



Gaze Control and Motor Performance in Motor Expertise Studies: Focused Review of Field Application Research on Perceptual Skill Training

Seungmin Lee^a & Jongseong An^{b*}

^aProfessor, Division of Physical Education, Chungnam National University, Daejeon, Korea

^bAssociate Professor, Division of Sports and Leisure Studies, Busan University of Foreign Studies,
Busan, Korea

Abstract

This research reviews studies on sports performance and visual exploration strategies in the field of sports proficiency and comprehension. Accepting visual information is conducted through visual search, now referred to as visual exploration. Visual exploration refers to the process of paying attention to appropriate key clues that contain the necessary information to prepare and execute actions in a given circumstance or to make pertinent decisions. The visual exploration study uses an eye-tracking system to measure gaze fixation time and position, and to discern the disparity in the process of obtaining information between experienced and amateurs depending on the various sports fields and presents meaningful results in revealing the characteristics of the former: experienced individuals. The Vision-in-Action system presents a methodology that can solve the limitations of the visual exploration paradigm. That is, the movement pattern of the gaze is recorded at the same time as performing the physical technical movement performed in the actual sporting event. This methodology is consistent with a theoretical flow that emphasizes the perceptual-action coupling process. Research on visual exploration and exercise performance has been conducted in various sporting events such as aiming, conceptual, and tactical tasks. Specifically, in aiming tasks, QED is a crucial facet linked to performance accuracy. Based on these exploration studies, perceptual technology training is applied. Perception technology training is applied as a method of QED and gaze control training, and it is reported that it has a distinctively positive effect on improving performance.

Key words: quiet eye, gaze control, motor expertise, review article

Introduction

Various motor techniques in sports often require

sophisticated and delicate execution of complex body movements. Mastering these skills require appropriate processing of enormous amounts of contextual and personal information related to such skills. For example, in tasks, such as golf putting, shooting, and archery, highly sophisticated programming must be performed

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Correspondence : dragonjosh@bufs.ac.kr

at the neural level (Vickers, 1996). When performing these techniques, even a small error or slight distraction can lead to a huge difference in performance. Therefore, accurate and efficient movements and perceptual skills are important for successful exercise performance. A high level of perceptual ability plays a very important role in executing accurate and efficient movements (Williams et al., 1999). Furthermore, these perceptual skills are very important for effective motor performance as they are closely related to the ability to predict future events based on information generated from various environmental changes. Therefore, scholars who study motor behavior have emphasized the importance of perceptual skills for successful motor performance among psychological, physiological, mechanical, and technical characteristics of skilled workers through motor expertise studies.

Among the characteristics of experts identified so far, the factors suggested by Abernethy (1993) are as follows: first, experts possess extensive task-based knowledge, considered an essential skill in sports performance, not simply based on experience. Second, skilled persons store information as long-term memory in a hierarchical system, and information generated during movement is transmitted to the higher centers and feedback is utilized. Third, experts have the ability to more quickly and accurately recognize information generated in game situations. Fourth, skilled persons have an excellent predictive ability to selectively accept and utilize information from the environment. Lastly, skilled persons can evaluate and correct their movements within a limited time.

This ability of a skilled person is an important perceptual ability to successfully perform exercises in a game situation with characteristics, such as time limitation, uncertainty of events, and diversity of the environment. Therefore, investigating the characteristics of perceptual/cognitive factors possessed by skilled individuals can provide very important information to improve motor performance and learn motor skills.

The main question is whether the learning method

facilitates the acquisition of perceptual skills based on the perceptual abilities of skilled individuals revealed so far. Can the perceptual skills possessed by a skilled person be taught?

If an effective perceptual skill training program is developed, and meaningful improvement in players' predictive ability and motor performance can be expected through such perceptual skill training, it is expected that such programs will provide a lot of information on training methods to improve performance.

So far, regarding perceptual skills training, studies have been conducted in a hardware approach for visual perception based on the fact that skilled people show excellent motor performance because they have excellent visual systems, such as static vision, dynamic vision, depth perception, and gaze. However, these studies show that the relationship between excellent motor performance and visual function in skilled individuals have a very low correlation, leading to the conclusion that visual function does not limit performance in sports. Furthermore, Wood & Abernethy (1997), in a study that verified the effectiveness of a "Sports vision" training program, found that a 4-week clinical vision training program improved some visual functions but did not significantly improve actual motor performance. Therefore, unlike these hardware-based studies, motor expertise studies were conducted in a software-based approach, and related gaze control and perceptual skill training for quiet eye (QE) will be reviewed.

Techniques for Measuring Perceptual Skills

Eye Movement-Tracking Device

Various eye movement measurement techniques have been used to measure human information processing behaviorally. Electrooculography (EGM), which is the starting point of eye movement measurement research,

uses the deflection of current flowing in the cornea. This method measures minute movements by passing vertical and horizontal currents through the eyeball. However, it is used only in the medical field because it is difficult to relate to, manipulate, and correct an actual visual object. The scleral search coil technique, developed by Robinson (1963), estimates eye movement by a lens containing an induction coil that is worn over the cornea and recognizing its movement. Corneal reflection is currently the most widely used measurement method for eye movement. The principle of this method is to measure the movement of the eyeball using the angle of reflection of the infrared rays on the cornea while looking at the object. Unlike other measurement methods, it is easy to change depending on the performer and is less affected by blinking of the eye or natural rapid eye movements. NAC-Eye Marker Recorder and ASL-Series 4000 models applied to the corneal-reflection method are the most commonly used equipment in exercise science. Recently, a mobile eye tracker (ASL) has been developed to facilitate field research.

Visual Search Strategy

In order to successfully exhibit exercise adeptness, one must have the ability to utilize all information that occurs in an exercise situation. In particular, optical information is considered very important for preparing an action before performing an exercise and making agile decisions about a situation or action. In order to perform most motor skills, appropriate clues required for a particular situation must be selected from the environment. In addition, vision is most pivotal in selecting these clues than other human senses. Visual information is accepted through a process called visual search. Visual exploration refers to the process of paying visible attention to appropriate clues in an exercise performance environment. In sports, a system that measures eye movement has been used to determine the difference between visual search strategies and information acquisition. The basic assumption of these

measurements reverses the perceptual strategies performed by performers to selectively pay attention and give meaning to cues that are appropriate for eye fixation (Abernethy, 1993). The biggest limitation of the visual exploration paradigm was that, unlike conventional sports performance, physical movements were excluded from the task. However, in recent studies, research has been conducted in various ways by virtualizing real situations.

Vision-in-Action System

Studies on ice hockey (Bard & Fleury, 1981), basketball (Ripoll et al., 1982), and baseball (Bahill & LaRitz, 1984), which were conducted in the early 1980s, were the basis for field-based research. In a study by Ripoll et al. (1982), it was shown that in basketball free throw tasks, skilled players maintain eye-head stability and fixed their eyes on the rim early before throwing the ball. In a study by Bahill & LaRitz (1984), the head movements of hitters tracking a ball were monitored using a pulley and a camera attached to the head, and eye movements were measured using EGM. The results of the study showed that when an expert tracked the ball, their gaze and head moved together, and anticipatory saccade movement of the eyeball occurred at the point where the ball and bat made contact. Recently, many attempts have been made to measure performers' gaze behavior in real-game situations. Vickers (1996) created and used a vision-in-action (VIA) system by combining the performer's gaze and performing motion in a basketball assignment. This system synchronized the signals of the eye image, gaze fixation position, and performance motion image and integrated them into one image Figure 1. Since then, the VIA system has been applied to many studies on sports, such as table tennis (Rodrigues et al., 2002), golf (Vickers, in progress), and badminton (Kim et al., 2007). This has made it possible to examine the relationship between gaze control and motor performance in more detail.



Figure 1. 4 frames of a video recorded with the Vision-in-Action (VIA) system

Category of Gaze Control

Elements of Gaze Control

In the 1980s, as human memory representations, such as motor programs described in schematic theory, could not explain all complex human motor coordination with numerous degrees of freedom, new theoretical approaches, such as dynamic systems and ecological theories, began to emerge. With the introduction of Bernstein's (1967) neurophysiological and biomechanical studies on motor behavior, integrated research methods for motor behavior through kinematic analysis and EMG analysis began to emerge. Additionally, there have been attempts to explain the mechanism of motor behavior by considering the organism, task, and environment as one system, rather than research limited to only organisms. This theoretical approach was supported by a constraints-led perspective that applied an integrated model of dynamic systems theory, ecological theory, and cognitive psychology (Newell, 1986; Newell & McDonald, 1994). In explaining the mechanism of human motor behavior, this model showed a tendency to explain human motor behavior using the perception-action cycle process rather than seeing perception and action as separate areas.

Newell & McDonald (1994), who proposed the

cyclical process of perceptual-motion association, described the relationship between body movements and the performer's gaze behavior in a specific situation. Recently, a motion analysis system and a mobile eye tracker were integrally combined to examine the relationship between the performer's gaze and motion. Through these research methods, it was found that the performer's gaze behavior differed in gaze behavior strategy according to the characteristics of the task performed (aim task, interceptive task, or tactical task).

Aiming Task and Gaze Control

In aiming tasks, the functions of gaze and attention play a role in controlling the target's position in space and accurate aiming. In particular, aiming tasks can be classified into the following three categories: fixed targets, moving targets, and abstract targets. First, in a fixed-target task, the target is fixed at a stable and predictable location in space (e.g., the rim of a basketball, the target of a shooting, etc.). In the abstract-target task, the targets for gaze and aiming are fixed, but it appears in various abstract forms in space (e.g., a golf green with a slope, billiards, etc.). Finally, in the moving-target task, the gaze and the aiming target are either moving, or another performer determines their movement (e.g., passing the ball in soccer or throwing a rugby ball).

Interceptive Task and Gaze Control

An interceptive task is when an object moves toward the performer, and the performer’s gaze and attention tracks the object’s movement to locate it. In this task, gaze and attention go through the following three consecutive processes: object recognition, tracking, and control. In the object recognition phase, gaze fixation and tracking movement are used to detect the movement of an object. In the object-tracking phase, a smooth tracking motion with a low angular velocity of eye movement appears while maintaining the image of the

object on the retina of the performer. However, smooth tracking motion is used to detect deceleration and acceleration, rotation, and changes in the direction of motion of an object. Finally, in the control phase, operations, such as grabbing an object using a performer’s hand, swinging a baseball bat to hit a ball, or receiving a volleyball, are performed Figure 2.

Tactical Tasks and Eye Control

In tactical tasks, the characteristics of gaze behavior that appear in aiming and interceptive tasks seem complex. This is used to identify attack and defense tactics in team ball games, such as basketball, baseball, and soccer or to determine the race direction in skiing and car racing and to send the puck to the desired location in field hockey. Although the movements induced in these cases are different, the problem of gaze behavior is almost the same. Moreover, performers need to make the best judgment by searching for clues that contain the most important and predictive information in the environment (Klein, 1999). The physical movements of tactical tasks are very different, but the problem of gaze control that occurs in them is similar in a tactical context. Pattern recognition and tactical awareness are essential in sports, such as basketball, volleyball, hockey, soccer, skiing, and skating Figure 3.

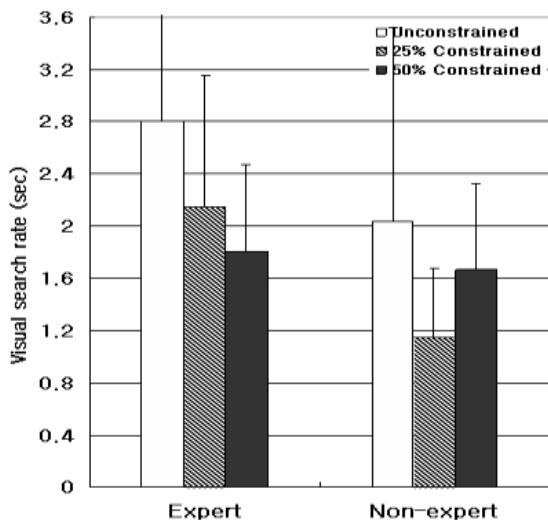


Figure 2. Comparison of visual search rate of an expert and non-expert at different constraints (assisted by an air pistol shooter)

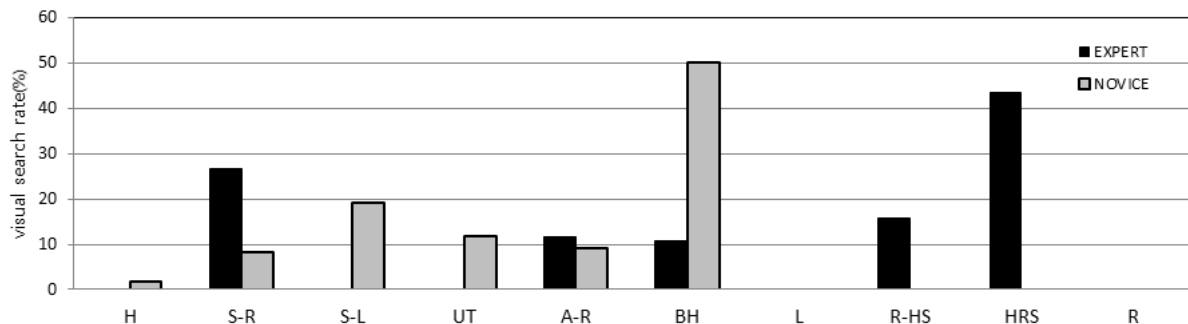


Figure 3. The comparison of visual search rates at different body anatomies between a expert and novice (H: head, S-R:shoulder-right, S-L:shoulder-left, UT: upper torso, A-R:arm-right, BH:ball-hand, L: leg, R-HS: head and shoulder space, HRS: head and release, R: release)

Factors That Influence Gaze Control

Number of Visuomotor Workspaces

The visuomotor workspaces refer to the spatial environment in which the performer's gaze actions and body movements occur. Visual search studies show that the number of visuomotor workspaces increases from a single aiming task to an interceptive task and then to a tactical task. There is one visuomotor workspace in a single aiming task (e.g., shooting, basketball free throw, etc.). In an interceptive task, the number of visuomotor workspaces is determined by the object's speed, size, and range of motion. Tactical assignments have the most significant number of visuomotor workspaces. For example, to search for the puck's movement in an ice hockey game, it is necessary to search for information about the location of nearby players and the speed of the puck. Therefore, it is very important for performers to extract the most valuable clues from the many clues in the visual motor area through gaze control before performing movements for successful movement and use them in the decision-making process.

Location and Number of Clues in the Visuomotor Workspace

Objects that appear in game situations, such as balls, pucks, shuttles, people (players, coaches, referees, etc.), and equipment, are crucial factors for performers to perform motions. While it is important to keep an eye on key cues in space, adepts use other strategies to acquire more useful information. For example, Tenenbaum (2003) suggests that the expert fixes his eyes on the spatial area and uses the "visual pivot" to get comprehensive information about the game through the environmental vision system rather than the focal vision system.

Gaze-Action Combination

The third factor is how the gaze is controlled at the

most critical moments during the performance of movement. Many researchers suggest that paying visual attention to the most appropriate location and cue at the right moment is an important factor in successful motor performance. For example, in a study on the darts task by Vickers et al. (2000), the effect of QE occurring before the main movement on exercise performance was analyzed. QE, first proposed by Vickers (1996), is related to the processing of visual information at a specific location before the performer performs the task and is an important temporal interval of cognitive information processing that is required to aim at the target accurately. As a result, the last gaze fixation time or QE occurs before the arm extension movement occurs, and there is no significant difference in the gaze fixation and duration of the section depending on success and failure. However, there are differences in the radial error of the gaze fixation position at the center of the target. These results indicate that it is important to know where to look and how much time is required for the aiming task; however, getting information about the target too soon or too late will achieve a different level of accuracy.

A Study on Gaze Control and Quiet Eye

Research on Single-Aim Tasks

Basketball Free Throw

To make an accurate shot in a basketball free throw task, it is important to fix the gaze on the target and maintain the gaze until the appropriate time (Harle & Vickers, 2001; Vickers, 1996). It has been shown that skilled players had less gaze fixation frequency than beginners or intermediate experts, and they also had less gaze fixation frequency when they threw more accurate shots. In addition, it was found that the error range of gaze fixation position of experts was smaller than that of unskilled performers. Although both players are

skilled, player A's free throw success rate in the previous season was 82%, while that of player B's was 65%. While player A fixed his gaze on one location while throwing free throws, player B showed an average of 2.3 eye fixations to the rim's front, back, and backboard. The movement of the gaze implies that the player's attention was switched (Corbetta, 1998; Deubel & Schneider, 1996); therefore, player A was more accurate in controlling gaze and focusing attention. However, player B's attention and gaze were not regulated at different levels. In addition to less frequent eye fixation, skilled players fix their gaze on the rim at the right time during the preparation and execution phases of the shot.

The QE duration of experienced players has four temporal-spatial characteristics related to performance accuracy. First, QE focuses on one key clue. Gaze fixation collects key information, and gaze fixation is defined as movement maintained at an angle of 30° or less for less than 100 ms. Second, the QE start point occurs before major physical movements occur. Third, the end-point of QE occurs when a movement of $35^\circ/\text{sec}$ or more appears. Finally, a long QE duration indicates a high level of skill and accuracy. The QE duration is "an important period of cognitive information processing in which factors constituting movement, such as speed, force, size, direction, are composed" (Williams et al., 2002).

Research on Abstract Aiming Tasks

Golf Putting

In the golf putting task, experts showed more effective gaze control than inexperienced participants (Kim, 2000; Vickers, 1992). In particular, it was found that experts used the quick eyeball movement between the hole and the ball while preparing for the golf stroke and fixed their gaze on the ball and hole for a longer time. On the other hand, it was found that beginners stared at the putter's head and tracked the ball after the stroke. In addition, it was found that skilled players fixed their gaze on a point behind the ball before performing the motion; however, the inexperienced person could not fix their gaze on a single point as in the basketball free throw task (Vickers, 2004). A study by Park & Kim (2004) also showed that the QE duration was longer in skilled people than in inexperienced people. In particular, the QE duration in skilled people was significantly longer when they made a successful putt than when they failed. However, when the putting was unsuccessful, QE duration was the same according to skill level.

Research on Interceptive Tasks

Volleyball Spike Serve Receive

In Lee's (2010) study on spike serve to receive, it



Figure 4. Gaze behavior of receiver during a volleyball spike serve's flight section (1: serve impact moment, 2: post-impact, 3: post-impact, 4: peak moment, 5: pre-reception, 6: pre-reception)

was found that skilled players mainly fixed their gaze on the attacker's shoulder and arm area during the ball toss section before serving, and their gaze-tracking movement toward the ball was faster after impact. However, in the flight section of the ball, the ball was tracked more consistently than the beginners. In particular, experts quickly moved their gaze to the point where the ball and arm were impacted before receiving (0.18–0.25 s), while beginners failed to track the ball (Figure 4). This gaze behavior pattern was similar to a cricket study (Land & McLeod, 2000) that moves the eyeball to the contact prediction point with rapid eye movement to accurately predict the receiving position where the ball and arm made contact.

Prediction of Badminton Serve Attack Direction

In the study by Kim et al. (2007), similar to the results of several previous studies, it was found that the higher the skill, the longer the QE duration. National team player used a strategy that involved a low search rate, in which the gaze was fixed for a long time, and the movement of their gaze was reduced. In addition, the player showed the characteristics of seeking and processing information more stably by increasing the QE start point and lengthening the QE duration. The duration of QE refers to the last fixation or tracking time on a target that occurs just before a major physical movement occurs. Therefore, the longer the QE duration, the higher the possibility of using a strategy with a low search rate.

Research on Tactical Challenges

Unlike aiming tasks, tasks, such as soccer, volleyball, ice hockey, and basketball, impose a large time limit on the performer's movement. In addition, the player selects the action to react to according to external factors, such as the movement speed and shape of the opponent. Williams et al. (1994) performed a task to predict an attack strategy by visualizing an 11 vs. 11

situation. They found that experts paid less attention to the ball than inexperienced players and paid more attention to the position and movement of players without the ball. Thus, experts showed higher visual search rates than inexperienced participants, as shown by more gaze fixation in a shorter period. However, in a 3:3 situation, experts showed a lower visual search rate than inexperienced people, suggesting conflicting results. This result shows that in the 11:11 situation, much information is required to predict the situation. It is difficult to acquire such information from only the environmental vision system. Hence, the frequency of movement of focal vision appears high. On the other hand, in a 3:3 situation where the amount of perceptual information is relatively limited, there is a “visual pivot” phenomenon in which the expert fixes their eyes on the player holding the ball and acquires information about the situation occurring in another area through the environmental vision system. Helsen & Starkes (1999) visualized free kicks, penalty kicks, dribbling, shooting, and passing situations from the point of view of a player with the ball and presented them as videos to experienced and unskilled players. Afterwards, the visual search strategy that appeared when predicting the situation and the actual exercise execution time were measured. The results revealed that when experts accept and predict appropriate information quickly and accurately, the burden of processing the information is reduced, which then results in a much faster exercise execution time than that of an unskilled person. Martell & Vickers (2004) examined the differences in gaze behavior according to skill proficiency in the defensive strategy process of ice hockey. The study's results revealed that skilled and unskilled players quickly recognized the game situation and appropriately moved their eyes. However, in the last situation assessment situation, compared to inexperienced players, experts fixed their gaze on one cue; moreover, their gaze was fixed for a longer period.

A Study on Perceptual Skills Training

QE Training

Golf Putting

Vickers (2007) conducted perceptual skills training (QE and eye control training) to improve the accuracy of putting in 14 golfers. The task was to putt into a hole cup at a distance of 4 or 6 feet. Before the pretest, no technical feedback related to stance or putting stroke was provided to the participants. After the pretest, the gaze control (GC) training group received feedback on GC by looking at the VIA data but were not provided with QE information, which appeared to significantly affect performance accuracy in the aiming task. The QE training group applied QE training similarly to the basketball free throw training (Harle & Vickers, 2001). In addition, the participants were presented with information regarding the QE of experienced players, as shown in a previous study (Vickers, 1992).

- Subjects keep the hole cup, putter, and stance in a straight line and keep their eyes on the back of the ball.
- After you are ready to putt, fix your eyes on the hole, the surrounding green, and the point where the ball curves.
- Observe the breakpoint of the ball on the green with the rapid movement of the eyeball from the hole to the ball.
- Repeat this process two to three times when putting.
- The last fixation keeps QE on the back of the ball. The starting point of QE occurs before the stroke of the putter and is maintained for about 2–3 s.
- Only move your eyes to the putter during the backswing and forward swing. QE remains on the green continuously for 200–300 ms after the impact of the ball and club.

The QE training group had a significant increase in

QE from 2 s to 3 s in the posttest and a substantial increase in time in the putting preparation section. However, the GC group did not show significant changes in QE. Both groups showed a considerable increase in putting accuracy. In the pretest, the GC group with low handicaps had an accuracy of 42%, the QE group had an accuracy of 50%, and the high handicap participants had a performance accuracy of 32% in both the groups. In the posttest following training, the GC group's performance accuracy increased to 46%, and the QE group's performance accuracy increased to 51%. In the transfer test, the low-handicap GC group had a performance accuracy of 70%, while the QE group had a performance accuracy of 77%. The QE group showed the highest performance accuracy, but there was no significant difference from the improvement in the GC group.

Basketball Free Throw

Harle & Vickers (2001) applied QE training to improve free throw accuracy in college basketball players over two seasons. During the training period, the participants were presented with VIA data, including gaze control of experienced players, and the following points were emphasized.

- Move your gaze to the front of the rim as quickly as possible. Keep your eyes on the rim with a preshot routine for a free throws.
- Catch the ball from the front and fix your gaze on a point on the rim (front, back, or center) for about 1 s. It is important to keep QE stable at one point.
- When ready, perform a free throw, moving the ball and your hand to the middle of the body. During the movement, the ball blocks your gaze in the visuomotor area for a short time.
- Shoot with a smooth and quick motion.

The VIA data were analyzed in three steps to allow

inexperienced players to learn the attentional patterns exhibited by experienced players. The first step was to adjust the QE of skilled players. Afterwards, using the frame analysis technique, the players explained the clues and their meanings. The unskilled players were then asked to look at their visual-motor data and recognize similarities and differences with those of experienced players. The third step asked the players to apply changes in their gaze behavior to the practice method. This analysis presented feedback to the players to lower the frequency of gaze fixation at one QE point and change the timing of the QE start point to appear earlier before the blocking section. As a result, the QE training team significantly increased the QE duration from 300 ms to 900 ms and spent a long time (for longer QE duration) in the free throw preparation section. After training, the free throw success rate improved by 12%, but there was no significant difference in the success rate (54.1%). However, the free throw success rate of the players trained in the second season increased by 22.6–76.7% in the match.

GC Training

Williams & Burwitz (1993) studied the relationship between key posture cues at the moment of a penalty kick and the direction of a penalty kick with novice goalkeepers as their experimental subjects. The results revealed that the goalkeeper's main clues were the kicker's buttocks and the angle of his torso and feet right before the ball was kicked. This predictive performance significantly increased after 90 min of video simulation training. Furthermore, Farrow et al. (1998) asked participants to predict the ball's direction by watching the tennis serve motion provided on a life-size video image. After 4 weeks of training using the visual blocking technique through videos, it was found that posture, ball, and racket cues were used as the most important cues to predict the direction of the serve. It was also found that the perceptual training group had better prediction performance than the

placebo or control group.

Kim et al. (2007) applied perceptual skill training to improve the opponent's batting ball prediction ability to eight national singles players in a badminton task. In the study, the contents of the perceptual skills training program were constructed based on the gaze behavior characteristics of the skilled workers made by Kim et al. (2007). Based on this, the perceptual skill training program for each player was applied to the training. Since the player's intention to hit the ball, especially in the case of an offensive ball, takes precedence over the actual ball, that intention is meant to be expressed in the batting motion, including the action of preparing for the batted ball. Therefore, training was conducted while emphasizing that understanding the characteristics of such batting motion is the most effective way to defend the opponent's batted ball. In addition, the participants were trained to understand the differences according to proficiency in searching for significant sources of information and information utilization. For perceptual skills training, using the VIA system used in previous studies, effective gaze behavior patterns were explained by comparing the gaze behaviors of skilled and unskilled people in videos taken during the experiment. Each player's self-awareness skills training program consisted of a total of five contents. It was conducted twice a week for 8 weeks under the supervision of male and female instructors for each player. The contents of the training are as follows.

- Step 1: Understand and revise the player's defensive strategy, and how to search for key sources of information
- Step 2: Training to focus attention on appropriate sources of information using the VIA system
- Step 3: Utilizing the VIA system, understanding and correcting training for the player's own defensive movements
- Step 4: Use the VIA system to identify specific movements and characteristics of the

- opponent when batting
- Step 5: Training to focus on appropriate sources of information to predict opponent-batted balls in real practice and game situations.

Through this eye control training, it was found that the players watched the opponent's batting motion for a longer time and moved to the "Run Batted In". In addition, even in the tracking movement of the gaze after impact, it was found that the training helped players track the ball more quickly at the batting point after impact.

Conclusion

Motor expertise is a research field, which identifies factors that are directly related to sports performance, including motor skills, perceptual skills, and decision-making processes, and deals with the acquisition process. Ericsson & Smith (1991) mentioned that motor expertise research is a field that understands and explains what can distinguish individuals who are superior to people in general or people in a specific area. Recently, scholars (including Dr. Abernethy, Elliott, Ericsson, Farrow, Ripoll, Vickers, Starkes, and Williams) studying the field of motor expertise are increasing rapidly. In addition, papers related to this field are featured in high-profile journals, such as *Human Movement Science*, *Journal of Sports Science*, and *Journal of Motor Behavior*. In particular, books on motor expertise as a single subject in the field of motor control are continuously being published, including "Cognitive issues in motor expertise," "Perceptual expertise in sport," "Expert performance in sports: advances in research on sport expertise," "The road to excellence," and "Perception, cognition, and decision training." In Korea, active research has been conducted on tasks, such as golf (Kim, 2000; Park & Kim, 2004), soccer (Kim et al., 2005), volleyball (Lee, 2010), and badminton (Kim et al., 2005).

Scientific research on motor expertise will provide

a lot of information that would help in understanding the process of motor skill acquisition, discovering and identifying potential elite athletes, and providing relevant information to exercise scientists, coaches, and learners. In particular, perceptual skills training is being applied in the field through various methods, such as time and space blocking techniques, reality-based feedback, and explicit and implicit feedback, and empirical research results supporting the possibility are presented. Improving players' cognitive/perceptual abilities through perception skill training requires a lot of effort from leaders and learners and cannot be solved within a short time. However, it is worth the effort.

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References

- Abernethy, B. (1993). *The nature of expertise in sport*. In S. Serpa, J. Alves, V. Ferreira, & A. Paula-Brito (Eds.), *Proceedings of the VIIIth World Congress of Sport Psychology* (pp. 18-22). Lisbon, Portugal: International Society of Sport Psychology.
- Bard, C., & Fleury, M. (1981). *Considering eye movements as predictor of attainment*. In I. M. Cockerill & W. W. MacGilvary (Eds.), *Vision and sport* (pp. 28-41). Cheltenham: Stanley Thornes.
- Bahill, A. T., & LaRitz, T. (1984). Why can't batters keep their eyes on the ball? *American Scientist*, **72**, 249-253.
- Bernstein, N. (1967). *The coordination and regulation of movements*. Oxford: Pergamon Press.
- Corbetta, M. (1998). Frontoparietal cortical networks for directing attention and the eye to visual locations: Identical, independent, or overlapping. *Proceedings of the National Academy of Sciences*, **95**, 831-838.
- Deubel, H., & Schneider, W. (1996). Saccade target selection and object recognition: Evidence of a

- common attentional mechanism. *Vision Research*, **36**(12), 1827-1837.
- Ericsson, K. A., & Smith, J. (Eds.). (1991). *Toward a general theory of expertise: Prospects and limits*. Cambridge University Press.
- Farrow, D., Chivers, P., Hardingham, C., & Sachse, S. (1998). The effect of video-based perceptual training on the tennis return of serve. *International Journal of Sport Psychology*, **29**(3), 231-242.
- Harle, S., & Vickers, J. N. (2001). Training quiet eye (QE) improves accuracy in the basketball free throw. *The Sport Psychologist*, **15**, 289-305.
- Helsen, W. F., & Starkes, J. L. (1999). A multidimensional approach to skilled perception and performance in sport. *Applied Cognitive Psychology*, **13**, 1-27.
- Kim, S. (2000). A study on the types of eye movement changes in the golf putting task. *Journal of the Korean Society of Sports Psychology*, **11**(2), 1-13.
- Kim, S., Lee, S., & Park, S. (2005). Goalkeeper's proficiency, predictive ability, and ability to use prior visual cues in soccer penalty kicks. *Journal of the Korean Society of Physical Education*, **44**(1), 91-101.
- Kim, S. J., Gu, H. M., Park, S. H., & Lee, S. M. (2007). Visual search strategies and reaction time differences between expert and intermediate badminton players. *The Korean Journal of Physical Education*, **46**(6), 179-190.
- Klein, G. (1999). *Sources of power: How people make decisions*. Cambridge, MA: MIT Press.
- Land, M. F., & McLeod, P. (2000). From eye movements to actions: How batsmen hit the ball. *Nature*, **3**(12), 1340-1345.
- Lee, S. M. (2010). Does your eye keep on the ball?: The strategy of eye movement for volleyball defensive players during spike serve reception. *International Journal of Applied Sports Sciences*, **22**(1), 128-137.
- Martell, S. G., & Vickers, J. N. (2004). Gaze characteristics of elite and near-elite athletes in ice hockey defensive tactics. *Human Movement Science*, **22**, 689-712.
- Newell, K. M. (1986). *Constraints on the development of coordination*. In M. Wade & H. T. A. Whiting (Eds.), *Motor development in children: Aspects of coordination and control* (pp. 341-360). Maastricht, Netherlands: Nijhoff.
- Newell, K. M., & McDonald, P. V. (1994). *Learning to coordinate redundant biomechanical degrees of freedom*. In S. Swinnen, H. Heurer, J. Massion, & P. Casaer (Eds.), *Interlimb coordination: Neural, dynamical, and cognitive constraints* (pp. 517-531). New York: Academic Press.
- Park, S. H., & Kim, S. J. (2004). Visual search strategy of defensive players in volleyball. *The Korean Journal of Physical Education*, **43**(6), 227-236.
- Ripoll, H., Bard, C., Paillard, J., & Grosgeorge, B. (1982). *Caracteristiques de la centraion de l'oeil et de la tete sur la cible et son role dans l'execution du tir en basketball*. In T. Orlick, J. T. Partington, & J.H.Salmela (Eds.), *New paths to sport learning* (pp. 33-36). Ottawa: Perceptives in Sport.
- Robinson, D. A. (1963). A method of measuring eye movemnent using a scieral search coil in a magnetic field. *IEEE Transactions on Bio-Medical Electronics*, **10**(4), 137-145.
- Rodrigues, S. T., Vickers, J. N., & Williams, A. M. (2002). Head, eye and arm coordination in table tennis. *Journal of Sports Sciences*, **20**, 187-200.
- Tenenbaum, G. (2003). *Expert athletes: An integrated approach to decision making*. In J. L. Starkes & K. A. Ericsson (Eds.), *Expert performance in sports: Advances in research on sport expertise* (pp. 191-218). Champaign, IL: Human Kinetics.
- Vickers, J. N. (1992). Gaze control in putting. *Perception*, **21**, 117-132.
- Vickers, J. N. (1996). Visual control when aiming at a far target. *Journal of Experimental Psychology: Human Perception and Performance*, **22**(2), 342-354.
- Vickers, J. N. (2004). The quiet eye: It's difference between a good putter and a poor one. *Golf Digest*,

- 96, 32-44.
- Vickers, J. N. (2007). *Perception, cognition, and decision training*. Champaign, IL: Human Kinetics.
- Vickers, J. N., Rodrigues, S. T., & Edworthy, G. (2000). Quiet eye and accuracy in the dart throw. *International Journal of Sports Vision*, **6**, 30-36.
- Williams, A. M., & Burwitz, L. (1993). Advance cue utilization in soccer. In T. Reilly, J. Clarys, & A. Stibbe (Eds.), *Science and football II* (pp. 239-244). London: E. & F. N. Spon.
- Williams, A. M., Davids, K., Burwitz, L., & Williams, J. G. (1994). Visual search strategies of experienced and inexperienced soccer players. *Research Quarterly for Sport and Exercise*, **65**, 127-135.
- Williams, A. M., Davids, K., & Williams, J. G. (1999). *Visual perception and action in sports*. London: E&FN Spon.
- Williams, A. M., Singer, R. N., & Frehlich, S. G. (2002). Quiet eye duration, expertise, and task complexity in a near and far aiming task. *Journal of Motor Behavior*, **34**, 197-207.
- Wood, J. M., & Abernethy, B. (1997). An assessment of the efficacy of sports vision training programs. *Optometry and Vision Science*, **74**, 646-659.