
ganzin
See the Wonders
Application of Eye Tracking in Sports Science:
The Case of the Quiet Eye Phenomenon

Advantages of eye-tracking technology

Photo source: Neuroscience News

- Vision is a key sensory factor in motor learning and execution [1].
  - Elite athletes demonstrate different gaze trajectories, fixation locations, and fixation durations compared to non-elite athletes during hitting tasks [2].
- Eye movement trajectories in the course of sports are a form of implicit behavior; elite athletes do not consciously alter their eye movement behavior, but rather develop it naturally [3].
- Eye-tracking technology can help reveal the implicit cognitive processes of elite athletes.
- Fixations and saccades are considered the two eye movement behaviors most closely related to cognition and learning.

Fixation

- To process specific visual information, the gaze remains fixed on a particular location for a period of time, keeping the information within the foveal region to obtain the clearest vision.
- Key parameters for comparing fixation behavior:
  - **Fixation location**: The spatial position of attention.
  - **Fixation duration**: The longer the gaze remains on a specific location, the more attentional resources are devoted to processing the visual information there.
- Fixation duration can be as short as several tens of milliseconds (ms) or as long as over 1000 ms, with most distributed around 200–300 ms [4].

Saccade

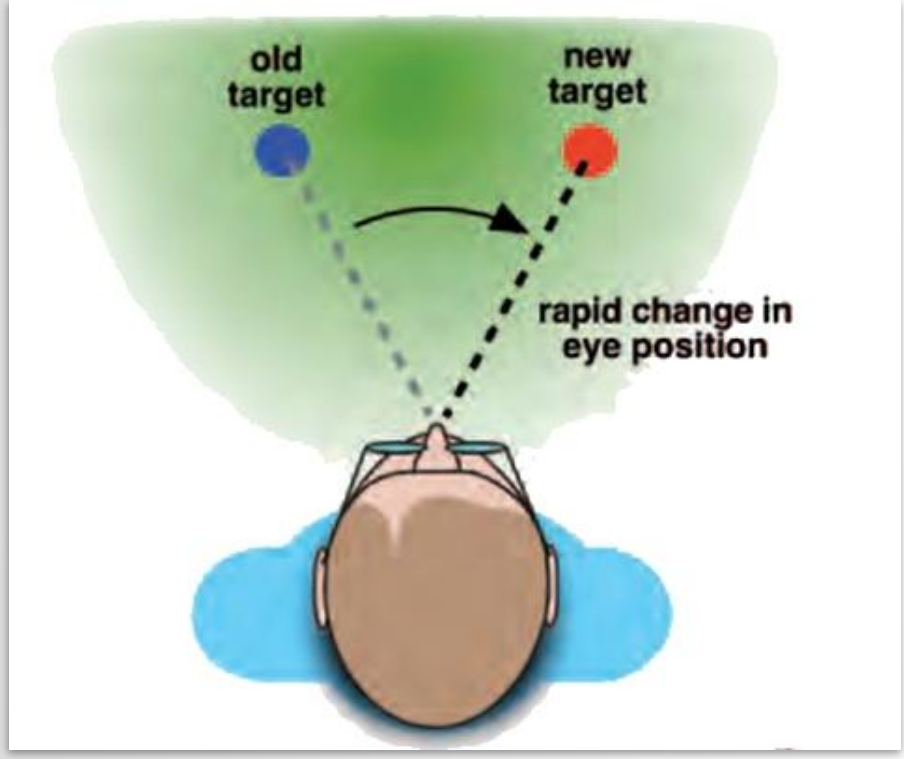


Photo source: https://www.nasafordoctors.co.za/

- The rapid movement of the eyes between different fixation points.
- **Saccade speed**: Minimum around 30°/sec, maximum can exceed 800°/sec [5].
- **Typical saccade amplitude**: Ranges between 4–20°.
- **Saccade duration**: Mostly falls between 30–80 ms.
- **Saccade latency**: The time required to determine the next fixation location and initiate the saccade, usually at least 80 ms.
- **Saccadic suppression**: Visual information becomes blurred during saccades.
- Reflects the process of shifting attention between different spatial locations.

Quiet eye

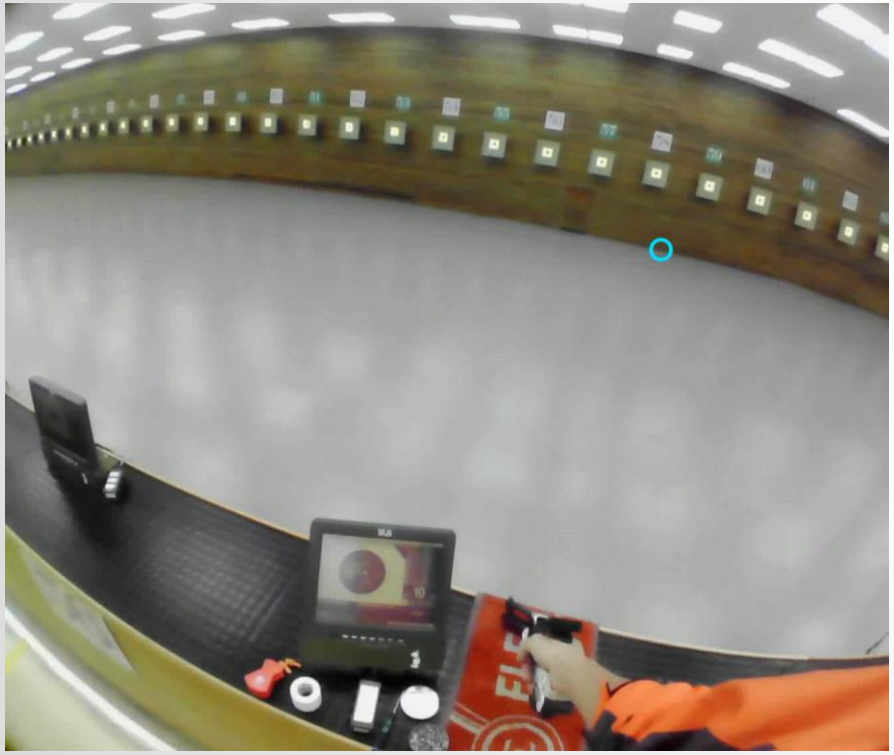
圖片來源: https://www.wholelifechallenge.com

- A phenomenon widely discussed in sports science.
- Elite athletes, compared to non-elite athletes, show their **final fixation** before executing a critical action occurring **earlier** and **lasting longer** [6][7].
- Represents the efficient allocation of attention to process key features of the critical action.
- Considered to reflect the **competitive state** of athletes [3].
- Related studies have been conducted in various sports such as basketball [8], tennis [9], and soccer [10][11].

Introduction to the wearable eyetracker

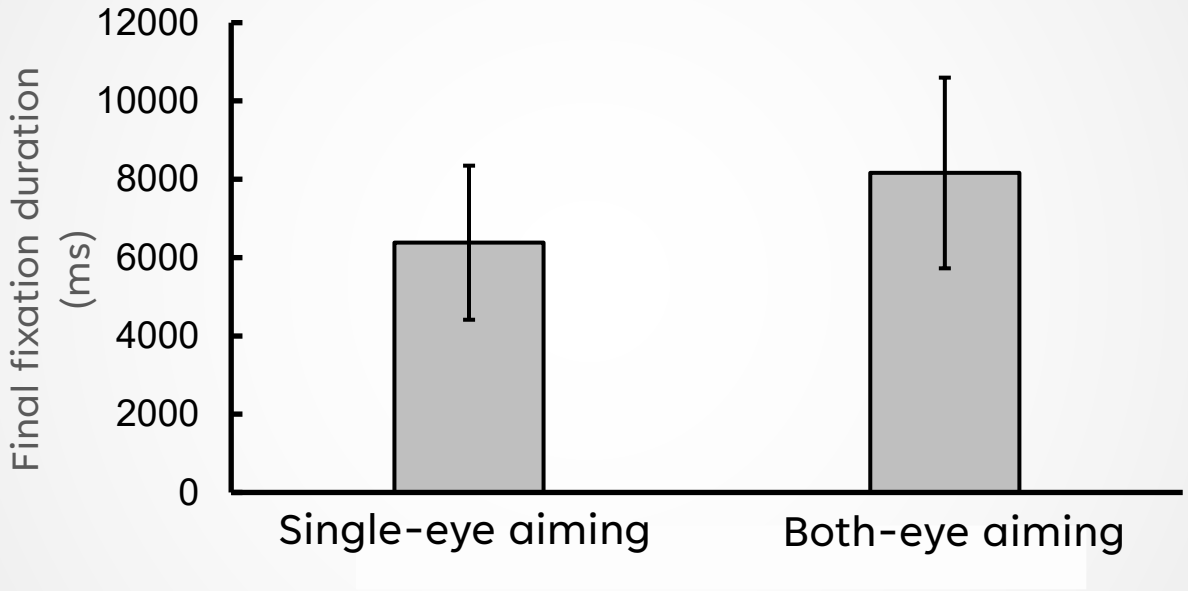
- Ganzin Technology: **Sol Glasses Wearable Eye-Tracker**
  - 110 Hz eye movement signal sampling rate
    - Provides 3D gaze, pupil size, blink information
  - Foreground camera resolution: 1328 × 1200 @ 30 FPS
  - Paired with dedicated analysis software **Caelus**
    - Capable of generating heat maps, gaze trajectory maps, and AOI statistical data
- **Demonstration Cases**
  - National air rifle athlete shooting
  - University tennis team cone-hitting drills

Sol Glasses Eye tracker × Air rifle shooting



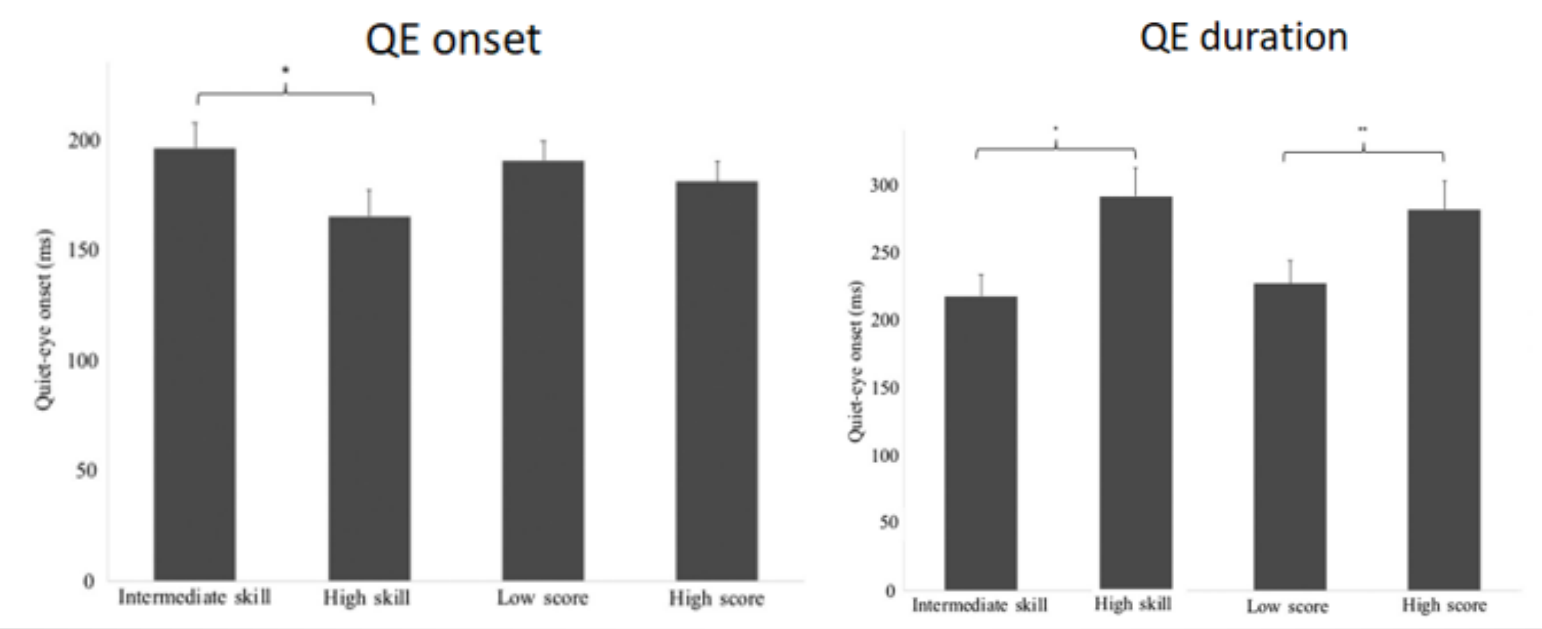
- Collect eye-tracking data of a national air pistol athlete during shooting.
- **Athlete's behavioral habits:**
  - **Before raising the pistol over the target:**
    - The athlete first looks forward; when the hand passes above the target, the eyes are closed.
  - **After raising the pistol over the target:**
    - Once the hand reaches the highest point, the athlete opens the eyes again.
    - After the final long fixation, the trigger is pulled.
- The athlete performs 10 shots each using **both-eye aiming** and **single-eye aiming**.

Quiet eye phenomenon in air pistol shooting



- Regardless of **single-eye** or **both-eye aiming**, the final fixation duration is very long, averaging over 6 seconds—far exceeding typical fixation durations (mostly within 1 second), reflecting a highly focused state during shot preparation.
- The final fixation duration is shorter during **single-eye aiming**, which may be related to the athlete being more accustomed to aiming with one eye.

Quiet eye phenomenon in Tennis



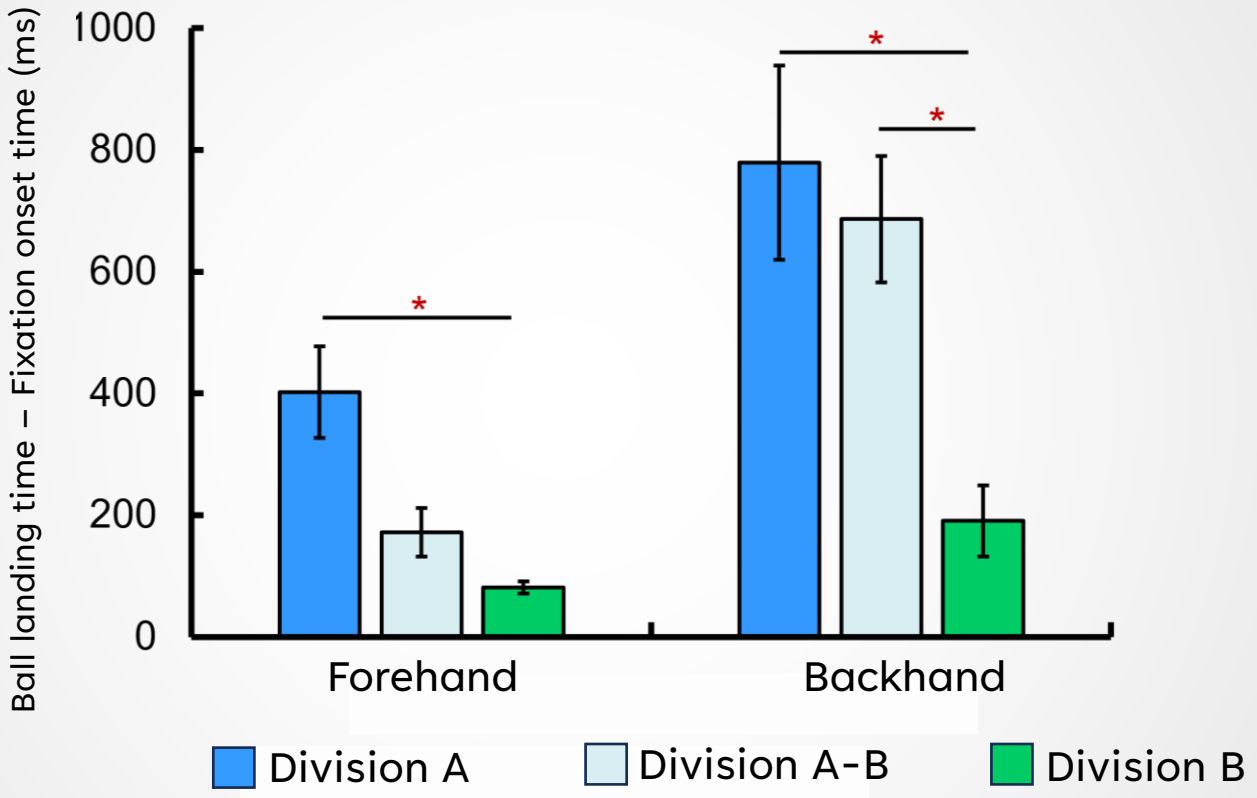
[9]

- Measure eye-tracking data of elite and intermediate players during serve-receive practice, before the ball crosses the net and lands [9].
  - ✓ Elite players exhibit an earlier occurrence of the final fixation point.
  - ✓ They spend more time fixating on the ball.

Sol Glasses Eye tracker x Tennis Practice

- Collect eye-tracking data during cone-hitting practice.
  - **Forehand:** 20 trials
  - **Backhand:** 20 trials
  - **Participants:**
    - University Division A player × 1 (female, 21 years old)
    - Player between Division A and B level × 1 (male, 18 years old)
    - University Division B player × 1 (female, 18 years old)
- **Objective:**
  To investigate whether more skilled players exhibit an earlier occurrence of the final fixation point before the ball lands, and whether the fixation duration is longer.

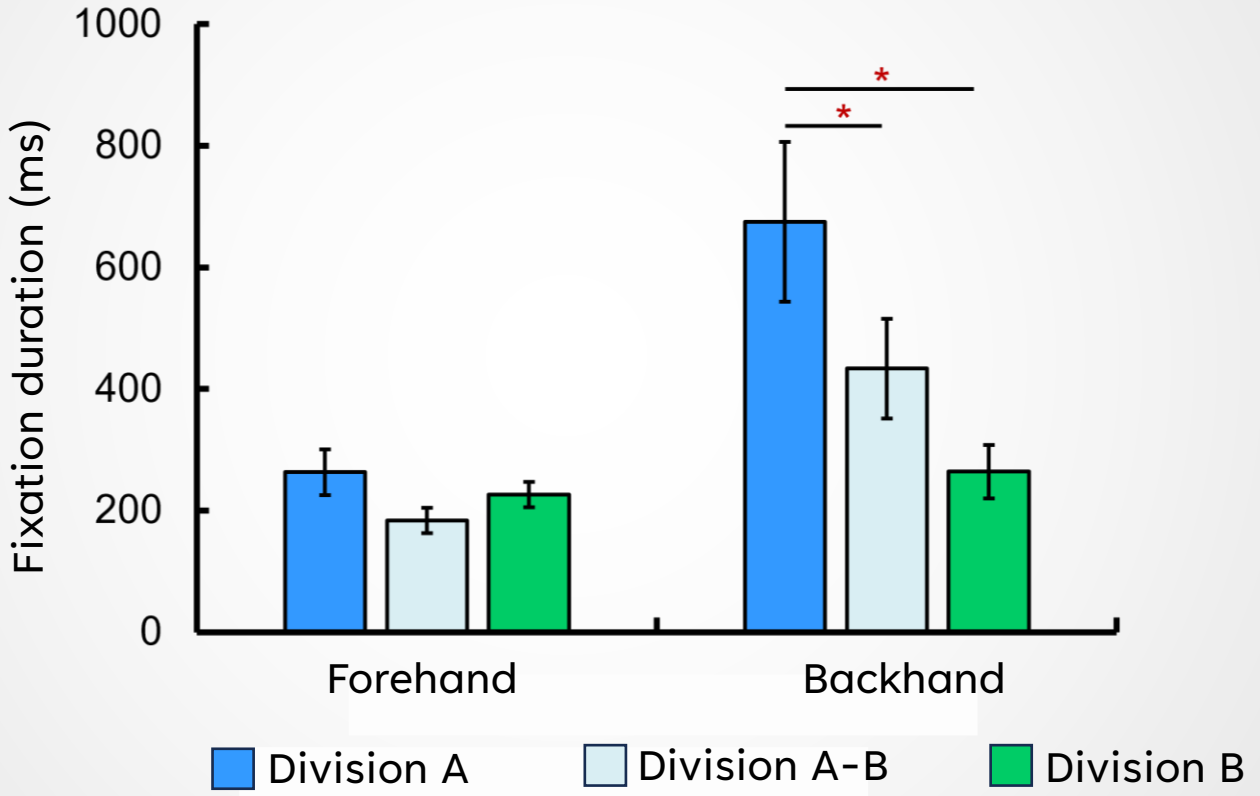
Final fixation onset time



Forehand: The final fixation of the Division A player occurs earlier than that of the Division B player.

Backhand: The final fixation of the Division A and A–B level players occurs earlier than that of the Division B player.

Final fixation duration



- During backhand shots, the final fixation duration of the Division A player is longer than that of the A–B level and Division B players.

Discussion and Research Limitations

- The **quiet eye phenomenon** was observed during cone-hitting practice.
  - **Backhand:** The final fixation of the Division A player occurs earlier and lasts longer than that of the Division B player.
  - **Forehand:** The final fixation of the Division A player occurs earlier than that of the Division B player.
  - The quiet eye phenomenon is more pronounced during backhand shots, possibly due to the higher difficulty of backhand strokes.
- **Main study limitations:**
  - Small sample size (N = 3)
  - Gender inconsistency: two females and one male, with the male player's skill level between Division A and B
- Despite the small sample size, differences between players of varying skill levels can still be observed from the eye-tracking data.

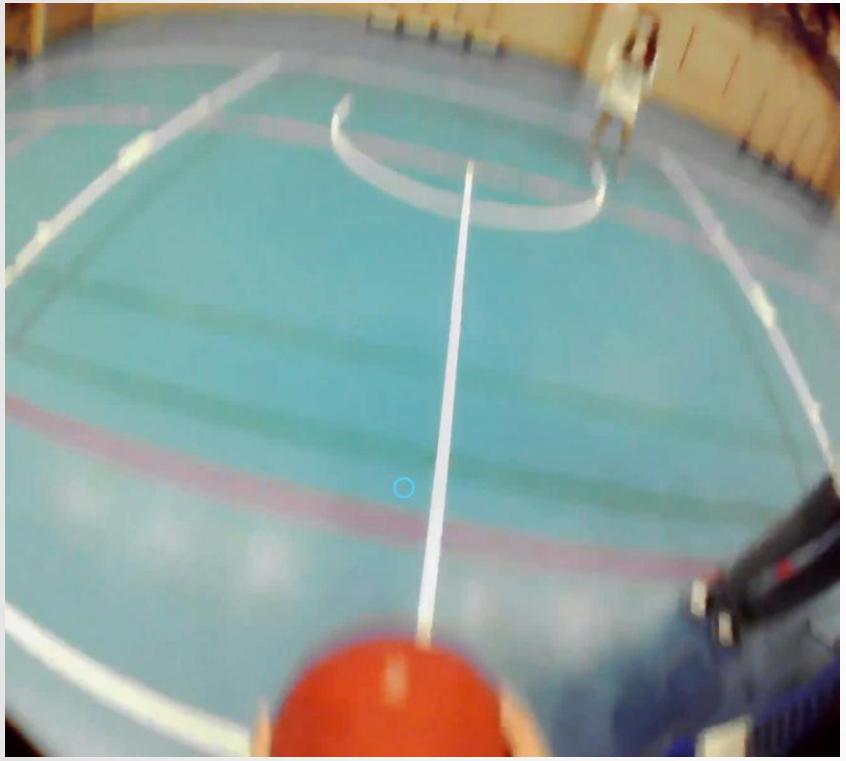
Summary

- How elite athletes achieve high-level performance are often difficult to express verbally, as they are bodily mechanisms naturally developed through long-term training.
- The advantage of eye-tracking technology in sports science lies in measuring the **attentional state** of **elite athletes** during movement, providing insights into their **implicit cognitive processes** and how these differ from non-elite athletes.
- It can be applied across various sports, such as shooting, tennis, and more.
- The quiet eye phenomenon is one of the widely studied topics, but there are believed to be many more areas worth exploring.

Appendix:
Examples of eye tracking data collection in basketball and taekwondo

Eye-tracking data of basketball team players and general students during free throws

General students



Varsity Team

- Extract eye-tracking data from the 1.5 seconds before the shot to the moment of release.
- Compare the attentional distribution of the Chung Yuan Christian University basketball varsity team with that of general students during free throws.

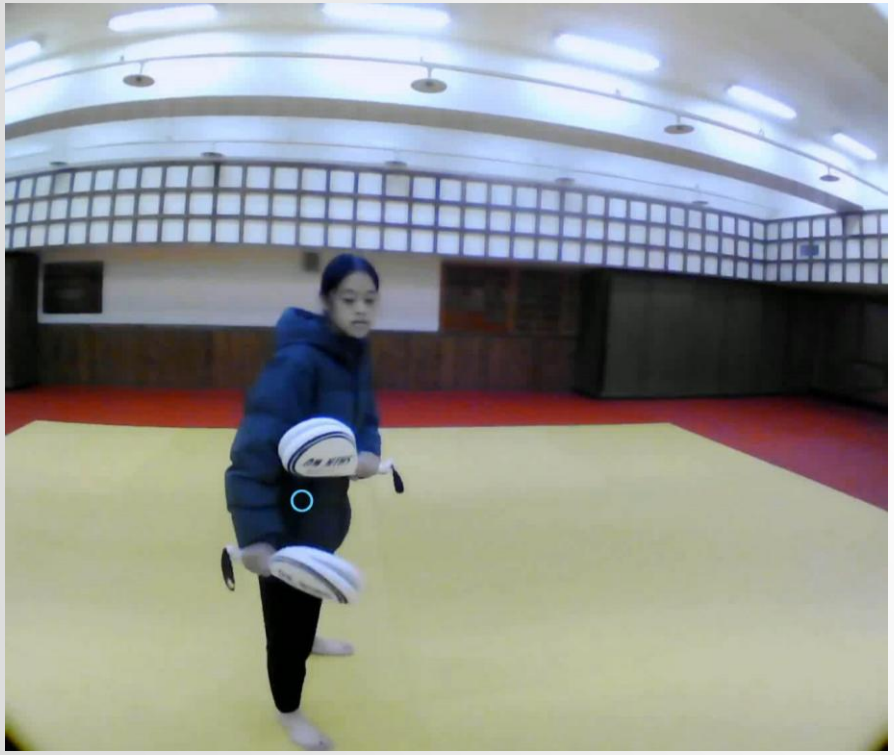
Varsity basketball team players have more focused attention

General student

Varsity Team

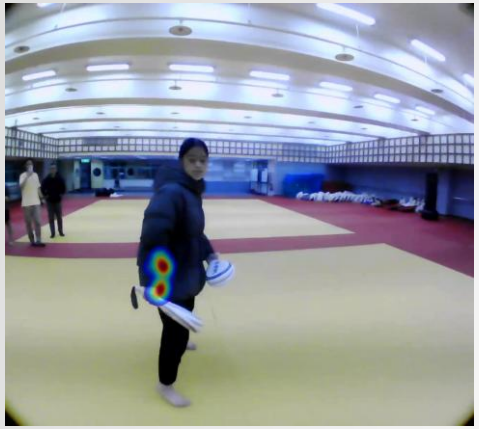
- Varsity team players were able to keep their attention focused on the basket during free throws.
- General students' gaze tends to deviate from the basket.

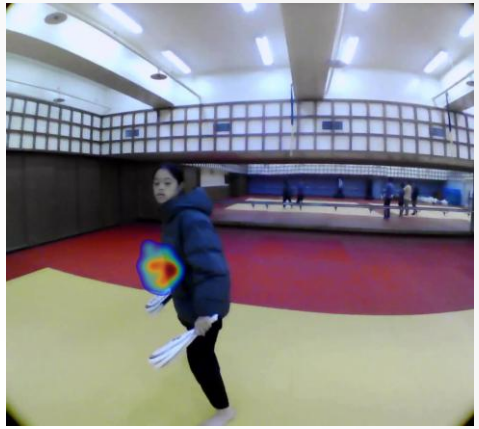
Taekwondo athlete speed pad practice

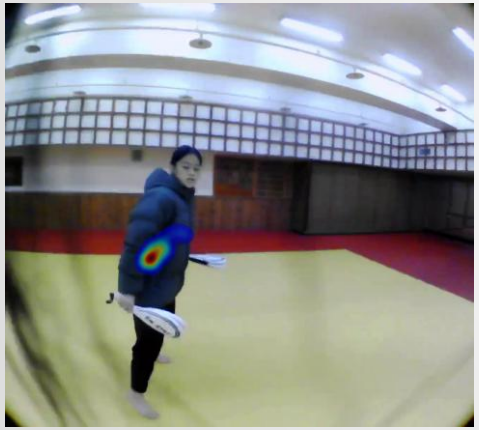
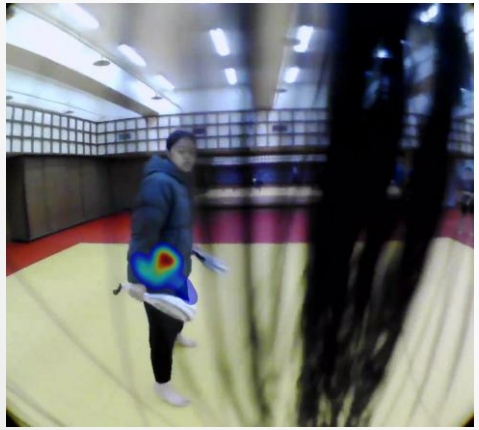


- **Participant:** University Division A Taekwondo athlete
- **Procedure:** The pad holder changes the target position, and the practitioner kicks toward the speed pad.
- **Analysis objective:** To examine attentional distribution before the start of each attack sequence.
- **Behavior:** In each attack sequence, from the moment the pad holder assumes position until the target is raised, across a total of eight attack sequences.

Heat map of each attack sequence





- Before the start of each attack sequence, the athlete tends to look at the pad holder's right hand.

Reference

[1] 林如瀚. (2011). 眼動儀在運動視覺控制研究的取向與發展. 中華體育季刊, 25(3).

[2] Land, Michael F., and Peter McLeod. "From eye movements to actions: how batsmen hit the ball." *Nature neuroscience* 3.12 (2000): 1340-1345.

[3] Lebeau, Jean-Charles, et al. "Quiet eye and performance in sport: A meta-analysis." *Journal of Sport and Exercise Psychology* 38.5 (2016): 441-457.

[4] Holmqvist, Kenneth, et al. *Eye tracking: A comprehensive guide to methods and measures*. Oup Oxford, 2011.

[5] Landis, Story C., James L. Roberts, and Larry R. Squire. *Fundamental neuroscience*. Eds. Michael J. Zigmond, and Floyd E. Bloom. Vol. 207. San Diego: Academic press, 1999.

[6] Vickers, Joan N. *Perception, cognition, and decision training: The quiet eye in action*. Human Kinetics, 2007.

[7] Vickers, Joan N. "Origins and current issues in Quiet Eye research." *Current Issues in Sport Science* 1 (2016): 1-11.

[8] Harle, Shawnee K., and Joan N. Vickers. "Training quiet eye improves accuracy in the basketball free throw." *The Sport Psychologist* 15.3 (2001): 289-305.

[9] Sáenz-Moncaleano, Camilo, Itay Basevitch, and Gershon Tenenbaum. "Gaze behaviors during serve returns in tennis: a comparison between intermediate-and high-skill players." *Journal of Sport and Exercise Psychology* 40.2 (2018): 49-59.

[10] Piras, Alessandro, and Joan N. Vickers. "The effect of fixation transitions on quiet eye duration and performance in the soccer penalty kick: Instep versus inside kicks." *Cognitive processing* 12 (2011): 245-255.

[11] Wood, Greg, and Mark R. Wilson. "Quiet-eye training for soccer penalty kicks." *Cognitive processing* 12 (2011): 257-266.