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1 Free Throw Performance in Non-expert Basketball Players: The Effect of Dynamic Motor
2 Imagery Combined with Action Observation

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1 Abstract

2 We investigated the effect of dynamic motor imagery (dMI) combined with physical practice
3 on free throw performances of advanced basketball players in two conditions: With and
4 without a video of a model. They performed a pre-test, participated in 5-weeks of intervention
5 sessions, and performed a post-test. During pre-test and post-test, they performed 10-free
6 throws followed by the “Evan Fournier test”: Maximum number of sequences of two
7 consecutive free throws and round trips to the midfield and shot zone in 45-seconds. During
8 intervention sessions, they were assigned to Control, Imagery or Model+imagery groups and
9 performed five blocks of two free throws. Before each block, they watched a video and
10 performed countdown or dMI. The results revealed that the Imagery and Model+imagery
11 groups had higher free throw performances in the post-test than in the pre-test. At the post-
12 test, the Model+Imagery group made more consecutive shots in the onfield-test Evan Fournier
13 than the two other groups.

14 *Key words:* Mental imagery, motor improvement, performance, model observation

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4 1 Introduction

5 According to Morris, Spittle, and Watt (2005), imagery is defined as the creation and
6 re-creation of an experience generated from memory and under the control of the imager that
7 involves quasi-perceptual, quasi-sensorial and quasi-affective characteristics. In the context of
8 sports, motor imagery (MI) is a conscious process that requires that individuals mentally
9 simulate a motor action (Robin et al., 2007). MI is a popular mental technique and a
10 frequently employed cognitive strategy to enhance motor learning and relearning, strength,
11 sports performances, rehabilitation, and confidence or motivation (Anuar, Williams, &
12 Cumming, 2016; Féry, 2003; Guillot & Collet, 2008; Lebon, Collet, & Guillot, 2010; Olsson,
13 Jonsson, & Nyberg, 2008; Robin, Coudeville, Hue, & Sinnapah, 2017).

14 During MI, the mental representation of a motor action is activated in order to imagine
15 the movements (Frank, Land, Popp, & Schack, 2014; Jeannerod, 2001; Kanthack et al., 2016).
16 Authors have shown that MI engages the sensorimotor system and that the brain plasticity
17 resulting from real movement execution also occurs as a result of MI (for a review see
18 Ruffino, Papaxanthis, & Lebon, 2017). Moreover, MI of tongue, hand and foot movements
19 was found to specifically activate the corresponding tongue, hand and foot primary motor
20 cortex regions (Ehrsson, Geyer, & Naito, 2003). Jeannerod and Frak (1999) also noted the
21 anatomical and functional correspondence between MI and real movement execution.

22 Many authors have pointed out that a combination of MI and physical practice can be
23 particularly beneficial to improve motor execution (Di Rienzo et al., 2015), accuracy (Ingram,
24 Kraeutner, Solomon, Westwood, & Boe, 2016; Robin et al., 2007), and learning (Goss, Hall,
25 Buckolz, & Fishburne, 1986), and can contribute to motor memory consolidation (Pearson,

1 Naselaris, Holmes, & Kosslyn, 2015). Most studies have used static MI in their research
2 protocols, asking the participants to perform MI without concomitant body movements
3 (Robin et al., 2007). However, in recent studies, participants have been asked to combine MI
4 with limited-amplitude movements of the hand or arm while simultaneously imagining their
5 own performances in a downhill ski slalom (Callow, Roberts, & Fawkes, 2006). In a ski jump
6 task, Guillot, Moschberger, and Collet (2013), reported that dynamic motor imagery (dMI)
7 intervention improved both imagery quality and motor performances.

8 Previous studies in basketball have shown the effectiveness of using MI to learn
9 strategy (Guillot, Nadrowska, & Collet, 2009) and improve performance, particularly in the
10 free throw (Post, Wrisberg, & Mullins, 2010; Wrisberg & Anshel, 1989). The latter is a
11 crucial skill, given its complexity and determining role in match results, especially when the
12 score is tight. Kanthack, Bigliassi, Vieira, and Altimari (2014) compared the effect of static
13 MI intervention on 10 free throw performances of young basketball players. They observed
14 that MI, used in advance, had only a short-term effect (i.e., on the first two free throws). More
15 recently, Kanthack et al. (2016) showed that dMI provided additional benefits by comparison
16 with more traditional static MI practice in high-level basketball free throw performances
17 except when participants were physically exhausted. It would be therefore interesting to
18 evaluate if dMI practice that seems to be efficient with experts would also be beneficial in
19 non-expert, advanced, basketball players.

20 Action observation (AO) is another form of motor simulation that activates the motor
21 system in the absence of overt motor execution (Grèzes & Decety, 2001). According to
22 Eaves, Riach, Holmes, and Wright (2016), AO evokes a cognitive representation of the
23 observed action, involving bottom-up and percept-driven processes that are under the
24 subconscious control of the observer (Holmes & Calmels, 2008). The beneficial effect of AO
25 seems to reflect involuntary activation of motor codes corresponding to observed motor

1 actions (Romano-Smith, Wood, Wright, & Wakefield, 2018). During AO, observers copy the
2 movement kinematics (e.g., speed) of the model, which is coded through biological motion
3 (Wild, Poliakoff, Jerrison, & Gowen, 2010). Many studies showed that AO is an effective
4 technique for improving motor learning and performance in variety of motor activities (for a
5 review, see Ste-Marie et al., 2012) that permits to reduce the number of physical practice
6 trials required to achieve a given performance (for a review, see Blandin, 2002).

7 Other authors have suggested using AO combined with MI to improve motor
8 execution and performance (Battaglia et al., 2014; Robin & Flochlay, 2017; Romano-Smith et
9 al., 2018; Taube, Lorch, Zeiter, & Keller, 2014). AO and MI are two forms of motor
10 simulation that activate the motor system in the absence of overt motor execution (Eaves et
11 al., 2016; Jeannerod, 2001) and evoke an internal motor representation of the movement
12 (Rizzolatti & Sinigaglia, 2010). Like MI, AO is an effective tool for improving motor
13 learning (Farsi, Bahmanbegloo, Abdoli, & Ghorbani, 2016; Ste-Marie et al., 2012). Grèzes
14 and Decety (2001) observed that AO and MI involve motor and motor-related cortex areas
15 that overlap extensively both with one another, and with the neural structures involved in
16 motor execution. However, other studies have revealed that distinct brain structures are
17 identifiable for AO, MI and real execution (Filimon, Rieth, Sereno, & Cottrell, 2015; Lorey et
18 al., 2013), supporting the effectiveness of AO and MI as independent instruction tools and
19 comparing the potential advantages and similarities versus the differences between these two
20 techniques (Filimon et al., 2015; Gatti et al., 2013; Gonzalez-Rosa et al., 2015). Recently,
21 researchers combined these two forms of motor simulation and showed the potential
22 advantages of them together (Eaves et al., 2016; Gatti et al., 2013; Sarasso, Gemma, Agosta,
23 Filippi, & Gatti, 2015; Taube et al., 2014; Vogt, Di Rienzo, Collet, Collins, & Guillot, 2013).
24 They observed that corticomotor activity and excitability were significantly increased when
25 these two techniques were used in combination (Ohno et al., 2011; Wright, Williams, &

1 Holmes, 2014) compared with when the same action was either imagined or observed
2 individually (Mouthon, Ruffieux, Wälchli, Keller, & Taube, 2015; Sakamoto, Muraoka,
3 Mizuguchi, & Kanosue, 2009; Taube et al., 2015; Tsukazaki, Uehara, Morishita, Ninomiya,
4 & Funase, 2012). The results of the studies noted above seem to argue for using a
5 combination of MI and AO for motor learning, but little behavioral evidence from the sports
6 domain supports this claim. Smith and Holmes (2004) showed that video-guided imagery
7 improved performances in a golf putting task more than MI alone. Improved strength was also
8 observed in a bicep curl test over a 6-week video-guided imagery intervention (Wright &
9 Smith, 2009). As noted by Eaves et al. (2016), the combination of AO and MI might offer an
10 effective adjunct to physical practice, and we tested this hypothesis using dMI plus AO,
11 which to our knowledge has never been done, especially with advanced basketball players.

12 The aim of this study was to (1) evaluate the effect of combining a video of a model of
13 the free throw with dynamic motor imagery practice before a free throw trial performed by
14 regional level non-expert basketball players, and (2) determine whether the beneficial effects
15 observed for a dMI intervention performed alone or in conjunction with AO are transferable
16 to a more dynamic task, the Evan Fournier test, which includes free throws, body
17 displacements and time pressure (i.e., 45-seconds). As previously showed by Kanthack et al.
18 (2016) in high-level basketball athletes, we hypothesized that the combination of dMI and
19 physical execution would permit greater improvement than the physical execution alone in
20 advanced but non-expert players. Moreover, in line with behavioral and neurological evidence
21 (Eaves & al., 2016), we hypothesized that adding AO to dynamic motor imagery and physical
22 execution would permit greater performance than physical practice alone or combined with
23 dMI and that it would facilitates the performance in the Evan Fournier test.

24

25 2 Methods

1 2.1 Participants

2 Forty-six self-declared right-handed basketball players ($M_{age} = 19.53$, $SD = 1.54$)
3 volunteered to participate in this study. All were recruited from West Indies University, had
4 been playing basketball for more than 2 years, and were competing at no higher than a
5 regional level. The participants provided written informed consent to take part in the study.
6 Ten players were excluded due to injury or because they had missed one experimental session
7 leaving a final sample of 36 of participants. The study was granted approval by the local
8 ethics committee at West Indies University and was conducted in accordance with the
9 Declaration of Helsinki.

10 2.2 Study design

11 A pre- post experimental design was used. Thirty-six participants were randomly
12 assigned to one of three groups: Control group ($n = 12$), Imagery group ($n = 12$), and
13 Model+imagery group ($n = 12$). There was one week of pre-tests, five weeks of practice, and
14 one week of post-testing.

15 2.3 Material

16 The experimental task was conducted on an indoor court meeting the international
17 standards for line distance, hoop height and ball weight. Each experimental session was held
18 at the same time of day for each condition (9-am) to avoid circadian effects (Gueugneau,
19 Mauvieux, & Papaxanthis, 2009) during a regularly scheduled class.

20 The participants received instructions and watched the video on a tablet (Samsung
21 Galaxy Tab4 model SM-T533, Android 5.1.1, 10.1 screen inches) with V7 over-the-head
22 stereo headphones (HA510).

23 2.4 Outcome, Measure and Task

24 2.4.1 Free throw test

25

1 During the pre-test and post-test, all the participants, who had to convert the ball, performed
2 10 free throws as accurately as possible. The experimenter was responsible for passing the
3 ball to the players before each throw and for collecting rebounds and netted shots.
4 Performance was evaluated in terms of converted free throws (from 0 to 10).

5 2.4.2 Evan Fournier test

6 The Evan Fournier Test consisted of scoring as many free throws as possible in 45-seconds.
7 The participants had to perform and convert several series of two free throws as accurately as
8 possible. After the two consecutive free throws, they had to run to the center circle, put the
9 right or left foot into the circle, and then run back to the free throw line. The experimenter
10 passed the ball to the player before each throw so that the participant did not have to leave the
11 free throw line during the two consecutive throws. The scores corresponded to the number of
12 successful free throws. This onfield test included free throws combined with body
13 displacement and time pressure constraints.

14 2.4.3 Video task

15 Participants of the Model+imagery group watched a video with an excellent regional
16 basketball player performing two free throws at normal speed on the tablet with sound (third-
17 person perspective). The written and auditory instructions, on the tablet, were “you have to
18 watch the video that will start in 5, 4, 3, 2, 1”. The observation was unguided: Participants
19 were not instructed to direct their attention to particular aspects of the player’s performance
20 (Al-Abood, Davids, & Bennett, 2001). The participants of the Control and Imagery groups
21 had to watch a video clip (i.e., flying trapeze figures).

22 2.4.4 Mental task

23 Participants of the Control group performed a mental task: Countdown from 10 to 0, which
24 corresponded approximately to the length of time that participants from other groups spent on
25 MI.

1 2.4.5 Imagery task

2 The dMI was performed on the basketball court on the line in front of the hoop. Participants
3 of the Imagery and Model+imagery groups were instructed to imagine the free throw
4 sequence as accurately as possible, from receiving the ball up to the final phase of shooting.
5 They were required to perform dMI by imagining being inside their bodies as if they were
6 looking with their own eyes and to perform slight arm movements and semi-flexing the legs,
7 miming the actual free throw task. Participants, in a standing position, were asked to imagine
8 the entire free throw, from the movements of the body with a mechanical image of the arm
9 and trajectory of the ball through the air, emphasizing the ball being released and entering the
10 hoop. Moreover, participants were instructed to consider the body as a generator of forces,
11 and therefore to combine internal visual imagery with kinesthetic imagery (for a similar
12 procedure see Guillot et al., 2013). As indices of MI quality, participants self-reported the
13 level of perceived vividness on a Likert scale ranging from 1 (“Unclear and inaccurate mental
14 representation”) to 6 (“Perfectly clear and vivid mental representation”) (for a similar
15 procedure see Kanthack et al., 2016).

16 2.5 Procedure

17 One week before the pre-test, the experimenter met with the participants to determine
18 their knowledge about MI. They were questioned about the frequency and nature of their
19 imagery use in order to exclude those participants who regularly performed imagery routines
20 including movements and/or those who were unfamiliar with motionless imagery (see Guillot
21 et al., 2013, for a similar procedure). The players were also given descriptions of external
22 visual imagery, internal visual imagery, and kinesthetic imagery and were instructed to use
23 kinesthetic imagery in combination with whichever visual perspective, or combination of
24 visual perspectives, they found beneficial. However, all the participants self-reported using
25 visual imagery more easily and frequently along with the kinesthetic imagery. This

1 combination was therefore considered in the imagery scripts.

2 2.5.1 Pre-test phase

3 During this session, held in week 1, participants had a standardized 20-minute warm-up,
4 performed 10 free throws, and then performed the onfield test: Evan Fournier test (see Figure
5 1).

6 2.5.2 Intervention phase

7 During weeks 2 to 6, the intervention phase was held at the West Indies University basketball
8 court. Each session lasted approximately 30 minutes and started with a 20 minutes warm-up.
9 The participants then carried out their task under the assigned condition. Specifically, they
10 were asked to follow the instruction given on the tablet and perform five blocks of two free
11 throws. Before each block, the participants of the Control and Imagery groups had to watch a
12 video clip, whereas the participants of the Model+imagery group had to watch the video of
13 the model performing two consecutive and successful free throws. Then, the participants of
14 the Control group counted down from 10 to 0, whereas the participants of the Imagery and
15 Model+imagery groups were required to perform dMI.

16 2.5.3 Post-test phase

17 In week 7, the participants performed a post-test, which was identical to the pre-test.

18

19

Figure 1 near here

20

21 2.6 Data Analysis

22 As first data analysis, the imagery vividness scores across the experimental conditions
23 were first examined to confirm that there were no differences between groups. Moreover, a
24 comparison of pre-test scores across groups (Control vs. Imagery vs. Model+imagery) was
25 computed using a one-way ANOVA.

1 The number of successful throws, marked during the pre-test and post-test, served as
2 dependent variables.

3 Concerning the Evan Fournier test, two different dependent variables were calculated.
4 The first corresponded to the number of successful throws during the 45-seconds of the test,
5 and the second corresponded to the number of two consecutive throws scored in the same
6 series as recommended by the French Basketball Federation.

7 The dependent variables were submitted to a 3 Group (Control vs. Imagery vs.
8 Model+imagery) x 2 Phase (pre-test vs. post-test) ANOVA with repeated measures on the
9 second factor. Moreover, a performance improvement index (PII) was computed: [PII = (post-
10 test - pre-test / pre-test scores)*100] in order to measure the percentage of change between the
11 pre-test and post-test free throws and Evan Fournier test performances. The PII-dependent
12 variables were submitted to a one-way ANOVA that compared Group (Control vs. Imagery
13 vs. Model+imagery). As multiple paired and unpaired t-tests were conducted for posthoc
14 analyses, to control for the possibility of a Type I and Type II errors occurring, Holm
15 Bonferroni adjustments were applied to the alpha level (e.g., 0.017 for the first rank value,
16 0.025 for the second, and 0.05 for the third, for post-test between group
17 comparisons). Normality was checked (Kolmogorov-Smirnov test), effect sizes (η_p^2) were
18 indicated, and α was set at .05 for all the analyses.

19

20 3 Results

21 3.1 Imagery Vividness and Descriptive Results

22 No participant reported difficulties performing dMI and no differences were found
23 when we compared the Imagery ($M_{score} = 4.40$, $SD = 0.53$) and Model+imagery ($M_{score} = 4.29$,
24 $SD = 0.89$) vividness [$t(22) = -0.35$, $p = .72$, $\eta_p^2 = 0.01$]. The one way ANOVA on free throw

1 scores revealed that there was no between group differences at pre- test [$F(2, 33) = 0.06, p =$
2 $.93, \eta_p^2 = 0.00$] (see Table 1 for descriptive results).

3
4 Table 1 near here
5

6 3.2 Effects of Condition on Ten Free Throws Task

7 The ANOVA computed on scores revealed no significant main group effect [$F(2, 33)$
8 $= 0.49, p = .61, \eta_p^2 = 0.03$]. However, the analysis revealed a significant main phase effect
9 [$F(1, 33) = 12.84, p = .001, \eta_p^2 = 0.28$] and an interaction between group and phase factors
10 [$F(2, 33) = 6.19, p = .005, \eta_p^2 = 0.27$]. As illustrated on Figure 2, the post-hoc test revealed
11 that the Imagery and Model+imagery groups had higher ten free throw performances at the
12 post-test than at the pre-test ($ps < .01$). The performances of the participants of the Control
13 group were not significantly different from pre-test to post-test ($p = .49$).

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15
16 Figure 2 near here
17

18 The ANOVA computed on PII (Ten Free Throws task) revealed a significant group
19 effect [$F(2, 33) = 5.11, p = .01, \eta_p^2 = 0.24$]. The post-hoc test revealed that the participants of
20 the Imagery (44%) and Model+imagery (43%) groups had significantly higher ten free throw
21 PII ($p = .02$ and $p < .01$, respectively) than the participants of the Control group (-4%)." There
22 was no statistical difference between the PII of the Imagery and Model+imagery groups ($p =$
23 $.92$).

24 3.3 Effects of Condition on Evan Fournier test

1 The ANOVA computed on the Evan Fournier test scores revealed no significant main
2 group effect [$F(2, 33) = 0.01, p = .97, \eta_p^2 = 0.00$]. However, the analysis revealed a
3 significant main phase effect [$F(1, 33) = 27.23, p = .001, \eta_p^2 = 0.45$] and an interaction
4 between group and phase factors [$F(2, 33) = 16.81, p = .005, \eta_p^2 = 0.50$]. As illustrated on
5 Figure 3, the post-hoc test revealed that the Imagery and Model+imagery groups had higher
6 Evan Fournier test performances in the post-test than in the pre-test ($ps < .01$). The
7 performances of the participants of the Control group were not significantly different from
8 pre-test to post-test ($p = .09$).

9 _____
10 Figure 3 near here
11 _____

12 The ANOVA computed on PII (Evan Fournier test) revealed a significant group effect
13 [$F(2, 33) = 8.34, p = .001, \eta_p^2 = 0.34$]. The post-hoc test revealed that the participants of the
14 Imagery (66%) and Model+imagery (62%) groups had significantly higher Evan Fournier test
15 PII than the participants of the Control group (-13%) ($ps < .01$). There was no statistical
16 difference between the PII of the Imagery and Model+imagery groups ($p = .67$).

17 The ANOVA computed on the number of two consecutive throws revealed no
18 significant main group effect [$F(2, 33) = 1.67, p = .20, \eta_p^2 = 0.09$]. However, the analysis
19 revealed a significant main phase effect [$F(1, 33) = 23.03, p = .000, \eta_p^2 = 0.41$] and an
20 interaction between group and phase factors [$F(2, 33) = 10.38, p = .000, \eta_p^2 = 0.39$]. As
21 illustrated on Figure 4, the post-hoc test revealed that the participants of the Model+imagery
22 groups increased their scores from pre-test to post-test ($p < .01$) and made more consecutive
23 throws at the post-test than the participants of the Control and Imagery groups ($ps < .01$), for
24 whom there was no difference between pre-and post-test scores ($ps > .05$)

25 _____

1 Figure 4 near here

2

3 4 Discussion

4 The aim of this study was to evaluate the effect of combining action observation and
5 dynamic motor imagery practice in non-expert basketball players. We first evaluated the
6 effect of a combination of dMI and physical practice on free throw performance.

7 4.1 Dynamic Motor Imagery Effect and Physical Execution

8 We hypothesized that the combination of dMI and physical execution (i.e., Imagery
9 group) would permit greater improvement than physical execution alone (i.e., Control group)
10 in regional level basketball players. The results did not confirm this hypothesis. Indeed,
11 although the participants of the Imagery group increased their free throw scores from pre-test
12 to post-test, whereas the performance of the control group remained stable, there was no
13 statistical difference between these two groups at the post-test. However, the participants of
14 the Imagery group had higher performance increase index (PII) than that of the participants of
15 the Control group. The latter result is in line with those obtained in previous studies showing
16 that MI intervention improves basketball performance from pre-test to post-test (Guillot et al.,
17 2009; Hall & Erffmeyer, 1983; Kanthack et al., 2014; Onestak, 1997; Post et al., 2010;
18 Wrisberg & Anshel, 1989) and more specifically that dMI interventions can have a beneficial
19 effect on free throw performance (Kanthack et al., 2016). However, it is important to note that
20 the latter authors observed that the shooting accuracy (i.e., 5 free throws) of high-level
21 athletes was higher following dMI than without it (i.e., control group). Although we found
22 that dMI improved performance from pre-test to post-test, in advanced players, we might
23 consider that the latter would have needed more MI intervention sessions than experts to take
24 full advantage of this mental technique (Robin & Flochlay, 2017), but the amount of practice
25 needed is not clearly indicated in the litterature (Weinberg, 2008).

1 The results of the current study (i.e., performance improvement) and those of the
2 studies mentioned in the previous paragraph have beneficial ecological implications for
3 advanced and high-level basketball players because the free throw is a complex but crucial
4 skill with a determining role for the final result, especially when the score is tight. However, it
5 is important to note that while the beneficial effect of dMI on individual improvement
6 performance during training has been demonstrated, the immediate influence of this mental
7 technique just before free throw execution during matches has yet to be investigated but will
8 be the subject of a future experiment in our laboratory.

9 Other experimental studies have provided evidence that dMI contributes to improving
10 motor performance, MI vividness and efficacy in applied sports settings (Guillot et al., 2013).
11 For example, Callow et al. (2006) showed that junior competitive skiers who moved their
12 bodies from side to side during dMI, as if they were in a race, experienced the most vivid
13 imagery and increased their confidence. Due to non-significant post-test free throw
14 differences between the Imagery (6.1 points) and Control groups (4,7 points), the findings are
15 partially in line with this result by showing that (1) dMI enhanced individual motor
16 performance from pre-test to post-test in advanced basketball players and (2) the beneficial
17 dMI effects not only concerned a classic free throw task but also a more dynamic task of free
18 throws combined with body displacement and time pressure constraints (i.e., Evan Fournier
19 test) confirming the results obtained by Taktek, Zinsser, and St-John (2008) in a transfer of a
20 closed motor skill, with the non-dominant hand, in young children. As previously noted, we
21 may speculate that dMI increased the basketball players' confidence. Moreover, as suggested
22 by Guillot et al. (2013), it is conceivable that moving while imagining (during dMI) enhanced
23 the entire timing of the imagery exercise and the temporal exactness of the free throw shot. In
24 line with these authors, we may also hypothesize that dMI provided time boundaries that
25 probably increased the efficacy of the preparation phase before free throw execution by

1 subdividing it into several sub-sequences associated with time boundaries that were mentally
2 reproduced, thus giving temporal references to the non-expert basketball players. However, it
3 is possible that the use of dMI, in advanced basketball players, would require a greater
4 amount of practice to improve time temporal exactness of the sub-sequences of free-throw,
5 and to be more effective than physical practice only. Further research should explore this
6 hypothesis. Finally, it is possible that the beneficial effect of combining dMI and physical
7 execution during training sessions could be transferable to other dynamic tasks or even usable
8 in real game situations requiring shots performed on or close to the free throw zone.

9 4.2 Model and Dynamic Motor Imagery Combination Effect

10 The second aim of this study was to evaluate the effect of combining the video of a
11 free throw model, dMI and physical execution on the performances of free throws and onfield
12 test in advanced basketball players. We hypothesized that adding AO to dynamic motor
13 imagery and physical execution would permit greater performance than MI practice combined
14 with physical practice. The results only partially validated our second hypothesis. Indeed, the
15 participants of the Model+imagery and Imagery groups increased, to a similar degree, their
16 free throw accuracy and Evan Fournier test score from pre-test to post-test whereas the
17 performances of the participants of the Control group remained stable, which does not
18 confirm the superiority of Model+imagery group. However, it is important to note that
19 during the post-test, the participants of the Model+imagery group performed more
20 consecutive throws than the participants of the Control and Imagery groups in the Evan
21 Fournier test. The latter result, admittedly modest, seems to suggest the benefits of using AO
22 plus dMI in comparison with dMI only during training sessions. This result is in line with
23 Eaves et al. (2016), who argued that a combination of AO and MI is an effective technique in
24 motor learning and performance improvement. Taube et al. (2015) showed that during
25 combined AO and MI, the increased neurophysiological activity was greater than the sum of

1 that reported during independent AO or MI. The result concerning the number of consecutive
2 free throws seem to support the combination of dMI and AO for motor performance in
3 advanced basketball players and add support to other behavioral evidence in the sports
4 domain – in a golf putting task (Smith & Holmes, 2004) and a bicep curl test (Wright &
5 Smith, 2009) – of the beneficial effects of these mental techniques. Holmes and Calmels
6 (2008) explained these benefits to motor performance by pointing out that the visual stimulus
7 in AO removes the need for the subject to generate a visual mental image that frees up
8 attentional resources, thereby allowing a specific focus on imagining the kinesthetic aspects
9 of the action to perform. Moreover, Smith and Holmes (2004) added that the video of the
10 model could also provide auditory, temporal and visual cues for successful performance.

11 However, the absence of other significant differences in the free throws and Evan
12 Fournier performances between the Imagery and Model+imagery groups seems to modulate
13 the “superiority” of combining AO and dMI over dMI only. This result is in line with Taube
14 et al. (2014), who observed a reduction in postural sway over a 4-week balance training
15 intervention including MI or a combination of AO and MI. The reduction was numerically but
16 not significantly larger in the AO and MI than the MI condition. Similar results were obtained
17 in the current study, as the Model+imagery group performed 28 more shots in the post-test
18 than the pre-test for the Evan Fournier test, while those of the Imagery group made only 23
19 more shots and those of the Control group had eight fewer shots. This absence of significant
20 difference between the dMI and AO + dMI interventions could be explained in different
21 ways.

22 First, apart from a conceivable plateau effect (e.g., the optimal improvement having
23 already been reached following dMI), the participants of the Model+imagery group may have
24 needed more trials and sessions to better improve their free throw performances. It may be
25 that the results of observing a video model combined with imagery training should not be

1 immediately expected, as in the study of Taube et al. (2014). Indeed, as previously noted, the
2 visual stimulus in AO allows players to specifically focus on the kinesthetic aspects of free
3 throw movement during dMI. However, Hardy and Callow (1999) reported that kinesthetic
4 imagery was beneficial only with an adequate degree of task expertise. We may therefore
5 assume that the participants needed more practice to fully benefit from the combination of AO
6 and dMI. Yet, Wright and Smith (2009) obtained strength increases with novice students, and
7 overall these findings remind us that relatively little is known about exactly how many
8 sessions are needed and indeed whether a specific quantity of practice is needed before
9 participants can use a combination of AO and MI as an instrument of performance
10 enhancement. In addition, it is important to note that in the current study, the number and
11 duration of sessions, as well as the number of trials, were conditioned by constraints related to
12 the availability of the University basketball court and the students.

13 Second, the participants of the current study may also have found it difficult to
14 generate kinesthetic imagery and imagine themselves performing the free throw task after
15 watching a video in which the model was another person (Callow & Hardy, 2004). As Eaves
16 et al. (2016) remarked, the conflict between the model used in AO and MI can be problematic
17 as it can decrease the effect of kinesthetic imagery, or the players may switch their focus
18 between another person executing the movement and kinesthetic imagery of themselves
19 performing the shot, rather than representing AO and dMI in parallel. Moreover, there are
20 inconsistencies across studies in relation to the perspective used in both the AO and MI
21 components of the interventions (Eave et al., 2016). Some researchers have filmed the
22 movement from a first-person visual perspective (Wright et al., 2014), while others have used
23 a third-person perspective (Mouthon et al., 2015; Taube et al., 2015) in the AO interventions.
24 In our study, we used the third-person perspective, although Eave et al. (2016) suggested that
25 a third-person perspective of a movement may need to be rotated and transformed during MI,

1 which can cause activity in motor brain areas (Chen, Bin, Daly, & Gao, 2013) and limit the
2 attentional resources available for kinesthetic imagery, for example. More research is needed
3 to manipulate the perspectives in studies using AO combined with dMI. The use of self-
4 observation could also be considered, as in Martini, Rymal and Ste-Marie's (2011) study.
5 These authors showed that self-modeling increased swimming performance by modifying
6 one's intrinsic motivation and self-efficacy beliefs (Clark & Ste Marie, 2007).

7 Third, as suggested by Veraksa and Gorovaya (2012) in football players, participants
8 with a "higher level of imagination" are more inclined to use MI, and non-expert athletes
9 usually have greater difficulties in feeling the movement (Guillot, Collet, & Dittmar, 2004). It
10 is possible that the basketball players of the Model+imagery group found it difficult to
11 perform dMI, limiting the effect of this technique; the performance increase in this case
12 would therefore have been mainly due to the effect of the video of the model (i.e., AO).
13 Moreover, Roberts, Lawrence, Callow and Roberts (2013) revealed that the relationship
14 between observational learning and successful imitation performance is moderated by
15 imagery ability. It is therefore important to control the latter factor in studies using AO. In
16 this study, the participants self-reported the level of perceived vividness of imagery after each
17 session, and the preliminary results showed that there was no difference between groups
18 according to this factor. Imagery ability thus does not explain the lack of difference between
19 the Imagery and Model+imagery groups.

20 Fourth, the ease in combining mental techniques (e.g., video and dMI), as well as
21 other types of techniques, is better acquired through regular deliberate practice (Battaglia et
22 al., 2014) but according to Weinberg (2008), practitioners are often reluctant to use them
23 during their training sessions. In our opinion, basketball players have to trust that these mental
24 techniques are effective and will have beneficial effects, which implies they have become
25 familiarized with them before any intervention is made.

1 Last, given that there was no statistical performance improvement difference (i.e., ten
2 free throw PII) between Model+imagery and Imagery groups, it might be the dMI strategy
3 (and nothing else) that has lead to performance improvements. The results did not confirm
4 this hypothesis. Indeed, although the participants of the Imagery group increased their free
5 throw scores from pre-test to post-test, their performance was not statistically different from
6 that of the control group at the post-test. Few studies compared AO versus MI strategies to
7 learn a motor task or improve its performance (Gatti et al., 2013). While Hall et al. (2009)
8 demonstrate that it is MI that is more commonly used by athletes than AO, Nelson, Czech,
9 Joyner, Munkasy, and Lachowetz (2002) found no difference between both intervention
10 strategies in baseball task performance, whereas Ram, Riggs, Skaling, Landers and
11 McCullagh (2007) showed that judged performance in a free-weight squat task was higher for
12 the AO than for the MI and the control groups. In addition to conflicting results, it is
13 important to note that in many of the experimental studies using a combination of AO and MI,
14 it was argued that this combination was effective, but oftentimes it was not well controlled
15 whether it was more effective than MI or AO alone. Ram and collaborators (2007), one of the
16 rare exceptions, found that AO alone or combined with MI permits greater performance, in a
17 balance stability task, that MI or no intervention in novice. According to Neuman and Gray
18 (2013), the relative effectiveness of imagery, observation, or a combination of both strategies,
19 might depend on an athlete's level of expertise or task difficulty, and more research need to
20 be investigated for better comprehension.

21 This study is not without limitations. Indeed, as already noted, the lack of difference in
22 improvement between the Imagery and Model+imagery groups can be explained by the low
23 number of learning interventions (i.e., 5). However, the experiment had to be completed
24 within 7 weeks because of limited student availability (e.g., exams) and tight scheduling for
25 the indoor basketball court. Indeed, French school holidays fall on average every 8 weeks,

1 and physical education teachers and coaches therefore usually have short periods for their
2 interventions at the university. It is important to note that experiments that take into account
3 this time constraint are needed in order to give practical recommendations to teachers,
4 practitioners and professionals. Another limitation might be the participants' fatigue, which
5 was not measured. Indeed, Kanthack et al. (2016) showed the selective efficacy of MI in
6 different states of physical fatigue, with dMI being less efficient in physically exhausted
7 basketball players. However, it is unlikely that the participants were tired because the sessions
8 all started at 9-am, with no practice beforehand, and all performed the same warm-up (20-
9 minute) that was not long or intensive enough to be fatiguing. It is also important to note that
10 the sample size was relatively small with 12 athletes that is why the results obtained in the
11 current should be interpreted carefully and confirmed before generalization. Finally, we may
12 envisage that the participants of the control group were less motivated than those of the other
13 groups due to experimental conditions. Since motivation is a factor that can influence
14 performance, it should be considered in future research using similar procedure.

15

16 5 Conclusion

17 The results of this study highlight the beneficial effect of using dMI to improve free
18 throw performance in non-expert basketball players. This improvement was also observed
19 when dMI was combined with AO with video, but it was not different to dMI only in the ten
20 free throw task. Indeed, in addition to allowing an increase in performance in a onfield test:
21 The Evan Fournier test, which includes free throws combined with body displacement and
22 time pressure constraints, AO plus dMI helped to increase the number of consecutive throws
23 in the test whereas the performance of the Imagery and Control groups remained stable. Last,
24 the current original study sheds light on the scheduling of video AO and/or dMI in basketball

1 training during short learning sessions. More research is now needed to investigate the effects
2 of the quality/type of the model, the video and the imagery perspectives in greater detail.

3

4 6 References

5 Al-Abood, S., Davids, K., & Bennett, S. (2001). Specificity of task constraints and effects of
6 visual demonstrations and verbal instructions in directing learners' search during skill
7 acquisition. *Journal of Motor Behavior*, 33, 295–305.

8 Anuar, N., Cumming, J., & Williams, S. E. (2016). Effects of applying the PETTLEP model
9 on vividness and ease of imaging movement. *Journal of Applied Sport Psychology*, 28,
10 185–198. doi:10.1080/10413200.2015.1099122

11 Battaglia, C., D'Artibale, E., Fiorilli, G., Piazza M., Tsopani, D., & ... di Cagno, A.
12 (2014). Use of video observation and motor imagery on jumping performance in
13 national rhythmic gymnastics athletes. *Human Movement Science*, 38(2), 225–234.

14 Blandin, Y. (2002). L'apprentissage par observation d'habiletés motrices : un processus
15 d'apprentissage spécifique ? *L'année psychologique*, 102(3), 523–554.

16 Callow, N., & Hardy, L. (2004). The relationship between the use of kinaesthetic imagery and
17 different visual imagery perspectives. *Journal of Sport Science*, 22, 167–177.

18 doi:10.1080/02640410310001641449

19 Callow, N., Roberts, R., & Fawkes, J. Z. (2006). Effects of dynamic and static imagery on
20 vividness of imagery, skiing performance, and confidence. *Journal of Imagery
21 Research in Sport and Physical Activity*, 1, 1–15.

22 Chen, X., Bin, G., Daly, I., & Gao, X. (2013). Event-related desynchronization in the alpha
23 band during a hand mental rotation task. *Neuroscience Letter*, 541, 238–242.

24 doi:10.1016/j.neulet.2013.02.036

25 Clark, S. E., & Ste-Marie, D. M. (2007). The impact of self-as-a-model interventions on

- 1 children's self-regulation of learning and swimming performance. *Journal of Sport*
2 *Science*, 25, 577–586.
- 3 Di Rienzo, F., Blache, Y., Kanthack, T. F. D., Monteil, K., Collet, C., & Guillot, A. (2015).
4 Short-term effects of integrated motor imagery practice on muscle activation and force
5 performance. *Neuroscience*, 305, 146–156. doi:10.1016/j.neuroscience.2015.07.080
- 6 Eaves, D., Riach, M., Holmes, P., & Wright, D. (2016). Motor imagery during action
7 observation: A brief review of evidence, theory and future research opportunities.
8 *Frontiers in Neurosciences*, 10, 514. doi:10.3389/fnins.2016.00514
- 9 Ehrsson, H. H., Geyer, S., & Naito, E. (2003). Imagery of voluntary movement of fingers,
10 toes, and tongue activates corresponding body-part specific motor representations.
11 *Journal of Neurophysiology*, 90, 3304–3316. doi:10.1152/jn. 01113.2002
- 12 Farsi, A., Bahmanbegloo, Z., Abdolis, B., & Ghorbani, S. (2016). The effect of observational
13 practice by a point-light model on learning a novel motor skill. *Perceptual and Motor*
14 *Skills*, 123(2), 1–12. doi:10.1177/0031512516662896
- 15 Féry, Y. A. (2003). Differentiating visual and kinesthetic imagery in mental practice.
16 *Canadian Journal of Experimental Psychology*, 57, 1–10.
- 17 Filimon, F., Rieth, C. A., Sereno, M. I., & Cottrell, G. W. (2015). Observed, executed, and
18 imagined action representations can be decoded from ventral and dorsal areas.
19 *Cerebral Cortex*, 25, 3144–3158. doi:10.1093/cercor/bhu110
- 20 Frank, C., Land, W., Popp, C., & Schack, T. (2014). Mental representation and mental
21 practice: Experimental investigation on the functional links between motor memory
22 and motor imagery. *PLoS ONE*, 9(4), e95175. doi:10.1371/journal.pone.0095175
- 23 Gatti, R., Tettamanti, A., Gough, P. M., Riboldi, E., Marinoni, L., & Buccino, G. (2013).
24 Action observation versus motor imagery in learning a complex motor task: A short
25 review of literature and a kinematics study. *Neuroscience Letters*, 540, 37–42.

- 1 doi:10.1016/j.neulet.2012.11.039
- 2 Gonzalez-Rosa, J. J., Natali, F., Tettamanti, A., Cursi, M., Velikova, S., Comi, G., & ...
- 3 Leocani, L. (2015). Action observation and motor imagery in performance of complex
- 4 movements: Evidence from EEG and kinematics analysis. *Behavioral Brain Research*,
- 5 281, 290–300. doi:10.1016/j.bbr.2014.12.016
- 6 Goss, S., Hall, C. R., Buckolz, E., & Fishburne, G. J. (1986). Imagery ability and the
- 7 acquisition and retention of movements. *Memory and Cognition*, 14, 469–477.
- 8 doi:10.3758/BF03202518
- 9 Gueugneau, N., Mauvieux, B., & Papaxanthis, C. (2009). Circadian modulation of mentally
- 10 simulated motor actions: implications for the potential use of motor imagery in
- 11 rehabilitation. *Neurorehabilitation and Neural Repair*, 23, 237–245.
- 12 Guillot, A., & Collet, C. (2008). Construction of the motor imagery integrative model in
- 13 sport: A review and theoretical investigation of motor imagery use. *International*
- 14 *Review of Sport and Exercise Psychology*, 1, 31–44.
- 15 doi:10.1080/17509840701823139
- 16 Guillot, A., Collet, C., & Dittmar, A. (2004). Relationship between visual vs kinesthetic
- 17 imagery, field dependence-independence and complex motor skills. *Journal of*
- 18 *Psychophysiology*, 18, 190–199.
- 19 Guillot, A., Moschberger, K., & Collet, C. (2013). Coupling movement with imagery as a
- 20 new perspective for motor imagery practice. *Behavioral and Brain Functions*, 9, 1–17.
- 21 doi:10.1186/1744-9081-9-8
- 22 Guillot, A., Nadrowska, E., & Collet, C. (2009). Using motor imagery to learn tactical
- 23 movements in basketball. *Journal of Sport Behavior*, 32, 189–206.
- 24 Grèzes, J., & Decety, J. (2001). Functional anatomy of execution, mental simulation,
- 25 observation, and verb generation of actions: A meta-analysis. *Human Brain Mapping*,

- 1 12, 1–19. doi:10.1002/1097-0193(200101)12:1<1::aid-hbm10>3.0.co;2-v
- 2 Hall, E., & Erffmeyer, E. S. (1983). The effect of visuo-motor behavior rehearsal with
3 videotaped modeling on free throw accuracy of intercollegiate female basketball
4 players. *Journal of Sport Psychology*, 5, 343–346.
- 5 Hall, C. R., Munroe-Chandler, K. J., Cumming, J., Law, B., Ramsey, R., & Murphy, L.
6 (2009). Imagery and observational learning use and their relationship to sport
7 confidence. *Journal of Sports Sciences*, 27, 327–337.
8 doi:10.1080/02640410802549769
- 9 Hardy, L., & Callow, N. (1999). Efficacy of external and internal visual imagery perspectives
10 for the enhancement of performance on tasks in which form is important. *Journal of*
11 *Sport and Exercise Psychology*, 21, 95–112.
- 12 Holmes, P., & Calmels, C. (2008). A neuroscientific review of imagery and observation use
13 in sport. *Journal of Motor Behavior*, 40, 433–445. doi: 10.3200/JMBR.40.5.433-445
- 14 Ingram, T. G., Kraeutner, S. N., Solomon, J. P., Westwood, D. A., & Boe, S. G. (2016). Skill
15 acquisition via motor imagery relies on both motor and perceptual learning. *Behavior*
16 *Neuroscience*, 130, 252. doi:10.1037/bne0000126
- 17 Jeannerod, M. (2001). Neural simulation of action: A unifying mechanism for motor
18 cognition. *Neuroimage*, 14, 103–109. doi:10.1006/nimg.2001.0832
- 19 Jeannerod, M., & Frak, V. (1999). Mental imaging of motor activity in humans. *Current*
20 *Opinion Neurobiology*, 9, 735–739. https://doi:10.1016/S0959-4388(99)00038-0
- 21 Kanthack, T. F. D., Bigliassi, M, Vieira, L. F., & Altimari, L. R. (2014). Acute effect of
22 motor imagery on basketball players' free throw performance and self-efficacy.
23 *Revista Brasileira de Cineantropometria & Desempenho Humano*, 16(1), 47–57.
- 24 Kanthack, T. F. D., Guillot, A., Altimari, R., Nagy, N. S., Collet, C., & Di Rienzo, F. (2016).
25 Selective efficacy of static and dynamic imagery in different states of physical fatigue.

- 1 *PLoS ONE*, 11(3), e0149654. doi:10.1371/journal.pone.0149654
- 2 Lebon, F., Collet, C., & Guillot, A. (2010). Benefits of motor imagery training on muscle
3 strength. *Journal of Strength and Conditioning*, 24, 1680–1687.
4 doi:10.1519/JSC.0b013e3181d8e936
- 5 Lorey, B., Naumann, T., Pilgramm, S., Petermann, C., Bischoff, M., Zentgraf, K., &
6 ...Munzert, J. (2013). How equivalent are the action execution, imagery, and
7 observation of intransitive movements? Revisiting the concept of somatotopy during
8 action simulation. *Brain Cognition*, 81, 139–150. doi: 10.1016/j.bandc.2012.09.011
- 9 Martini, R., Rymal, A. M., & Ste-Marie, D. M. (2011). Investigating self-as-a-model
10 techniques and underlying cognitive processes in adults learning the butterfly swim
11 stroke. *International Journal of Sports Science Engineering*, 5(4), 242–256.
- 12 Mouthon, A., Ruffieux, J., Wälchli, M., Keller, M., & Taube, W. (2015). Task-dependent
13 changes of corticospinal excitability during observation and motor imagery of balance
14 tasks. *Neuroscience*, 303, 535–543. doi: 10.1016/j.neuroscience.2015.07.031
- 15 Morris, T., Spittle, M., & Watt, A. P. (2005). *Imagery in Sport*. Campaign, IL: Human
16 Kinetics.
- 17 Neuman, B., & Gray, R. (2013). A direct comparison of the effects of imagery and action
18 observation on hitting performance, Abstract. *Movement & Sport Sciences*, 79, 11–21.
- 19 Ohno, K., Higashi, T., Sugawara, K., Ogahara, K., Funase, K., & Kasai, T. (2011).
20 Excitability changes in the human primary motor cortex during observation with
21 motor imagery of chopstick use. *Journal of Physical Therapy Science*, 23, 703–706.
22 doi: 10.1589/jpts.23.703
- 23 Olsson, C. J., Jonsson, B., & Nyberg, L. (2008). Internal imagery training in active high
24 jumpers. *Scandinavian Journal of Psychology*, 49, 133–140.
- 25 Onestak, D. M. (1997). The effect of visuo-motor behaviour rehearsal (VMBR) and video-

- 1 taped modelling (VM) on the free-throw performance of intercollegiate athletes.
2 *Journal of Sport Behavior*, 20, 185–198.
- 3 Pearson, J., Naselaris, T., Holmes, E. A., & Kosslyn, S. M. (2015). Mental imagery:
4 Functional mechanisms and clinical applications. *Trends Cognition in Sciences*,
5 19(10), 590–602. doi:10.1016/j.tics.2015.08.003
- 6 Post, P. G., Wrisberg, C. A., & Mullins, S. (2010). A field test of the influence of pre-game
7 imagery on basketball free throw shooting. *Journal of Imagery Research in Sport and*
8 *Physical Activity*, 5, 1–15.
- 9 Ram, N., Riggs, S. M., Skaling, S., Landers, D. M., & McCullagh, P. (2007). A comparison
10 of modeling and imagery in the acquisition and retention of motor skills. *Journal of*
11 *Sports Sciences*, 25, 587–597.
- 12 Rizzolatti, G., & Sinigaglia, C. (2010). The functional role of the parieto-frontal mirror
13 circuit: Interpretations and misinterpretations. *Nature Review in Neuroscience*, 11,
14 264–274. doi:10.1038/nrn2805
- 15 Roberts, R. J., Lawrence, G. P., Callow, N., & Roberts, R. (2013). Watch me if you can:
16 Imagery ability moderates observational learning effectiveness. *Frontiers in Human*
17 *Neuroscience*, 7. doi: 10.3389/fnhum.2013.00522
- 18 Robin, N., Coudeville, G. R., Hue, O., & Sinnapah, S. (2017). Effects of tropical climate on
19 mental rotation: The role of imagery ability. *American Journal of Psychology*, 130,
20 455–465.
- 21 Robin, N., Dominique, L., Toussaint, L., Blandin, Y., Guillot, A., & Le Her, M. (2007).
22 Effects of motor imagery training on service return accuracy in tennis: The role of
23 imagery ability. *International Journal of Sport and Exercise Psychology*, 5, 175–186.
24 doi:10.1080/1612197X.2007.9671818
- 25 Robin, N., & Flochlay, C. (2017). Imagerie mentale en sport et applications en EPS. [Mental

- 1 imagery in sports and physical education]. *Revue EPS*, 377, 16–19.
- 2 Romano-Smith, S., Wood, G., Wright, D. J., & Wakefield, C. J. (2018). Simultaneous and
3 alternate action observation and motor imagery combinations improve aiming
4 performance. *Psychology of Sport and Exercise*, 38, 236–252.
5 <https://doi.org/10.1016/j.psychsport.2018.06.003>
- 6 Ruffino, C., Papaxanthis, C., & Lebon, F. (2017). Neural plasticity during motor learning
7 with motor imagery practice. *Neuroscience*, 341, 61–78.
8 <https://doi.org/10.1016/j.neuroscience.2016.11.023>
- 9 Sakamoto, M., Muraoka, T., Mizuguchi, N., & Kanosue, K. (2009). Combining observation
10 and imagery of an action enhances human corticospinal excitability. *Neuroscience*
11 *Research*, 65, 23–27. doi: 10.1016/j.neures.2009.05.003
- 12 Sarasso, E., Gemma, M., Agosta, F., Filippi, M., & Gatti, R. (2015). Action observation
13 training to improve motor function recovery: A systematic review. *Archives of*
14 *Physiotherapy*, 5, 1. doi:10.1186/s40945-015- 0013-x
- 15 Smith, D., & Holmes, P. S. (2004). The effect of imagery modality on golf putting
16 performance. *Journal of Sport & Exercise Psychology*, 26, 385–395.
- 17 Ste-Marie, D. M., Law, B., Rymal, A. M., Jenny, O., Hall, C., & McCullagh, P. (2012).
18 Observation interventions for motor skill learning and performance: An applied model
19 for the use of observation. *International Review of Sport Exercise Psychology*, 5, 145–
20 176. doi: 10.1080/1750984X.2012.665076
- 21 Taktek, K., Zinsser, N., & St-John, B. (2008). Visual versus kinesthetic mental imagery:
22 Efficacy for the transfer of closed motor skill in young children. *Canadian Journal of*
23 *Experimental Psychology*, 62(3), 174–187. [http://dx.doi.org/10.1037/1196-](http://dx.doi.org/10.1037/1196-1961.62.3.174)
24 1961.62.3.174
- 25 Taube, W., Lorch, M., Zeiter, S., & Keller, M. (2014). Non-physical practice improves task

- 1 performance in an unstable, perturbed environment: motor imagery and observational
2 balance training. *Frontiers in Human Neurosciences*, 8, 972. doi:
3 10.3389/fnhum.2014.00972
- 4 Taube, W., Mouthon, M., Leukel, C., Hoogewood, H. M. Annoni, J. M., & Keller, M. (2015).
5 Brain activity during observation and motor imagery of different balance tasks: An
6 fMRI study. *Cortex*, 64, 102–114. doi: 10.1016/j.cortex.2014.09.022
- 7 Tsukazaki, I., Uehara, K., Morishita, T., Ninomiya, M., & Funase, K. (2012). Effect of
8 observation combined with motor imagery of a skilled hand-motor task on motor
9 cortical excitability: difference between novice and expert. *Neurosciences Letter*, 518,
10 96–100. doi:10.1016/j.neulet.2012.04.061
- 11 Veraksa, A., & Gorovaya, A. (2012). Imagery training efficacy among novice soccer players.
12 *Procedia - Social and Behavioral Sciences*, 33, 338–342.
13 doi:10.1016/j.sbspro.2012.01.139
- 14 Vogt, S., Di Rienzo, F., Collet, C., Collins, A., & Guillot, A. (2013). Multiple roles of motor
15 imagery during action observation. *Frontiers in Human Neuroscience*, 7, 807. doi:
16 10.3389/fnhum.2013.00807
- 17 Weinberg, R. S. (2008). Does imagery work? Effects on performance and mental skills.
18 *Journal of Imagery Research in Sport and Physical Activity*, 3, 1–21.
19 doi:10.2202/1932-0191.1025
- 20 Wild, K. S., Poliakoff, E., Jerrison, A., & Gowen, E. (2010). The influence of goals on
21 movement kinematics during imitation. *Experimental Brain Research*, 204(3), 353–
22 360. <http://dx.doi.org/10.1007/s00221-009-2034-8>
- 23 Wright, C. J., & Smith, D. (2009). The effect of PETTLEP imagery on strength performance.
24 *International Journal of Sport and Exercise Psychology*, 7, 18–31.
25 doi:10.1080/1612197X.2009.9671890

1 Wright, D. J., Williams, J., & Holmes, P. S. (2014). Combined action observation and
2 imagery facilitates corticospinal excitability. *Frontiers in Human Neuroscience*, 8,
3 951. doi:10.3389/fnhum.2014.00951

4 Wrisberg, C. A., & Anshel, M. H. (1989). The effect of cognitive strategies on the free throw
5 shooting performance of young athletes. *The Sport Psychologist*, 3, 95–104.

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1 Table 1
 2 *Free throw and Evan Fournier test scores across the groups during pre- and post tests*

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 4 *M = Mean scores, SD = Standard Deviation.*
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Groups	<u>Ten free throw scores</u>		<u>Evan Fournier test scores</u>		21
	<i>Pre-test</i>	<i>Post-test</i>	<i>Pre-test</i>	<i>Post-test</i>	22
	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>	23
Control (n = 12)	5.0 (2.66)	4,7 (2.53)	5.8 (2.71)	5.2 (3.01)	
Imagery (n = 12)	4.6 (2.26)	6.1 (1.56)	4.5 (1.78)	6.4 (1.72)	
Model+imagery (n = 12)	4.8 (1.46)	6.3 (1.23)	4.4 (1.72)	6.8 (2.13)	

Week 1	Week 2 to week 6	Week 7
<p>Pre-test - 10 free throws</p> <p>- Evan Fournier Test (maximum free throws and round trips in 45-seconds)</p>	<p>Control group (Video clip + countdown+ 2 free throws) * 5</p> <hr/> <p>Imagery group (Video clip + dMI + 2 free throws) * 5</p> <hr/> <p>Model+imagery group (Video model + dMI+ 2 free throws) * 5</p>	<p>Post-test - 10 free throws</p> <p>- Evan Fournier Test (maximum free throws and round trips in 45-seconds)</p>

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2 *Figure 1.* Time course of the experimental design

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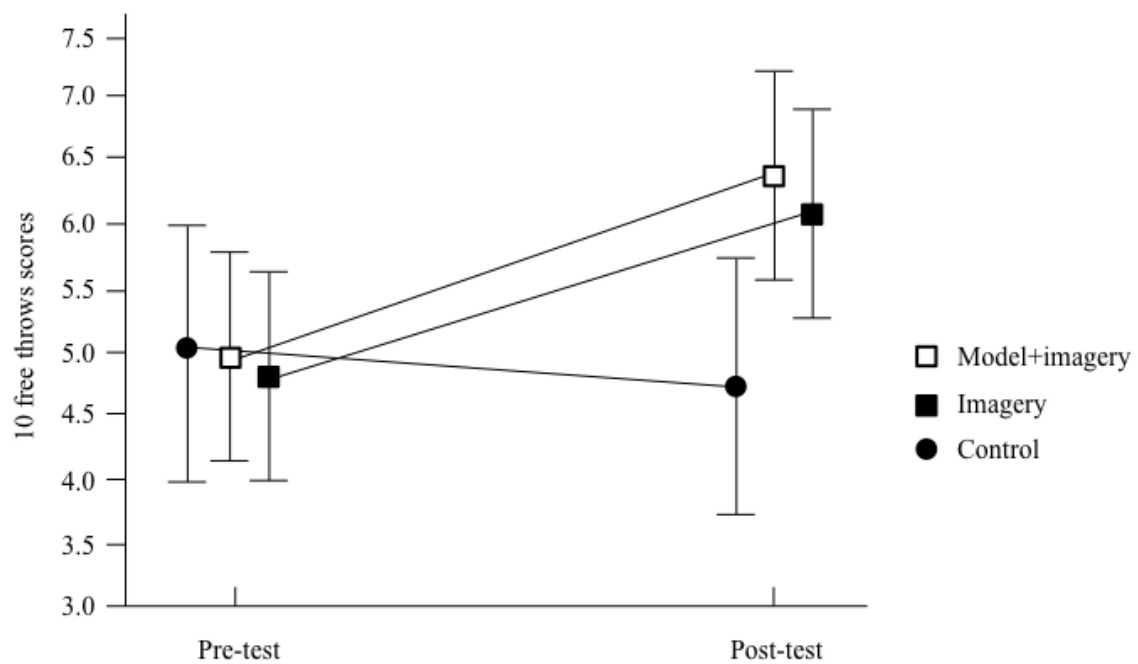
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2 *Figure 2.* Significant interaction between the phase (pre-test vs. post-test) and the group
 3 (Model+imagery vs. Imagery vs. Control) for free-throw scores.

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5 *Note.* * $p < .05$. ** $p < .01$. I-beams indicate the 95% confidence intervals for the mean values.

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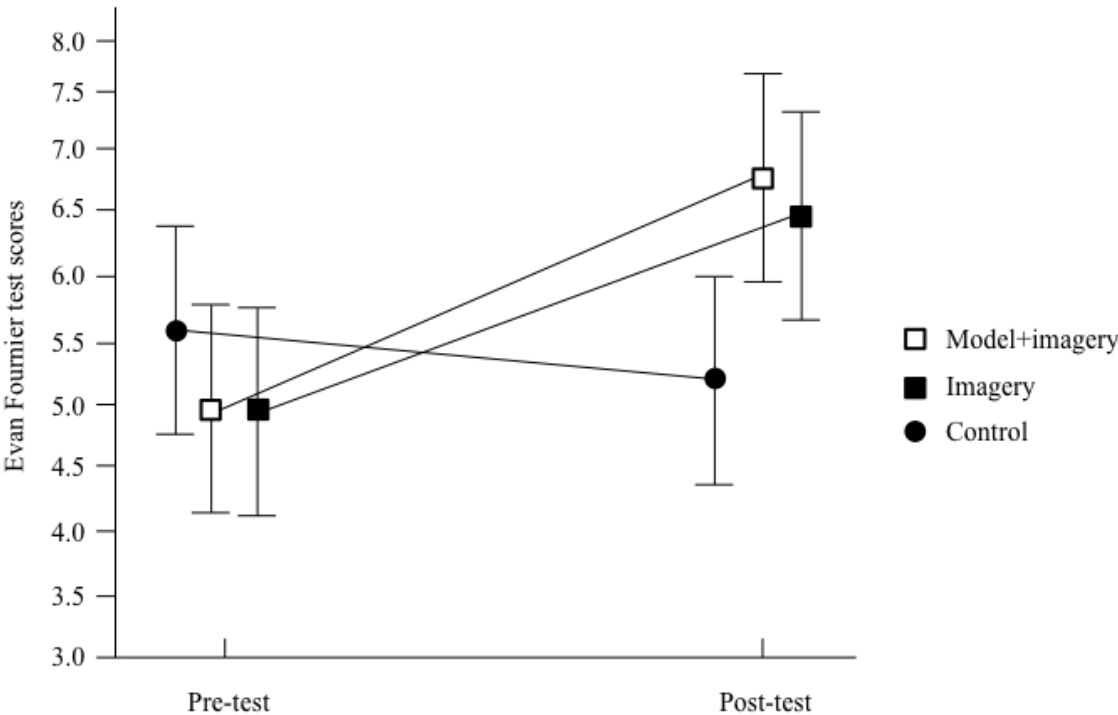
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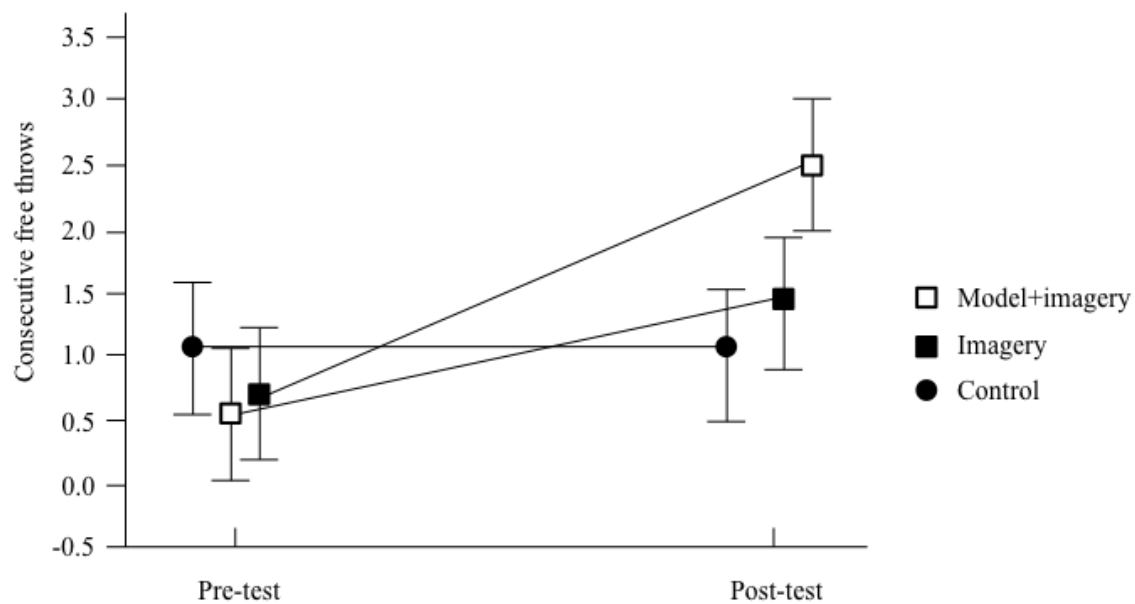
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2 *Figure 3.* Significant interaction between the phase (pre-test vs. post-test) and the group
3 (Model+imagery vs. Imagery vs. Control) for Evan Fournier test scores.

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5 *Note.* ** $p < .01$. I-beams indicate the 95% confidence intervals for the mean values.

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2 *Figure 4.* Significant interaction between the phase (pre-test vs. post-test) and the group
 3 (Model+imagery vs. Imagery vs. Control) for Evan Fournier test consecutive throws.

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5 *Note.* * $p < .05$. ** $p < .01$. I-beams indicate the 95% confidence intervals for the mean values.

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1 **Captions**

2 Table 1. *Free throw and Evan Fournier test task scores across the groups during pre- and*
3 *post tests*

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5 Figure 1. Time course of the experimental design.

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7 Figure 2. Significant interaction between the phase (pre-test vs. post-test) and the group
8 (Model+imagery vs. Imagery vs. Control) for free-throw scores. $p < .05$. I-beams indicate the
9 95% confidence intervals for the mean values.

10

11 Figure 3. Significant interaction between the phase (pre-test vs. post-test) and the group
12 (Model+imagery vs. Imagery vs. Control) for Evan Fournier test scores. $p < .05$. I-beams
13 indicate the 95% confidence intervals for the mean values.

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15 Figure 4. Significant interaction between the phase (pre-test vs. post-test) and the group
16 (Model+imagery vs. Imagery vs. Control) for Evan Fournier test consecutive throws. $p < .05$.
17 I-beams indicate the 95% confidence intervals for the mean values.

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