Toward a Psychophysiology of Performance: Sport Psychology Principles Dealing With Anxiety

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In this applied case study during an off-season period, a unique and innovative internal imagery/video/electroencephalogram (EEG) biofeedback protocol was used to train visual attention and increase self-confidence of a collegiate baseball player struggling to recover from a serious eye injury. Results from the ensuing competitive season revealed that self-confidence increased and hitting and fielding performance improved dramatically. In the subsequent competitive season, without psychological skill training, hitting and fielding performance declined to preintervention levels. Although EEG biofeedback has been slow to gain acceptance among applied practitioners, used in conjunction with video and internal imagery, it appears to have potential as a tool for training visual attention in athletes within a variety of externally paced sports, such as baseball, softball, and racquet sports.

Keywords: visual attention, EEG biofeedback, imagery, self-confidence, anxiety

Outstanding performance within elite sport competition often requires simultaneous information processing, decision making, and reaction that are dependent on acquisition of the most relevant visual data from the environment (Singer, 2000). Over the past 2 decades, sport psychology researchers have used sophisticated technology to identify and measure many of the components of visual attention associated with optimal performance by elite athletes in a variety of sports (Hatfield & Hillman, 2001; Singer & Janelle, 1999). However, within elite athlete populations, where physical talent and skill differences are often minute, interindividual differences in performance are often great, and fluctuations within individual performances are common.

Sport psychology deals with these discrepancies by seeking to answer

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the question of why talented athletes often fail to meet the achievement expectations warranted by their physical talent. Sport psychology researchers have postulated that excessive anxiety disrupts attentional functioning, and numerous investigations of this hypothesis have offered unequivocal support for their contention (Janelle, 2002). Thus, the conventional wisdom that has developed within the field is that much of the variance in performance can be attributed to the effects of heightened levels of precompetition anxiety. Therefore, although negative emotions such as anxiety may be functionally necessary to spur motivation in a win–lose context such as competitive sport (Seligman, 2002), they may become a detriment as well.

Achieving elite sport performance depends not only on perfecting the biomechanical efficiency of required movements but also on the efficient utilization of cognitive resources. However, the majority of coaches use instructional time to develop the physical talents and skills of their athletes. Although many implore their athletes to focus or concentrate, few fully understand the meaning of those concepts, and athletes are often left wondering, "*How,* exactly do I do that?"

Although laboratory research has identified the attentional states critical to elite performance and how they are affected by anxiety, there is still a wide gulf between the lab and actual competition (Singer, 2000). Many applied practitioners have focused great effort on designing methods and protocols to reduce anxiety and its detrimental effects, yet few are prepared to offer coaches and athletes meaningful interventions targeted specifically to enhance attention and alertness. In addition, there remains disagreement about the definitions, measurement, and effectiveness of the various protocols designed to improve performance (Carlstedt, 2001; Elchami, 2003).

The purpose of this article is to demonstrate to sport psychologists, coaches, and athletes the merits of integrating electroencephalograph (EEG) biofeedback into applied interventions aimed at maximizing the psychological skills of alertness and concentration. By improving these attentional functions, athletes may also develop vital tools that are beneficial in minimizing the attention-altering effects of anxiety and increase the critical psychological construct of self-confidence. The protocol used to entrain the critical attentional aspects of concentration and alertness outlined in our applied case study is based on empirical and theoretical concepts derived from research and practice undertaken with athletes from many sports. Although this information is specific to the sport of baseball and the task of hitting, we illustrate its applicability to a variety of other sports, discuss its limitations, suggest future research, and describe new technologies that may further psychophysiological research and applied biofeedback within sport.

VISUAL ATTENTION AND ANXIETY

Because sport is predominantly a visual activity, the ability to maintain alertness and focus attention on the most relevant visual aspects of the task is critical for success. Athletes performing certain tasks in externally paced sports often have little certainty of the stimulus that must be perceived and of the opportunity to control the timing of its presentation, which forces them to devote maximal attentional resources to (a) visually searching for the most important information within the environment, (b) anticipating and reacting to an opponent's moves, (c) deciding when and how to respond, and (d) initiating the appropriate motor response in consideration of the variables encountered (Singer, 2000).

Efforts within both laboratory and field settings have focused primarily on the cognitive processes and brain states associated with visual attention and alertness. Investigations, often comparing the differences in fixations and saccades between experts and novices, have occurred in the sports of tennis (Singer, Cauragh, Chen, Steinberg, & Frehlich, 1996), soccer (Savelsbaugh, Williams, Van Der Kamp & Ward, 2002; Williams, 2000), volleyball (Vickers & Adolphe, 1997), table tennis (Williams, Vickers, & Rodrigues, 2002), and baseball (Kato & Fukuda, 2002). All of these studies suggest that experts in externally paced sports use smoother visual pursuits and search patterns and have longer and less frequent gaze fixations on the most relevant areas of the visual field than do novices. Skilled performers thus possess the ability to visually track objects for a longer period of time, which enables them to detect relevant cues faster and with greater accuracy, acquire more task-specific knowledge, and discern greater meaning from that information. This results in faster information processing, decision making, and reaction with the appropriate motor movement, all of which leads to skilled performance (Singer & Janelle, 1999).

Elite athletes often appear to be performing the complex motor tasks required of them without conscious thought; many refer to this as being "in the zone" or as *automaticity* (Singer, 2002). This state, typically demonstrated at higher levels of expertise, is also associated with an external focus of attention. Rather than consciously focusing on the internal kinesthetic movements required, skilled performers focus on the external aspects, such as the basket or target (Liao & Masters, 2002; Radlo, Steinberg, Singer, Barba, & Melnikov, 2002).

According to Hatfield and Hillman (2001), quality performance associated with elite competition is typified by efficient attentional functioning, requiring very little conscious effort. Less skilled or poor performance is associated with inefficiency of attentional activity, characterized by more effortful and conscious processing, resulting in distortions of muscle sequencing and increased left hemispheric involvement prior to and during motor execution. Efficiency theories suggest that explicit control of motor movements (a rule-based, internal focus) is less efficient than implicit control (less rule-based, external focus) and results in increased anxiety and reduced performance (Janelle, 2002).

When athletes, even elite ones, experience increased anxiety, they often perform less than optimally. Processing efficiency theory (PET) provides an explanation of how heightened levels of anxiety may affect attention and subsequent motor performance. This theory asserts that attentional capacity is limited; therefore, the increased negative cognition associated with high-anxiety conditions consumes processing resources available to working memory, leading to reductions in performance of high working memory tasks— unless the individual is somehow able to muster greater mental effort. The theory also asserts that state anxiety levels are a function of threat appraisal and trait anxiety. Highly trait anxious athletes are thus more likely to appraise situations as threatening and subsequently are more susceptible to decreases in processing efficiency and decrements in performance (Eysenck & Calvo, 1992, as cited in Janelle, 2002).

Three distinct studies provide support for the PET. Williams, Vickers, and Rodrigues (2002) determined that high levels of anxiety cause a reduction in performance of tasks requiring high working memory, and Murray and Janelle (2003) confirmed that high anxiety produces an increase in visual search rates during competition and a subsequent decline in performance. Also, Smith, Bellamy, Collins, and Newell (2001) demonstrated that higher levels of mental effort expended by highly trait-anxious performers during critical moments of competition do not necessarily lead to improvements in performance.

Other hypothesized changes in attentional functioning associated with the psychophysiological effects of increased anxiety (or other negative emotions) are narrowing, distraction, and reinvestment. The concept of attentional narrowing, first suggested by Easterbrook (cited in Janelle, 2002), posits that as an individual experiences higher intensities of negative emotion, physiological arousal and motivation for specific action increase which causes the attentional field to narrow. This narrowing decreases peripheral vision and causes hyperfocusing on central stimuli, resulting in increased performance on primary tasks while reducing performance on peripheral tasks. However, if emotion intensity increases to extreme levels, distraction may occur, causing visual search to wander to threatening or irrelevant cues and leading to deterioration of primary task performance (Janelle, Williams, & Singer, 1999).

In contrast to the automatic processing and external focus associated with optimal performance states, high anxiety or negative emotion may cause an athlete to reinvest in conscious processing by becoming inwardly focused (the conscious processing hypothesis). Rather than maintaining focus on relevant external cues, attention shifts to thoughts, feelings, or movements of the performer, causing relevant cues to be missed and motor movements to be less efficient, which may produce a decline in performance (Janelle, 2002).

BASEBALL PERFORMANCE AND ANXIETY

Many athletes, coaches, and members of the sports media have described successfully hitting a baseball as the most difficult task within all of competitive sport (Mihoces, 2004). A popular baseball phrase of unknown origin states that the object of hitting is to "squarely hit a round ball with a round bat." At the highest levels of competition, pitchers can throw the ball at speeds exceeding 90 mph and are also able to make pitches bend and break at sharp angles just as they near the batter. A pitch thrown at 90 mph travels 60.5 ft (18.4 m) to home plate in just over four tenths of a second. This provides the hitter with less than two tenths of a second to determine whether the pitch will be a strike and whether he will swing at it. Clearly, the ability to devote maximum attentional resources to this complex motor task is critical to success, perhaps even more so than the ability to execute a mechanically efficient swing.

Baseball hitting comprises elements of both self- and externally paced tasks. Although an actual competitive at-bat takes only a precious few seconds, for many hitters there is what seems like an eternity between pitches, at-bats, or games. What occurs cognitively within the mind of the hitter during that time may have the greatest effect on the ultimate success or failure of the hitter. At elite levels of baseball competition, a typical hitter bats four times during the course of a game, usually seeing a total of 12 to 20 pitches. This means that within a typical baseball game, a batter must maximally focus his attention for a period less than 1 min. That leaves much time for a negative emotion, such as anxiety (or fear, shame, guilt, or contempt), to develop.

Although much sport psychology research has focused on the effects of precompetition anxiety and its relationship with performance, the sport of baseball—in particular the task of hitting—offers evidence that focusing solely on preperformance anxiety levels ignores a significant portion of the performance process. Hanin (2000) has suggested that performance is a cyclical, multistage endeavor, incorporating preparation (preperformance), execution (during performance), and evaluation (postperformance). Immediately following evaluation, preparation occurs, and the cycle begins anew.

For a baseball hitter, these three segments may occur on both a macro and a micro basis. From a macro perspective, *preparation* connotes pregame, *execution* connotes during the game, and *evaluation* connotes postgame. Most hitters begin the process of attending to the cognitive demands of performing during pregame batting practice, the purpose of which is both to warm up the body and to begin to focus attention on the upcoming game. However, environmental factors, interpersonal variables, and intrapersonal considerations may affect the attentional resources brought to bear by a hitter during the game that day. A hitter may begin the game in a positive emotional state, with peak levels of alertness and concentration, yet events during the game may create anxiety (or another negative emotion), reducing his attentional functioning and affecting his performance for the remainder of the competition. The process of evaluation is also very critical to managing and focusing an athlete's attention. Berating or critical comments regarding performance by a coach, a teammate, the media, or a family member or in the form of self-talk may create negative emotions and stress that adversely affect attention. If not dealt with directly, this negative affect may linger into the preparation and possibly the execution phase of a future game, adversely affecting performance.

On a micro level, the performance process occurs with each pitch. This also illustrates how baseball hitting combines aspects of externally and self-paced tasks. During an at-bat, elite hitters often use a prepitch preparation routine designed to make them comfortable and confident and to provide an internal mechanism to focus alertness and concentration on the ensuing pitch.

The evaluation phase that occurs after each pitch may be the most important phase during an at-bat. Elite hitters, because of their exceptional visual tracking skills, are able to follow the baseball longer and thus are able to gain more information from the pitch. Whether a pitch is taken, swung at and missed, fouled off, or put in play, the hitter analyzes the information derived immediately. He may also receive feedback from a coach, teammates, opponents, or the fans, which could produce anxiety that disrupts the performance cycle as the hitter attempts to begin the preparation phase for the next pitch.

As mentioned earlier, the time elapsed during the actual pitch delivery is approximately 2 s, with about 20 s between pitches. Many elite hitters, when they are performing well, may not even be consciously aware of the performance process while or after it occurs. Often, when asked afterward what they were thinking during an excellent at-bat, elite hitters say, "Nothing," because they are unable to consciously verbally recall their thoughts during performance. Yet it is obvious that these players are performing at heightened states of alertness and concentration, their attention focused maximally. What they *are* often able to recall during an evaluation of a successful at-bat is *visual* information—that the ball looked much larger or seemed to slow down or that they were able to detect the spin on the ball very quickly (identifying the type of pitch).

When elite hitters are suffering the attentional effects of heightened anxiety or other negative emotions, however, they often claim to be unable to "pick the ball up," see the spin of breaking pitches, or "pull the trigger" on a good pitch. When they reach two strikes, anxious hitters may also consciously become aware of ironic or negative thinking patterns, telling themselves via self-talk, "Don't strike out," or, "Here it goes, I'm gonna whiff again." As their attention narrows, they consciously try harder, which causes them to become distracted and focus on irrelevant cues instead. Perhaps they shift their focus from the pitcher and the area of ball release to some portion of their body that they wish to consciously control during the pitch. Regardless, the performance process of each takes only a handful of seconds, and unless the hitter is alert and focusing his attention on the right thing at the right time, for the right amount of time, he is destined to fail.

To demonstrate the principles of visual attention outlined above and to test the hypothesized interaction of confidence and anxiety associated with baseball hitting performance, we present here an applied case study in which a unique and innovative imagery/video/EEG biofeedback protocol is used. The case study was performed during the off-season period of a collegiate baseball player struggling to regain confidence after a serious eye injury.

METHOD

Participant

The participant in this applied case study was a 21-year-old collegiate baseball player at a National Collegiate Athletic Association Division I university beginning his junior (3rd) year of collegiate competition. He had played organized baseball since the age of 8, had been an All-State player in high school, and was voted a Freshman All American after the completion of his first season at the college level. Five months prior to our meeting, he had suffered a serious eye injury during his sophomore competitive season. While batting, he was hit in the face with a pitch, which fractured his cheekbone and eye socket; initially it had appeared he would miss the remainder of that season and perhaps have irreversible damage to his vision. After surgery, however, he healed rapidly and was given medical clearance to return to competition just 6 weeks later.

After finishing out the season in disappointing fashion, posting batting statistics well below that of his prior All American season, he reported to the same highly competitive summer team he had played for the year before. In a league of other elite collegiate players, he performed poorly, which led to his request for a sport psychology consultation with the lead author. After he arrived back on campus for the fall semester, an initial meeting between the player and the lead author was arranged. Both the head coach and the batting coach of the hitter's collegiate team were aware of the consultation and endorsed the process.

Measures and Procedure

No standardized sport psychology instruments were appropriate to gather information for a pre-/postintervention measurement. Instead, we decided to rely on an extensive qualitative interview and evaluation format. Statistical measures of baseball performance—in particular, batting average, on-base percentage, and strike out/at-bat ratio during the upcoming competitive season—provided the qualitative assessment of changes associated with this intervention.

The consultation was divided into three stages: (a) interview and evaluation, (b) implementation of the intervention, and (c) follow-up and assessment of intervention efficacy. At the initial meeting, the player expressed to the consultant that he had been bothered by recurring doubts about whether his vision was 100%, yet he could not pinpoint any exact problems. He was worried that lingering effects from the injury were affecting his performance. However, his surgeon had recently made a final examination and given him a clean bill of health, and he also had been examined by his ophthalmologist, who assured him that he had no permanent damage to his eye and that his vision was normal.

That summer, the hitter had struck out more often than usual and had begun to feel cognitively anxious whenever he reached two strikes during an at-bat. He did not report any increase in somatic anxiety; he stated he was never really "nervous" prior to or during at-bats before his injury, and he had felt no different after the injury. It seemed apparent to the consultant that the traumatic injury, although physically healed, had left a psychological scar, perhaps in the form of an especially threatening emotional "memory" that was affecting the hitter's attention and eroding his self-confidence.

Recent neuroscientific research illustrates how emotional memories such as this may occur (Johnson, 2003). It appears that especially threatening or harmful emotional events (e.g., being hit in the face by a pitch) are "underlined" by the brain's cortex and then stored in the amygdala for future emotional reference. When a similar threatening situation occurs, information processed via the visual cortex takes a "low road" immediately to the amygdala, bypassing the area of the cortex involved with cognition, activating the stored fear response without cognitive appraisal. The effect is an exceptionally strong emotional response.

The consultant suggested to the hitter that perhaps he was experiencing an unconscious fear of being hit and injured again or anxiety created by his doubts regarding his visual acuity. These negative emotions were damaging his ability to concentrate and maintain alertness while batting during games. The hitter appeared relieved after receiving reassurance from the consultant that, although it was reasonable to be fearful in this circumstance, as his injury was especially frightening, painful, and traumatic, the fear and anxiety were manageable. The consultant also suggested that although the hitter's doctors might have deemed his vision normal, the visual demands of hitting a baseball traveling close to 90 mph are extraordinary, and, as an elite hitter, he should trust his instincts. If he felt his vision was not 100%, then it probably was not. Eager to perform at the level he expected from himself and was accustomed to, the hitter was open to this intervention.

The consultant explained the concepts of attention and concentration and the high levels of each needed to be a successful elite hitter and also explained how EEG biofeedback could be used to shape them. Although conventional sport psychology wisdom suggests that anxiety has a positive inverse correlation with performance, a pair of recent meta-analyses cast doubt on this premise, instead finding that self-confidence exhibited a stronger and more consistent relationship with performance than either measure of anxiety (Craft, Magyar, Becker, & Feltz, 2003; Woodman & Hardy, 2003). Thus, the goal of the consultant was to create an intervention that could sharpen and enhance the hitter's concentration and attention, improving his ability to focus externally on each pitch, thereby increasing his self-confidence and thus improving performance. A multimethod intervention was designed, incorporating traditional breathing (relaxation) training, a series of visual tracking exercises, imagery, and EEG biofeedback.

The intervention lasted a total of four 1-hr sessions, conducted once per week after the initial interview and evaluation meeting. Each session followed this format in this order:

1. Using a simple metronome program, the hitter performed diaphragmatic breathing to a beat of 6 s inhalation and 4 s exhalation for approximately 5 min. The hitter was instructed to attempt to maintain this breathing pattern on his own for the rest of the session.

2. Next, the hitter performed the Brain Gym (Dennison & Dennison, 1989) exercise "cross-crawl" for 2 min. While standing with both arms at the side, one lifts one's left arm and right leg slowly, with elbow and knee touching. Then one lifts one's right arm and left leg in the same fashion. The object of this exercise is to improve *laterality*, or coordination, between the hemispheres of the brain.

3. For the next 10 min, the hitter performed the visual exercises. First, he

performed Brain Gym "lazy eights", in which one extends an arm in front of the body and, while holding the thumb upward, moves the hand slowly in a figure-eight pattern while focusing vision on the thumb and tracking its movement. Beginning with the second session, the hitter drew figure eights of various sizes with pencil on paper while tracking the path of the pencil visually. During the third and fourth sessions, he visually tracked baseballs moved by the consultant through his field of vision in figure-eight patterns at various distances away from him. The second vision exercise, which used the HRA Sports Vision (Silver Spring, MD) mini vision ring, followed. This apparatus is a plastic ring 12 in. (30.48 cm) in diameter, with a plastic wiffle ball attached to the ring. The object of the exercise is to visually track the ball while the ring spins toward you (after being tossed by a partner) and then catch the ball only (not the ring) with both hands.

4. The hitter finished each session with 30 min of imagery used in conjunction with EEG biofeedback. The EEG biofeedback device used was a NeuroTek Technologies (NeuroTek, LLC, Goshen, KY) Peak Achievement Trainer. The instrument has a reinforcing suppression of 0–40 Hz brain wave activity, the idling rhythms associated with strong interest or absorption in a mental task.

During the first session, the hitter received auditory assistance with the EEG biofeedback. By the next session, he was able to use the protocol without auditory feedback. While the hitter imagined an at-bat, the biofeedback data were monitored and feedback was reflected to the hitter regarding his concentration and alertness levels. The instructions to the hitter for the internal imagery were to visualize himself hitting a pitch low and on the outside half of the strike zone and to feel the ball squarely hitting the bat. During the next session, the hitter began with the imagery training, only now he performed it while in his batting stance, holding a baseball bat in his hands. His instructions for the imagery were the same as in the prior session. In the fourth and final session, the hitter performed internal imagery, but did so while viewing a video display of a pitcher who wound up and delivered a baseball toward home plate. The video was captured from directly behind the catcher, a very close approximation of what a batter would see while standing in the batter's box—in essence, a "hitter's eye" view. The hitter was instructed to "lock in" on the pitcher just as he would during a game and imagine swinging and hitting the baseball, also focusing on the kinesthetic feel of the impact of the ball against the bat. After each video play (which lasted 3 s), the biofeedback results were reviewed to determine whether the hitter had achieved an optimum level of concentration and alertness.

After the implementation of the complete four sessions of the intervention, the hitter and the consultant spoke occasionally via telephone during the next several months to periodically review the hitter's progress while he participated in scheduled team practice sessions. They also spoke occasionally during the competitive season. The conversations were typically brief, friendly, and informal.

RESULTS

During the spring season that followed the intervention, the hitter enjoyed renewed success and surpassed the statistical achievements of his first 2 years. His batting average improved to .356 from the prior season's .294 when he had been injured (and bettered the .310 he had achieved the year before that). Even more remarkable was his strike-out ratio. During the season of his injury he had struck out once every 4.76 at-bats, which had worsened from the ratio of once every 5.05 at-bats he had experienced as a freshman. After the sport psychology intervention, the ratio improved over 100%, as the hitter limited his strike outs to one every 10.61 at-bats. His slugging percentage also improved, jumping to .534 from the .429 of the prior season and the .460 mark of his 1st year. Although the intervention had been aimed at improving his hitting performance, a noteworthy byproduct was the hitter's fielding—he made only one error in 49 games, for a .995 fielding percentage, an improvement from .965 the season prior. Following the season he was named a third-team All American.

During the next season, the hitter had no sport psychology training with the consultant, simply following traditional baseball training methods that he had used during his freshman and sophomore years before the eye injury. At present, the hitter's statistics have regressed to levels that existed immediately after the injury at the lowest level of performance. The results are summarized in Table 1.

DISCUSSION

Compared with past seasons, the only substantial difference in the hitter's off-season preparation was the intervention provided by the consul-

Table 1. Pre- and Postintervention Statistics for Case Study With a Collegiate Baseball Player

Year/season	Bat Avg.	Slug %	AB/SO Ratio	Fielding %
Freshman (no training)	.310	.460	5.05	.992
Sophomore (preintervention)	.294	.429	4.76	.965
Junior (postintervention)	.356	.534	10.61	.995
Senior (no training)	.316	.497	5.67	.979

Note. Bat avg. = batting average, base hits/official times at-bat
Slug % = slugging percentage, total bases/official times at-bat
AB/SO Ratio = official times at-bat/strike outs
Fielding % = fielding percentage, total fielding chances minus fielding errors/total fielding chances

tant. The primary purpose of the intervention was to increase the hitter's self-confidence. Although no self-confidence instruments were used, interviews and one-on-one interaction between the consultant and the hitter were extensive. Postintervention interviews made it clear that the hitter did feel more confident. The EEG biofeedback gave the hitter an understanding of what it meant to concentrate maximally and attain a state of heightened alertness—that is, the mental skills necessary for baseball success at an elite level—and he was able to transfer these skills from an applied to a competitive setting and consistently perform at the substantial level of his physical skills. When asked at the completion of the competitive season to rate the effect of the intervention on his self-confidence on a 7-point scale, with 4 being neutral, the hitter replied, "At least a 6." Further, there is unequivocal evidence that his performance did improve. However, because of the multiple components it comprised, how can we be certain that the imagery/biofeedback training was the cause of the effect?

There are several reasons why multiple methodologies were used within the applied intervention. One physiological consequence of stress is shallow breathing patterns; therefore, the traditional stress management technique of relaxation training was incorporated (Hafen, Karren, Frandsen, & Smith, 1996). The Brain Gym exercises and vision ring were used to (a) give the hitter the belief that he was doing something to strengthen and improve his vision and (b) test it in a dynamic visual task similar to that required for hitting. This combination was expected to demonstrate to the hitter that his vision was not compromised by the injury. Imagery training has been documented as categorically improving self-confidence (Beauchamp, Bray, & Albinson, 2002; Jones, Bray, Mace, MacRae, & Stockbridge, 2002; Taylor & Shaw, 2002), and the hitter expressed that his self-confidence was low; thus, imagery training was deemed a critical component of the intervention.

Although imagery training is a standard component of many sport psychology interventions and is generally accepted as an effective means of improving performance, there remains much disagreement among sport psychologists as to its underlying neural mechanisms (Collins & Hale, 1997; Keil, Holmes, Bennett, Davids, & Smith, 2000). Keil et al., on the basis of the dual-pathways visual system theory proposed by Milner and Goodale (1995), suggested that the dorsal pathway, ending in the parietal cortex, is more closely associated with perception–action coupling and has a significant role in motor imagery and the development of attention in athletes. Because athletes are rarely able to verbally recall optimal performance in visuomotor terms, Keil et al. questioned the use of verbal imagery scripts that develop ventral processing. Instead, they predicted that visuomotor experiences, such as imagery that integrates nonconscious visual and kinesthetic attentional processes, could lead to a reorganization in the dorsal pathway and to improved performance. Thus, the challenge to sport psychologists is to design methods of realistic imagery that abet mental rehearsal through the dorsal stream.

EEG biofeedback, primarily used to train attention, is a relatively new mode of applied psychophysiological intervention within sports psychology (Carlstedt, 2001). However, Carlstedt (2001) argued that the invasiveness of EEG equipment makes it impractical, if not impossible, to realistically train attention in athletes using EEG biofeedback. Although we agree with the impracticalities of monitoring EEG data during competition, we believe that our EEG biofeedback/video/internal imagery protocol provides athletes in a variety of sports a feasible and realistic method of training attention through the dorsal pathway suggested by Keil et al. (2000).

There are several keys to our training protocol that allow applied sport psychology practitioners to train the perception–action systems used during motor execution. First, the use of advanced video technology enables the creation of visual stimuli that are vividly realistic and gamelike. Second, the only imagery instruction necessary for the athlete is to focus on the kinesthetic feel of optimal performance. Although elite athletes typically are unable to verbally describe excellent performance, they *are* able to describe the feel of the experience. The sweet crack of the ball off of the bat or racket is often indelibly etched into the brain, and the act of experiencing that feel during the video/imagery training should enhance self-confidence. Also, EEG biofeedback allows an applied practitioner to determine the magnitude of attentional function—in other words, did the athlete get in the zone at the right time, and how long did the athlete stay there? This creates learning opportunities not otherwise available during competition.

Another advantage derived from EEG/video training is the ability to train and monitor the focus of attention used by the athlete. Although using an external focus of attention has been shown to result in improved performance of self-paced tasks (Liao & Masters, 2002; Radlo et al., 2002), our case study suggests that training externally paced sport athletes to focus externally produces superior results as well. At elite levels of many externally paced sports, balls are traveling at speeds approaching or beyond 100 mph. Athletes do not have time to focus on internal kinesthetic aspects of their swing but instead must react automatically, trusting their body and individual biomechanics. EEG biofeedback data enable the sport psychology consultant to monitor the quality and efficiency of the athlete's attention while the athlete focuses on the most essential task of the sport, seeing the ball. (In our case study, the hitter was instructed to focus on the task of visually tracking the baseball and to feel the result of making a good swing—the solid feel of ball hitting bat.)

The visual phenomenon known as the "quiet eye" has been illustrated in a variety of sports. In essence, the quiet eye refers to the final gaze and fixation before a motor movement begins (Vickers, 1996). In many self-paced tasks, experts have exhibited a longer final fixation than less-skilled performers. Harle and Vickers (2001) have demonstrated that basketball players may be trained to lengthen quiet eye periods, which results in improved free-throw shooting performance. Our case study also suggests that the quiet eye can be trained via a video/biofeedback protocol and that this protocol could easily be extended to softball and racquet sports such as tennis, badminton, squash, and racquetball.

Because self-confidence has been exhibited to have a greater correlation with performance than anxiety (Covassin & Pero, 2003; Hassmen, Raglin, & Lundqvist, 2004; Voight, Callahan, & Ryska, 2000; Woodman & Hardy, 2003), it appears that applied practitioners should focus interventions on methods to improve self-confidence rather than reducing anxiety. Although our case study illustrates that using EEG biofeedback in conjunction with internal imagery and video stimulus presentation appears to increase self-confidence, these results should be replicated with other athletes in baseball and sports such as softball, tennis, badminton, squash, or racquetball. The same type of video of a pitcher used in our baseball case study could be made to use with softball hitters. In the racquet sports mentioned, video from the perspective of receiving a stroke from an opponent could easily be captured and used to train the attention of a performer in a specific sport.

Although the biofeedback equipment used in this case study requires a headphone and sensors connected by wires to a laptop computer, which thus makes it difficult to use during actual skill performance, new technology developed since has created a wireless version of the Peak Achievement Trainer. This wireless version perhaps provides the capability to monitor neural activity in actual practice environments. Also, new technologies are being developed that allow sensors (with the ability to capture heart rate data, which may be a suitable indicator of attention, as Carlstedt, 2001, suggested) to be woven directly into fabrics, enabling uninvasive monitoring during competition or practice settings.

Although many sport psychologists have been reluctant to embrace psychophysiology and technology allowing data capture and training of critical attentional functions, a small cadre of practitioners has embraced it. As technology becomes more sophisticated and user friendly, the possibilities for innovative sport scientists to expand their practices through creative and beneficial uses of these technologies may increase greatly.

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