

Assessment in Action

Neurofeedback and Target Sports

An EEG stress assessment identifies problematic areas of cognitive flexibility for athletes in target sports. Next, EEG monitoring while aiming and shooting, plus athlete self-report, reveals the cognitive experiences that distinguish good shots from less accurate ones. The results of these assessments guide the subsequent neurofeedback training. Practicing raising alpha waves and SMR and lowering beta waves, for example, increases the ability to shift into that mental state when desired. This cognitive shift is added to the preshot routine to improve accuracy and confidence.

required by their sport. These training protocols are individually developed for athletes based on their psychophysiological stress assessment profiles. Generally, neurofeedback training may include variations of these protocols designed to do the following:

- Reduce internal distraction (suppression of 8-10 Hz low alpha) and increase calm focus (elevation of 12-15 Hz SMR) prior to execution of a motor task.
- Increase calm external awareness (elevation of 11-12 Hz high alpha) and (13-15 Hz SMR) and decrease worry (19-35 Hz).
- Move in and out of a state of problem solving (16-18 Hz) or mental work (39-41 Hz). Athletes practice clearing their minds and refocusing.
- Augment imagery skills (increase 6-10 Hz theta-alpha). Closed eyes strengthen this ability.

Visual Assessment

The fastest muscle movement in the human body is a saccade at 1,000 degrees per second (Holmqvist & Nystrom, 2011). The purpose of a saccade is to move the eye from one relevant location (or cue) to another. An athlete's ability

to track objects and react appropriately develops with experience and at an individualized pace. Visual attention, perceptual information processing, and response selection can be disrupted by anxiety and distraction. Training to improve the allocation of attentional resources can enhance the development of these skills and protect them against the effects of pressure (Vine, Moore, & Wilson, 2014).

Benefits of Visual Search Assessment

Effective use of visual gaze behaviors (see table 10.2) and, in turn, the assessment of perceptual-cognitive skills, provides the following benefits:

- **Anticipation:** Looking at the right spot at the right time and making sense of what is seen enhances the ability to predict future events (Farrow & Abernathy, 2002; Savelsbergh, Williams, van der Kamp, & Ward, 2002).
- **Attention:** Efficient use of attentional resources involves focusing on the most important cues while ignoring distractions to take in the minimum amount of essential information. This results in the most efficient processing (Williams & Davids, 1998).
- **Memory:** Synthesis of past events into meaningful chunks of information enables athletes to employ effective strategies and tactics (Abernathy, Baker, & Cote, 2005).
- **Pattern recognition:** The ability to read plays based on experience (North & Williams, 2008) allows athletes to synthesize patterns and learn from them.
- **Problem solving:** The ability to conceptually organize thoughts based on visual information processing influences athletes' ability to determine what has worked and what hasn't (McPherson & Kernodle, 2003).
- **Decision making:** Athletes with effective perceptual-cognitive skills can read, anticipate, and make accurate decisions quickly (Vaeyens, Lenoir, Williams, Mazyn, & Philippaerts, 2007).

Table 10.2 Characteristics of Visual Perception (Gaze Behaviors) for Expert Athletes Compared With Less Experienced Athletes

Experts	Less experienced
Fewer visual cues	Many more visual cues
High consistency in visual search	High variability in visual search
View cues in the same order	View cues in varying order
Accurate interpretation of what is seen	Guesswork
Look only at relevant cues	Many irrelevant cues
Consistent eye routines	Unsystematic visual search; no routines

- **Situational awareness:** The ability to perceive and understand the environment (Caserta & Abrams, 2007) improves as athletes know what is visually important and what to ignore.
- **Motor efficiency:** The result of effective perception and cognition in sport is often motor efficiency (Williams & Ericsson, 2007).
- **Stress reduction:** A further benefit of effective perceptual-cognitive skills is reduced stress (Gerstenberg, 2012). Being more focused and reducing information processing can lead to a cascading reduction in stress (Vickers & Lewinski, 2012).
- **Alertness and resilience:** The ability to stay alert over time is an important benefit of perceptual-cognitive skills. In any situation with a potential for fatigue, the more efficient the perceptions, cognitions, and motor responses, the greater the alertness and resilience (Williams, Hodges, North, & Barton, 2006).

Eye Tracking

Unlike biomechanical changes, which are readily observable, visual and cognitive processes are not so easily scrutinized. An eye tracker is a special pair of glasses that records athletes' point of gaze upon the environment, taking pictures of the location of the gaze at various frame rates (e.g., 60 times per second), similar to a camera. Eye-tracking technology enables us to make three types of visual feedback assessments.

Gaze Location

An eye tracker examines the location of a person's focal vision (gaze point) within an environment to determine if the subject is attending to the appropriate cues (see figure 10.4). For example, research has demonstrated that looking at the contact point when returning a serve in tennis assists in ball tracking (Murray & Hunfalvy, 2016). In baseball, the pitcher's hand positioning on the ball helps hitters determine the type of pitch that will be thrown (Takeuchi & Inomata, 2009).

Assessment of visual feedback gaze location using eye trackers is based on research using temporal occlusion (Farrow, Abernathy, & Jackson, 2005), where the task being viewed is stopped at various points before completion and athletes are asked to extrapolate information about what will happen in the future, such as the direction a ball will travel. Visual feedback is also based on cue occlusion (also called *spatial occlusion*) research (Muller & Abernathy, 2006), where important cues are blocked from view to determine their impact on performance. These assessment paradigms measure performance outcomes using additional tools such as pressure-sensitive floor mats and infrared beams that detect response time (Williams & Ericsson, 2005).

Common assessments of gaze error include missed cues, scattered visual search, and late tracking. Missed cues (see figure 10.5) are often caused by a lack of perceptual-cognitive expertise or a failure to understand what the cue reveals, why it is important, and how it can be used to improve performance.

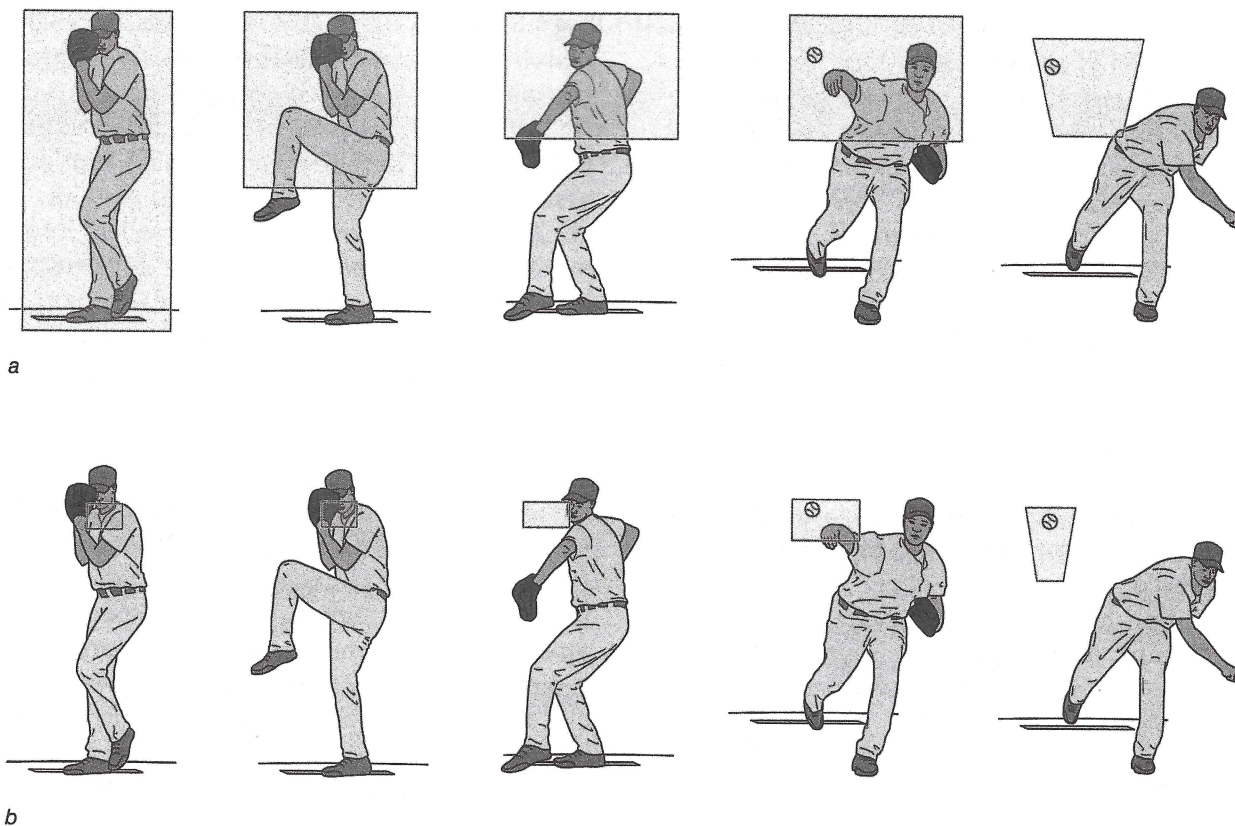


Figure 10.4 (a) Minor League Baseball aggregate visual search cues versus (b) Major League Baseball aggregate visual search cues. Major leaguers demonstrate attention to fewer and more localized visual cues.

Static image of where athlete was looking and ideal visual cue	Arms	Ball	Contact	
RightEye score out of 100	97	0 MISSED CUE	40	20

Figure 10.5 Gaze location and important visual cues. Solid circles represent important visual cues. Dotted circles represent the athlete's actual gaze location. Convergence of the two is scored out of a possible 100. Here, the missed cue in the toss phase results in failure to target the contact point and late ball tracking.

A second common error in gaze location is a scattered visual search pattern. Figure 10.4a demonstrates the wider visual search area of a less experienced baseball player. Research demonstrates that experts exhibit fewer fixations of longer duration compared with less skilled performers (Gegenfurtner, Lehtinen, & Säljö, 2011; Mann, Ward, Williams, & Janelle, 2007). Less skilled athletes who display a scattered search pattern end up processing too many cues because they are unsure where to look and what is important.

Late tracking is another common error in gaze location. This occurs especially in fast-moving, open-skilled sports when athletes start late and do not have time to catch up. This can be due to a lack of expertise or a lack of attention or readiness. Late tracking in the beginning of a sequence has negative consequences that multiply further along the biomechanical phases.

Decision Making

In addition to the techniques used in gaze location assessment, the assessment of tactics, strategy, and sequences of play includes showing video (Vickers, 2007) or static images (Bilalic, Langner, Erb, & Grodd, 2010). Alternatively, athletes can be asked to recall certain aspects of what they saw (e.g., the type of play or location of an opponent). Then, athletes are asked to determine what they expect to happen next (event probability) and what would be the best response based on what they perceived (Crognier & Fery, 2005). The assessment includes measured recognition of offense and defense strategies, which guides subsequent training to improve the speed of recognition (Caserta & Abrams, 2007).

Psychological States

Eye-tracking assessment helps us understand the perceptions and thoughts of athletes. Disruptions in visual routines, such as changes in back-and-forth gazes, visual cues, and how fast the eyes move from one cue to another, can be indicators of stress. Inattention, uncertainty,

cognitive overload, or rushing can disrupt visual search patterns and reduce the quality of information available for decision making.

With increasing perceptual-cognitive expertise comes the development of visual routines, a subset of preperformance routines (Kim et al., 2008). Visual routines extract salient information from the environment by consistently looking at the same cue at the same time within a biomechanical sequence. For example, eye-tracker research shows that when returning a serve in tennis, the visual routine should follow this sequence: focal attention on the general body position of the opponent, tossing arm, toss, contact point, and then ball tracking (Hunfalvy, 2004). Repetition of the same sequence of visual cues limits the cognitive load required to process the information. The more specific the visual routine, the more effectively information is tracked and processed. Visual search routines can be assessed under various cognitive load conditions, such as at the beginning of practice without fatigue, during drills, and toward the end of practice, when athletes begin to tire and their perceptual-cognitive skills decline.

Part of the perceptual-cognitive preperformance routine is dynamic shifts in visual fixations in which athletes look at a near target and then at a far target for at least one sequence (Hunfalvy et al., in preparation). There may be several reasons for this sequence, including warming up the eye muscles to prepare for fast movement (similar to warming up other muscles before performance) and relaxing and focusing (similar to a preperformance routine). Depending on the task, athletes may dynamically shift between one and three times (Bridgeman, 2007). Performance is poor if the calibration is too short (indicating inattention, rushing, or stress) or too long (indicating indecision or cognitive overload). Changes in perceptual-cognitive psychological states can be measured through a variety of eye-tracking data (see table 10.3).

These states influence each other, and a disruption in one can have a cascading negative effect on performance (see figure 10.6).

Table 10.3 Perceptual-Cognitive Psychological States Measured Through Eye-Tracking Data

Assessment metric	Defined	Possible indicators
Visual routine	Refers to a consistent pattern of gaze location and timing.	Without a routine there is distraction, cognitive overload, lack of skill, and stress.
Gaze fluidity	Movement of the eyes from one location to another. Reduced fluidity resembles stage fright: The eye remains still, looking at one location for several seconds.	Cognitive overload and stress; indicators include reduced reaction time.
Pupil dilation	Indication of stress. Pupil dilation is the size of the pupil, measured in millimeters.	Jomier, Rault, and Aylward (2004) show pupil dilation as an indicator of stress. Difficult to measure unless assessment is conducted in an environment with controlled lighting.
Search rate	Refers to the number of fixations divided by task time.	Increases in fixations with shorter duration could mean information overload or confusion.
Dynamic shifts	Refers to at least one repetition between a near and far target before the initiation of an action.	If absent when previously present, indicates inattention, cognitive overload, or stress.
Quiet eye	A final fixation or tracking gaze on a specific location or object within the visuomotor workspace (Vickers, 2007) allows for information processing (Klostermann, Kredel, & Hossner, 2013).	Absence of quiet eye may be related to indecision and feelings of being rushed, adding to stress levels.

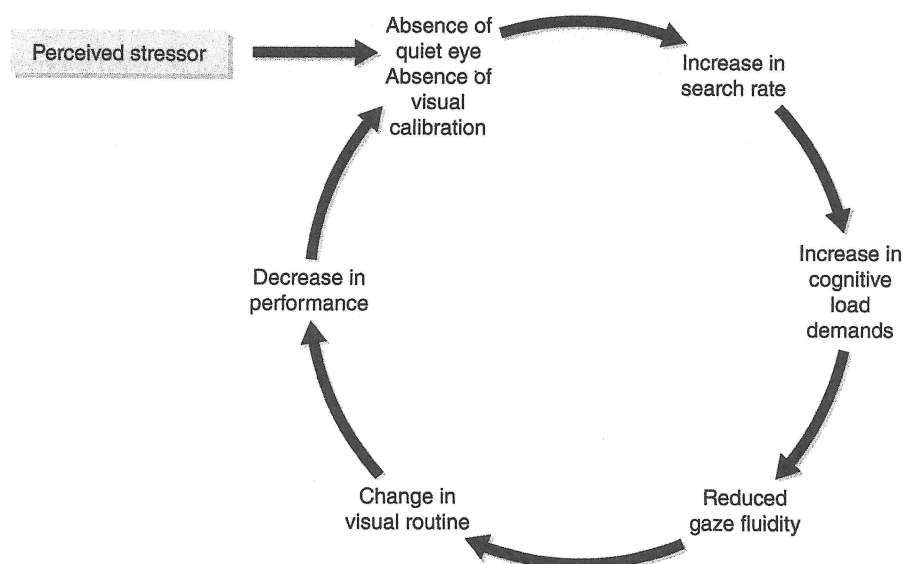


Figure 10.6 Potential downward spiral seen in eye-tracking assessment data.

Assessment in Action

Eye Tracking and Basketball

A visual search assessment is given to an athlete while shooting free throws. The results reveal an abbreviated quiet-eye period under conditions of fatigue or anxiety. Giving this feedback to the athlete increases awareness of the importance of a steady gaze on the target before movement initiation. Quiet-eye training under stress can make goal-directed visual control more resilient to pressure (Vine et al., 2011, 2014; Wilson, Vine, & Wood, 2009).

Visual and Perceptual-Cognitive Training With Athletes

Effective assessment of perceptual-cognitive skills allows the practitioner to create awareness. Awareness is a precursor to developing strategies for skill enhancement and redirecting what is ineffective.

Phases

There are three phases of training: awareness, association, and automaticity. *Awareness* refers to consciousness of where one should be looking (e.g., looking at the hand placement on a ground stroke in tennis). During the *association* phase, athletes increase their knowledge of what information comes from the cue (e.g., placement of the hand on a tennis racket is an early indicator of spin). *Automaticity* refers to the phase where tracking the cue has been practiced until it requires little conscious thought.

Training should be designed with these three levels in mind. Training for awareness would include calling out a cue word when the hand placement is recognized (e.g., *western* indicating a western grip). Associations would include calling the spin as soon as it is recognized (e.g., *topspin*). Automaticity could include an interception timing drill where the person has to call the spin and then intercept it at the highest point.

Tools

Visual perception is attracted by the size, color, and movement of an object (Karwowski, 2006). Practitioners should use visual attractors such as highlighting, special effects, colored balls, and equipment to attract attention to important areas while reducing irrelevant areas of the visual field. This method engages the recognition and learning loop of visual perception (Braun & Deco, 2013).

A Word of Caution

Psychophysiological assessment is a sophisticated methodology that requires formal education. Supervised training and experience in both the implementation and analysis of biofeedback, neurofeedback, and visual feedback are essential. Due to the sensitivity of the equipment and the measures, improper use can easily compromise data quality and its value (Holmqvist & Nystrom, 2011). Certification in biofeedback and neurofeedback is strongly recommended for consultants who wish to perform psychophysiological assessment. Biofeedback Certification International Alliance (BCIA) is the certifying organization recognized by the Association for Applied Psychophysiology and Biofeedback (AAPB) and the International Society for Neurofeedback and Research (ISNR).