Research Article

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Cardiorespiratory response patterns during multifunctional imagery-assisted biofeedback training – a case study

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Abstract

Objectives: The study aimed to expand the knowledge of cardiorespiratory response patterns while engaging in multifunctional imagery-assisted biofeedback training in a young cricketer.

Methods: The athlete was asked to engage in imagery (e.g. facing the bowler in an over: six ball) and cardiorespiratory responses were monitored using biofeedback equipment. The study involved a total of 19 sessions. Phases 1 & 2 focused on need analysis and action plan respectively and phases 3 to 5 focused on imagery–assisted biofeedback training *viz.* Motivational Specific-MS (six sessions); Motivational General-Mastery MG-M (six sessions); Cognitive Specific-CS-PETTLEP (7 sessions). The qualitative feedback was taken after each session from phases 3 to 5.

Results: A higher heart rate (HR) was observed while facing the second ball in an over during MS (83 % of the time) and MG-M type of imagery (50 % of the time). While doing CS imagery, the higher HR was observed while facing the fifth ball in an over (57 % of the time). No consistent pattern was observed in the respiration rate (RR) while engaging in imagery training. The athlete's feedback revealed that in MS and MG-M, the initial attention was on staying focused while facing the bowler. During the CS imagery, the difference in the HR patterns probably happened because the athlete focused on appropriate skill execution.

Conclusions: Understanding an athlete's cardiorespiratory patterns can be helpful in training an athlete's self-regulation to reach the optimal zone of functioning.

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Cardiorespiratory responses, particularly heart rate response to stress are important in evaluation and training [1]. No studies to date have documented the patterns of heart rate responses in athletes, during engaging in multifunctional imagery-assisted biofeedback training. A growing body of published research highlights the usefulness of biofeedback for the assessment of cardiorespiratory responses and getting into the zone of performance. Imagery, a form of cognitive training, involves 'thinking in pictures' and is a powerful mental training tool [2]. Using one's senses (visual, auditory, olfactory, tactile, and kinaesthetic) to create a new experience in the mind helps the brain to interpret different images to actual situations [2]. While engaging in applied work, we have observed that athletes could integrate new experiences and build images from their long-term memory. This research stems from the theoretical framework of the two-dimensional model by Paivio [3]: motivational and cognitive functions which operate at general and specific levels. Building on Paivio's framework, five different types or functions of imagery were identified viz. Motivational Specific, Motivational General – Mastery, Motivational General – Arousal, Cognitive Specific and Cognitive General [4].

Imagery-assisted biofeedback and sports performance

Biofeedback is widely used in self-regulation enhancing sports performance [5, 6] and has positively influenced an athlete's cognition (e.g., [7]). Cognitive interventions such as Imagery-assisted biofeedback training can facilitate better control of thoughts and associated emotions. The changes in heart rate and breathing rate can be triggered by emotions generated during an imagery session. Imagery-assisted biofeedback training can teach athletes to voluntarily control autonomic responses such as heart rate (HR) and respiration rate (RR) to regulate emotions and perform at an individual potential [8, 9]. The benefits of cognitive interventions on sports performance have been well documented [10]. Researchers have shown that biofeedback training enhances the self-regulation abilities of athletes [9]. Weinberg and Gould [11] indicated that the ultimate goal of biofeedback training is for athletes to effectively function independently (without the guidance of a coach or sports psychologist).

Sports psychologists have used biofeedback since the 1980s as a means to train athletes on different self-regulation strategies [5, 12].

Biofeedback training involves different modalities such as heart rate (HR), respiration rate (RR), skin conductance (GSR), heart rate variability (HRV), electromyography (EMG), and neuro feedback (EEG). A researcher can also train an athlete by combining the different modalities. Biofeedback provides ongoing psychophysiological assessments in real-time, which helps athletes and coaches to quantify responses [6, 9].

The areas with known performance-enhancing effects of HR and RR documented in the literature [13] formed the basis of this study. Ferguson et al. [8] have indicated that respiration has a direct impact on heart rate. In the research literature, imagery is a well-researched topic, however, there is a gap in the sports performance literature that examines the patterns of heart rate and respiration rate while combining the different functions of imagery. Individual athletes coming from different contexts understand the imagery-assisted biofeedback modalities differently. Therefore, in this study, we decided to initially train the athlete with heart rate (HR) and respiration rate (RR) only, where the bodily responses can be easily understood and monitored by the athlete during the competition. Our interest was to examine the cardiorespiratory response patterns of the athlete while engaging in multifunctional imagery. Further, we wanted to analyse if the qualitative feedback of the athlete would correspond to the response pattern experiences during imagery training.

Methods

Participants and the context

The participant was an aspiring male cricket player aged about 20 years who represented at the divisional level of cricket. He trained daily for 4 h. An informed consent form was signed as a requirement for applied work. He started training at the age of seven and represented multiple clubs in the second division in the under-19 category. He started to play fifth-division matches at the age of 14 (the senior level). Currently, the athlete represented the fourth division and was selected into the squad for the third division club.

Measures

Biofeedback data were recorded on a five-channel ProComp5 Infiniti™ (SA7525) manufactured by Thought Technology, Montreal, Quebec, Canada. The data capture of the respiration rate was done using – Respiration Sensor (P/N: SA9311M) placed under the diaphragm. A Blood Volume Pulse (BVP): HR/BVP SENSOR (P/N: 9308M) was placed on the ring finger to measure the HR. Once the athlete was connected to the encoders, it was possible to monitor the ongoing physiological process in real time. Though the visual and auditory feedback were available, this athlete did not use the visual pacer stimulus or auditory feedback but preferred to independently do the imagery, to avoid distraction.

Imagery-assisted biofeedback protocol

Initially, a basic briefing and familiarization of the equipment sensors was given to the athlete. The explanation of how the sensor works was demonstrated, combined with a graphical data display. Familiarization helped the athlete to reduce the apprehensions associated with biofeedback training.

Following the sensor fitting, the athlete was briefed about the two steps of the biofeedback intervention protocol: (a) readying and (b) imagery training. The athlete was also briefed about the multimodal functions and the sequence of the different phases of the imagery-assisted biofeedback training. Initially, Motivational specific (MS) type of imagery was considered. Here the athlete had to image the task in a specific setting which boosts motivation and effort. Following this, Motivational general mastery (MG-M) was directed towards developing the ability to sustain focus for overcoming challenges. Thereafter, cognitive specific imagery (CS) was considered to refine the self-regulation strategies to generate productive thoughts and the focus was on correcting the required skills for each ball (Figure 1). Research has documented positive effects after CS interventions [14]. Nordin-Bates and Cumming [15] indicated that the appropriate images meaningful to the task and the athlete is a critical aspect of imagery use. For example, the athlete was instructed to judge the line and length of the ball once the bowler releases the ball. Length of the ball, in cricket, implies the position where the ball first touches the pitch (e.g., furthest from the batsman is termed "short length", little closer is termed "good length", further closer is

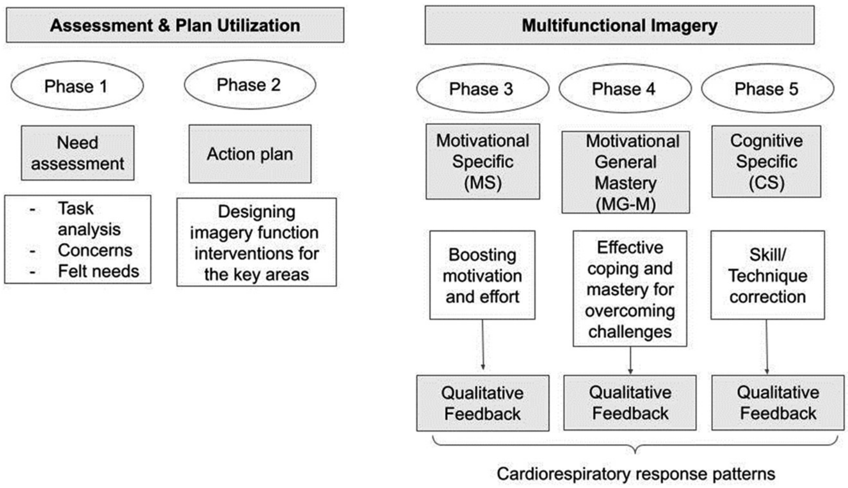

Figure 1: Plan of imagery training.

termed “full length” and closest to the batsman’s foot is termed “yorker”). The line, in cricket, is the direction of the ball’s trajectory (e.g., towards off stump, outside leg stump).

The study approach

Preintervention

Initially, we also sought to know if the athlete had any previous experiences with sports psychology support and gathered that he had very little understanding of the benefits, but no practical experience. The key question was ‘What areas need to be addressed?’

The initial briefing to the athlete provided a basic understanding of the action plan that he would engage in.

Phase 1 – individual need assessment

The need assessment revealed three major areas that needed attention (1) effort and motivation (2) overcoming challenges (3) sustaining focus. Thus, the intervention plan focused on a sequence of training. The five-phase integrated imagery–assisted biofeedback training was designed to achieve the goal of the athlete being able to self-regulate his autonomic responses, cope with challenges, and refine focusing skills.

Phase 2 – action plan

Having identified the key areas, we adopted motivation-specific (MS) imagery in weeks one and two, motivation general-mastery (MG-M) imagery in weeks three and four, and cognitive specific (CS) imagery in weeks five and six. A log book was maintained to schedule the imagery training and write the subjective experiences after each session. Qualitative feedback in each session helped the athlete be more aware and reflect on the bodily responses and outcome.

Initial procedure

The athlete was given some practice sessions in creating mental images prior to starting the interventions. The primary researcher guided the athlete about the focus of the imagery theme. The researcher further explained the possibilities of disruptions in holding the mental images during the initial sessions and how the athlete can restart the images. This was done to make the athlete feel comfortable even if he was not able to hold the images.

Having gone through a few practice sessions, the athlete imagined batting six balls (one over consists of six bowling actions) bearing in mind, the core theme of boosting effort and motivation. The athlete took approximately 2 min to ready himself, followed by the imagery session. The athlete would signal the researcher when imagery started and ended, by raising his ring finger. The time markers were noted by the researcher to denote the beginning and the ending of each ball during the imagery session for further analysis.

The physiological measures (i.e., heart rate and respiration rate) were recorded during each session. Heart rate was obtained using a sensor measuring blood volume pulse (BVP), placed on the ring finger of the non-dominant hand. The sensors detected time-to-time changes in peripheral blood flow to determine the heart rate per min. Respiration rate (RR) was obtained using respiration sensors placed horizontally below the diaphragm. The recordings were done in breaths per min. The testing sessions lasted for approximately 17–20 min and the qualitative feedback took approximately 10–12 min after each session. Nineteen imagery training sessions were conducted on different dates (MS-6 sessions S1-S6; MG-M-6 sessions S7-S12; CS-7 sessions S13-S19).

Phase 3 – boosting motivation and effort: motivational-specific imagery (MS)

The third phase (MS), consisted of six sessions (S1-S6) of which the athlete was encouraged to imagine facing the bowlers and the batting. The emphasis was on creating vivid images and controlling the created images. The imagery was to boost the self-confidence of the batsman to be able to stay focused. The process consisted of generating the images (e.g., mental representation without an actual stimulus), holding the images (e.g., control), exploring the inner meaning of the generated images to an objective reality (e.g., interpreting the feelings), and manipulating the images to suit the context (e.g., modifying the mental images).

Phase 4 – effective coping for overcoming challenges: motivational general – mastery (MG-M)

The fourth phase (MG-M), consisted of six sessions (S7-S12). The athlete was briefed about consciously overcoming the challenges, being aware of the bodily responses similar to the actual situation, and gaining mastery to control any disturbances that lead to less-than-successful performance. The imagery session also intended to replace the athlete's disturbing thoughts with facilitative and challenging opportunities.

Phase 5 – rehearsing for specific skill: cognitive specific (CS)

The fifth phase (CS), consisted of seven sessions (S13-S19). Mental rehearsal for technique correction was emphasized by focusing on batting elements such as body position, eye on the ball, foot movement and swing of the bat [15] have indicated that clarity of one image can serve several purposes and several images can serve to enhance performance. For example, in this study, the correction of batting technique during imagery was focussed to refine required skills for each ball. The athlete was instructed to imagine facing each ball with a positive intent. This can facilitate an athlete's needs to be functionally effective for execution of skills in critical situations.

Qualitative feedback for multifunctional imagery (phases 3–5)

The significance of the qualitative feedback was explained to the athlete, stating the relevance of individual subjective experiences that complement the quantitative values. With the post-session feedback, the researcher elicited details of the athlete's experiences of imagery. The feedback provided the initial challenges that the athlete encountered during imagery. Further, it helped to sensitize the athlete to his cardiorespiratory response patterns while engaging in imagery training.

Results

The cardio-respiratory response patterns of the 19 sessions of imagery-assisted biofeedback are provided in this section.

Cardio-respiratory response patterns MS imagery (S1-S6)

In cricket, a bowler is given six deliveries of ball, which is termed as one over. Out of six balls in an over, the athlete's HR increased 83 % of the time while facing the second ball during MS imagery. The range for the increased HR (S2 – S6) was 72 beats/min to 82 beats/min (Mean HR=78.49 beats/min). The athlete's RR however did not show any consistent pattern of increase during the MS imagery (range=10 to 19 breaths/min across six sessions.). The higher respiration rate (RR) varied during MS imagery while facing different balls. (e.g., S-1=18 breaths/min in ball 2; S-2=18 breaths/min in ball 1; S-3=18 breaths/min in ball 6; S-4=17 breaths/min in ball 4; S-5 =19 breaths/min in ball 1; S-6 =17 breaths/min in ball 2). In the qualitative feedback, the athlete expressed difficulty in holding the images in the first two sessions, which gradually came into control. Following this, the athlete reported that he could hold images without breaking and could experience his emotions. The researcher observed occasional body movements, in the latter sessions (S5-S6).

Cardio-respiratory response patterns during MG-M imagery (S7-S12)

While doing MG-M imagery, out of six balls, the higher HR was observed 50 % of the time while facing the second ball. The range for the increased HR (S-8, S-10, S-12) was 78 beats/min to 86 beats/min (Mean HR=81 beats/min). The RR was higher 50 % of the time while facing the first ball. The range for the increased RR was 16 breaths/min to 18 breaths/min (S-8, S-10, S-12). The RR ranged between 10 and 18 breaths/min during in MG-M imagery. The athlete reported feeling less nervous, focus better, feeling confident, and in control.

Cardio-respiratory response patterns during CS imagery (S13-19)

While engaging in CS imagery, out of six balls, the higher HR was observed 57 % of the time while facing the fifth ball. The range for the increased HR (S-13, S-16, S-18, S-19) was 74 beats/min to 88 beats/min (Mean HR=84 beats/min). The athlete's RR however did not show any consistent pattern of increase during the CS imagery (range=15 to 19 breaths/min across seven sessions).

The mean HR (CS=84 beats/min) indicated a higher value while the athlete engaged in CS imagery, in comparison to MS and MG-M imagery (MS=78 beats/min, MG-M=81 beats/min). The higher HR was observed 57 % of the time while imagining the fifth ball. The range while facing the fifth ball was 74–88 beats/min.

The higher respiration rate (RR) varied during CS imagery while facing different balls.

(e.g., S-13=17 breaths/min in ball 4; S-14=17 breaths/min in ball 2; S-15=15 breaths/min in ball 6; S-16=17 breaths/min in ball 6; S-17=18 breaths/min in ball 1; S-18=19 breaths/min in ball 6; S19=16 breaths/min in ball 1).

The athlete reported feeling more balanced in the stance, better focus on the trajectory of the ball, appropriate footwork and swing of the bat.

Discussion

The main purpose of the study was to examine the cardiorespiratory response patterns of an athlete while engaging in imagery–assisted biofeedback training. The second purpose was to explore the subjective experiences experienced by the athlete while engaging in different types of imagery training.

Athletes consider imagery essential for mind training [16]. Imagery involves all the senses related to a task. There is a history related to imagery training with relaxation techniques to control stress and improve performance [17]. This study displays the patterns of cardiorespiratory changes (HR and RR) while engaging in different types of imagery (MS, MG-M, & CS).

We drew on Paivio's two-dimensional model [3] consisting of motivational and cognitive functions. The motivational function helps in experiencing goal attainment, effective coping, and arousal management (relaxing/getting energized). The cognitive function provides experiences of executing specific skills, correcting the techniques, and planning strategies.

Motivational specific imagery (MS)

Prior to starting the sessions, the athlete was trained in imagery by using geometrical shapes (e.g., circle), increasing and decreasing the size, and changing shapes and colors inside the circle. In phase 1, however, while engaging in MS imagery, the athlete expressed a little difficulty in holding the sports image in the first two sessions, which gradually was in control. Following this, the athlete presented a relatively consistent heart rate across sessions three, four, five, and six (S3-S6). The higher HR was observed while imagining facing the second ball in an over. The corresponding qualitative data from the athlete revealed that during training/competition, the athlete typically leaves the first ball, without batting as a readying strategy and faces the second ball more seriously. While doing MS, the respiration rate, presented no specific patterns. The athlete's qualitative feedback attributed using breathing as his reason to self-regulate and stay motivated to focus on the ball.

Motivational general – mastery (MG-M)

In phase 2 while doing MG-M, the athlete reported that his focus was better, although the slight nervous feeling continued. Studies conducted by [18] reported a decrease in the variability of imagery use indicating mastery. The athlete was able to sustain more steady imagery use from session to session during the training phase. The HR patterns while facing the second ball displayed an increase of 50 % (S-8, S-10 & S-12). The imagery aimed at gaining mastery to stay focused and in control. This could have heightened the athlete's arousal level. Towards the 12th session, the athlete was able to gain mastery by using the muscle-to-mind technique, which involves breathing and calming down. This was evident from the qualitative feedback, where the athlete reported that he used the muscle-to-mind technique (e.g., breathing & calming) to gain confidence and stay in control. Research related to motivational general-mastery imagery have shown that athletes' have the ability to enhance levels of self-confidence and self-efficacy [19, 20].

Contrary to the heart rate pattern, 50 % of the time the respiration rate presented a higher value while facing the first ball. From the corresponding qualitative feedback, we attributed this increase in respiration rate to athlete's arousal level as he was preparing to face the bowler.

Cognitive-specific (CS)

In phase 3, the athlete was engaged in cognitive-specific imagery where he had the freedom to use the words/phrases that served as triggers to engage in an action that facilitated his task. Gould et al. [21] indicated that triggers can involve any of the five senses and that an effective trigger leads to the creation of a desired image. Therefore, the athlete was instructed to match the component of each session with his personal style of batting. The individualized words/phrases helped the athlete to focus better on movement components. In earlier days, research has documented ample support for functional equivalence of visual imagery [2, 22], and similar activation in the specific regions of the brain was reported [23–25].

In the third and fourth phases, we used a more traditional -visualization-based approach [26]. In the fifth phase, we instructed the athlete to focus on specific technical aspects of batting, to refine the mental images of the skill. For instance, the athlete reported feeling balanced which implies equilibrium of forces acting on the body. A stable balanced body helps in efficient transfer of energy during batting. The athlete also reported that he could focus on the release of the ball and follow its trajectory. Studies have documented the significance of tracking the ball from the point of release, till it reaches the batsman [27].

Limitation

The imagery-assisted biofeedback training should be monitored over a longer period of time to identify the individual optimal zone. In this preliminary study, we only monitored the response patterns of one athlete. Therefore, we cannot generalize the results to all athletes and different sports. Future research should look at the variations in cardiorespiratory responses in different sports, different positions in a sport, different ages and genders. The transfer effect of laboratory training to actual competitive sport environment could not be done, which poses a major limitation to this study. The outcome of this study should be interpreted with caution until a larger sample is considered.

Conclusions

In this study, the cardio-respiratory response patterns of the athlete, showed some consistency while engaging in imagery, particularly while facing the second ball in an over. The respiration pattern, however, did not display a concurrent increase. The imagery-assisted biofeedback training facilitated subtle changes to the autonomic system that gradually resulted in the desired effect while engaging in imagery. The objective measurement provided the athlete with information about the body's responses during imagery training. Over time, we expect that the learning can endure without the use of an instrument.

Applied implication

The findings lent support to integrating the imagery technique for training and competition. Understanding individual cardiorespiratory patterns during imagery-assisted biofeedback sessions can be useful in mental preparation. The cardio-respiratory responses provide athletes with evidence of how powerful the imagery technique can be to mentally rehearse the movement/skill, even during injury rehabilitation. The understanding of the response patterns can help the individual athlete to self-regulate to reach the optimal zone of functioning with meaningful practice.

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Informed consent: Obtained.
Author contributions: Aravind Athrey – Planning, interventions, writing. Jolly Roy – Conceptualisation, protocol formulation, and research writing. Cheryl Xavier – Reviews, data analysis, research writing, and intervention support. Samruddhi Sonar – Reviews, data analysis, organizing of paper, and research writing.
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