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Imagery training for reactive agility: Performance improvements for decision time but not overall reactive agility

Abstract

This study investigated the effects of imagery training on reactive agility and whether reacting to unpredictable stimuli could be improved using imagery. Forty-seven female athletes (M_{age}=21.51, *SD*=2.32) were randomly assigned to either a three-week physical training, imagery training, or control condition. Physical training condition involved physically rehearsing the reactive agility task, whereas the imagery training condition involved imagining the presenting stimulus and performing the reactive agility task. The control condition did no reactive agility training. A 3 (training conditions) x 7 (reactive agility performance components) mixed-model MANOVA was conducted to examine changes in reactive agility performance from the training interventions. Physical training improved decision time components and overall reactive agility performance. Imagery training improved Stimulus-Decision Time and Stimulus-Foot performance, but not overall reactive agility performance. No performance improvements occurred for the control condition. Findings support imagery use for the decision time variables associated with light-stimulus reactive agility performance. The lack of overall reactive performance improvement may indicate that imagery training is not effective for all components of perceptual-motor performance. Performance change inconsistencies appear to indicate that participants may not have generated unpredictable stimuli during imagery. Future investigation as to whether imagery improvements translate to sport-specific reactive tasks is needed.

Keywords: Imagery Representation; Unpredictability; Reactive Task; Imagery Training; Perceptual-Motor Skills

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Reactive tasks are prevalent in many open, dynamic sports, such as basketball, tennis, netball, or soccer, where successful performance necessitates that players constantly adapt their actions relative to changes in the environment (Araújo, Davids, & Hristovski, 2006). During reactive tasks, athletes process varying degrees of temporal and spatial stimulus complexity (i.e., simple reactive tasks such as the flight of the ball to more complex reactive tasks involving interpreting movements and actions of multiple team mates and opponents), within varied sporting context (i.e., structured soccer attack vs. reacting to a deflection with limited time or pre-cue information), to make appropriate decisions. Consequently, reactive tasks are synonymous with unplanned and unanticipated performance rather than self-determined or pre-determined performance that rely predominantly on perceptual-cognitive skills (Paul, Gabbett, & Nassis, 2016). For example, a soccer goalkeeper can anticipate the direction of a penalty, yet he/she still needs to react correctly to the speed and positioning of the ball once kicked to save the shot successfully. Athletes use available information in the environment to transition the course of action, rather than use a set of discrete choices at separate decision points, to facilitate successful performance (Araújo et al., 2006).

The ability to adapt to the environment is crucial to high-level performance in sport (Williams & Ford, 2008). It is therefore important that appropriate approaches to training skills specifically for reactive task performance are identified (Williams & Grant, 1999). One psychological technique proposed to rehearse reactive tasks is imagery (e.g., MacIntyre & Moran, 2007; Morris et al., 2005; Paivio, 1985, Williams & Grant). Minimal research, however, has examined the effectiveness of imagery for rehearsing perceptual-cognitive skills, game strategies or routines, and reactive tasks (Munroe-Chandler & Morris, 2011).

Morris, Spittle, and Watt (2005) conceptualized imagery in sport as "the creation or recreation of an experience generated from memorial information, involving quasi-sensorial, quasi-perceptual, and quasi-affective characteristics that are under the volitional control of the imager" (p. 19). Imagery is beneficial because the image generated contains realistic sensory, perceptual and affective characteristics that would be present during overt performance (MacIntyre, Moran, Collet, & Guillot, 2013). Notably, imagery contains realistic perceptual components that are under the volitional control of the imager (Morris et al., 2005), providing the imager an opportunity to improve skill performance by imagining different experiences related to their sport (Paivio, 1985). Functional equivalence of imagery research illustrates that similar neurological activation and/or psychological demands (e,g., task difficulty, programming rules, and temporal regularities) influence imagery performance in a similar way to physical performance (see Guillot, Di Rienzo, & Collet, 2012; Jeannerod, 2006).

Imagery training is beneficial for technical skill performance (Driskell, Copper, & Moran, 1994), yet, a potential task-analytic issue may influence the use of imagery for reactive task performance (Paivio, 1985). Imagery rehearsal may be problematic for reactive task performance as imagery involves volitional, cognitive effort to imagine a deliberate scenario (Paivio, 1985; Raisbeck, Wyatt, & Shea, 2012). Consequently, generating an image of an unpredictable event may be difficult because there is really no environmental unpredictability in imagery because the imager must generate the image themselves (Munroe, Giacobbi, Hall, & Weinberg, 2000; Spittle & Morris, 2007). Borst and Kosslyn (2008) argued that different cognitive processes potentially prevent reactive components being generated, as imagery is a top-down process whereas perception is environmentally driven. Differences in cognition would have applied implications for the effectiveness of imagery training.

To our knowledge, no research has directly examined whether imagery can improve reactive task performance, and imagery training research using sport-specific perceptual-cognitive tasks has provided equivocal results. Positive effects have been identified from imagery training for anticipation, visual search behavior and tactical awareness using sport-specific tasks (Caliari, 2008 – table tennis; Guillot, Nadrowska, & Collet, 2009 – Basketball; Jordet, 2005 – Football; Robin et al., 2007 – Tennis; Smeeton, Hibbert, Stevenson, Cumming, & Williams, 2013 – cricket). Other studies have indicated limited or no effects of imagery training for sport-specific perceptual-cognitive skills (Munroe-Chandler, Hall, Fishburne, & Shannon, 2005; Post, Young & Simpson, 2018). More research is needed to better understand the conceptual nature of imagery and its effects on reactive tasks to draw appropriate conclusions about the nature and possibility of imagining reactive tasks involving unpredictability. If athletes cannot recreate stimulus unpredictability of reactive tasks, then imagery may not be appropriate for rehearsing skills for improved reactive task performance.

Imagery theorists (Holmes & Collins, 2001; Wakefield, Smith, Moran, & Holmes, 2013) argue that imagery is most likely to be effective when the characteristics of the image generated simulates physical performance as closely as possible. Imagery scripts are then used to focus on key performance characteristics to systematically improve the effectiveness of imagery and provide specific details on the content to be imagined (Wakefield et al). Yet, development of detailed imagery interventions for reactive tasks promotes potential confounding factors that influence interpretation of research findings. These issues may include (but are not limited to): providing specific details relating to when to present the stimulus or what stimulus to imagine (Caliari, 2008; Smeeton et al., 2013); presenting videos to model imagery (Jordet, 2005); creating specific imagery scripts that contain a realistic reactive scenario and instructing participants to recreate and focus on particular events of the script (Guillot et al., 2007; Munroe-Chandler et al., 2005); or combining physical and imagery training (Robin et al., 2007).

Providing information of the task may potentially change the stimulus imagined from being unpredictable to more predictable during imagery. Rather than improving skills associated with reacting, imagery may create a predictable link between the stimulus and response (Grouios, 1992). Athletes may imagine and rehearse 'what-if' scenarios (Hallman & Munroe-Chandler, 2009; MacIntyre & Moran, 2007) where the athlete improves performance response if certain stimuli arise. Imagery would then improve the stimulus-response performance (Boschker, Bakker, & Michaels, 2002), representing improvements to technical skill performance in reactive situations (i.e., recognizing and performing movements associated with specific stimuli) rather than reacting to stimulus unpredictability. Additional research is necessary to understand whether imagers generate unpredictable stimuli during imagery, and identify whether using imagery for reactive skills is efficacious, which may help provide clearer justifications for the applied use of imagery for reactive sports/tasks.

One task that could be used to examine whether unpredictable stimuli are generated during imagery is reactive agility. Reactive agility is, "a rapid whole body movement with change of velocity or direction in response to a stimulus" (Sheppard & Young, 2006, p.922). Research has identified that decision time (DT), the time required to perceptually identify the stimulus and react to it, positively correlates to reactive agility performance, with stimulus identification and decision making related to quicker agility performance than movement factors (Scanlan, Humphries, Tucker & Dalbo, 2014; Young, Miller, & Talpey, 2015). Serpell, Young, and Ford (2011) identified that a three-week, guided discovery training condition improved DT and overall reactive agility time significantly in rugby league players but no improvements in movement time, compared to a control condition. This finding indicates that DT skills were trainable and the training led to performance improvements (Serpell et al., 2011). Since reactive agility performance is directly influenced by the time required to react to a stimulus, and physical training improves reacting (Serpell et al., 2011), we expect that if unpredictable stimuli were generated during imagery, then imagery rehearsal could improve reactive agility performance.

Thus, the purpose of this study was to investigate the effects of imagery training on reactive agility performance and examine whether imagery could improve reacting to unpredictable stimuli. Based upon previous research (Scanlan et al., 2014, 2016; Serpell et al., 2011; Young et al., 2015), it was expected that physical training would improve the perceptual components and overall reactive agility performance, but demonstrate no improvement on movement related components. It was expected, based on a functional equivalence of imagery framework, that if unpredictable reactive tasks were generated during imagery then improvements to reactive performance should improve the perceptual components of reactive agility performance. To further explore the relationship between imagery and physical reactive performance, performance analysis of the training intervention was also conducted to examine whether potential performance differences between physical and imagery training existed. Finally, to determine that participants were adhering to the imagery program, a manipulation check was included by comparing imagery ability changes across the training intervention. It was expected that imagery condition would improve their imagery ability because of the rehearsal experienced during the intervention, with no changes in imagery ability for the other training conditions.

Method

Participants

Forty-seven female athletes ranging in age from 19 to 28 years (M_{age} = 21.51, *SD* = 2.32) were recruited. All participants were actively participating in reactive-based organized sports with key components of the sport involving reacting to a moving target and/or themselves moving while performing the skill, as defined by Paivio (1985). The sports reported as main sports included: Netball (*n* = 32), Soccer (*n* = 4), Touch Football (n = 3), Basketball (*n* = 2), Hockey (*n* = 2), Tennis (*n* = 1), Badminton (*n* = 1), Squash (*n* = 1), and Ultimate Frisbee (*n* = 1). Participants indicated that their competition level was either local (*n* = 24), state (*n* = 19), national (*n* = 3) or international (*n* = 1) standard.

Materials

Reactive Agility Test (RAT). The RAT involved a three timing gate course that was modified from the procedures used by Serpell et al. (2011). The RAT involved running through timing gate 1 towards the screen where a light stimulus of a left or right arrow would present on a screen. Participants were required to react to the stimulus and run out the timing gate of the direction of the arrow (i.e., timing gate 2 or 3) as fast as possible (see Figure 1). The arrow stimulus was activated as participants ran through timing gate 1, and appeared randomly on the screen either 0.8, 1.0, 1.2, or 1.6 seconds afterwards. The stimulus was maintained on the screen to the completion of each trial. The RAT was used for the pre- and post-test, and the task for the physical training condition. Participants were not provided information about the direction or presentation time of the stimulus at any point during the study.

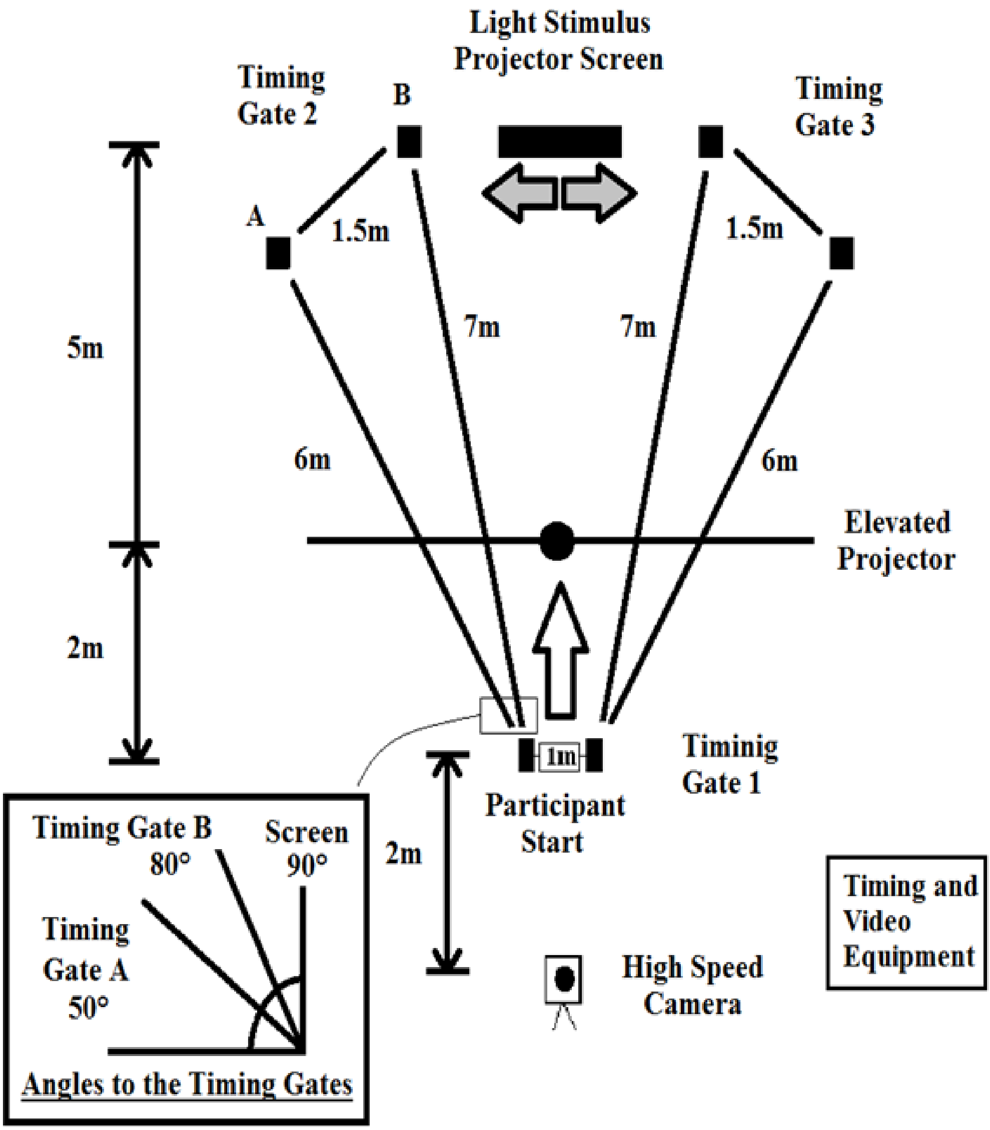

Figure 1. Aerial diagram of the RAT with arrow stimulus.

The use of a light stimulus allowed an exploration of the conceptual representation of imagery and examine whether imagery training was for reactive agility. The light stimulus used in the current project was an arrow pointing either right or left, with participants instructed to run in the direction the arrow was pointing (see Figure 2). Arrow stimuli have been used in previous RAT research as a reliable method of assessing perceptual and physical components of agility, with the use of a light stimuli to trigger reactive agility based upon the focus of the research (see Paul et al., 2016, for a review). The arrow stimulus was chosen for this research because it contained highly unpredictable spatial (direction of the stimulus) and temporal (when the stimulus presented) characteristics. The use of the arrow stimulus provides an unambiguous event for the reactive response, with athletes required to effectively identify and react to the presentation of the arrow, rather than using pre-cue performance information available from the environment to inform performance (Paul et al., 2016).

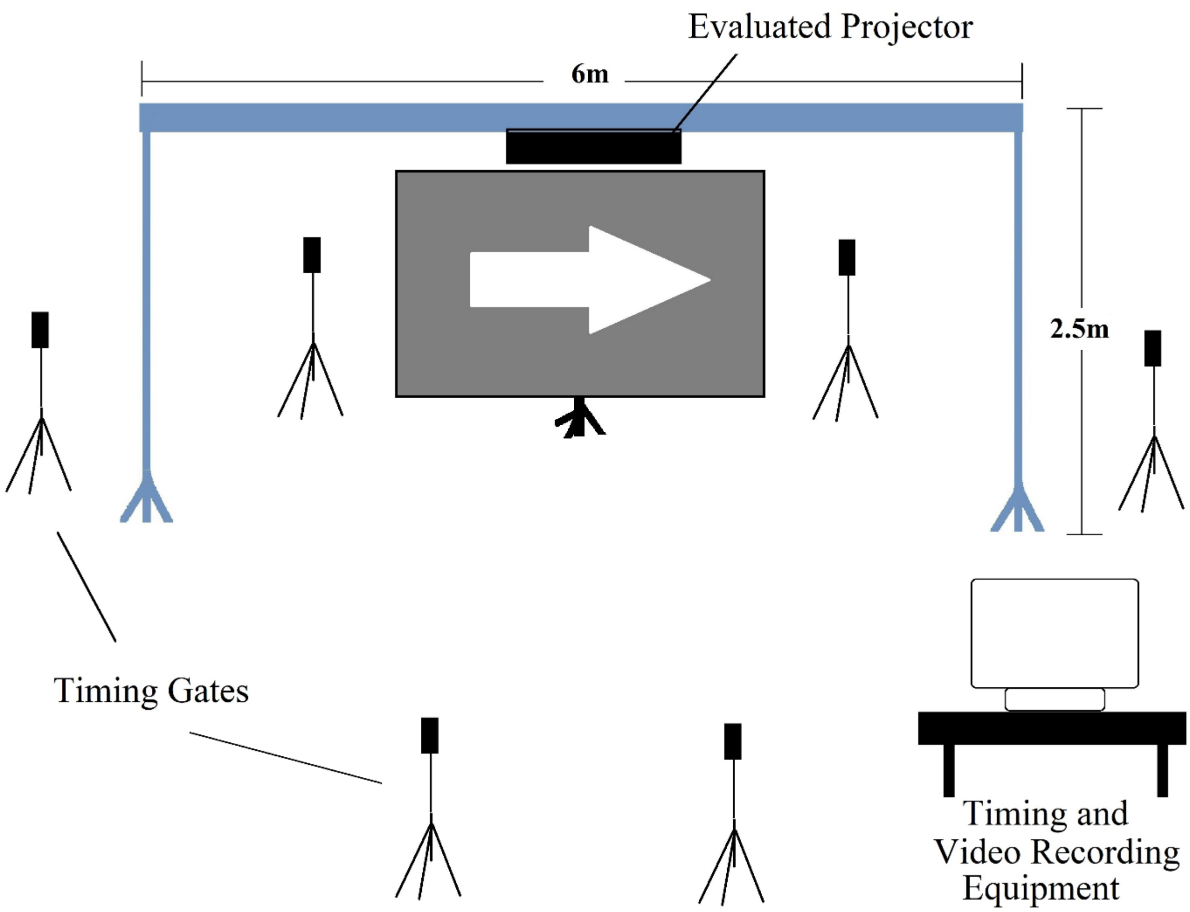

Figure 2. Visual representation of the RAT from participants' perspective.

RAT Equipment. Timing gates (Swift Performance Equipment, Australia) were interfaced with an ASUS M6000 laptop computer with purpose-built software designed to automatically start playing the video clips of the stimulus. Stimulus clips were projected using a Sony VPL-EW5 projector (Sony, Australia) attached onto a "soccer crossbar" frame elevated 2.5m above the ground and five meters from the projector screen. Video clips were projected onto a two meter by two meter white projector screen, raised 0.8m above the ground.

Reactive agility performance was recorded using a Redlake PCI 2000 S (Integrated Design Tools, Tallahassee, Florida, USA) high speed camera, which recorded at 250Hz frame speed and 1/250 shutter speed per section. The high-speed camera was positioned 0.5 meters above the ground and positioned to capture foot movements and the stimulus presentation. High-speed camera recording was initiated automatically when participants ran through timing gate 1.

Vividness of movement imagery questionnaire-2 (VMIQ-2; Roberts, Callow, Hardy, Markland, & Bringer, 2008). The VMIQ-2 is a 12-item measurement of vividness in imagery of movement scenarios that involves imagining 12 different movement scenarios, using the three different perspectives of imagery (i.e., internal, external, and kinaesthetic imagery). Participants imagined the scenario in the perspective and then reported the clarity and vividness of the image, ranging from 1 to 5, with lower total scores demonstrating clearer, more vivid imagery ability. Researchers have found the VMIQ-2 to be psychometrically acceptable, with test–retest reliability and concurrent validity of the instrument being acceptable, and high internal consistency values reported (Roberts et al., 2008).

Reactive Agility Performance Variables

Seven performance variables of reactive agility were measured, including two DT variables, three movement/running variables, and two variables related to overall reactive agility performance. The two DT variables were Stimulus-DT and Stimulus-Foot. The Stimulus-DT, based on Henry et al. (2011; 2012) recommendation, represented the time between the presentation of the stimulus and the first definitive lateral movement of the foot that initiates the change of direction. Stimulus-Foot represented the time between the presentation of the stimulus and the foot leading to the reactive movement making initial contact with the ground.

Motor variables consisted of DT-Foot, DT-Total Time and Foot-Total Time. DT-Foot represented the time between the first definitive foot movement and that foot making initial contact with the ground. DT-Total Time was the time between when the participant initiated their definitive foot movement to the time participants passed through one of the exit timing gates. Foot-Total time was recorded from the time between the initial ground foot contact was made to when they passed through one of the exit gates.

The two overall reactive agility performance variables were Total Time and Total Time-Stimulus. Total Time was the time taken to complete the reactive agility trial (i.e., from when participants passed the initial timing gate to the time they passed through one of the exit gates, including the time before the presentation of the stimulus). Total Time-Stimulus was recorded between the presentation of the stimulus to when participants passed through one of the exit gates.

Reactive agility performance was measured through the combination of the timing gates and high-speed video recordings, consistent with previous research (e.g., Henry et al., 2011; Serpell et al., 2011). Perceptual, perceptual-motor and DT-Foot variables were measured by analyzing the frames between the presentation of the stimulus to the defined performance movements using high-speed video recordings, whereas other motor variables and overall reactive agility performance were measured from the initiation of the movement, measured by high-speed video recording, to the conclusion of the trial by running out of the exit timing gate. All performance variables were analyzed by two researchers. In situations where there was a time difference from the video analysis (approximately <1% of clips analyzed), both researchers re-analyzed the clip independently and discussed the results. This resulted in a consensus on the appropriate time point.

Training Conditions

Participants in the physical and imagery conditions performed 20 RAT trials per session, completing two sessions per week over a three week period (120 trials in total). The amount of rehearsal was consistent with, or more than, imagery perceptual-cognitive training (e.g., Smeeton et al., 2013) and physical training literature (e.g., Serpell et al., 2011). As Serpell et al. (2011) demonstrated reactive agility performance improvements from less physical rehearsal, it was expected that if imagery and physical practice similarity exists for reactive task performance, then the amount of practice conducted should be sufficient to identify whether imagery improvements occur for both the physical and imagery training conditions. Participants were not provided any information regarding the direction or presentation time of the stimulus for any training condition to ensure unpredictability of the stimulus and minimize anticipation. Analysis of participants between conditions indicated no skill level (i.e., highest level played), $F(2, 44) = .121$, $p > 0.05$, $\eta^2 = .01$, or age, $F(2, 44) = .459$, $p > 0.05$, $\eta^2 = .02$, differences.

Physical training condition. Participants ($n = 15$) in the physical condition completed training sessions that involved physical performance of the RAT. The task of the physical training condition consisted of the same procedure as the pre-test RAT performance. The direction of the stimulus during the training trials were presented in a randomized order with participants completing 60 trials in each direction across the six training sessions. Within each session, the direction of the stimulus for the 20 trials was randomized with 10 trials in each direction. Participants were not provided any directional information or informed that each session consisted of 10 trials to each direction. Commencement of each trial was completed in the participant's own time, and had approximately one minute rest between trials to allow for appropriate recovery.

Imagery training condition. For the imagery training condition, participants (*n* = 16) completed imagery training of the reactive agility trials. Prior to the commencement of the training, participants were educated on imagery use and how to develop an effective image. Participants were instructed to: "*imagine the stimulus presenting on the screen in front of you, and you reacting and running out of the timing gate as quickly as possible*". Participants were not provided instructions regarding the stimulus or stimulus direction to imagine performing. Limited instructions were purposely provided, to prevent directing the participants to imagine a specific event and using perceptual-cognitive skills related to anticipation of a stimulus. While providing limited information contradicts the recommendation for imagery training procedures (i.e., PETTLEP; Holmes & Collins, 2001), ascertaining the internal processes involved with imagery of reacting needs to be examined without explicit instruction from the researcher to examine the image generated in response to unpredictability.

Each trial during imagery training was self-timed using a stopwatch with performance time and imagined running direction recorded. Participants started the stopwatch on commencement of imaging the task and stopped the watch when they imagined running through the exit timing gate. Researchers have used self-timing in many functional equivalence studies with findings demonstrating similarities in time between imagery and physical performance (see Jeannerod, 2006, for a review). Participants were instructed to commence each imagery trial of the RAT in their own time, and to wait a minute between trials to maintain equivalence with the physical training condition.

Control condition. Participants (*n* = 16) in the control condition completed no specific physical or imagery reactive agility training or instructions. There was a three week break between pre-test and post-test that corresponded to the three week training for the other groups.

Procedure

Participants signed an informed consent form approved by the University Human Research Ethics Committee, then completed the VMIQ-2 and the pre-test of the RAT. The pre-test and post-test RAT consisted of four practice trials and 12 RAT trials (a total of 16 trials per session). The RAT test involved equal numbers of trials to the right and left. The direction of each trial was randomized and unknown to the participant. Commencement of each trial was completed in participant's own time, and had approximately one minute rest between trials to allow for appropriate recovery. Participants were then randomly assigned into one of the three training conditions.

On a different day to the pre-test, participants commenced the first of the six training sessions. Before the start of the first training session, participants were provided information and instructions relating to their training program. Participants in the imagery and physical training conditions completed each training session in the same location as the pre- and post-test RAT, and were given the opportunity to ask the researcher questions if required. Each training session lasted approximately 20 mins, and all participants adhered to at least a 24-hour break between training sessions. Following the completion of all six training sessions, all (including the control group) participants completed the post-test and the VMIQ-2 again. The post-test was scheduled for a similar time of day that the pre-test was completed, and participants wore similar attire (e.g., running clothes, running footwear). The pre- and post-tests, as well as the physical training condition, were completed on a concrete floor that had a non-slip coating applied. All testing occurred at the conclusion of the playing season when participants were not actively involved in training or competition.

Statistical Analysis

Data was entered into SPSS v.21 for analysis. Prior to any statistical analysis, pre- and post-test trials with initial movement times of greater than 800ms and shorter than 80ms in the correct direction were excluded from the data to eliminate possible outliers or response errors. Grouios (1992) adopted an upper data exclusion criteria to maintain participants were reacting to the presentation of the stimulus. Lower exclusion criteria was included to maintain that participants were reacting to the stimulus, and not anticipating the stimulus presentation.

Reactive Agility and Imagery Ability Performance. To examine changes in performance from the pre- to post-test, separate mixed model multivariate analysis of variance (MANOVA) were conducted for the reactive agility and imagery ability performance. For reactive agility performance, the independent variable was the three different training conditions (i.e., physical, imagery and control), and the dependent variables were performance of the seven reactive agility variables. For imagery ability performance, the independent variable was the three different training conditions, and the dependent variables were internal, external and kinaesthetic imagery perspectives. Follow up univariate ANOVA with Tukey's HSD post-hoc tests analysis examined significant reactive agility and imagery ability performance to identify specific performance changes variation between each condition. Assumption testing was met for both MANOVA tests.

Training Performance. To investigate similarities between the average performance time to complete a trial during imagery and physical conditions training, a one-way repeated measures ANOVA was conducted across the total performance time in the six training sessions. Assumption testing was met for this analysis.

Results

Reactive Agility Performance

The findings from the mixed model MANOVA demonstrated there was a significant effect for Test, $F(7, 38) = 13.278$, $p < 0.001$, partial $\eta^2 = .71$, and the interaction of Test and Condition, $F(14, 76) = 5.953$, $p < 0.001$, partial $\eta^2 = .52$. There was no significant difference among Conditions, $F(7, 38) = .971$, $p > 0.05$, partial $\eta^2 = .15$ (see Table 1 for descriptive statistics).

Univariate analysis on the effectiveness of the training programs indicated that the physical training condition, $F(7, 38) = 21.979$, $p < .001$, partial $\eta^2 = .802$, and imagery training condition, $F(7, 38) = 5.998$, $p < .001$, partial $\eta^2 = .525$, significantly improved reactive agility performance from pre-test to post-test. The control condition did not improve reactive agility performance, $F(7, 38) = 1.260$, $p > 0.05$, partial $\eta^2 = .188$. Post-hoc analysis indicated that there was a significant difference between pre- and post-test for Stimulus-DT [$F(1, 44) = 74.974$, $p < 0.001$, partial $\eta^2 = .63$], Stimulus-Foot [$F(1, 44) = 17.257$, $p < 0.001$, partial $\eta^2 = .28$], DT-Foot [$F(1, 44) = 18.207$, $p < 0.001$, partial $\eta^2 = .29$], and Total Time [$F(1, 44) = 4.786$, $p = 0.034$, partial $\eta^2 = .10$]. The effect between Stimulus-Total Time approached significance [$F(1, 44) = 3.303$, $p > 0.05$, partial $\eta^2 = .07$], and there was no significant effect for Foot-Total Time [$F(1, 44) = .399$, $p > 0.05$, partial $\eta^2 = .10$], or DT-Total Time [$F(1, 44) = .388$, $p > 0.05$, partial $\eta^2 = .10$].

Analysis examining the interaction between Test and Condition indicated that there was a significant difference for Stimulus-DT [$F(2, 44) = 46.860$, $p < 0.001$, partial $\eta^2 = .68$], Stimulus-Foot [$F(2, 44) = 16.220$, $p < 0.001$, partial $\eta^2 = .42$] and DT-Foot [$F(2, 44) = 6.818$, $p = 0.003$, partial $\eta^2 = .24$]. Follow up analysis indicated a significant interaction between time and condition for the physical condition for Stimulus-DT (mean diff. = 73.96 msecs, $p < .001$), Stimulus-Foot (mean diff. = 48.22 msecs, $p < .001$), DT-Foot (mean diff. = -27.35

msecs, $p < .001$), and Total Time (mean diff. = 51.61 msecs, $p = .005$) performance variables. There was a significant interaction for the imagery condition for the Stimulus-DT (mean diff. = 37.29 msecs, $p < .001$), Stimulus-Foot (mean diff. = 16.83 msecs, $p = .026$), and DT-Foot (mean diff. = --20.46 msecs, $p = .001$) performance variables. A significant difference also existed for the control condition for the Stimulus-DT (mean diff. = -14.36 msecs, $p = .030$) but this represented a decrease in performance. There were no other interactions between time and condition differences for all other performance variables for all conditions.

Table 1.

Reactive Agility Mean (and Standard Deviations) for each Training Condition in milliseconds during the Pre-Test and Post-Test (lower score represents faster performance).

		Conditions					
		Physical		Imagery		Control	
		Pre-Test	Post-Test	Pre-Test	Post-Test	Pre-Test	Post-Test
Decision time Components	Stimulus-DT	275.30 (21.24)	201.34 (20.67)	267.54 (36.74)	230.24 (23.82)	231.31 (19.39)	245.67 (19.51)
	Stimulus-Foot	413.07 (24.25)	366.46 (22.71)	410.85 (36.03)	394.02 (29.92)	381.93 (30.09)	393.39 (26.38)
	DT-Foot	137.77 (19.08)	165.12 (22.69)	143.31 (14.67)	163.78 (15.01)	150.62 (20.61)	147.72 (18.30)
Motor Components	Foot-Total Time	1250.92 (44.51)	1235.77 (98.51)	1270.74 (75.77)	1274.35 (55.97)	1311.77 (115.15)	1303.34 (92.63)
	DT-Total Time	1388.69 (38.75)	1402.67 (87.34)	1414.05 (76.86)	1438.13 (50.32)	1462.38 (112.20)	1443.94 (82.69)
Reactive Agility Performance	Stimulus-Total Time	1663.99 (52.60)	1609.05 (80.98)	1681.59 (75.78)	1668.37 (58.57)	1693.70 (112.15)	169.03 (93.98)
	Total Time	2855.75 (43.84)	2804.13 (86.61)	2879.84 (75.56)	2865.06 (59.26)	2889.31 (111.35)	2891.46 (93.69)

Imagery Ability Performance

The mixed model MANOVA identified a significant difference between pre- and post-test in imagery ability performance, $F(5, 40) = 5.759$, $p < 0.001$, partial $\eta^2 = .42$, and the interaction between Imagery and Condition, $F(10, 80) = 2.500$, $p = 0.011$, partial $\eta^2 = .24$. There was no significant difference for Condition, $F(6, 84) = 1.128$, $p = 0.354$, partial $\eta^2 = .08$ (see Table 2 for descriptive statistics).

Post-hoc analysis comparing imagery ability performance from pre- to post-test indicated that there was a significant effect for the physical condition, $F(5, 40) = 3.605$, $p = .009$, partial $\eta^2 = .311$, and imagery condition $F(5, 40) = 4.912$, $p = .001$, partial $\eta^2 = .380$, with these conditions significantly improving imagery performance. The control condition pre-test performance was significantly different to the post-test performance, $F(5, 40) = 2.65$, $p = .037$, partial $\eta^2 = .249$, however, this represented a decrease in performance.

Table 2.

Mean (and standard deviation) of the pre- and post-test imagery ability performance for the three conditions.

	Conditions					
	Physical		Imagery		Control	
	Pre-Test	Post-Test	Pre-Test	Post-Test	Pre-Test	Post-Test
External	32.27 (8.24)	27.67 (7.72)	30.38 (9.44)	26.81 (8.43)	24.88 (9.71)	28.94 (9.41)
Internal	27.00 (10.15)	24.40 (9.63)	23.69 (7.34)	23.50 (7.56)	24.44 (11.91)	27.06 (9.38)
Kinaesthetic	29.00 (12.01)	25.73 (11.97)	28.19 (8.59)	23.50 (7.33)	29.69 (11.92)	30.50 (11.21)

The Test x Condition interaction indicated a significant effect for external imagery, $F(2, 44) = 11.290$, $p < 0.001$, partial $\eta^2 = .34$, and kinaesthetic imagery, $F(2, 44) = 4.523$, $p =$

0.016, partial $\eta^2 = .17$. Internal imagery approached significance, $F(2, 44) = 2.993$, $p = 0.060$, partial $\eta^2 = .12$. Follow up analysis indicated a significant interaction between time and condition for the physical condition for external (mean diff. = 4.60, $p = .003$), and kinaesthetic (mean diff. = 3.27, $p = .023$) imagery ability performance variables. There was a significant interaction for the imagery condition for external (mean diff. = 3.56, $p = .014$), and kinaesthetic (mean diff. = 4.68, $p = .001$) imagery ability performance variables. A significant difference also existed for the control condition for external imagery ability performance (mean diff. = -4.06, $p = .006$) but this represented a decrease in performance. There were no other interaction between time and condition differences for any other imagery ability performance variables.

Analysis of Reactive Agility Training Performance

Findings from the repeated-measured ANOVA demonstrated a significant difference for the training sessions, $F(5, 25) = 6.572$, $p < 0.001$, partial $\eta^2 = .57$, and the interaction between training sessions and condition, $F(5, 25) = 4.836$, $p = 0.003$, partial $\eta^2 = .49$ (See Figure 3). There was no significant difference between the imagery and physical condition, $F(1, 29) = .203$, $p = 0.655$, partial $\eta^2 = .10$, and pairwise t-test comparison between the conditions at each training sessions did not demonstrate any significant differences.

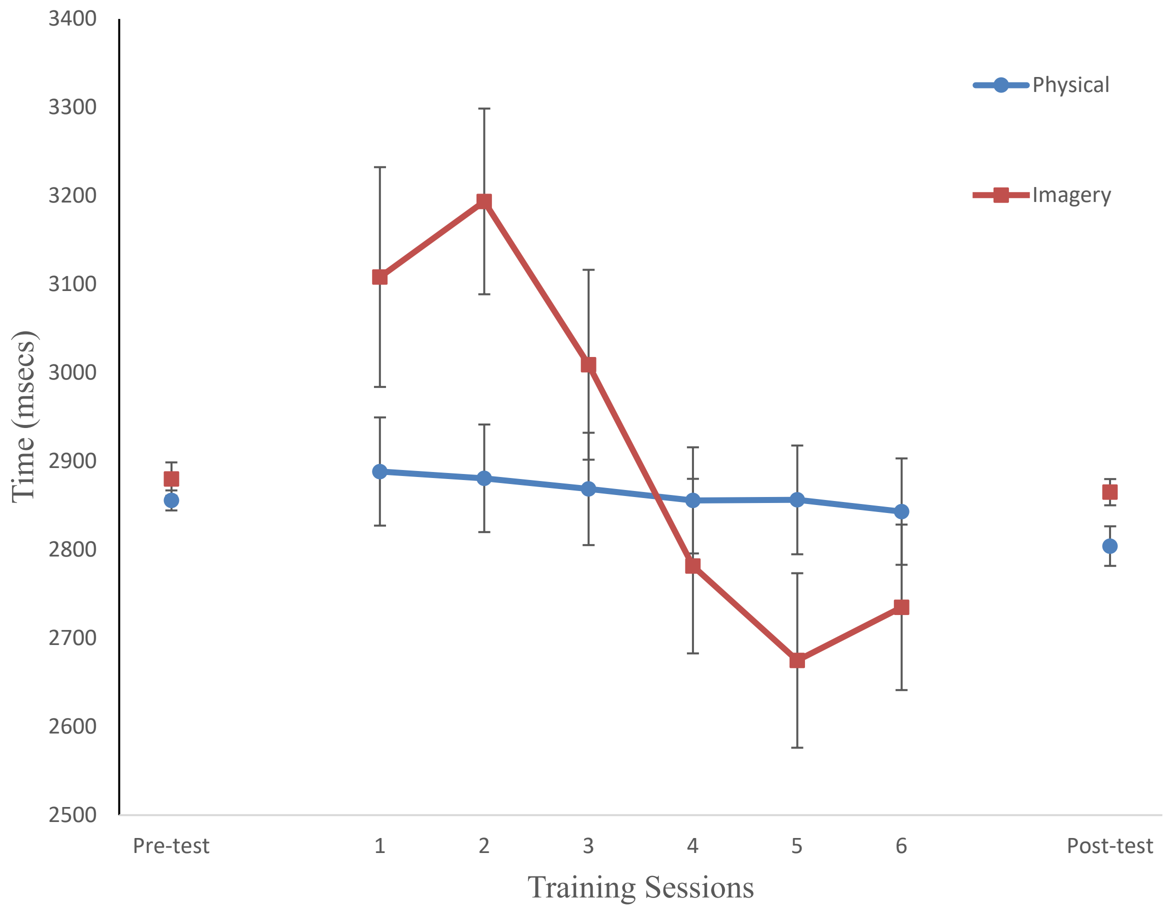

Figure 3. Mean total performance time (with standard error bars) for the imagery and physical training conditions at pre-test, across the six training sessions, and post-test.

Discussion

This study investigated the effects of imagery training on reactive agility performance and whether reacting to unpredictable stimuli could be improved using imagery. The physical condition had a greater effect on improving DT and overall reactive agility performance than the imagery or control conditions, consistent with previous research (Serpell et al., 2011). Reactive agility performance from physical training improved due to DT changes rather than motor performance, consistent with previous research (Scanlan et al., 2014, 2016; Young et al., 2015). Based upon the functional equivalence view, it was expected that if imagery replicated the performance components to react to an unpredictable stimuli, imagery rehearsal would be similar to physical rehearsal, and improvements in perceptual components would translate into overall reactive agility performance. The imagery condition had a moderate effect on improving the DT and DT-Foot components; however, imagery had limited effect on improving total reactive agility time. Differences between improvements to the performance components and lack of change for total reactive agility performance appear to indicate that crucial components important for overall performance were not rehearsed during imagery. The difference in skill improvements may illustrate that the self-generational nature of imagery limits the effectiveness of imagery for improving reactive agility performance.

Performance improvements to DT demonstrate that imagery can effectively improve reacting to the presentation of the stimulus. Similar to perceptual-cognitive performance improvement from imagery rehearsal (Guillot et al., 2007; Jordet, 2005; Smeeton et al., 2013), imagining the stimulus presenting enabled improved speed of reacting and provided an advantage to respond to the stimulus quicker, even though participants did not complete any physical rehearsal. Imagery training was more effective than the control condition, but not as effective as physical training. Imagery improvements potentially support the relationship between imagery and reacting, and imagery as an effective psychological technique to rehearse a reactive task. Thus, practitioners should conduct physical rehearsal, however, where not possible, imagery reactive task rehearsal can improve DT components of reactive performance. Further research is needed to determine if improved reactive task performance translates to sport specific perceptual-cognitive skill tasks.

Based upon the previously reported importance of perceptual-motor skills for faster reactive agility performance (Scanlan et al., 2016), it was expected that as imagery improved the DT components, imagery training should translate into improved overall reactive agility performance. The lack of transition between DT performance and overall reactive agility performance may have represented the difference between imagery and physically reacting, with crucial task components not generated during imagery. That is, important components that affect perceptual detecting into effective movement strategies that take place during physical performance appear not to have been replicated during imagery. This inability to generate important perceptual-motor components (i.e., temporal and spatial unpredictability of the stimulus) supports the task-analytic issue associated with being able to generate an image that contains unpredictability. This may also represent the cognitive processing differences between imagery and perception because of the difficulty to generate an image that requires responding to an environmental stimulus (Borst & Kosslyn, 2008). Imagery may provide an experience where athletes rehearsed the unpredictable component of performance but due to the lack of physical performance, the perceptual-motor link could not be strengthened.

The lack of overall reactive agility performance improvements may illustrate that due to the nature of the task (i.e., reacting), imagery may be less effective for this skill. The difference between DT and overall reactive agility performance potentially demonstrates that not all components of performance were rehearsed with imagery, supporting that the type of task moderates the effectiveness of imagery (Driskell et al., 1994). Researchers suggest that perceptual-cognitive skills are improved from imagery rehearsal (Guillot et al., 2007; Jordet, 2005; Smeeton et al., 2013). This, however, does not appear to translate to a reactive task using unpredictable stimuli where sport-specific perceptual-cognitive skills were not employed. These differences may support the issues associated with generating an unpredictable event based upon the conceptual nature of imagery (Munroe et al., 2000; Paivio, 1985; Spittle & Morris, 2007). The implication is that while imagery can improve perceptual skills and performance that can be predetermined, unpredictability may not be imagined or rehearsed precisely as it may happen in real-world situations.

A possible alternative explanation is that imagery primes performance responses for specific stimuli that may occur. Researchers (Grouios, 1992; Hallman & Munroe-Chandler, 2009; MacIntrye & Moran, 2007) have argued that imagery is beneficial for developing the stimulus-response relationship related to specific task performance if a certain stimulus occurred rather than improving reacting. It is possible that imagery was beneficial because participants rehearsed skills associated with determining which response was required before the stimulus was presented that effectively led to quicker reactions. For example, participants may have generated an image of the stimulus, which then primed the performer by making the task more familiar (i.e., direction of the stimulus, how the stimulus appeared on the screen) and/or required movements (i.e., left or right direction). This may indicate that imagery training is effective for rehearsing 'what if' responses rather than reactive processes. Therefore, quicker reactions occur from imagery training because participants rehearsed a pre-determined image of the task that promoted their knowledge of the stimulus and required performance outcome, similar to rehearsing a technical skill as the stimuli were consistent from trial to trial. This behavior appears not to constitute reacting and may be because imagery performance involved different performance mechanisms to physical reactive. This conclusion is consistent with the suggestion that it is easier to generate a known task than generating an unknown or unpredictable event during imagery (Borst & Kosslyn, 2008; Guillot et al., 2009; Munroe et al., 2000; Spittle & Morris, 2007).

Imagery training performance cannot be objectively evaluated due to imagery being an internal process, yet, analysis of training performance and imagery ability supports that participants generated an image as instructed during the training intervention. Self-recorded imagery times produced similar time between conditions. Time fluctuation during the imagery training occurred at the initial stages of the intervention, potentially indicating that the imagery condition were overestimating the time to complete the course. Performance overestimation may have occurred as the reactive task had a high level of difficulty, which is in line with Guillot and Collet (2005) that task difficulty often leads to performance overestimations. Yet, over the imagery intervention, motor learning of the task potentially occurred as participants developed a better understanding of the task. The greater congruency between the two conditions at the end of the training session, with equivalent time durations to the physical condition, may indirectly support that the image generated maintained certain performance components that resembled real-world performance (Morris et al., 2005). It was expected that if participants had not generated an image of the task, times would have been faster than actual performance as participants were not performing imagery.

Additional support for the use of imagery comes from the imagery and physical conditions improving imagery ability across the training, whereas the control condition did not. It was expected that participants in the imagery intervention would improve imagery because of participating in imagery rehearsal. The physical condition, however, was expected to show no significant improvement. One explanation for this unexpected result was that while participants in the physical condition were not instructed to perform imagery, participants may have involuntarily completed imagery in reviewing their previous training trial leading to improvements in overall imagery ability. These findings support that the imagery intervention was adhered to during the training intervention.

Limitation and Future Research

The findings should be considered in regards to certain conceptual and applied issues. One potential issue of this study was using the arrow stimulus to trigger reactive agility performance. While sport-specific stimuli have been recommended for reactive agility tests to create a realistic representation (Young & Farrow, 2013), the arrow stimulus was appropriate to examine the processes associated with reacting to an unpredictable stimulus. By incorporating the arrow stimulus, potential stimulus pre-cues were removed that may have provided additional early information regarding the stimulus and allowed a clear investigation on the role of imagery for reacting to unpredictable stimuli. These findings demonstrate that using imagery improved performance components associated with reacting on this task.

Future research is needed to validate the findings of this study, and contribute greater understanding of the role of imagery for training skills that involve reacting to stimulus unpredictability. Adopting real-world or simulated sport-specific task is necessary to examine whether reactive performance improvements transfer to sport-specific situations. It is possible that due to the task-analytic issue of imagery (Paivio, 1985), there may be differing effects on certain reactive task components (i.e., spatial vs. temporal performance factors) or perceptual-cognitive skills with imagery use. Furthermore, researchers may investigate the similarity of imagery to physical performance by exploring whether pre-cues information that informs anticipation, perceptual-cognitive skills, and other relevant performance components that impact reactive task performance are generated during imagery. For example, soccer goalkeepers can use pre-cue information to help anticipate the direction of a penalty shot. It is possible that a realistic image of the reactive task is generated during imagery, but certain perceptual-cognitive skills associated with detecting unfamiliar pre-cue information are not rehearsed due to the conceptual nature of imagery. Greater research utilizing sport-specific stimuli could lead to clearer understanding of the mental representation and underlying mechanisms associated with reactive agility performance.

Imagery may have improved the stimulus-response compatibility as rehearsal and test performance were similar (i.e., performance familiarity in similar movement patterns). For example, participants improved perceptual performance for reactive agility performance because of priming the stimulus-response unit; yet, reactive skills used successfully were not improved. This supports the theoretical view that imagery may provide an opportunity to rehearse distinct characteristics of performance in specific situations, similar to rehearsing technical skills in reactive situations (Grouios, 1992; Hallman & Munroe-Chandler, 2009; MacIntyre & Moran, 2007). Future research incorporating alternative practice-test conditions to examine the reactive processes should be encouraged to understand whether the skill is effectively rehearsed.

Exploration of whether performance differences occur as a result of sport expertise, reactive agility skill levels, performance tasks (i.e., perceptual vs. perceptual-motor vs. perceptual-cognitive skills), imagery ability skill levels (i.e., high vs. low skilled populations), and/or whether different imagery perspectives facilitate changes in performance would identify the success of specialized imagery training programs. Continued focus identifying whether performance discrepancies exist within certain sporting populations and different tasks would ensure that theorists and practitioners comprehensively understand the effects for training reactive performance, and further conceptually explain whether imagery contained reactive characteristics. For example, incorporating a task with greater unpredictability (i.e., four possible options instead of two) may lead to clearer assumptions regarding the role of imagery. This research may highlight clearer performance differences illustrating that key components of the task were not captured. It is important that research examines whether perceptual-motor components of reactive performance are improved from imagery training, or illustrates whether type of task moderates imagery training effectiveness. A final consideration for future research could be to examine the influence of different imagery instructional approaches for skill acquisition. In this study, researchers provided minimal instructions during the imagery intervention on the reactive task. Based upon the improvement in perceptual skills, it appears that participants developed an accurate image without explicit instruction influencing the reactive nature of the task. Providing no or minimal instructions may allow imagers to self-select attentional focus to the task demands necessary to improve the components of performance. Yet, imagery scripts outlining specific performance characteristics are commonly used to simulate the physical performance experience. Future research could focus on identifying whether providing specific instructions improves specific performance skills or the whole performance task. For example, if participants were provided instructions focused explicitly on the movement component (i.e., footwork/directional movement) of the reactive agility task, would the perceptual skills improve or total reactive agility performance. More research determining difference between limited (or implicit) instructions compared with specific performance (or explicit) instruction is needed to understand how best to implement imagery interventions

Conclusions

This study provided empirical understanding of the theoretical and applied use for training tasks requiring reacting to an unpredictable stimulus with imagery. Imagery provided an opportunity to rehearse performance components associated with reacting. Performance improvements support that athletes are able to generate an image that realistically captures important DT performance components necessary for performance, but this did not translate to overall performance improvements. The differences in performance change between variables from imagery training potentially indicates that important perceptual-motor components of reactive task performance were not rehearsed during imagery. Sport psychology practitioners, coaches and athletes should be encouraged to use imagery for rehearsing reactive tasks; however, more research is needed to understand the role of imagery for reactive tasks. Future research is necessary to determine whether the positive findings of imagery training can translate to sport-specific reactive task performance and further to perceptual-cognitive skill performance in sport, while clarifying any limitations of using imagery training for tasks that involve reacting to unpredictable stimuli, and explain why these performance differences exist.

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