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Do Individual Sports Shape the Vividness and Modalities of Motor Imagery in Adolescents?

Mohamed-Ali Dhouibi^{1,2*}, Said Ben Hassen^{1,2}, Soufiane Kaabi^{1,2,3*}, Ahlem Belgacem¹, Nidhal Jebabli⁵, Rachad Djeddi¹, Asem Al Sayed¹, Sebastian Puschkasch-Möck⁶, Haithem Rebai¹, Phillippe Passelergue³

1. Tunisian Research Laboratory Sports Performance Optimization, National Center of Medicine and Science in Sports (CNMSS), Tunisia,
2. Higher Institute of Sport and Physical Education of Ksar Saïd, University of Manouba, Tunisia,
3. Université de Pau et des Pays de l'Adour, France, 4EA4445 Laboratoire Mouvement, Equilibre, Performance, Santé (MEPS), France,
4. Scientific Center of Research and Sports Performance, Sharjah Women's Sports, UAE.
5. Higher Institute of Sport and Physical Education Kef, University of Jendouba, Tunisia.
6. Department of Exercise Science, Olympic Training and Testing Center of Hessen, Frankfurt, Germany.

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Abstract

To date, little is known about the effects of individual sports and their practice environments on the determination of motor imagery vividness and modality. 240 boys and girls athletes (athletes, gymnastic and swimming) aged 13 to 15 years took part in this study. Visual motor imagery (VMI) and kinesthetic motor imagery (KMI) vividness were assessed using the MIQ-Rs questionnaire. Three neuropsychological tests (Corsi, TONI2 and RVRT) were used to assess visuospatial and visuoconstructive memories and reasoning processes. Results show that athletes develop higher VMI ($p < 0.001$; ES = large) unlike gymnasts and swimmers who develop KMI to a greater extent from VMI ($p < 0.001$; ES = large); older subjects had greater motor imagery than younger ones ($p < 0.001$; ES = large) and boys are more imagers than girls ($p < 0.001$; ES = large). In addition, a large positive association between VMI and KMI was noted ($r = 0.58$; $p < 0.001$). Conclusion: MI vividness and modalities seem to be determined by the type and the environment of the individual sport practiced.

Keywords: Track and field; Gymnastics; Swimming; Children; Teenager, Motor Imagery.

1. Introduction

As a cognitive strategy, motor imagery (MI), which has several modalities such as visual (VMI) or kinesthetic (KMI) ones, allows acquisition and improvement of motor skills (Decety et al., 1991 b; Dickstein & Deutsch, 2007; Giacobbi et al., 2003; Guillot & Collet, 2013). Indeed, Smith et al. (2007) and more recently Behrendt et al. (2021) agree that MI improves sporting performance especially when used immediately prior to movement execution. Conversely, Dhouibi et al. (2021) recently demonstrated that sport and physical practices improve MI. Their study was carried out on young people practicing several sports, without specifying either the type or the environment in which these sports were practiced. It should be noted that several studies have considered individual differences in imagery vividness (Isaac & Marks, 1994), but few have solicited athletes samples, let alone young athletes (Miller, 2017). In this sense, unlike adults, young's ability for MI is not well understood (Choudhury et al., 2007). Moreover, research on sports imagery focused on adolescents' based-age and gender have emerged equivocal findings; where some studies have noted that there are significant differences between boys and girls (Habacha et al., 2014), while others have not (Campos, 2014). It is important to note that, to our knowledge, few studies have examined the relationship between MI and both individual sports types and their practice environments. It is well known that sports have neither the same requirements (technical, strategic, perceptive, cognitive...) nor the same practice environment (full air, sports halls, swimming pools, mountains...) nor the same infrastructure (natural spaces, artificially landscaped spaces...) nor the same equipment (witnesses, hedges, fixed bar, springboard, board, pull-buoy...). Therefore, it is obvious that these differences could also have an effect on MI skill. Referring to the taxonomy of Parlebas (1999), the ranking tree of sports situations and motor behavior, precisely psychomotor behaviors, brings together athletics, gymnastics and swimming in the same category. Despite their differences, these sports have the same

characteristics: practiced in isolation (without partners or opponents) and in a stable environment. Regarding the "environment" factor, this classification emphasized not only the "stability and/or instability" but also the "type" of this environment". By type of environment, we refer to the spatial context in which the activity takes place, and its degree of resemblance/difference to the environment considered to be the natural environment of the human being. Based on such an explanation, the "natural environment" was attributed to athletics, given the similarity between the practice characteristics and the daily human motor skills (walking running, jumping and throwing). Moreover, the "artificial environment" was attributed to gymnastics since acrobatics bears no resemblance to everyday human motor skills and requires sophisticated and standardized equipment; and finally the "different environment" was attributed to swimming, since water has never been the natural environment of man. The first two sports (i.e. athletics and gymnastics) adopt the natural body position of the human being which is the vertical bipedal station (Carini et al., 2017) and that Paillard (1971) described as a "fundamental erect posture" (or postural reference space). The third one (i.e., swimming) does not respond to this rule, where the body adopts a horizontal position without pedestrian supports and immersed in the water that De Coubertin (1922) and, Moricot and Rosselin-Bareille (2021) described as a "hostile element". The practice of these sports effectively solicits sensory and perceptual systems in different ways. This leads us to think, hypothetically, that the kinds and the environments of individual sports could determine MI vividness and modality (VMI or KMI). Similarly, gender and age could influence these vividness and modality too.

Materials and Methods

1.1. Participants

240 adolescents (120 boys and 120 girls) were recruited to participate in this study. This sample was divided into 2 equal age-groups: age-group 1 (A-G1) with 13 years \leq age \leq 14 years 6 months with (M age = 13.79 \pm 0.42 years), and, age-group 2 (A-G2) with 14 years 6

months < age < 16 years with (M age = 15.32 ± 0.32 years). Each group was sub-divided into three sub-groups depending on the type of sport and its environment of practice: 40 athletes, 40 gymnasts and 40 swimmers (20 girls and 20 boys in each category) (Table 1). All subjects are engaged each year in training in the sports club for at least the last 5 years.

Table 1: Distribution of participants by sport practiced activity age and gender

Groups	Age groups	Age ranges	Sexe	N	Age	Practice duration
Athletes	A-G 1	13.0-14.5 y	Boys	20	13.87 ± 0.43	5.49 ± 0.59
			Girls	20	13.82 ± 0.46	5.24 ± 0.40
	A-G 2	14.5-16.0 y	Boys	20	15.36 ± 0.35	6.14 ± 0.54
			Girls	20	15.26 ± 0.22	5.94 ± 0.77
Gymnasts	A-G 1	13.0-14.5 y	Boys	20	13.90 ± 0.47	7.74 ± 0.56
			Girls	20	13.77 ± 0.52	7.39 ± 0.48
	A-G 2	14.5-16.0 y	Boys	20	15.42 ± 0.33	8.79 ± 0.43
			Girls	20	15.14 ± 0.37	8.99 ± 0.59
Swimmers	A-G 1	13.0-14.5 y	Boys	20	13.80 ± 0.33	7.94 ± 0.44
			Girls	20	13.58 ± 0.31	7.84 ± 0.51
	A-G 2	14.5-16.0 y	Boys	20	15.55 ± 0.32	9.34 ± 0.56
			Girls	20	15.16 ± 0.35	9.14 ± 0.54

Legend. A-G1 with $13 \text{ years} \leq \text{age} \leq 14 \text{ years } 6 \text{ months}$; A-G2 with $14 \text{ years } 6 \text{ months} < \text{age} < 16 \text{ years}$; N: sample size.

1.2. Course of study

A descriptive statement of the research including the purpose and the survey explanation of the study was sent to the sports club managers. After agreement, a second letter was sent to potential subjects' parents/guardians requesting their agreement regarding the participation of their children in this study. For all groups, the administration of tests and questionnaires were conducted before the training sessions. All subjects met the following inclusion criterion: (a) to have practiced sport at least five successive and continuous years in their specialty (Table 1); (b) none of the subjects reported any motor problems or disabilities; (c) none of the participants reported any neuropsychological disease (Table 2).

2.3. Preliminary study

Three non-verbal neuropsychological tests were administered to all participants : the Corsi Block Task to evaluate spatial short-term memory (Corsi, 1972); the Bent on Visual Retention Test 4th edition (BVRT) to evaluate visuospatial, visuomotor, and visuoconstructive memory functions (Benton, 1974) and the Test Of Nonverbal Intelligence-2nd edition (TONI-2) to evaluate the nonverbal intelligence (Brown, 1990). All participants achieved results within the norms, indicating normal intellectual functioning. (Table 2).

Age Groups	Sexe	Brown non verbal intelligence test		Corsi block task test	Benton visualretention test					
		IQ	percentile	M ±SD	Adm B (correct score)		Adm C (error score)		Adm D (correct score)	
					M ±SD	IQ	M ±SD	IQ	M ±SD	IQ
A-G 1	Boys	120 ± 512	91	6.48± 0.82	7.24 ± 0.48	105	0.29 ± 0.12	85-115	7.23 ± 0.61	105
	Girls	119 ± 725	88	6.35± 0.70	7.27 ± 0.54	105	0.43 ± 0.25	85-115	7.23 ± 0.41	105
	Total	119 ± 032	88	6.42 ± 0.76	7.26 ± 0.51	105	0.56 ± 0.19	85-115	7.23 ± 0.59	105
A-G 2	Boys	120 ± 501	91	6.63 ± 0.79	7.33 ± 0.60	95-109	0.30 ± 0.19	95-109	7.32 ± 0.58	95-109
	Girls	119 ± 819	88	6.52 ± 0.73	7.29 ± 0.58	95-109	0.45 ± 0.24	95-109	7.20 ± 0.44	95-109
	Total	120 ± 660	91	6.58 ± 0.76	7.31 ± 0.59	95-109	0.37 ± 0.21	95-109	7.26 ± 0.51	95-109

Legend. A-G1 with 13 years ≤ age ≤ 14 years 6 months; A-G2 with 14 years 6 months < age <16 years; IQ: Intellectual quotient; Adm: Administration mode; M: Mean; SD: Standard deviation.

2.4. Main study

The French assessed version of the “Movement Imagery Questionnaire-Revised 2nd version”(MIQ-Rs) was used in this study (Loison et al., 2013). This questionnaire consisted on 14 items: 7 to evaluate VMI and 7 to evaluate KMI.

2.5. Data analyses

All values were expressed in the form of mean \pm standard deviation. The normality of distribution was verified by the Shapiro-Wilk W-test test, before using the parametric tests. The MANOVA multivariate variance analysis (2x3x2x2) was used to analyze data. Factors included two MI perspectives (called Conditions): VMI and KMI, three activity-group levels (Athletes, Gymnasts and Swimmers), two gender-groups (Boys and Girls) and two age-groups: A-G1 and A-G2. When a significant F value was achieved, a Bonferroni post-hoc analysis was performed. The effect size was calculated for all variance analyses using partial eta squared (η^2_p). Values of 0.01, 0.06 and 0.15 were considered small, moderate and large respectively (Cohen, 1988). The relationship VMI and KMI, were analyzed via the Pearson correlation coefficient. Statistical analyses were performed using statistical software (SPSS Inc. Chicago IL, version 18.0) where the significance level was set at $p < 0.05$ *a priori*.

3. Results

Means and standard deviations values of the four dimensions relating to the optimal study are presented below. MANOVA indicated significant interactions between activity-group levels and MI perspectives ($F = 470.15$; $p < 0.05$; $\eta^2_p = 0.80$); activity-group levels, MI perspectives and ages ($F = 23.94$; $p < 0.001$; $\eta^2_p = 0.17$); activity-group levels, MI perspectives and genders ($F = 12.30$; $p < 0.001$; $\eta^2_p = 0.10$) and finally between activity-group levels, MI perspectives, ages and genders ($F = 4.78$; $p < 0.01$; $\eta^2_p = 0.04$). Moreover, analysis revealed a significant main effect of activity-group levels ($F = 1.28$ $p < 0.28$; $\eta^2_p = 0.01$), MI perspectives ($F = 181.62$; $p < 0.001$; $\eta^2_p = 0.44$), ages ($F = 12.13$; $p < 0.001$; $\eta^2_p = 0.51$) and genders ($F = 79.10$; $p < 0.001$; $\eta^2_p = 0.26$). KMI was greater than VMI ($F = 0.56$; $p < 0.001$; $ES = 3.26$) (Table 3). Athletes

showed a more vivid VMI than the KMI ($F = 389.87$; $p < 0.001$; $ES = 3.22$) while gymnasts and swimmers perform better in KMI ($F = 127.85$; $p < 0.001$; $ES = 2.06$ and $F = 780.46$; $p < 0.001$; $ES = 4.50$ respectively) (Table 4). All subjects (boys and girls) belonging to A-G2 were more imager than younger subjects belonging to A-G1 ($F = 0.16$; $p < 0.001$; $ES = 1.30$) (Table 5). Boys showed better imagery scores than girls in both VMI and KMI ($F = 0.24$; $p < 0.001$; $ES = 1.83$) (Table 6). Pearson correlation coefficient showed a large association between VMI and KMI ($r = 0.58$; $p < 0.001$).

Table 3: Individual sport effects on the determination of motor imagery modality and its vividness

Groups	Age Groups	Sexe	MotorImageryModality		ES
			Visual	Kinesthetic	
ATHLETES	A-G 1	Boys	6.10 ± 0.44 ^a	3.90 ± 0.44	5.00
		Girls	4.86 ± 0.37 ^a	3.82 ± 0.50	2.36
	A-G 2	Boys	5.46 ± 0.22 ^a	4.62 ± 0.27	3.41
		Girls	5.10 ± 0.26 ^a	4.52 ± 0.29	2.11
GYMNASTS	A-G 1	Boys	4.14 ± 0.38	5.33 ± 0.90 ^b	1.72
		Girls	4.22 ± 0.20	5.34 ± 0.54 ^b	2.75
	A-G 2	Boys	4.77 ± 0.27	5.74 ± 0.71 ^b	1.81
		Girls	4.20 ± 0.17	5.10 ± 0.63 ^b	1.95
SWIMMERS	A-G 1	Boys	3.89 ± 0.55	6.03 ± 0.22 ^a	5.11
		Girls	3.60 ± 0.42	5.41 ± 0.34 ^a	4.74
	A-G 2	Boys	4.00 ± 0.54	5.86 ± 0.24 ^a	4.45
		Girls	3.78 ± 0.51	5.40 ± 0.35 ^a	3.70

Legend. A-G1 with 13 years ≤ age ≤ 14 years 6 months; A-G2 with 14 years 6 months < age < 16 years; ^a Significantly higher than the two other groups ($p < 0.001$); ^b Significantly higher than one other group ($p < 0.01$).

Table 4 :Individual sport effects on the determination of motor imagery modality and vividness (comparison 2 by 2)

MotorImagery Modality	Age Groups	Sexe	Groups			ES		
			Athletes	Gymnasts	Swimmers	A vs G	A vs S	G vs S
Visual	A-G1	Boys	6.10 ± 0.44 ^a	4.14 ± 0.38 ^b	3.89 ± 0.55	4.77	4.44	0.53
		Girls	4.86 ± 0.37 ^a	4.22 ± 0.20 ^b	3.60 ± 0.42	2.15	3.18	1.88
	A-G2	Boys	5.46 ± 0.22 ^a	4.77 ± 0.27 ^b	4.00 ± 0.54	2.80	3.54	1.80
		Girls	5.10 ± 0.26 ^a	4.20 ± 0.17 ^b	3.78 ± 0.51	4.10	3.26	1.10
Kinesthetic	A-G1	Boys	3.90 ± 0.44	5.33 ± 0.90 ^b	6.03 ± 0.22 ^a	2.02	6.12	1.07
		Girls	3.82 ± 0.50	5.34 ± 0.54 ^b	5.41 ± 0.34 ^a	2.92	3.72	0.15
	A-G2	Boys	4.62 ± 0.27	5.74 ± 0.71 ^b	5.86 ± 0.24 ^a	2.08	4.85	0.23
		Girls	4.52 ± 0.29	5.10 ± 0.63 ^b	5.40 ± 0.3 ^a	1.18	2.74	0.59

Legend. A-G1 with 13 years ≤ age ≤ 14 years 6 months; A-G2 with 14 years 6 months < age <16 years; ^a Significantly higher than the two other groups ($p < 0.001$); ^b Significantly higher than one other group ($p < 0.01$).

Table 5: Age effect on the determination of motor imagery modality and its vividness

Motor Imagery Modality	Sexe	Groups	Age Groups		ES
			A-G 1	A-G 2	
VISUAL	Boys	Athletes	6.10 ± 0.44 ^a	5.46 ± 0.22	1.84
		Gymnasts	4.14 ± 0.38	4.77 ± 0.27 ^a	1.91
		Swimmers	3.89 ± 0.55	4.00 ± 0.54 ^b	0.20
	Girls	Athletes	4.86 ± 0.37	5.10 ± 0.26 ^a	0.75
		Gymnasts	4.22 ± 0.20	5.34 ± 0.54 ^a	2.75
		Swimmers	3.60 ± 0.42	3.78 ± 0.51 ^b	0.38
KINESTHETIC	Boys	Athletes	3.90 ± 0.44	4.62 ± 0.27 ^a	1.97
		Gymnasts	5.33 ± 0.90	5.74 ± 0.70 ^a	0.51
		Swimmers	6.03 ± 0.22 ^a	5.26 ± 0.24	3.34
	Girls	Athletes	3.82 ± 0.50	4.52 ± 0.29 ^a	1.71
		Gymnasts	5.34 ± 0.54 ^b	5.20 ± 0.63	0.24
		Swimmers	5.41 ± 0.34	5.40 ± 0.35	0.03

Legend. A-G1 with 13 years ≤ age ≤ 14 years 6 months; A-G2 with 14 years 6 months < age < 16 years; ^a Significantly higher than A-G1 ($p < 0.001$); ^b Significantly higher than A-G1 ($p < 0.01$).

Table 6: Gender effect on the determination of motor imagery modality and its vividness

Age Groups	Motor Imagery Modalities	Groups	Sexe		ES
			Boys	Girls	
A-G 1	Visual	Athletes	6.10 ± 0.44 ^a	4.86 ± 0.37	3.05
		Gymnasts	4.14 ± 0.28	5.22 ± 0.20 ^a	4.34
		Swimmers	3.89 ± 0.55 ^a	3.60 ± 0.42	0.77
	Kinesthetic	Athletes	3.90 ± 0.44	3.82 ± 0.50	0.17
		Gymnasts	5.33 ± 0.90	5.34 ± 0.54	0.01
		Swimmers	6.03 ± 0.22 ^a	5.41 ± 0.34	2.16
A-G 2	Visual	Athletes	5.46 ± 0.22 ^a	5.10 ± 0.26	5.65
		Gymnasts	4.77 ± 0.27 ^a	4.20 ± 0.17	2.53
		Swimmers	4.00 ± 0.54 ^b	3.78 ± 0.51	0.42
	Kinesthetic	Athletes	4.62 ± 0.27 ^b	4.52 ± 0.29	0.36
		Gymnasts	5.74 ± 0.71 ^a	5.10 ± 0.63	0.95
		Swimmers	5.86 ± 0.24 ^a	5.40 ± 0.35	1.53

Legend. A-G1 with 13 years ≤ age ≤ 14 years 6 months; A-G2 with 14 years 6 months < age < 16 years; ^a Significantly higher than adolescents of the other sex ($p < 0.001$); ^b Significantly higher than adolescents of the other sex ($p < 0.05$).

4. Discussion

This study aimed, firstly to verify the effect of individual sports and their practice environments in determining the MI modality and its vividness, then to show the effect of gender and age on imaging vividness and finally to identify the visual and kinesthetic properties in young athletes. The results show that effectively, individual sports and their practice environments determine MI modality and vividness. In this sense, analysis reported that athletes, boys and girls in both A-G, recorded better scores in VMI than in KMI. Moreover, this group is also far more imager in the VMI than the groups of gymnasts and swimmers. Conversely, gymnasts and swimmers groups recorded a predominance of the KMI modality, and that swimmers perform better than gymnasts and athletes. However, it should be noted that the overall effects of the "group" factor show no significant difference between the three groups of athletes. This means that, despite their differences, individual sports develop the ability and the vividness of a single MI modality. According to the results, this similarity is due to a close resemblance to the values of the group-specific averages. In this way, Parker and Lovell (2012) showed that generally young athletes generate clear images fluctuating between VMI and KMI. These results corroborate those of Dhouibi et al. (2022) and Di Corrado et al. (2019) who noted that the type of sport affects both MI ability and modality. In this sense, Guillot et al. (2004) underlined that organizing action in space, as in athletics, requires the recruitment of visual spatial information and effectively influences the athletes by signals coming from this environment (where to run where to take off where to land). That is why the VMI is seen to be more developed than the KMI. In gymnastic, mastery and memorization of skills require the solicitation of the proprioceptive system activating internal perceptions, which allow the evocation of the KMI modality (Calmels & Fournier, 1999). At the same time, the use of visual cues is required in order to recruit the maximum of visual spatial information to accomplish the requested task. That is why gymnastics enhances the MI vividness and determines its two modalities (VMI and KMI) in a similar way. The

literature has shown that MI shifts to a kinesthetic mode as the athlete progresses to expertise and when the action is bodily somesthetic information (Guillot et al., 2004). In swimming, water exerts hydrostatic pressure on the body and it is perceived as a second skin enveloping the body (Giromini et al., 2015; Guignard, 2017; Le-Cam & Guillot, 2016). This allows the activation of the skin receptors, which provide information on pressure levels such as: Pacini corpuscles (Le-Cam & Guillot, 2016). It is clear that perception can only be realized through the proprioceptive system and primary source of information for the kinesthetic modality of MI. This corroborates the work of Parker and Lovell (2011) and Saimpont et al. (2013) who argue that the determination of the MI modality and vividness is linked to the evoked sensory modality and its manifestation during the information treatment process. It means that the representations set stored in working memory is likely to facilitate the imaging process and to determine its modality (VMI or KMI). Similarly, Guilbert et al. (2016) have tried to verify whether the accuracy of imagined movement in children is not related to a developmental tendency in the use of sensory afferents to control movement. Golomer et al. (2008) raised the issue of training load and suggested that it is possible that the latter could influence the determination of the MI perspective. These discoveries made it possible to reject the hypothesis of Dey et al. (2012) that sports practice is not associated with improved MI performance. It is important to note that our findings confirmed the results of Hall and Fishburne (2010) who assert that type of sport in which coaches and teachers participated is a possible influencing and determining factor of MI modality. Overall, results recorded in this study showed that boys are much better than girls in motor imaging. These results corroborate the findings of Monsma Eva et al. (2009), Dhouibi et al. (2021) and Dhouibi et al. (2022) who note that the development of MI could be influenced by gender, in young and adults, and that sports practice and motor experiences could be the determinants of the difference between boys and girls (Emma Yoxon et al., 2012). Indeed, to increase the use of motor imagery, it is

preferable to increase participation in sporting events. De Caroli and Sagone (2007) and Hoyek et al. (2009) reported that because of their ability to retain the temporal organization of an imagined movement, boys are better able than girls to construct a dynamic mental image of movements. Gao et al. (2014) further suggested that game preferences in childhood play a decisive role: boys develop their body image and visuospatial skills, while girls develop their communication skills. It should be noted that in some previous studies, gender has only a minimal effect on the use of imagery (Hall Craig, 2001). Indeed, Munroe-Chandler et al. (2007) found no difference between boys and girls aged 7 to 14 in their ability to form mental images. Munroe-Chandler et al. (2007) found no difference between boys and girls aged 7 to 14 in their ability to form mental images. It is possible that similar results would be recorded depending on the type of sport practiced, which highlights the need for further research to be confirmed (Hall Nathan & Fishburne Graham, 2010). This study showed that the development of MI vividness is age-dependent: subjects from group A-G2 had better imaging abilities than their counterparts from group A-G1. These results are in line with those of Dhouibi et al. (2021) and Dhouibi et al. (2022). Arvinen-Barrow et al. (2008) have shown that, among teenage synchronized skaters, the 18.5 age group is a better imager than the 15.3 age group, which is itself a better imager than the 12.90 age group. Kosslyn et al. (1990) argue that the development of imagery ability is related to the maturation process, hence the influence of age on this process. Choudhury et al. (2007) explain this process by neuronal maturation, mainly in the parietal cortex, which may reflect synaptic pruning and myelination during this period (Gogtay et al., 2004; Toga et al., 2006) which could differentiate between the MI capacity of adolescence and that of adulthood. Further studies are required to determine the importance of cortical circuits in MI in adolescents (Choudhury et al., 2007). (Parker & Lovell, 2012) add that with age, and in relation to other skills, improved imagery vividness affects visual and kinesthetic perspectives. This could be reached through greater volumes of sports or physical

practices, offering more opportunities to use imagery and allowing good imagers to be distinguished from bad imagers (Robert S. Weinberg & Gould., 2003). Overall, the results recorded in this study show that boys in both A-G are more imager than girls in VMI and KMI.

5. Conclusion

The aim of this study was to clarify the relationship between MI and individual sports and their practice environments in adolescents. Our results are of great use to coaches and athletes regarding the optimal use of MI to improve sports performance. They show that sporting commitment is associated with a specific MI modality and increased vividness. They also show that boys are better imagers than girls and those older adolescents are better than younger ones. Finally, further studies are needed to establish the causal impact of the type of sport and its environment on MI.

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Declaration of conflicting interests

The authors declare that there is no conflict of interest.

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