gentili, R , & Pozzo, T (2002) Imagined and actual arm movements have similar durations when performed under different conditions of direction and mass

Experimental Brain Research, 143, 447-452 Pie, J S , Tenebaum, G , Bar-Eli, M , Eyal, M N , Levy-Kolker, N , Sade, S , & Landers, D M

(1996) Imagery orientation and vividness: their effect on a motor skill performance *Journal of*

Sport Behavior, 19, 32-49 Reed, C L (2002) Chronometric comparisons of imagery to action: visualizing versus physically performing springboard dives *Memory and Cognition, 30,* 1169-78 Roure, R , Collet, C , Deschaumes-Molinaro, C , Delhomme, G , Dittmar, A , & Vernet-Maury, E

(1999) Imagery quality estimated by autonomic response is correlated to sporting perfor-

mance enhancement *Physiology and Behavior, 66,* 63-72 Schmidt, R A (1993) Apprentissage moteur et performance Paris, Vigot White, A , & Hardy, L (1995) Use of different imagery perspectives on the learning and perfor-

mance of different motor skills *British Journal of Psychology, 86,* 169-180 Wulf, G , McNevin, N H , Fuchs, T , Ritter, F , & Toole, T (2000) Attentional focus in complex skill learning *Research Quarterly for Exercise and Sport, 71,* 229-39.