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Original article

Imagery perspective among young athletes: Differentiation between external and internal visual imagery

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Abstract

Purpose: This study aimed to investigate the construct of external visual imagery (EVI) *vs.* internal visual imagery (IVI) by comparing the athletes' imagery ability with their levels of skill and types of sports.
Methods: Seventy-two young athletes in open ($n = 45$) or closed ($n = 27$) sports and with different skill levels completed 2 custom-designed tasks. The EVI task involved the subject generating and visualizing the rotated images of different body parts, whereas the IVI task involved the subject visualizing himself or herself performing specific movements.
Results: The significant Skill-Level × Sport Type interactions for the EVI task revealed that participants who specialized in open sports and had higher skill-levels had a higher accuracy rate as compared to the other subgroups. For the IVI task, the differences between the groups were less clear: those with higher skill-levels or open sports had a higher accuracy rate than those with lower skill-levels or closed sports.
Conclusion: EVI involves the visualization of others and the environment, and would be relevant to higher skill-level athletes who engage in open sports. IVI, in contrast, tends to be more self-oriented and would be relevant for utilization by higher skill-level athletes regardless of sport type.

Keywords: External visual imagery; Internal visual imagery; Open sports; Skills; Youth

1. Introduction

Motor imagery can be divided into visual (or termed visuomotor) imagery (VI) and kinesthetic imagery (KI).[1,2] VI involves the visualization of a movement from the first- (internal VI, IVI) or third-person (external VI, EVI) perspective. IVI requires an individual to mentally generate movements by oneself, which is analogous to visualization taking place while a camera is mounted in one's own head and scans one's own body. EVI requires an individual to visualize the movements generated by others in their surroundings, whilst the observer is a spectator. KI, on the other hand, emphasizes the feelings and sensations associated with the movements being visualized.[3–5] KI has been found to be helpful in facilitating the performance of complex movements in a relatively stable environment,[5,6] such as diving and gymnastics. The focus of this paper is to investigate the constructs of EVI from IVI, which has been reported less in the literature.[7–9]

In terms of mental processing, IVI was reported to rely heavily on visual and visuo-spatial processes, which were mediated by the superior parietal lobe and the occipital cortex.[8] Since a third-person perspective was used, EVI required additional visuo-spatial transformation, and was found to be mediated by the lingual gyrus.[10] The practice of EVI would require athletes to engage in more complex mental processing than IVI. A few studies have explored the utility of EVI and IVI in sport training. Barr and Hall[11] used a self-report method and showed that rowers tended to use IVI rather than EVI prior to competition as a preparation strategy. White and Hardy[5] reported that EVI was more effective than IVI for enhancing skill learning in

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sports, particularly gross movement patterns such as in gymnastics. Glisky et al.[12] found that EVI was more useful than IVI for learning new moves in fencing, whereas IVI was more useful than EVI for developing and refining strategies for competitions. White and Hardy[13] reported that gymnasts employed more mental imagery than slalom canoeists. Hardy and Callow[4] reported that both experienced athletes and novices benefited significantly more from using EVI than IVI when learning new skills in karate, gymnastics, and rock climbing. There are 2 conclusions that can be made on the results of the 5 above studies. First, EVI was useful for learning new skills regardless of the type of sport, such as karate (open sports) *vs.* rock climbing (closed sports). Second, IVI was more useful than EVI for the development of strategies regardless of the type of sport, such as fencing or rowing. These findings are counter-intuitive, because EVI involves higher level mental processing such as visual transformation, which should be for practicing response strategies, particularly in open-sport competition.

Recent studies on the employment of visual imagery in sports have shifted their focus to the competence level or type of sport. For instance, Arvinen-Barrow et al.[14] and Watt et al.[15] reported that elite athletes tended to employ cognitive-related imagery (measured by the Sport Imagery Questionnaire, SIQ) more frequently than non-elite athletes. Athletes specializing in open sports (rugby and martial arts) engaged in more imagery than those in closed sports (golf and figure skating).[14] Athletes who specialized in closed sports employed more mental imagery such as visualization than those who specialized in open sports.[16] Roberts and co-workers[17] reported that athletes with higher skill-levels had a better ability to conduct visual imagery than those with lower skill-levels. Other researchers reported similar results: higher level athletes tended to have a higher capability for imagery than lower level athletes.[18,19] One potential reason for this superiority in imagery ability was that higher level athletes had more opportunities to engage in imagery practice than lower level athletes.[16,20] There are 2 main drawbacks in these studies. First, the researchers did not attempt to categorize the visual imagery into EVI and IVI despite their uniqueness in mental processing. Second, except for 1 study, the level of competence of the athletes was not taken into account for the different types of sports.

This study was motivated by the fact that EVI and IVI were loosely defined in previous studies. Even if they had been clearly defined, researchers tend to rely on the participants' self-report of preference of using VI. Another issue was that the level of skill (or competence) and the type of sports were not commonly incorporated as one of the main effects in the same study. Open sports are characterized as sports in which the participants perform in environments that are changing rapidly and execute externally-paced actions. In contrast, closed sports are characterized by participants who perform under relatively static environments and execute self-paced actions.[21] We investigated the characteristics of EVI and IVI in terms of the athletes' level of skill and type of sports. Rather than using a self-report format, 2 custom-designed EVI and IVI tasks were used to quantify the athletes' ability for imagery. The participants were adolescent athletes, with their physical and mental sports-related skills developing rapidly.[22,23] They had been receiving intensive training, and gaining experience in open competition in both open and closed sports. It was hypothesized that the abilities of different imagery perspectives developed by young athletes would be associated with the type of sports they engaged in and their level of skill. Young athletes who specialized in open sports and have a higher level of skill would have a stronger EVI ability than those who specialized in closed sports or have a lower level of skill. The rationale is that athletes who compete in unpredictable environments (i.e., open sports) and achieve better results would need a higher EVI ability than those in closed sports for developing and refining strategies when facing their opponents. Those who participated in closed sports or achieved a higher level of skill would have stronger IVI ability than those who specialized in open sports or have a lower level of skill. This is because IVI would enable these athletes to further refine their movements, speed, and gestures by mentally generating movements as if in actual execution of these movements. Thus, visualization of the movements would enhance motor execution during the competition.

2. Methods

2.1. Participants

The participants were 72 young athletes recruited from the Guangdong Sports and Technology School that provides education to young athletes in Guangdong, a southern province of China. There were 35 males (14.70 ± 0.96 years, mean ± SD) and 37 females (13.90 ± 1.11 years). Among them, 27 specialized in closed sports, including weight lifting, diving, track and field, and shooting, and the other 45 in open sports, including fencing, judo, and wrestling. The participants were further classified into high and low skill-levels. The criterion behind this classification was the participants' recent performance in open competitions. Participants who won prizes in open competitions organized at the provincial level or above in 2009–2010 were classified as high skill-level, and those who had won prizes in open competitions organized at the municipal level or below were classified as low skill-level. Each participant engaged in practice for about 20 h per week. Written informed consents were obtained from the participants or their guardians prior to the study. Ethical approval for this study was obtained from The Hong Kong Polytechnic University Institutional Review Board.

2.2. Instruments and experiment design

2.2.1. EVI task

The EVI task adopted a mental rotation paradigm,[24,25] which measured the participants' ability to generate and visualize rotated images of different body parts. This task required the participants to superimpose a human body figure onto a computer-generated figure composed of small white circles (called an artificial figure) displayed on a screen (Fig. 1A). The human body figure was captured from 5 sets of 4-s video clips

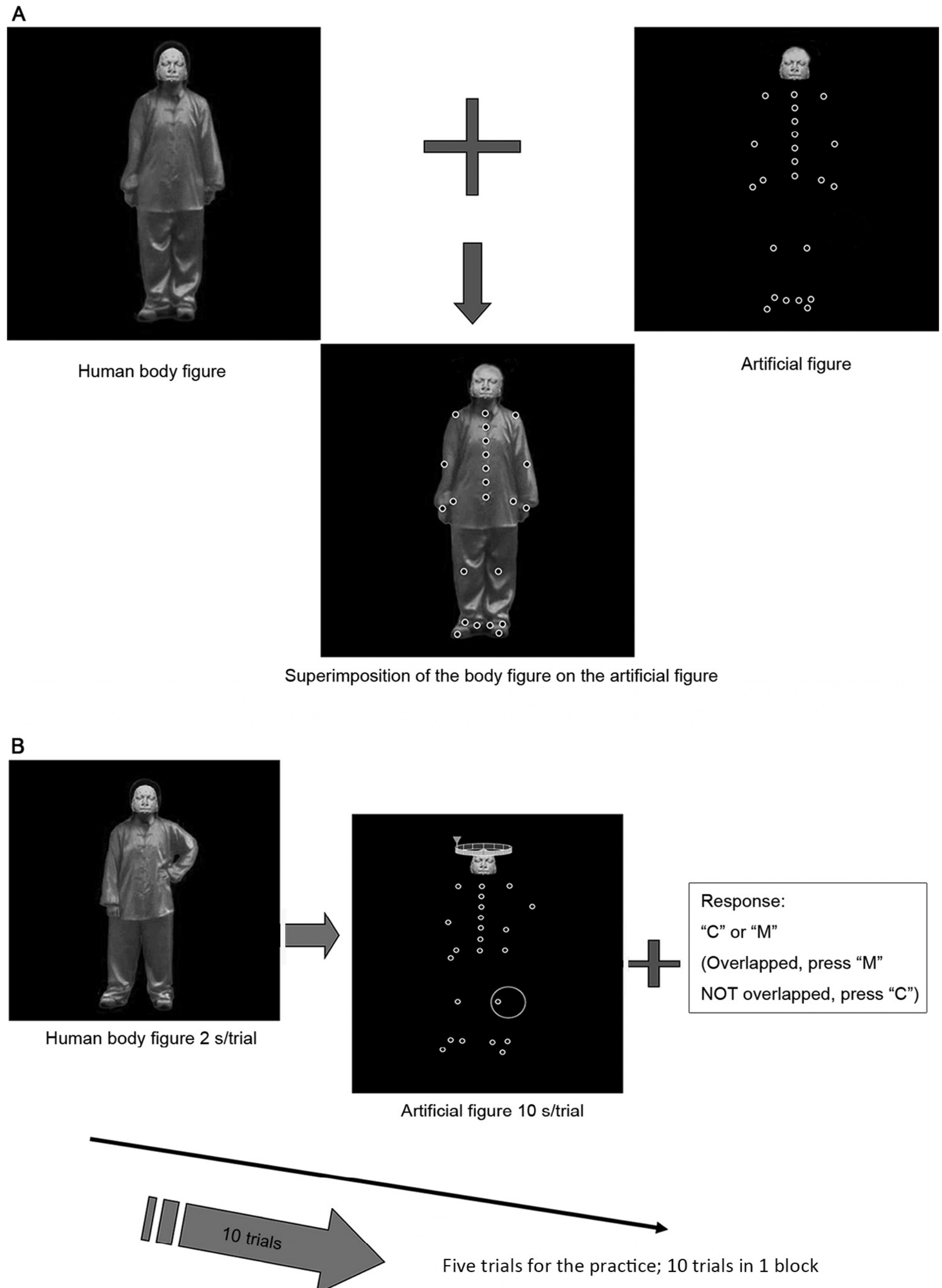

Fig. 1. The external visual imagery task. (A) The participant was required to recognize the posture of a human figure (top left), and then associate it with an artificial figure (top right) by superimposing the former on the latter (below). (B) The participant was presented with a human figure, which they had previously learned in training, for 2 s. An artificial figure was then presented with a specific angle of rotation (which appeared in a halo) for 10 s. The participant was then expected to generate the human body figure image. The task was to superimpose the image onto the artificial figure, and then rotate it to a position so that it aligned with the angle specified by the halo. Finally, the participant had to visualize the position of the body parts of the human body figure image and decide whether any of these overlapped with the circle that appeared on the screen. In 10 s, the participant pressed "M" on the keyboard if any part of the human body figure overlapped with the circle, or "C" if no part overlapped.

of movements fabricated with Movie Maker software (Windows Live Movie Maker Version 2.0; Microsoft Co., Redmond, WA, USA), and constructed into an artificial figure using Photoshop (Photoshop CS4; Adobe System Inc., San Jose, CA, USA). A typical trial required the participant to view a human body figure (limbs in specific postures) presented on a computer screen for 2 s (Fig. 1B). The participants then viewed the artificial figure (duration 10 s) with a halo indicating the angle of rotation of the image generated and superimposed on the human body figure. The superimposition covered the posture of the trunk and the upper and lower limbs. After mentally rotating the image generated to the angle specified by the halo, the participants were instructed to mentally locate the position of the body parts of the image and to decide whether any of them would have overlapped with the white circle that appeared on the screen. The participants pressed the "M" or "C" key for "overlap" or "not overlap", respectively. There were 5 practice trials and 10 trials in 1 block, and a total of 3 blocks in the task. The whole task took 20 min to complete. The task was run with E-prime Version 1.0 software (Psychological Software Tools, Pittsburgh, PA, USA). The accuracy rates of the participants and the time required for a response to be generated were recorded.

Evidence on the validity of the custom-designed EVI task was gathered by a literature review and an expert panel evaluation. Steenbergen et al.[25] used a contrast-group method to validate the mental rotation of the body parts (orientation of different postures of the hands) for EVI. In the current study, an expert panel reviewed the validity and difficulty level of the 30 artificial figures fabricated for the EVI task. The panel members were 5 coaches and 10 high-level athletes in the areas of track and field, weight lifting, judo, and fencing. The panel members were asked to evaluate the extent to which the mental rotation of these figures involved EVI. They then completed each artificial figure and rated the difficulty level using a 5-point scale from 1 (*very easy*) to 5 (*very difficult*). The results indicated that all panel members agreed that this task involved EVI. The difficulty level of the figures ranged from medium to high (2.1–4.3), which was verified by a pilot study (athletes, $n = 23$) which yielded mean accuracy rates from 0.35 to 0.83.

Each participant received training on the EVI task, which involved generating and superimposing images of the artificial figures. The participant looked at artificial figures (labeled 1–4), which were displayed after a human figure, for 4 s. The participant then responded by pressing the appropriate number on the keyboard to indicate the match. The participant was required to reach an accuracy rate of 12 out of 15 trials (80% accuracy) before proceeding to the EVI task.

2.2.2. IVI task

The design of the IVI task followed a mental chronometry method.[8,26–29] The method of testing[26] was estimating the functional equivalence by comparing the time taken to physically complete an action (termed the execution condition) with the time required to mentally visualize the same task (termed the mental condition). A higher functional equivalence means that the disparity of time between the mental and execution conditions is smaller. The IVI task in this study required the participant to mentally visualize a 4-s segment of the morning exercises, which was practiced by all students, including the participants from the Mainland of China (e.g., Fig. 2). A video clip capturing the body movements performed in the 4-s segment was produced. The tempo of the change in body movements/postures within the 4-s segment was 1 Hz. In other words, the transition of one movement/posture to another was 1 s. For example, the first movement was a "step forward with left leg with knees slightly flexed, both arms fully extended above the head, and looking ahead" (Fig. 2). During their training, each participant viewed the video clip, and simultaneously listened to the synchronized 1 Hz clicking sounds produced from a notebook computer. The participant was encouraged to practice the movements/postures as shown in the video clip. The participant's training ended when he or she could execute the movements/postures 3 times skillfully. The training took about 15 min to complete.

The testing procedure was modified from studies of Guillot and Collet[26] and Guillot et al.[8] Each participant was blindfolded, and asked to execute the movements/postures 3 times (termed the execution condition). The participant then mentally rehearsed the movements/postures 3 times. The instructions to the participant were to visualize his/her performance of the movements without any sensation in the muscles (termed the imagery condition). The participant used 2 verbal cues, "start" and "stop", at the beginning and at the end of the execution and the imagery processes, respectively. The duration between these 2 verbal cues was recorded by a timer. The absolute differences (*d*-values) in the time taken between the execution and imagery conditions were calculated as the scores on the IVI task. The order of the execution and imagery conditions was randomized among the subjects. A post-task questionnaire was administered to record the type of imagery perspective employed by the participant during the IVI task, and whether the participant visualized any sensation in

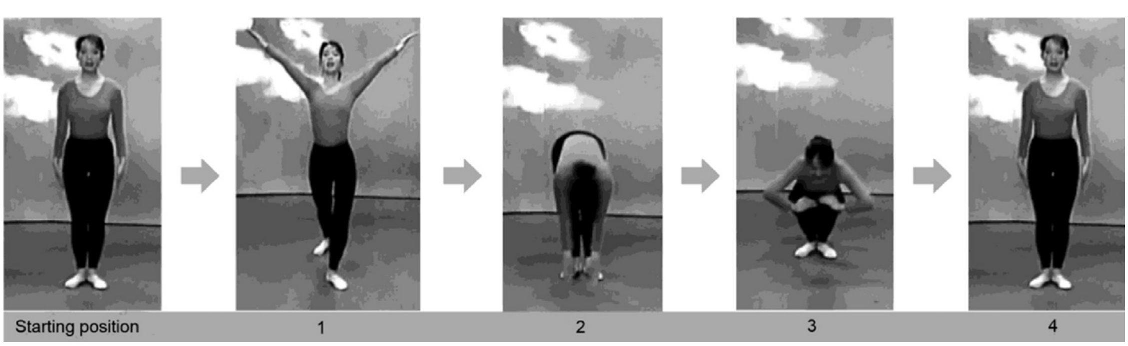

Fig. 2. The design of the internal visual imagery task (extracted from a morning exercise practiced by all students in the Mainland of China). The starting position of the 4-rhythmic-step movement: stand with feet and legs together and arms at the sides. First step: step forward with left leg with knees slightly flexed, both arms fully extended above the head, and looking ahead. Second step: lower arms and bend forward at the waist; touch toes with fingertips. Third step: bend down and do a full squat; place hands (fingertips facing toward each other) on the knees and look at the floor ahead. Fourth step: return to the starting position.

their muscles during the visualization process. The trials in which the participant had not reported employing IVI and felt any sensation in the muscles were excluded from the data analysis.

2.3. Procedure

Each participant completed the EVI and IVI tasks. The data collection was performed at the Guangdong Sports and Technology School. The testing took place in the evening, after the participants finished their coursework and dinner, and was carried out in a spacious multimedia computer room. The EVI task was first administered in a group format, whereas the IVI task was conducted on an individual basis. For the EVI task, 6 to 8 participants were seated in an upright, relaxed position (elbows, hips, and knees at 90°–100°) on comfortable chairs in front of desktop computers. A 15-inch CRT monitor (Lenovo Co., Beijing, China) for displaying the visual stimuli was placed at a distance of 65–75 cm. The responses of the participants were captured by the desktop computers. The IVI task was conducted in the same venue. The participants took turns to complete the training and testing.

2.4. Data analysis

The age and experience (years in the sport) of the subjects in open *vs.* closed sports were not significantly different ($t = 0.325$, $p = 0.746$; $t = -0.516$, $p = 0.608$, respectively). There was no significant difference in age between the high and low skill-level groups ($t = -1.491$, $p = 0.140$), but the athletes in the high skill-level group (3.31 ± 1.31 years) were more experienced than those in the low skill-level group (2.44 ± 1.00 years) ($t = -3.144$, $p = 0.002$). The 2 main effects studied were the types of sports the participants engaged in, and the participants' skill levels. The dependent variables were the scores on the EVI and IVI tasks. The 2-way ANCOVA: Sport Type (open *vs.* closed) and Skill-Level (high *vs.* low) had years of experience as the covariant for each task. The significance level was set at $p \leq 0.05$. All of the analyses were performed using SPSS software (Version 17.0 for Windows; SPSS Inc., Chicago, IL, USA).

3. Results

When the performance of male subjects on the IVI and EVI tasks was compared to females, it was clear that across all dependent variables, gender effects were not statistically significant ($p > 0.05$). As a result, the results obtained from both male and female participants were pooled, and the gender effect was removed from all subsequent comparisons.

3.1. Test of EVI ability

The Skill-Level and the Sport Type effects on the mean accuracy rate were not statistically significant ($F(1, 67) = 1.66$, $p > 0.05$, partial $\eta^2 = 0.024$; $F(1, 67) = 0.039$, $p > 0.05$, partial $\eta^2 = 0.001$, respectively). The covariate of Years of Experience was statistically significant ($F(1, 67) = 5.97$, $p = 0.017$, partial $\eta^2 = 0.082$) (Table 1). On the other hand, the interaction effect between Sport Type and Skill-Level was statistically significant ($F(1, 67) = 6.50$, $p = 0.013$, partial $\eta^2 = 0.088$). *Post hoc* pairwise comparisons with the Bonferroni adjustment revealed that the participants who specialized in open sports and had a relatively higher skill-level (62.4% ± 8.1%, mean ± SD) performed more accurately on the task than those who specialized in open sports but had a relatively lower skill-level (53.6% ± 7.4%) ($p = 0.001$). Those who specialized in closed sports fell in between these 2 groups, but the differences in accuracy rates between the 2 sub-groups were not statistically significant. In terms of response time, no significant main or interaction effects were observed.

Table 1
Participants' performance on the external visual imagery task stratified by the Sport Type and Skill-Level (mean ± SD).

	Accuracy rate (%)	Response time (ms)
High skill-level and open sports	62.4 ± 8.1	3337 ± 1267
Low skill-level and open sports	53.6 ± 7.4	3254 ± 1327
High skill-level and closed sports	57.2 ± 9.1	3275 ± 1450
Low skill-level and closed sports	57.8 ± 6.1	3213 ± 894

3.2. Test of IVI ability

A total of 11 trials were excluded from analysis, which was due to the fact that the participants reported not using IVI in these trials. The Skill-Level ($F(1, 67) = 12.64$, $p = 0.001$, partial $\eta^2 = 0.159$) and Sport Type effects ($F(1, 67) = 5.70$, $p = 0.02$, partial $\eta^2 = 0.078$) on the *d*-values were statistically significant (Table 2). The covariate of Years of Experience was not statistically significant ($F(1, 67) = 0.51$, $p > 0.05$, partial $\eta^2 = 0.009$). The interactions between the 2 main effects were not statistically significant ($F(1, 67) = 0.18$, $p > 0.05$, partial $\eta^2 = 0.003$). *Post hoc* comparisons suggested that the participants who had a higher skill-level (431 ± 253 ms) had smaller mean *d*-values than their counterparts with lower skill-level (702 ± 338 ms) ($p = 0.001$); the participants who specialized in open sports (495 ± 281 ms) also performed better on the task than those who specialized in closed sports (685 ± 365 ms) ($p = 0.02$).

4. Discussion

The main finding was that the sport type and skill-level of young athletes were related to their VI ability. More importantly, the relationships between the types of sports and the levels of skill with EVI and IVI abilities were different, which suggests uniqueness in their constructs. Young athletes who

Table 2
Participants' performance on the internal visual imagery task stratified by the Sport Type and Skill-Level (*d*-value (ms), mean ± SD).

	High skill-level	Low skill-level	Total
Open sports	365 ± 208	644 ± 283	495 ± 281
Closed sports	563 ± 292	783 ± 398	685 ± 365
Total	431 ± 253	702 ± 338	

Note: the *d*-value is defined as the absolute difference in the time taken between the execution and the imagery conditions.

specialized in open sports and had a higher level of skill also had a stronger EVI ability than those who specialized in closed sports and/or with a lower level of skill. In contrast, the specificity for IVI was less clear. Those who specialized in open sports still possessed higher IVI ability. In contrast to EVI, young athletes who possessed a higher level of skill regardless of the sport specialization were found to possess higher IVI ability. Differences in mental processing, particularly EVI involving the visual transformation of others and the environment, would benefit the development and refinement of strategies in competition with opponents. The complex mental processing required by the EVI would possibly be related to the overall higher skill-level among these athletes.

The significant interaction effects of skill-level and sport type on the participants' external, but not internal, VI ability represent new findings. These results provide insight into possible differences between the constructs of EVI and IVI. Those participants who engaged in open sports and had a higher skill-level attained the highest accuracy rate on the EVI task. In contrast, those participants who engaged in open sports but had a relatively lower level of skill attained significantly lower scores on the task. Our findings further support Féry and colleagues' studies[1,30] reporting that participants who performed well in competitions were found to possess a higher level of mental skills. These researchers further suggested that the higher achievements in sports could be attributable to the athletes' ability on visualizing movement-related space, size, and forms more vividly. Our results are further related to the model proposed by Hall et al.,[31] which classifies imagery functions into 5 types. The EVI defined in this study mostly corresponds to the cognitive specific (CS) and cognitive general (CG) types, but less to the motivational general-arousal (MG-A), motivational general-mastery (MG-M) and in particular, loosely to the motivational specific (MS) types. The reason is that the external perspective requires an individual to visualize the movements generated by others in their surroundings, during which the observer is a spectator, and hence EVI would be beneficial for practicing response strategies employed when competing against opponents. The cognitive specific type refers to imagery of the skills required by the sport, whereas the cognitive general type refers to the imagery of strategies, routines and game plans, which coincides with the characteristics of the EVI perspective. Nordin and Cumming[32] reported that the CS and CG perspectives could be predicted by the functioning of the athletes. In their study, the CS type was found to be the most effective perspective for enhancing skill execution and performance by athletes, whereas CG was the most effective for the development and execution of strategies. In open sports such as judo and fencing, the execution of both skills and strategies involve the skills and strategies displayed by the opponent.[12] Thus, the EVI perspective would enable the athletes to vividly visualize the movements and strategies generated by their opponents, and hence react with prompt and effective responses in open sports. These skills would increase the probability of winning in competitions, and thus result in better achievements for these athletes.

Different from the external perspective, the specificity of the IVI perspective was found to be less clear. Participants in this study who specialized in open sports performed better on the IVI task than those who specialized in closed sports, which does not support our hypothesis. The findings are also somewhat inconsistent with 2 earlier studies. Highlen and Bennett[33] found no differences between wrestlers (open sports) and divers (closed sports) in terms of imagery utilization, vividness, and control. Weinberg et al.[34] reported that athletes engaging in closed sports (track and field, golf) employed more imagery than those who engage in open sports (e.g., tennis and basketball). These studies employed a self-report method based on the athletes' preference. However, comparisons of these results should be made with caution. Other studies[35–37] suggested that the stable environment in which closed sports were performed was conducive to the use of imagery by athletes during practice and competition. Similarly, the discrepancy in the findings across these studies is likely to be caused by differences in the constructs used to measure the imagery. In this study, the IVI perspective was operationalized by performance on the IVI task, which is a measure of ability. Those studies mentioned operationalization in terms of engagement in mental imagery, such as the frequency of practice or perceived difficulty. The construct of practice is not equivalent to that of ability, and more frequent practice does not necessarily translate to higher ability. However, it is interesting to assert the notion that open-sport athletes possess higher ability for IVI than their closed-sport counterparts. Previous studies have stressed the importance of accurate and instantaneous planning to produce effective motor responses when competing in open sports.[38,39] They further explained that VI would enable open-sport athletes to predict both their own actions and those of their opponents by reproducing the rehearsed movement patterns. In other words, both open- and closed-sport athletes would need to possess the ability to perform IVI. Open-sport athletes would inevitably need to possess greater ability for IVI than closed-sport athletes due to the ever-changing external environments during competitions. Future study should verify this hypothesis, and explore the mechanisms responsible for this phenomenon. Last but not least, these results suggested that young athletes who had a higher level of sport skill tended to possess a higher ability for IVI than those who possessed a lower level of sport skill. Our findings are consistent with previous studies. These previous studies further explained that the superiority of their imagery ability was due to the fact that higher skill-level athletes underwent more frequent training than lower skill-level athletes.[16,20,40] In this study, the young athletes with higher skill-levels were those who won medals in competitions held at the provincial or national level, whereas those with lower skill-levels had won medals in competitions held at the municipal level or below. It is obvious that more resources were available for training athletes for higher than lower level competitions. The research design of this study does not allow for further conclusions to be drawn on the causal effect of practicing IVI over winning in competitions. This would be an important topic for future studies.

This study has a few limitations. First, the participants were young athletes under the age of 17 who engaged in certain types of sports. These findings may be confounded by the rapid but variable development of the athletes' cortical functions such as in the parietal cortex,[41,42] and hence motor imagery capability.[22,23] Furthermore, these findings may not be accurately generalized to athletes who are older or participate in sports that were not covered in this study. Second, the sample size was relatively small, particularly when the participants were further divided into the 4 subgroups, thus weakening the power of the statistical analyses. These results should therefore be interpreted with caution. Third, the types of sports included in this study may not be the best representatives of open and closed sports, and the results are specific to the samples recruited in this study. The generalization of these findings should be limited to other sports sharing similar skill sets and competition strategies. Different types of sports included with open or closed sports could inflate the within-group variability and attenuate the between-group differences, and hence lower the power of the analyses. Fourth, the EVI and IVI tasks were administered in the evening, and fatigue experienced by the participants could have hampered their performance on the EVI and IVI tasks. These results could also have been confounded by an order effect bias, because all participants performed the EVI and IVI tasks in the same order. Fifth, this study attempted to control several individual differences, including years of training, age and gender of the participants. However, the preference for the imagery perspective (termed the cognitive style) and other imagery ability (such as auditory and tactile) of the participant were not controlled. This could have influenced the results, particularly for young athletes who possessed the capability but not the inclination to use this perspective. Last but not least, these results were largely dependent on the constructs measured by the EVI and IVI tasks used in this study. The generalization of these results would only be meaningful if the tasks employed in other studies were comparable in terms of their constructs and methods of measurement. Future studies should attempt to address these issues.

5. Conclusion

Mental imagery is part of an athlete's training. This study employed 2 custom-made ability tasks to quantify EVI and IVI. The EVI perspective was found to be exclusive to young athletes who specialized in open sports and possessed high sport skills. Their ability for EVI was significantly higher than those in the closed sports and/or lower sport skill-level groups. These results suggest the uniqueness of the EVI perspective for assisting open-sport athletes to win in competitions. The mental processes for visualizing the performance of one-self in the context of other opponents and changes in the environment are likely to account for the value of EVI in open sports competition. In contrast, the IVI perspective was found to be less exclusive, despite the fact that young athletes who specialized in open sports or possessed higher sport skills also had higher ability in this perspective. Although the mental visualization processes involved in the internal perspective are less complex than those in the external perspective, it would be useful for facilitating motor planning and execution in competitions. Our findings further substantiate the differences in these constructs and the potential applications of the EVI *vs.* IVI. These results also shed light on designing specific VI training programs to enhance the athletes' skill and competitiveness in sports.

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Authors' contributions

QHY conceived of the study, carried out the study, and wrote the manuscript; ASNF conceived of the study, assisted in data analysis and drafted the manuscript; AK carried out the study and drafted the manuscript; JL carried out the study and drafted the manuscript; XHS carried out the study and drafted the manuscript; CCHC conceived the study, conducted data analysis and drafted the manuscript. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

Competing interests

None of the authors declare competing financial interests.

References

1. Féry YA. Differentiating visual and kinesthetic imagery in mental practice. *Can J Exp Psychol* 2003;**57**:1–10.
2. Fishburne GJ. The development of visual and kinesthetic imagery capacity in children (Le développement de la capacité d'imagerie visuelle et kinesthésique chez les enfants). *STAPS* 1990;**22**:11–6. [in French].
3. Cumming JL, Ste-Marie DM. The cognitive and motivational effects of imagery training: a matter of perspective. *Sport Psychol* 2001;**15**:276–88.
4. Hardy L, Callow N. Efficacy of external and internal visual imagery perspectives for the enhancement of performance on tasks in which form is important. *J Sport Exerc Psyol* 1999;**21**:95–112.
5. White A, Hardy L. Use of different imagery perspectives on the learning and performance of different motor skills. *Br J Psychol* 1995;**86**:169–80.
6. Guillot A, Collet C, Dittmar A. Relationship between visual *vs.* kinesthetic imagery, field dependence-independence and complex motor skills. *J Psychophysiol* 2004;**18**:190–9.
7. Callow N, Hardy L. The relationship between the use of kinaesthetic imagery and different visual imagery perspectives. *J Sports Sci* 2004;**22**:167–77.
8. Guillot A, Collet C, Nguyen VA, Malouin F, Richards C, Doyon J. Brain activity during visual versus kinesthetic imagery: an fMRI study. *Hum Brain Mapp* 2009;**30**:2157–72.
9. Roosink M, Zijdewind I. Corticospinal excitability during observation and imagery of simple and complex hand tasks: implications for motor rehabilitation. *Behav Brain Res* 2010;**213**:35–41.
10. Jackson PL, Meltzoff AN, Decety J. Neural circuits involved in imitation and perspective-taking. *Neuroimage* 2006;**31**:429–39.
11. Barr K, Hall C. The use of imagery by rowers. *Int J Sport Psychol* 1992;**23**:243–61.
12. Glisky M, Williams G, Kihlstrom J. Internal and external mental imagery perspectives and performance on two tasks. *J Sport Behav* 1996;**19**:3–18.

13. White A, Hardy L. An in-depth analysis of the uses of imagery by high-level slalom canoeists and artistic gymnasts. *Sport Psychol* 1998;**12**:387–403.
14. Arvinen-Barrow M, Weigand DA, Thomas S, Hemmings B, Walley M. Elite and novice athletes' imagery use in open and closed sports. *J Appl Sport Psychol* 2007;**19**:93–104.
15. Watt AP, Spittle M, Jaakkola T, Morris T. Adopting Paivio's general analytic framework to examine imagery use in sport. *J Imagery Res Sport Phys Activ* 2008;**3**:121–9.
16. Callow N, Hardy L. Types of imagery associated with sport confidence in netball players of varying skill levels. *J Appl Sport Psychol* 2001;**13**: 1–7.
17. Roberts R, Callow N, Hardy L, Markland D, Bringer J. Movement imagery ability: development and assessment of a revised version of the vividness of movement imagery questionnaire. *J Sport Exerc Psyol* 2008;**30**:200–21.
18. Isaac AR, Marks DF. Individual differences in mental imagery experience: developmental changes and specialization. *Br J Psychol* 1994;**85**:479–500.
19. Oishi K, Maeshima T. Autonomic nervous system activities during motor imagery in elite athletes. *J Clin Neurophysiol* 2004;**21**:170–9.
20. Cumming J, Hall C. Athletes' use of imagery in the off-season. *Sport Psychol* 2002;**16**:160–72.
21. Hall CR. Imagery in sport and exercise. In: Singer R, Hausenblas H, Janelle C, editors. *Handbook of sport psychology*. 2nd ed. New York, NY: Wiley; 2001.p.529–49.
22. Choudhury S, Charman T, Bird V, Blakemore SJ. Adolescent development of motor imagery in a visually guided pointing task. *Conscious Cogn* 2007;**16**:886–96.
23. Choudhury S, Charman T, Bird V, Blakemore SJ. Development of action representation during adolescence. *Neuropsychologia* 2007;**45**:255–62.
24. Lust J, Geuze R, Wijers A, Wilson P. An EEG study of mental rotation-related negativity in children with developmental coordination disorder. *Child Care Health Dev* 2006;**32**:649–63.
25. Steenbergen B, van Nimwegen M, Crajé C. Solving a mental rotation task in congenital hemiparesis: motor imagery versus visual imagery. *Neuropsychologia* 2007;**45**:3324–8.
26. Guillot A, Collet C. Duration of mentally simulated movement: a review. *J Motor Behav* 2005;**37**:10–20.
27. Malouin F, Belleville S, Richards CL, Desrosiers J, Doyon J. Working memory and mental practice outcomes after stroke. *Arch Phys Med Rehabil* 2004;**85**:177–83.
28. Malouin F, Doyon J, Dumas F, Jackson P, Evans A, Richards C. Mental representation of locomotion: a PET study. *Neuroimage* 1997;**5**(Suppl. 1): S132.
29. Malouin F, Richards CL, Jackson PL, Dumas F, Doyon J. Brain activations during motor imagery of locomotor-related tasks: a PET study. *Hum Brain Mapp* 2003;**19**:47–62.
30. Féry YA, Morizot P. Kinesthetic and visual image in modeling closed motor skills: the example of the tennis serve. *Percept Mot Skills* 2000;**90**:707–22.
31. Hall CR, Mack DE, Paivio A, Hausenblas HA. Imagery use by athletes: development of the Sport Imagery Questionnaire. *Int J Sport Psychol* 1998;**29**:73–89.
32. Nordin SM, Cumming J. Types and functions of athletes' imagery: testing predictions from the applied model of imagery use by examining effectiveness. *Int J Sport Exerc Psychol* 2008;**6**:189–206.
33. Highlen PS, Bennett BB. Elite divers and wrestlers: a comparison between open-and closed-skill athletes. *J Sport Psychol* 1983;**5**:390–409.
34. Weinberg R, Butt J, Knight B, Burke KL, Jackson A. The relationship between the use and effectiveness of imagery: an exploratory investigation. *J Appl Sport Psychol* 2003;**15**:26–40.
35. Gregg M, Hall C, Nederhof E. The imagery ability, imagery use, and performance relationship. *Sport Psychol* 2005;**19**:93–9.
36. Gregg M, Hall C, McGowan E, Hall N. The relationship between imagery ability and imagery use among athletes. *J Appl Sport Psychol* 2011;**23**:129–41.
37. Short SE, Tenute A, Feltz DL. Imagery use in sport: mediational effects for efficacy. *J Sports Sci* 2005;**23**:951–60.
38. Blumenstein B, Lidor R, Tenenbaum G. Periodization and planning of psychological preparation in elite combat sport programs: the case of judo. *Int J Sport Exerc Psychol* 2005;**3**:7–25.
39. Yarrow K, Brown P, Krakauer JW. Inside the brain of an elite athlete: the neural processes that support high achievement in sports. *Nat Rev Neurosci* 2009;**10**:585–96.
40. Gregg M, Hall C. The relationship of skill level and age to the use of imagery by golfers. *J Appl Sport Psychol* 2006;**18**:363–75.
41. Gogtay N, Giedd JN, Lusk L, Hayashi KM, Greenstein D, Vaituzis AC, et al. Dynamic mapping of human cortical development during childhood through early adulthood. *Proc Natl Acad Sci U S A* 2004;**101**:8174–9.
42. Toga AW, Thompson PM, Sowell ER. Mapping brain maturation. *Trends Neurosci* 2006;**29**:148–59.