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# 1 **Mental Imagery and Tennis: A Review, Applied Recommendations and New Research**

## 2 **Directions**

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## 21 **Abstract**

22 Mental Imagery (MI), which can be defined as the brain's ability to recreate motor  
23 experiences in the absence of actual actions, is a mental strategy commonly used by tennis  
24 players and coaches in the context of learning and performance. The purpose of this review  
25 was to examine the MI use, interventions and effects on the performance of tennis players.  
26 Preferred reporting items for reviews and meta-analyses guidelines were employed and  
27 research studies were collected via SCOPUS, PubMed, PsycINFO, Science Direct and Google  
28 Scholar, in English and French, from the earliest record up to August 2021. Forty-one studies  
29 met the inclusion criteria. This review (number 2020-05-87) resulted in a wide variety of MI

30 use in tennis and its beneficial effects, whatever the level or age of the players. MI  
31 interventions generally improve motor performance, motivational or affective outcomes.  
32 Moreover, MI is frequently combined with other mental skills and integrated in pre-  
33 performance routines including breathing, positive self-talk, and/or concentration. This study  
34 also highlighted the weak representation of female tennis players that's why future research is  
35 needed to better explore the gender effect in MI interventions in tennis. Overall, MI appears  
36 to be beneficial for players, whatever their age or level, and should be incorporated in training  
37 programs. Practical implications are discussed.

38 *Key words:* Motor imagery; performance; review; tennis; training.

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54 **Imagerie mentale et tennis : Revue de littérature, recommandations appliquées et**  
55 **nouvelles orientations de recherche**

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57 **Résumé**

58 L'imagerie mentale (IM), définie comme la capacité du cerveau à recréer des expériences  
59 motrices en l'absence d'actions réelles, est une stratégie mentale communément utilisée par les  
60 joueurs de tennis et les entraîneurs dans le cadre de l'apprentissage et de la performance. Le  
61 but de cette revue était d'examiner l'utilisation de l'IM et ses effets sur la performance des  
62 joueurs de tennis. La méthode PRISMA a été utilisée et les travaux de recherche ont été  
63 collectés via SCOPUS, PubMed, PsycINFO, Science Direct et Google Scholar, en anglais et  
64 en français, jusqu'en août 2021. Quarante-et-une études ont respecté les critères d'inclusion.  
65 Cette revue a révélé une grande variété d'utilisation de l'IM au tennis et des effets bénéfiques,  
66 quel que soit le niveau ou l'âge des joueurs sur les performances motrices, les affects et la  
67 motivation. De plus, l'IM est fréquemment associée à d'autres habiletés mentales et intégrée  
68 dans les routines de pré-performance. Cette étude a mis en évidence la faible représentation  
69 des joueuses de tennis, des recherches futures sont donc nécessaires pour explorer s'il existe  
70 un effet du genre en lien avec l'IM. Dans l'ensemble, l'IM semble être bénéfique pour les  
71 joueurs, indépendamment de leur âge ou de leur niveau et devrait être intégrée dans les  
72 programmes d'entraînement. Des recommandations pratiques sont proposées.

73 *Mots clés:* Entraînement ; imagerie motrice ; performance ; revue de littérature ;  
74 tennis.

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## 78 **Mental Imagery and Tennis: A Review, Applied Recommendations and New Research**

### 79 **Directions**

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### 81 **Introduction**

82 Tennis, which is one of the racket sports that involves hitting a mobile like a ball  
83 (Lees, 2003), requires the development and use of technical, physiological, tactical, mental  
84 skills and cognitive processes (Cece et al., 2020). For example, researchers highlighted the  
85 importance of attention control and focus in tennis (e.g., Guillot et al., 2013; Schmid et al.,  
86 2001). Akpinar et al. (2012) added that this sport requires coincidence-anticipation, accuracy  
87 in every stroke and requires a significant amount of practice, learning sessions and repetitions,  
88 generally spread over several years and of which the achievement and quality can be  
89 facilitated by the use of mental techniques such as mental imagery (Cece et al., 2020). The  
90 aim of the current study was to review the studies that concerned Mental Imagery (MI)  
91 specifically in tennis in order to provide consistency from data and to identify the main  
92 findings concerning the MI effects, uses, outcomes and characteristics in order to give  
93 information, precisions or applied recommendations to coaches and practitioners and also to  
94 identify limitations and new research directions.

### 95 **Tennis and Psychological Components**

96 Tennis players need to invest psychological resources (e.g., motivation), by notably  
97 using MI (Dana & Gozalzadeh, 2017), in order to improve learning, to progress, to continue  
98 participation and to obtain long-term performance (Crespo & Reid, 2007). In addition,  
99 because of dual competition and the need to continue playing despite of under-performance,  
100 errors or defeats, Covassin and Pero (2004) identified self-confidence as a salient factor in  
101 tennis. Moreover, anxiety control (Bolgar et al., 2008) and the emotional regulation of control  
102 (Laborde et al., 2014) have also been considered as really important mental skills to take into

103 account, especially before and during tennis competitions. Indeed Jackson and  
104 Csikszentmihalyi (1999) argued that athletes competing at their best characterized their ideal  
105 state of performance as feeling confident and in control; and conceptualised these optimal  
106 experiences as flow state including pleasure, concentration or experiencing a balance between  
107 the challenges and one's ability levels. Authors found that awareness and flow was related to  
108 tennis performance and that a MI intervention increased flow state and performance in tennis  
109 competition (Koehn et al., 2013), and that the use of this mental technique was particularly  
110 useful in tennis (Cece et al., 2020). For example, during a match, tennis players perform an  
111 intermittent activity, consisting of playing time interspersed with frequent rest times between  
112 points and games during which they can use MI to notably improve their accuracy, strategy,  
113 concentration or emotional control (Dohme et al., 2019; Mathers, 2017). That's why we  
114 reviewed the use and the potential beneficial effect of MI to improve learning, performance  
115 and motivational or affective outcomes, and to give practical suggestions, to tennis players  
116 and coaches, in order to incorporate this mental technique in training programs as suggested  
117 by Di Corrado et al. (2020).

### 118 **Imagery Definition**

119       According to Kosslyn et al. (1995), imagining places, sounds and actions in the  
120 absence of appropriate stimuli for the relevant perception is done through MI. White and  
121 Hardy (1998) evoked that athletes use MI in various ways including analysing past  
122 performance, reducing anxiety, improving self confidence, focus, quality of training or mental  
123 rehearsing of match strategies or motor actions specifically called motor imagery. Motor  
124 imagery can be defined as a dynamic state during which the representation of a specific motor  
125 action is reactivated in the brain without any over movements (Decety & Jeannerod, 1995).  
126 Finally, MI is considered a mental technique that uses all senses to re-create or create an  
127 experience in the brain and programs the mind and body to respond optimally (Williams et

128 al., 2012).

### 129 **Imagery Outcomes**

130 MI is commonly used by tennis players and coaches (Dominique et al., 2021; Lindsay  
131 et al., 2019), on its own and usually implicitly or as a part of a mental training program  
132 combined with other techniques or mental skills such as relaxation, breathing, self-talk,  
133 arousal regulation or concentration (Cece et al., 2020). MI is generally associated with a wide  
134 range of positives outcomes in the context of tennis such as motor learning (e.g.,  
135 Cherappurath & Elayaraja, 2017; Guillot et al., 2012), motor performance (e.g., Cherappurath  
136 et al., 2020a; Dominique et al., 2021; Fekih et al., 2020b), regulation and emotional control  
137 (e.g., Dohm et al., 2019), anxiety (e.g., Mousavi & Meshkini, 2011) or self-confidence (e.g.,  
138 Mamassis & Doganis, 2004).

### 139 **Imagery Function**

140 Authors evoked that MI can affect motor behaviour through both cognitive and  
141 motivational mechanisms operating at a general or specific level and identified five  
142 subcategories of MI practice also called function (Hall et al., 1998; Paivio, 1985). Cognitive  
143 Specific (CS) imagery involves the rehearsal of specific sport skills (e.g., imagining yourself  
144 performing a flat serve down the middle) whereas the Cognitive General (CG) imagery,  
145 focuses on playing strategies, routines and tactical points that players can use during matches  
146 (e.g., imagining performing a serve-volley and winning with a drop shot). Motivational  
147 Specific (MS) imagery (e.g., seeing your self winning a match) entails imaging specific goal  
148 and the ways to achieve it, influencing intrinsic motivation; Motivational General-Arousal  
149 (MG-A) imagery (e.g., imagining the anxiety associated with significant competition) is  
150 associated with stress, anxiety and arousal regulation, and Motivational General-Mastery  
151 (MG-M) imagery is associated with self-confidence, control and beliefs over an individual's  
152 abilities (e.g., seing yourself coping under challenging situations like after losing a set).

### 153 **Imagery Modality**

154           Regardless of the type (i.e., subcategories) of MI practice, many authors pointed out  
155 that MI modalities and perspectives are very important factors to consider (Cumming & Ste-  
156 Marie, 2001; Robin et al., 2020). Indeed, each MI modality can have differentiated impacts on  
157 motor performance (Hardy & Callow, 1999). The kinesthetic imagery (KI) modality is  
158 defined as what one feels during an action and includes sensations such as force, relaxation  
159 and effort involved in movement (Callow & Waters, 2005). Visual imagery modality consists  
160 to see an object, an action or a scene. It can be done from an external perspective (i.e., the  
161 athlete “views him or herself from another person’s perspective”) or an internal perspective  
162 (i.e., an individual “views the image through their own eyes”) (Williams et al., 2012, p. 631).  
163 Given the existence of different imagery modalities and perspectives, clear and precise  
164 instructions must be given to participants before MI intervention (Callow et al., 2013; Hall et  
165 al., 1992; Robin et al., 2020). Finally, it is important to note that the effectiveness of the MI  
166 intervention may depend on the athlete’s capacity to generate mental images (Seiler et al.,  
167 2015).

### 168 **Imagery Ability**

169           MI ability, which can be defined as an individual’s capability to form vivid,  
170 controllable images and retain them for sufficient time to effect the desired rehearsal appears  
171 as a variable moderating the effects of imagery on sport outcomes (Martin et al., 1999).  
172 Indeed, studies showed that individuals with higher imagery abilities (i.e., good imagers)  
173 achieved higher levels of performance than participants with lower imagery abilities (i.e.,  
174 poor imagers) after MI intervention (Goss et al., 1986; Robin et al., 2007). Therefore,  
175 Cumming and Ramsey (2009) suggested that it seems important to screen athletes for MI  
176 abilities before and during MI practice.

### 177 **Aim and Objectives**

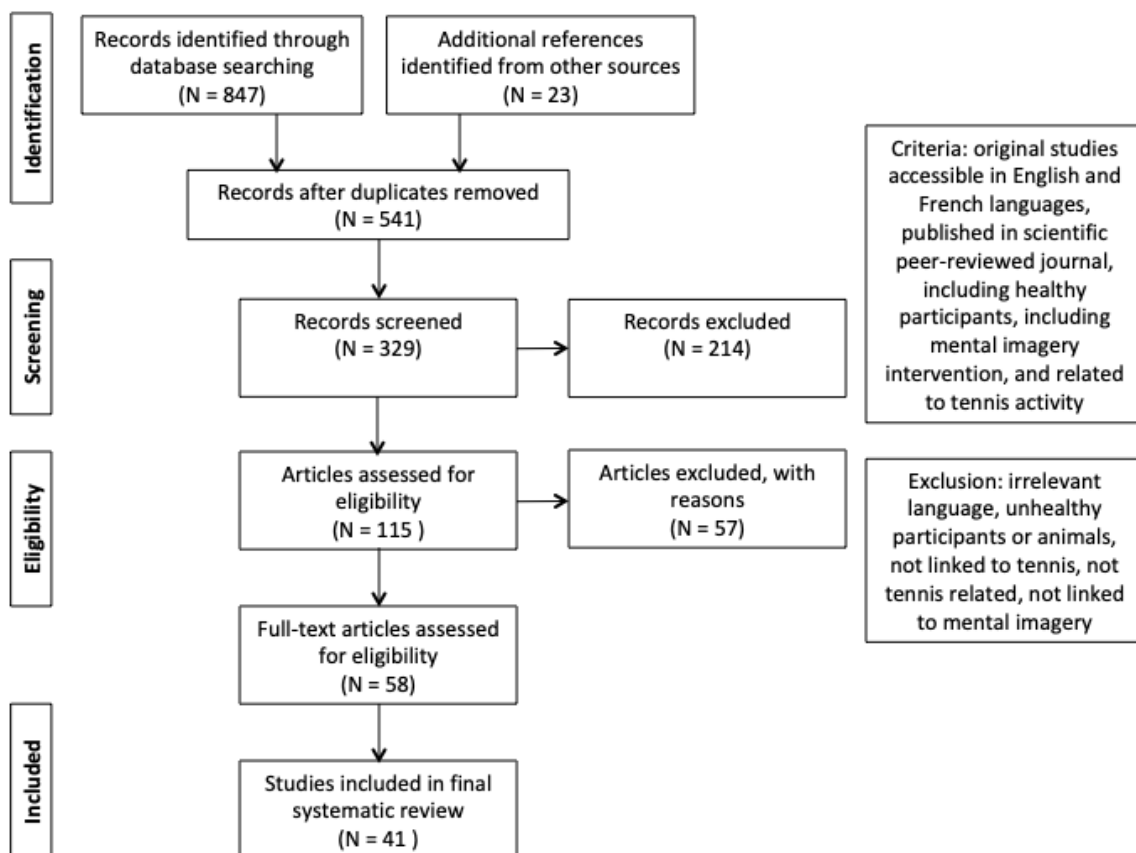


178 According to Dominique et al. (2021), the mental aspect of performance in tennis  
179 represents a central preoccupation for players and coaches. Cece et al. (2020), who reviewed  
180 the use of mental training program in racket sports, recently showed that the most frequently  
181 used mental skill was MI. However, the use of this mental technic requires certain knowledge,  
182 know-how and precautions on the part of the users and to our knowledge no studies has so far  
183 synthetized the literature to make an inventory of the characteristics, effects and uses in the  
184 field of MI, in particular in tennis. Therefore the main aim of the current study was to provide  
185 a synthesis of the researches focused on both tennis and MI. The first objective was to list and  
186 collect the researches that concerned MI uses and interventions in healthy non-expert (i.e.,  
187 novice and intermediate levels) and expert tennis players, regardless of their age (i.e., child,  
188 teenager and adult), in particular to verify if this mental technique can be beneficial whatever  
189 the age or the level of the players, and to provide an organized synthesis of these studies in  
190 order to better understand the effects of MI interventions on outcomes such as learning,  
191 performances or affective and motivational psychological factors (e.g., motivation, anxiety,  
192 self-confidence) and to give arguments to use it. The second objective was to propose  
193 practical recommendations to the players, coaches, researchers or even parents who wish to  
194 use imagery in the context of tennis. Finally, the third objective was to suggest potential  
195 further investigations concerning MI and tennis.

## 196 **Materials and Methods**

197 The present review was performed in accordance with Preferred Reporting Items for  
198 Systematic Reviews and Meta-analyses (PRISMA) guidelines (Moher et al., 2009). The  
199 protocol was written before conducting the review. The literature search procedure, including  
200 the systematic approach of identification, screening, eligibility, and inclusion, is detailed by  
201 using a PRISMA flow diagram (Figure 1). The present review was obtained through  
202 electronic journal and manual searches, from the earliest record up to August 2021, in

203 SCOPUS, PubMed, PsycINFO, Science Direct and Google Scholar databases. The searches,  
 204 restricted to English and French language publications, were carried out using the following  
 205 Boolean phrases: 'mental imagery' OR 'motor imagery' OR 'mental rehearsal' AND 'tennis'.  
 206 The authors (who are both Ph.D in sport science university, doctor in psychology, tennis  
 207 coaches and mental trainers) screened all the studies, based on the information available in the  
 208 title and the abstract, meeting the inclusion and exclusion criteria. This study assessed quality  
 209 and included: (1) original studies, (2) published in scientific peer-reviewed journal, (3)  
 210 including healthy participants, (4) using mental or motor imagery interventions, (5) in relation  
 211 to tennis activity. The exclusion criteria were: Publication language other than English or  
 212 French, MI realized during hypnosis or MI not related to movements or tennis environments.  
 213 This review was approved by the local ethics committee of the university (registration number  
 214 2020-05-87) and was conducted in accordance with the Declaration of Helsinki.



215  
 216 *Figure 1.* Flow diagram.

217 The authors independently realized the search and identified records ( $N = 870$ ) through  
218 database searching ( $N = 847$ ) and from other sources ( $N = 23$ ). Articles duplicated in two or  
219 more databases were identified and removed from this review. Then, the authors screened the  
220 records ( $N = 329$ ) and excluded articles that do not meet the criteria (e.g., irrelevant language  
221 or subjects, unhealthy participants, not tennis related). In order to determine the interrater  
222 reliability concerning the eligibility of the articles, Cohen's Kappa (McHugh, 2012) was  
223 calculated and showed a strong level of agreement (Kappa = 0.893) between the reviewers.  
224 Then during meetings, the authors compared and discussed their findings, and a third external  
225 reviewer was consulted to resolve any disagreements and avoid bias. The articles assessed for  
226 eligibility ( $N = 115$ ) were independently screened (e.g., title, abstract and key-words) to  
227 determine if they met the criteria and could be included in the review. The authors screened  
228 the full-text articles assessed for eligibility ( $N = 58$ ), for bias such as lack of blinding, absence  
229 of randomization, lack of study design or disclosure of conflicts of interest. The selected  
230 studies ( $N = 41$ ), found identically by the two authors, were extracted according to references,  
231 type of study (e.g., laboratory, ecological condition), MI modalities (e.g., internal visual,  
232 external visual, kinesthetic imageries) and types (i.e., cognitive specific, cognitive general,  
233 motivational general-arousal, motivational general-mastery, motivational specific)  
234 characteristics of the sample (i.e., sample size, gender, mean age, athletic level), experimental  
235 groups and duration, outcome measures and main results. The latter were analysed using  
236 descriptive statistics with the software package Statistica 12, and the characteristics of the  
237 selected studies were summarised (see Table 1).

238 The evaluation of the quality was realized by using two rating lists because studies  
239 with different quantitative designs were included in this review. Randomised controlled trials  
240 and non randomized trials were evaluated on the basis on the Physiotherapy Evidence  
241 Database guidelines (Maher et al., 2003) with a maximum of eleven points or eight points

242 respectively. Single cases experimental designs were evaluated by using the Single Case  
243 Experimental Design guideline (Tate et al., 2008) with a maximum of eleven points (Schuster  
244 et al., 2011). Therefore, the studies ( $N = 41$ ), which were included in the final review and  
245 were independently scrutinized by the experimenters, received one point for fulfilled  
246 methodological criterion such as random allocation of the participants to the groups, similar  
247 pre-intervention levels, blinding of all the participants and assessors, statistical comparisons  
248 reported, replication and generalisation on the respective rating list (see Table 1) with the  
249 higher the score obtained, the better the quality of the study. The evaluation of the quality,  
250 which may help the reader to interpret and to use the results of a study with caution especially  
251 for a low score, was performed by the authors (for similar procedure see Schuster et al.,  
252 2011). A third external reviewer was consulted to resolve any disagreements.

253 Table 1.

254 *Summary of article characteristics*

Authors and years	Titles	Study type	Mental imagery modalities and types	Participants (N, Gender, mean age) and athletic level	Intervention group(s) and duration	Outcomes measures	Main findings or results	Quality ratings
Atienza et al. (1998)	Video modelling and imaging training on performance of tennis service of 9- to 12-year-old children	Experimental Ecological condition	Externally guided motor imagery. CS	(22 females, 10 yr.), school tennis players	Physical, Physical + video, Physical + video + MI. 24 weeks	Tennis service Pre-post	Mental practice (i.e., MI and/or video) groups had greater post intervention performances than the control group.	6
Bisio et al. (2014)	The tool as the last piece of the athlete's gesture imagery puzzle	Experimental Laboratory	Kinesthetic imagery CS	(11 males, 9 females, 25 yr.), 10 expert tennis players, 10 novices	Expert and, novices groups. Real movement, 60 MI trials with racket, tennis-like racket or umbrella 1 session	Movement Imagery Questionnaire-R Real and MI durations, Movement kinematic	MI and real movement durations were similar with the rackets. When not handled specific tool, MI duration increased but not in the control condition.	7
Blankert & Hamstra (2017)	Imagining success: Multiple achievement goals and the effectiveness of imagery	Experimental Ecological condition	Internal visual and kinesthetic imagery, CS	(49 males, 16 females, 27 yr.), tennis players level (4-7 US rating)	Mastery goal, performance goal, mastery plus performance goal groups 1 session	Service Pre-post	Post imagery intervention service performance was greater in the mastery plus performance goal group than in the other groups.	6
Cherapurath & Elayaraja (2017)	Combined effects of SAQ and PETTLEP imagery training: A study on the learning process of new skills among novice tennis players	Experimental Ecological condition	Internal visual and kinesthetic imagery, CS	(40 males, 10-12 yr.), novice tennis players	Speed, Agility and Quickness training group, MI group, SAQ and MI group, control group 12 weeks	Forehand, backhand, volley Movement Imagery Questionnaire-R Pre-post	Experimental groups had higher post intervention performances than control group, and the SAQ + MI group had greater performance than the other groups.	6

Cherapurath et al. (2020)	PETTLEP imagery and tennis service performance: An applied investigation	Experimental Ecological condition	Internal visual and kinesthetic imagery, CS	(44 males, 13 yr.), 2-6 yr. practice	Service training, MI, service training + MI, control groups 12 weeks	Service Movement Imagery Questionnaire-R Pre-post	Service training and MI group had higher performance than other groups.	7
Coelho et al. (2007)	Imagery intervention in open and closed tennis motor skill performance	Experimental Ecological condition	Mutli-modal imagery MG-M	(48 males, 17 yr.), national tennis players	Technical practice, MI + technical practice 2 months	Service and service return Pre-post	MI intervention improved service performance.	6
Coelho et al. (2012)	Use of multimodal imagery with precompetitive anxiety and stress of elite tennis players	Experimental Ecological condition	Mutli-modal imagery, control imagery: good moments on the beach, MG-M	(46 males, 17 yr.), elite tennis players	Multimodal imagery, placebo imagery, control groups 9 weeks	Competitive State Anxiety Inventory Perceived Stress Scale Pre-post	Multi-modal MI can lower cognitive anxiety and perceived stress levels and to build self-confidence.	7
Cumming & Hall (2002)	Deliberate imagery practice: The development of imagery skills in competitive athletes	Experimental	Deliberate MI uses CS, CG, MS, MG-A, MG-M	(78 males, 72 females, 21 yr.), novice (n = 50), provincial (n = 50) and national (n = 50); 5 tennis players	Recreational athletes, provincial athletes, national athletes groups. 1 session	Deliberate Imagery Practice Questionnaire Time spent performing mental imagery	National athletes perceived MI more relevant to improving performance and competition effectively than recreational. Provincial and national athletes use more often MI than recreational.	6
Dana et al. (2017)	Internal and external imagery effects on tennis skills among novices	Experimental Ecological condition	Internal and external imagery CS	(36 males, 15-18 yr.), novice tennis players	Internal imagery, external imagery, control groups 6 weeks	Forehand, backhand Service. Pre-post	Internal MI group had higher serve and External MI group had greater forehand performances.	6

Daw et al. (1994)	Evaluation of a comprehensive psychological skills training program for collegiate tennis players	Experimental Ecological condition	Psychological skills training CS, MG-M	(13 males, 13 females, 18-23 yr.), intermediate (collegiate) tennis players	Psychological skills training group, control group 3 sessions	Forehand, backhand stroke, Service. Pre-post	Participants who had psychological skills training exhibited greater self-confidence and committed fewer double faults than the control group.	6
de Sousa Fortes et al. (2019)	Effect of motor imagery training on tennis service performance in young tennis athletes	Experimental Ecological condition	Video before MI First person imagery CS	(28 males, 15 yr.), regional tennis players	Imagery training, control groups 8 weeks	Movement Imagery Questionnaire-3 Service, Pre-post	The first person imagery training improved the running speed and performance of the tennis service.	7
Dereceli (2019)	Investigating the imagination levels of students playing tennis	Experimental	CS, CG, MS, MG-A, MG-M	(57 males, 94 females, 8-16 yr.), students recreational level	Age, gender, persistence of sporting 1 session	Sport Imagery Questionnaire	The level of imagery did not differ significantly based on age or gender in the students engaged in tennis.	4
Desliens et al. (2011)	Imagerie motrice et précision au service: Etude de cas [Motor imagery and service accuracy: A case study]	Experimental Case study Ecological condition	Visual imagery, Kinesthetic imagery CS	(1 males, 24 yr.), expert tennis player	Imagery modality, number of mental repetition, context 1 session	Service	4 MI repetitions, in serving position, improved accuracy. Visual MI practice, in serving position, improved consistency.	6
Di Corrado et al. (2019)	Imagery ability of elite level athletes from individual vs. team and contact vs. no-contact sports	Experimental Laboratory	Mental imagery transformation, Kinesthetic imagery, Internal visual imagery, External visual imagery CS	(64 males, 56 females, 24 yr.), national (16 males, 14 females), control (28 males, 32 females, 23 yr.)	Gender, contact /no-contact sports, team/individual sports 1 session	Vividness of Visual Imagery Questionnaire Vividness of Movement Imagery Questionnaire-2 Mental Image Transformation	Individual sports exhibit better vividness of visual MI ability, and kinesthetic and external visual imagery scores than team sports, and internal visual imagery scores than team and contact sports.	6
Dohm et al. (2019)	Development, implementation, and evaluation of an	Experimental Ecological	Psychological skills training (self-talk, imagery and	(11 males, 8-15 yr.), elite youth tennis	3 phases: pre-intervention, intervention,	Observation, field notes, athlete-	Psychological skills training improved the players' regulation,	7

	athlete-informed mental skills training program for elite youth tennis players.	Condition	performance routines) CS	players	evaluation. 15 month	workshop data and semi-structured interview with the coach	emotional control and use of psychological skills.	
Domini-que et al. (2021)	Effect of a routine based on mental imagery on service efficiency of expert tennis players	Experimental Ecological Condition	External visual MI + breathing + ball rebound CS	(27 males, 13 females, 18 yr.), expert tennis players	MI, control groups 20 weeks of a routine based MI + practice.	Service Mental imagery vivacity scales Pre-post	Service routine (breathing + ball rebound + MI) induces higher post-test performance than control condition.	7
Fekih et al. (2020a)	The Impact of a motor imagery-based training program on agility, speed, and reaction time in a sample of young tennis athletes during Ramadan fasting: Insights and implications from a randomized, controlled experimental trial	Experimental Ecological Condition	Visual imagery External visual imagery Kinesthetic imagery CS	(27 males, 17 yr.), national tennis players	Imagery group, control group 4 weeks	MAT-Agility test, Speed (ZIG-ZAG test), Movement Imagery Questionnaire-RS MI duration Pre-post	Fasting during Ramadan reduced speed, agility, and reaction time performance. Mental imagery intervention can reduce the effect of fasting by stabilizing reaction time, speed and agility performance.	7
Fekih et al. (2020b)	Effects of motor mental imagery training on tennis service performance during the Ramadan fasting: A randomized, controlled trial	Experimental Ecological Condition	Visual imagery Kinesthetic imagery Video First person perspective CS	(38 males, 16 yr.), national tennis players	Imagery, control groups 4 weeks	Service performance, Movement Imagery Questionnaire Pre-post	The imagery group improved the accuracy, running speed and performance of the service, mitigating the negative effects of Ramadan.	7
Féry et al. (2000)	Kinesthetic and visual image in modelling closed motor skills: the	Experimental Ecological Condition	Visual imagery (VI) Kinesthetic imagery (KI)	(32 males, 21 yr.), novice tennis players	Kinesthetic modelling + KI, visual modelling + VI, kinesthetic	Vividness of Visual Imagery Questionnaire	Participants who realized MI practice had beneficial effect on tennis serve precision. Novices who	6



	example of the tennis serve		CS		modelling, visual modelling and control groups 6 sessions	Service Pre-post	performed KI had higher form and speed scores than those who performed VI or control.	
Fourkas et al. (2008)	Kinesthetic imagery and tool-Specific modulation of corticospinal representations in expert tennis players	Experimental Laboratory	Kinesthetic imagery  CS	(14 males, 2 females, 20-33 yr.), 8 expert tennis players, 8 novices	Expert tennis players, novice groups  1 session	Movement Imagery Questionnaire Transcranial Magnetic Stimulation	Novices were not modulated across sport. Muscles of expert tennis players showed increased corticospinal facilitation during MI of tennis but not table tennis or golf.	7
Gabr. (2010)	Mental imagery and self-talk as approach to cope with pressure among individual sports	Experimental Ecological condition	Visual imagery, auditory imagery, kinesthetic imagery, emotional + control imagery  CS, MS, MG-M	(22 NC, NC yr.), NC	Fencing player, tennis player, karate player groups  8 weeks	Multi-dimensional Mental Imagery Scale in Sport, Self-Talk Scale in Sport, Skills of Facing Sports Pressure Scale Pre-post	All the groups had higher post treatment scores in all the dependant variables.	3
Guillot et al. (2005)	Duration of mentally simulated movement: A review	Experimental Laboratory	Mental Imagery  CS	(10 males, NC), 10 expert tennis players, 10 gymnasts	Expert tennis players, Experts gymnasts  1 session	Duration of actual and MI actions: service + volley	Durations of actions were longer during MI than during actual performance in both gymnastics and tennis athletes.	5
Guillot et al. (2004)	Relationship between visual and kinesthetic imagery, field dependence-independence, and complex motor skills	Experimental Laboratory	Visual imagery (VI) Kinesthetic imagery (KI)  CS	(10 males, 10 females, 16-35 yr.) 10 expert players, 10 gymnasts	Expert tennis players, Experts gymnasts  1 session	Skin resistance as peripheral indicator or mental imagery MI duration	50% of the tennis players make better use of VI than KI, whereas the other makes better use of KI than VI.	6
Guillot et al. (2012)	Motor imagery and 'placebo-racket effects' in tennis serve performance	Experimental Ecological condition	Combination of visual, auditory and kinesthetic imagery	(15 males, 7 females, 14-16 yr.), regional	Imagery, placebo, control groups. 6 weeks	Movement Imagery Questionnaire-R Service	MI improved service performance. Placebo racket + MI induced greater serve accuracy	7

			CS	players		Pre-post	compared to MI alone.	
Guillot et al. (2013)	Motor imagery and tennis serve performance: The external focus efficacy	Experimental Ecological condition	Mental imagery with external focus CS	(7 males, 5 females, 11 yr.), elite tennis players	2 consecutive conditions: 8 weeks control, then 8 weeks MI. 16 weeks	Movement Imagery Questionnaire-R Service Test-retest	An increase in the service accuracy, velocity, and first successful serves was showed after MI practice.	6/10
Guillot et al. (2015)	Implementation of motor imagery during specific aerobic training session in young tennis players <sup>[1]</sup>	Experimental Ecological condition	Combination of internal visual, external visual and kinesthetic imageries CS	(6 males, 4 females, 13 yr.), young elite tennis players	Two playing training session: a session including mental imagery and a control session	Movement Imagery Questionnaire-R Forehand and backhand Pre-post	Embedding MI during high intermittent training sessions increases physical fitness and preserves forehand and backhand performances.	6
Hegazy et al. (2015)	The effect of mental training on motor performance of tennis and field hockey strokes in novice players	Experimental Ecological condition	Photo and video of expert tennis players Visualization CS	(24 males, 19-20 yr), novices	Experimental group, 16 sessions	Visualization test Forehand and backhand Pre-post	The participants of experimental group significantly improved their forehand and backhand performances.	4
Jung et al. (2015)	Effect of imagery tennis training on cerebral activity	Experimental Laboratory	Visual imagery CS	(11 males, 25 yr), novice players	Experimental group 1 session	Electroencephalography	MI of tennis activates the hippocampal-occipital alpha networks.	4
Koehn et al. (2014)	Imagery intervention to increase flow state and performance in competition	Experimental Ecological condition Case study	CS, CG, MS, MG-M	(4 males, 14 yr.), national tennis players	6 weeks baseline flow state and performance, and 6 weeks intervention phase	Sport Imagery Ability Measure Flow State Scale-2 <sup>[1]</sup> Single-case A-B multiple-baseline design	3/4 tennis players increased flow experiences. All of them improved service and groundstroke performances, and ranking-list position.	6
Mamassis (2005)	Improving serving speed in young tennis players	Experimental Ecological condition	External visual imagery CS	(48 males, 10 yr.), intermediate tennis players	Service, service + strength training, mental training +service, mental training + service + strength, control	Service Imagery quality rating Pre-post	Mental training + service had higher performances than the other groups. Mental training + service + strength training group	5

					groups. 8 weeks		had greater performances than the control group.	
Mamassis et al. (2004)	The effects of a mental training program on juniors pre-competitive anxiety, self-confidence, and tennis performance	Experimental Ecological condition	Mental training program (MTP) CS, CG	(9 males, 14 yr.), elite junior tennis players	Experimental, control groups Season-long mental training program	Competitive State Anxiety Inventory-2 Overall tennis score. Vividness imagery scores Pre-post	Higher scores in the direction of the somatic and cognitive anxiety and self-confidence, on the intensity of self-confidence, and overall tennis performance after MTP.	6
Mathers (2017)	Professional tennis on the ATP tour: A case study of mental skills support	Experimental Ecological condition Case study	Mental skills External Visual Imagery CS, MG-M	(1 male, 27 yr.), international tennis player	3 years	Mental skills development Global tennis performance	Mental skills and pre-service routine improved tennis performance and outcomes.	6
McAleeney et al. (1990)	Effects of flotation restricted environmental stimulation on intercollegiate tennis performance	Experimental Ecological condition	Visual imagery of optimal shots CS	(10 males, 10 females, 19 yr.), inter-collegiate	Flotation REST with MI, MI only groups. 3 weeks	Service Pre-post	Flotation REST with MI group had higher post-treatment first service accuracy than the MI only group.	7
Mizuguchi et al. (2015)	The effect of somatosensory input on motor imagery depends upon motor imagery capability	Experimental Laboratory	First imagery perspective CS	(12 males, 5 females, 19-29 yr., 22 yr), 2-12 yr. practice	Forehand and backhand with racket, MI of forehand and backhand with or without racket, congruent or incongruent grips 1 session	Vividness of MI scores Time for real and MI movement with congruent or incongruent grips	A congruent grip improves whereas an incongruent grip deteriorates motor imagery of the backhand swing. A congruent forehand grip did not improve motor imagery of the forehand swing.	7
Morais et al. (2019)	Pre-service routines, mental toughness and performance enhancement of young tennis athletes	Experimental Ecological condition	Mental toughness including: Visualization CS, MG-M	(10 males, 1 females, 12 yr.), amateur competitors	Performance baseline and intervention phases 10 sessions	Service Pre-post	More service games won after the program.	5

Mousavi et al. (2011)	The effect of mental imagery upon the reduction of athletes' anxiety during sport performance	Experimental	MG-A	(50 males, NC), NC	Experimental group, control group 1 session	Kettle anxiety questionnaire Pre-post	MI reduced post intervention tennis players' anxiety.	2
Noel (1980)	Effect of visuo-motor behavior rehearsal tennis performance	Experimental Ecological condition	Visual imagery CS	(14 males, NC), novice players	Visuo-motor behaviour rehearsal, Control groups, 10 days	Service Pre-post	The visuo-motor behaviour rehearsal group marginally improved first serve %.	5
Robin et al. (2007)	Effects of motor imagery training in service return accuracy in tennis: the role of imagery ability	Experimental Ecological condition	Internal visual imagery CS	(30 males, 19 yr.), expert tennis players	Good imagers, Poor imagers, Control groups, 10 weeks	Return service Movement Imagery Questionnaire Pre-post	MI groups had higher post-test scores than control group. Good imagers had higher scores than poor imagers.	6
Spittle et al. (2007)	Internal and external imagery perspective measurement and use in imagining open and closed sports skills: An exploratory study	Experimental Ecological condition	Internal imagery perspective External imagery perspective CS	(23 males, 18 females, 19 yr.), novice tennis players	1 condition 1 session	Imagery Use Questionnaire Rating scale on MI perspectives Retrospective verbalisation <sup>[1]</sup> <sub>[SEP]</sub>	A general imagery participants' perspective preference is not a good predictor of MI uses. Participants experienced less external than internal MI.	5
Turan et al. (2019)	The impact of cognitive-based learning and imagery training on tennis skills	Experimental Ecological condition	Visual imagery and video CS	(16 males, 19-25 yr.), 3 yr. practice	Experimental, control groups 8 weeks	Hewitt test (forehand and backhand) Pre-post	Cognitive-based learning and MI training improved forehand and backhand performances.	4
Türk et al. (2019)	Technical parameters and mental toughness in tennis players	Experimental Ecological condition	Mental toughness including: Visualization MG-A, MG-M	(24 males, 25 females, 13 yr.), NC	Experimental group 1 session	Ground shots, volley, Service, Mental Toughness Inventory Questionnaire	A negative relationship was found between ground stroke depth, volley, ground shots precision power tests, and service performance and imagery in participants.	3

256 *Note.* Cognitive Specific (CS), Cognitive General (CG), Motivational Specific (MS), Motivational  
257 General-Arousal (MG-A), Motivational General-Mastery (MG-M), Mental Imagery (MI).

258

## 259 **Results**

### 260 **Type of Participants and Sample Size**

261 This review included a total of 1341 tennis players, from 41 studies, including children  
262 (12.1%), teenagers (38,7%), and adults (49,2%). An over-representation of males (70.5%)  
263 compared to females (29.5%) was highlighted. The participants were novice (N = 227,  
264 16.9%), or had intermediate (N = 402, 29.9%), regional to national (N = 571, 42.6%) or  
265 international (N = 71, 5.3%) levels. Only 3 articles were considered as case studies (7.3%)  
266 with less than 5 participants (and only 1 for two articles), the majority of the studies had  
267 sample size from 10 to 49 participants (N = 32, 78.0%), and 6 studies had 50 or more  
268 participants (14.6%).

### 269 **Outcomes and Tasks**

270 Most of the studies reviewed (N = 31, 75.6%) found beneficial effects of MI  
271 interventions, primarily on performance improvements (i.e., accuracy, speed, efficacy,  
272 technique of the strokes, global performance, rank and match wins, see Table 2). Among the  
273 studies that showed improved performance, this improvement was observed during tests (N =  
274 22, 53.65%), practice matches (N = 11, 26.82%), or real competitions (N = 8, 19.51%). More  
275 specifically, during matches, MI was performed only prior to execution (N = 6, 14.63%), only  
276 during execution (N = 5, 12.19%) or during both (N = 7, 17.07%). The outcome measures of  
277 the studies reviewed mainly focused on quantitative motor performance gains (e.g., accuracy,  
278 speed, percentage of success) in service (N = 18, 43.9%), forehand, backhand and volley (N =  
279 17, 41.15%), service return (N = 2, 4.9%) or duration of movement (i.e., isochrony between  
280 real and imagined movement; N = 4, 9.8%). In addition, other dependant variables concerned

281 psychological factors such as anxiety, perceived stress, flow or self-talk (N = 16, 39.0%)  
 282 mainly evaluated by means of questionnaires, scales and interviews, or physiological  
 283 activities such as skin resistance, electroencephalography or electromyography activities (N =  
 284 3, 7.3%) measured by specific tools.

285 Table 2.

286 *Summary of the main results concerning the effects of motor imagery*

Outcomes	Positive results	Neutral results	Negative results
Service performance	N = 15	N = 2	N = 1
Service return performance	N = 2	-	-
Forehand performance	N = 8	N = 1	N = 1
Backhand performance	N = 7	N = 1	-
Volley performance	N = 2	N = 1	-
Global match performance	N = 18	-	-
Speed/agility performance	N = 2	-	-
Emotional control and flow state	N = 10	N = 2	-
Self-confidence	N = 6	-	-
Physiological activity	N = 3	N = 1	-

287

288 **Imagery Function**

289 Most of the studies used the Cognitive Specific (CS; N = 36, 87.8%) and 4 the  
 290 Cognitive General (CG; 9.8%) functions of MI, while 11 studies used the Motivational  
 291 General-Mastery (MG-M; 26.8%), 4 the Motivational General-Arousal (MG-A; 9.8%), and 4  
 292 the Motivational Specific (MS; 9.8%) functions of MI.

293 **Imagery Modality**

294 Concerning the modalities used during MI interventions, 16 articles (39.0%)  
 295 mentioned the use of kinesthetic imagery, most of the time combined with visual imagery  
 296 modality (N = 14). Twenty-five studies (61.0%) reported the use of visual imagery modality  
 297 only. Specifically, 10 studies (24.4%) reported the use of external visual imagery, and 6

298 indicated (14.6%) the use of internal visual imagery perspectives.

### 299 **Imagery Ability**

300 Several studies have used questionnaires or Likert-type scales to measure: MI ability  
301 (N = 19, 46.3%), MI use (N = 7, 17.1%), anxiety (N = 5, 12.2%), flow (N = 1, 2.4%), or  
302 perceived stress (N = 1, 2.4%). Most studies controlled the MI ability of the participants (N =  
303 18, 43.91%). One study revealed that national level tennis players exhibit better vividness  
304 visual MI ability scores than participants of team sports and another study revealed that good  
305 imagers had greater performance than poor imagers.

### 306 **Imagery and Practice**

307 Concerning the practice, 25 studies (61.0%) used MI technique alone, while other  
308 studies (N = 11, 26.8%) included MI in mental training programs or routines (i.e., pre-  
309 performance or pre-competitive). For example, MI was combined with techniques such as  
310 relaxation (N = 2, 4.8%), breathing (N = 1, 2.4%), video observation (N = 5, 11.2%), goal  
311 setting (N = 1, 2.4%) or positive self-talk (N = 2, 4.8). Finally, 29 studies (70.7%) used MI  
312 intervention in combination with physical practice.

313 Concerning the experimental procedures, twenty-five studies (61.0%) used a pre- post  
314 measurement design. The duration was: 1 day for 14 studies (34.1%), more than 4 weeks and  
315 12 sessions for 23 studies (56.1%), and up to 1 year (N = 1, 2.4%) or more (N = 2, 4.8%). The  
316 intervention times varied between 10 and 120 minutes per session and between 1 and 3  
317 sessions per week. While only 7 studies (17.1%) were carried out in laboratory, the others  
318 were performed in ecological (N = 35, 85.4%) conditions (i.e., on the court).

319 *[Table 1 near here]*

### 320 **Discussion**

321 Apart from a recent study that reviewed the effects of mental training programs in  
322 racket sports, to our knowledge, no review has specifically investigated the effects of MI in

323 tennis context. Based on 27 studies, including 12 studies that concerned tennis players, Cece  
324 et al. (2020) found that the most frequently used technique in mental training programs was  
325 MI, which confirms previous researches (e.g., Daw & Burton, 1994; Defrancesco & Burke,  
326 1997). The current review revealed that MI is effective in tennis by improving learning and  
327 performance in different tennis tasks, regardless of participant type, as well as positive  
328 influence on motivational and affective factors. However, it is important to specify that the  
329 current review revealed that MI is generally combined with other techniques such as: Goal  
330 setting (e.g., Mamassis & Doganis, 2014), arousal regulation (e.g., Daw & Burton, 1994),  
331 positive statement (e.g., Mathers, 2017), self-talk (e.g., Dohm et al., 2019), relaxation (e.g.,  
332 Koehn et al., 2013), breathing (e.g., Dominique et al., 2021; Mamassis, 2005), or video (e.g.,  
333 Atienza et al., 1998; de Sousa Fortes et al., 2019). The latter combination can be used  
334 whatever the age or level of the participants (Di Corrado et al., 2020). For example, the use of  
335 the video of a model can make it easier to activate the mental representation of the action that  
336 will be used in MI (McNeill et al., 2020). This is why it seems recommended to coaches and  
337 players to use video of a model before MI, especially for tennis players who have difficulty in  
338 imagining actions, and to develop the use of psychological skills whatever the level or age of  
339 the participants.

#### 340 **Imagery and Participants**

341 The present review revealed that MI can be used with tennis players of all skill levels.  
342 Indeed, while beneficial effects have been observed in novice players (e.g., Dana &  
343 Gozalzadeh, 2017; Féry & Morizot, 2000; Jung et al., 2015), other studies have also shown  
344 improvements in performance in intermediate level (e.g., Cherappurath et al., 2020; de Sousa  
345 Fortes et al., 2019; Morais et al., 2019) or experts (e.g., Di Corrado et al., 2019; Dominique et  
346 al., 2021; Hegazy et al., 2015) tennis players. These results confirm those of previous studies  
347 which have shown that MI interventions can be beneficial regardless of the level of practice



348 of the participants (Toth et al., 2020) and can be used by children and pre-teens (Cherappurath  
349 et al., 2017; Dereceli, 2019; Di Corrado et al., 2020; Dohm et al., 2019; Guillot et al., 2013) in  
350 motor learning context. Therefore, it is suggested that tennis coaches start using MI with  
351 beginners and school tennis players, and encourage them to use it as they progress. It is  
352 possible that the use of a particular imagery modality (e.g., kinesthetic imagery), which may  
353 be difficult to use in young players (Martini et al., 2016) could induce a lack of (short-term)  
354 performance improvement, especially among non-experts. That's why authors suggested the  
355 use of general MI training, in the targeted imagery type, to make the athletes more aware of  
356 the stimulus and response information in their MI (Smith & Holmes, 2004), and to  
357 progressively increase the amount of detail and complexity of the MI instructions (Calmels et  
358 al., 2004). Apart from studies on deliberate imagery use (e.g., Cumming & Hall, 2002), few  
359 tennis studies investigated the effects of MI intervention according to skill level. Further  
360 research is needed to compare, the potential difference in the effects of imagery modalities  
361 (e.g., kinesthetic, internal visual, external visual), in tennis players of different skill levels  
362 (i.e., novice, intermediate and experts), performing the same tennis tasks such as service or  
363 service return for examples.

#### 364 **Imagery and Outcomes**

365 A recent meta-analysis revealed that MI interventions can enhance motor  
366 performance, motivational and affective outcomes (Simonsmeir et al., 2020). These results  
367 were corroborated in the current review, in which it was observed that MI was used to  
368 increase intrinsic motivation (e.g., Gabr, 2010; Whitbread & Newell, 2013), self-confidence  
369 (e.g., Coelho et al., 2012; Mamassis & Doganis, 2004), or emotional control (Di Corrado et  
370 al., 2019; Dohm et al., 2019), and to lower anxiety (e.g., Mamassis & Doganis, 2004;  
371 Mousavi & Meshkini, 2011) or perceived stress (Coelho et al., 2012) in tennis players. As  
372 suggested by Cumming and Hall (2002), it seems important for tennis players to realize that

373 MI should not only be used as a strategy to improve motor performance but can have other  
374 functions such as cognitive general (e.g., use of different tactical solutions during a match) or  
375 motivational specific (e.g., seeing your self winning a medal) for examples, that can be  
376 beneficial to progress and perform in match.

### 377 **Imagery Function**

378         Although participants reported using MI for all five functions: cognitive specific,  
379 cognitive general, motivational general-arousal, motivational general-mastery, motivational  
380 specific imageries (Cumming & Hall, 2002), motivational general-mastery and cognitive  
381 specific imageries were the most frequently used by the tennis players as generally observed  
382 in the literature (Slimani et al., 2016). Indeed, studies revealed that MI facilitated the learning  
383 and increased performance in service (e.g., Blankert & Hamstra, 2017; Cherappurath et al.,  
384 2020; Dominique et al., 2021; Fekih et al., 2020b; Noel, 1980), service return (Coelho et al.,  
385 2007; Robin et al., 2007), volley (Cherappurath et al., 2017; Türk et al. 2019), forehand and  
386 backhand stroke (Dana & Gozalzadeh, 2017; Hegazy et al., 2015; Koehn et al., 2014), or  
387 general (Mathers, 2017; Morais et al., 2019) performances. One applied implication is the  
388 importance of educating tennis players, especially beginners and non-experts, on the value of  
389 using different function of MI (Cumming & Hall, 2002), including the motivational specific  
390 function which can influence intrinsic motivation and the motivational general-arousal  
391 function which is associated with stress, anxiety and arousal regulation which will find its use  
392 especially during competitions. The different functions of MI can be performed by using  
393 different imagery modalities that we will now discuss.

### 394 **Imagery Modality**

395         Each imagery modality can have differentiated effects on performance depending on  
396 the constraints of the actions to be performed (Callow & Roberts, 2012; Munroe et al., 2000).  
397 Indeed, while proprioceptive imagery (i.e., rediscovering sensations of movement, force,

398 stretching) seems to be beneficial for motor actions involving inter-segmental coordination  
399 (Féry, 2003) or execution speed (Féry & Morizot, 2000), other authors have put in evidence  
400 the superiority of internal visual imagery (i.e., to the first person as if one were looking with  
401 his own eyes) for tasks carried out in which environmental changes induce planning  
402 constraints as for the service return in tennis (Robin et al., 2007). In addition, it has been  
403 shown a superior effect of external visual imagery when it comes to reproducing with  
404 precision of forms (Hardy & Callow, 1999) or to pay attention to the trajectory of the ball as  
405 is the case for the service on the tennis court (e.g., Atienza et al., 1998; Dominique et al.,  
406 2021; Guillot et al., 2013; Mamassis, 2005). Finally, authors using a combination of  
407 kinesthetic and visual MI showed beneficial effects in forehand and backhand (Guillot et al.,  
408 2015) or service (Desliens et al., 2011) performances in experts, but lesser positive effects  
409 were obtained in beginners (e.g., Cherappurath & Elayara, 2017), or non-experts players  
410 (Cherappurath et al., 2020). Indeed, Hardy and Callow (1999) have suggested that the use of  
411 kinesthetic imagery is more beneficial when participants have certain degree of expertise at a  
412 task, non-experts usually have more difficulties in feeling motor actions that they have to  
413 imagine (Guillot & Collet, 2005). It will therefore be recommended to favour visual imagery  
414 with novice tennis players and to gradually use kinesthetic imagery with the players  
415 especially those who have difficulty in performing MI.

#### 416 **Imagery Ability**

417         It is important to remember that while all tennis players are able to perform MI (Goss  
418 et al., 1986), and that it is not necessary to be a good imager to begin MI training, its degree  
419 of effectiveness depends upon the athlete's ability to generate mental images. Indeed, Robin  
420 et al. (2007) showed that good imager tennis players had greater service return performances  
421 than poor imagers, who still performed better than participants in a control group who did not  
422 performed MI. That's why many authors evoked the necessity to control the tennis player's

423 imagery ability when using MI interventions (e.g., Cherappurath et al., 2020; Dominique et  
424 al., 2021; Fekih et al., 2020a,b; Guillot et al., 2012; Mizuguchi et al., 2015; Spittle et al.,  
425 2007). Indeed, Cumming and Williams (2012) suggested that if an athlete is not able to  
426 accurately form images of particular content or from a certain modality, the potential for  
427 using MI to improve the movement or performance can be considerably reduced and it will  
428 need more practice time. For example, Goss et al. (1986) showed that good imagers acquired  
429 simple movements in fewer trials than poor imagers and that good<sup>[1]</sup>imagers were able to  
430 reproduce movement patterns more accurately. However, it is important to note that, even if  
431 they are poor imagers, all tennis players can benefit from MI interventions (Robin et al.,  
432 2007) and can improve their MI ability after training (Cumming et al., 2004; Rodgers et al.,  
433 1991) by first imagining simple actions or parts of movements and then gradually increasing  
434 the complexity of MI scripts. As previously evoked, the use of video (e.g., Atienza et al.,  
435 1998) could help poor imagers to access to the motor representation of the action to imagine  
436 during MI practice.

### 437 **Imagery and Practice**

438 It is very important to note that in most of the studies reviewed, MI was used in  
439 addition to physical practice, which is likely due to the facts that imagery practice alone is  
440 known to have smaller effect than that following physical practice alone (Toth et al., 2020).  
441 However, MI combined with physical practice is generally more effective than physical  
442 practice alone (Lindsay et al., 2019; Simonsmeir et al, 2020), that's why coaches should  
443 frequently include MI in training sessions. For example, the positive effects of the  
444 combination of MI and physical performance were demonstrated in a recent study in which  
445 Dominique et al. (2021) showed the beneficial effects of a pre-performance routine consisting  
446 of breathing, ball bounces and MI, performed before serving. The use of routines is very  
447 common in skilled and professional tennis players (e.g., Mamassis & Doganis, 2004; Mathers,

448 2017). For example, Morais and Gomes (2019) developed, in tennis athletes, a systematic  
449 behavioural and cognitive preparation prior to serve that notably included concentration and  
450 MI (i.e., the players imagined hitting their shots exactly where they wanted). More  
451 importantly, the routine was individualized and automatized during training as recommended  
452 by Dominique et al. (2021). The latter authors, also suggested to specify to the participants the  
453 imagery modality and/or perspective they must use during MI intervention and/or routine.

#### 454 **More Applied Recommendations**

455 In order to facilitate the construction of mental representation in racket sports, Guillot  
456 et al., (2015) suggested performing MI on the court, wearing sport clothing, hearing the ball  
457 bounces and handling the racket. Indeed, Mizuguchi et al., (2015) suggested that tactile input  
458 associated with holding the tennis racket could improve imagery vividness especially in poor  
459 imagers or beginners. In addition, Bisio et al. (2014) found, in expert tennis players, that the  
460 duration of an imagined tennis gesture was similar to that of the same gesture physically  
461 performed when holding a tennis racket while an absence of isochrony was observed when  
462 they held a tennis-like racket (i.e., an object resembling a racket, of the same mass: 300 grams  
463 but different size) or an umbrella. It is conceivable that the prolonged use of a tennis racket, in  
464 skilled tennis players, could induce neuroplastic modification of the body representation in  
465 the brain incorporating the racket in their own body representation (Maravita & Iriki, 2004)  
466 and considering it as an extension of the hand (Fourkas et al., 2008). Moreover, the fact that  
467 MI can be performed on the court indicates that tennis players can use it during competition  
468 before serving, between points and when changing sides for examples.

469 During tennis competition, pressure is an important problem facing most of the players  
470 that can lead to loss of flow experience and performance (Gabr, 2010). Koehn (2014),  
471 examining the effectiveness of an MI intervention on improving performance and the  
472 experience of flow state, showed an increase in flow experiences in three of four junior tennis

473 players. Although these results need to be confirmed by further research, the idea that MI  
474 interventions might facilitate optimal flow experiences in competition (e.g., being focused on  
475 the task, totally absorbed, feeling in control and confident) is particularly interesting because  
476 cognitive and motivational imagery can be easily incorporated into training and competition  
477 preparation (Koehn et al., 2013). Indeed, Koehn (2014) mentioned that linking flow  
478 dimensions of sense of control and challenge-skills balance with motivational general mastery  
479 imagery appears to have a beneficial effect on the positive experience, especially on tennis  
480 players' confidence. In addition, the use of cognitive specific imagery (e.g., before  
481 performing a service or a service return) could allow the tennis players to be more focused  
482 and know what to do during a rally. Moreover, cognitive general imagery, focussed on  
483 tactical points and strategies, could cognitively better prepare tennis players to react to  
484 different match situations. That's why we recommend athletes to use MI both before and  
485 during matches. In addition, it is also important to note that tennis mental trainers also  
486 recommend athletes to use MI after matches in order to "keep in memory what worked well"  
487 and on the contrary "erase" or "replace" with positive imagery of actions (Coelho et al., 2007)  
488 or strategies the negative outcomes.

489         Moreover, it is important to note that MI intervention do not consistently provide a  
490 beneficial effect on learning and performance. For example, studies showed a lack of service  
491 improvement (e.g., Noel, 1980; Withbread & Newell, 2013) after MI intervention probably  
492 due to low amount of MI training session or trials. In addition, Guillot et al. (2005), who  
493 found that tennis players systematically overestimate self-estimation of tennis movement  
494 duration during MI, mentioned that MI training might be based upon individual  
495 characteristics such as MI abilities and preferences. Indeed, in novice tennis players, Dana  
496 and Gozalzadeh (2017) who showed similar backhand strike performance between the  
497 Control and MI groups, also revealed greater service accuracy when using internal MI and

498 forehand accuracy when using external MI. It seems that clear MI instructions and a sufficient  
499 amount of practice are recommended in order to benefit from positive effects of MI whatever  
500 the level or type of participant.

501         Indeed, it is finally important to note that the female tennis players improved their  
502 performance (e.g., Atienza et al., 1998; Blankert & Hamstra, 2017) when benefited from  
503 motor imagery and had similar MI uses (e.g., Derecli, 2019; Guillot et al., 2004) than males,  
504 that's why it is recommended to use this mental technic regardless of gender. But the current  
505 study highlighted the weak representation of female tennis players within the studies'  
506 participants highlighting a male tennis player predominance in researches that used MI  
507 interventions in tennis or racket sports (Cece et al., 2020). Although many studies have not  
508 found gender difference in MI ability and vividness (Robin et al., 2020; Subirats et al., 2018),  
509 more research is needed to better explore the gender influence in MI interventions in tennis.

#### 510 **New Research Directions**

511         Whereas it was previously mentioned that the beneficial effects of MI could be  
512 influenced by the imagery ability of the tennis players (e.g., Robin et al., 2007), we may  
513 envisage that the combination of MI with other mental technics such as instructional self-talk  
514 could help the participants to imagine all the parts of complex motor actions to imagine such  
515 as the service. A study will soon be carried out in our laboratory to test this hypothesis in  
516 novice tennis players; and further research will also be conducted to assess the potential  
517 beneficial effect of combining model video, coach feedback and MI as previously shown by  
518 Robin et al. (2020) in a precision task.

519         Likewise, although several studies showed that MI was effective to improve  
520 performance, most of them used acute (e.g., a single day; Deslins et al., 2011; Di Corrado et  
521 al., 2019) or short duration interventions (i.e., a few sessions or weeks; Fekih et al., 2020a,b;  
522 Turan et al., 2019) and very few studies (i.e., less than 10%) used long (several months; e.g.,

523 Atienza et al., 1998; Dominique et al., 2021) or chronic (i.e., one year and more; e.g., Dohm  
524 et al., 2019; Mamassis et al., 2004; Mathers, 2017) interventions. Therefore, further research  
525 is needed to determine, using post-performance measures long after the MI intervention,  
526 whether the effect of motor imagery lasts over time to stabilize a good performance or could  
527 be considered an acute intervention that could be beneficial before a competition for example.  
528 Whereas the use of pre-competition positive MI seems beneficial in closed tennis skill  
529 performance (Malouff et al., 2008), more research is needed to better explore the effect of  
530 positive MI during and after competition in open tennis skill (e.g., service return) and match  
531 performances.

532 Finally, due to many different outcomes (i.e., learning, performance improvement,  
533 preferences, uses, mental chronometry or neurophysiological measures), participant's  
534 characteristics (age, level, gender) and sample sizes, MI interventions durations (only one,  
535 weeks, months, years), types of studies, experimental groups and procedures and the  
536 differences in study's quality, there are risks of bias and the use of a meta-analysis did not  
537 seem relevant which can be considered as a limitation of this study. The increase in number  
538 and quality research in the field of tennis, especially in the motor learning or performance  
539 improvement following MI intervention context, should make it possible to have more similar  
540 studies allowing the realization of meta-analysis in the future.

#### 541 **Conclusion**

542 This study, based on the review of 41 selected published studies, examined the effect  
543 of MI on novice to expert tennis players and revealed that most studies used the cognitive  
544 specific (e.g., rehearsal of specific sport skills such as service) and motivational general  
545 mastery (e.g., self confidence or control of emotions during challenging tennis situations)  
546 function of MI. More precisely, this study revealed that MI interventions significantly  
547 enhanced motor performance (i.e., improvement of forehand, backhand or volley quality, and



548 service efficacy) as well as motivational and affective outcomes for tennis players, regardless  
549 of their level and age. In addition, MI was frequently combined with other mental skills and  
550 integrated in pre-performance individualized routines including breathing, positive self-talk,  
551 ball bounces and/or concentration. In addition, MI can be used between point and during side  
552 changes and it is also recommended to employ it after competition. However, the results of  
553 the review highlighted the unequal distribution of the population with over-representation of  
554 males in the studies reviewed. To conclude, this review proposed potential implications for  
555 tennis players, coaches, parents or researchers, and suggested that the regular practice of  
556 motor imagery should be incorporated in tennis player training programs and that could also  
557 concerns other dual and racket sports such a table tennis, badminton, paddle or beach-tennis.

#### 558 **Declaration of Interest Statement**

559 The authors declare that they have no competing interests.

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