Psychophysiological Interventions in Biathlon: Final Report

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Contents

Abstract

Biathlon places a huge demand on psychophysiological processes (Josefsson et al, 2021) yet there is limited research to investigate these. This study aimed to investigate the effect of quiet eye and heart rate variability interventions on shooting performance. Nine biathletes (M=18.11, SD=3.01, 6 male) took part in a cross-over design study where their shooting performance was measured at baseline and post intervention. During the shooting testing participants had their heart rate variability and gaze behaviour measures. For the workshops participants were split into two groups, quiet eye and slow-paced breathing, that were counterbalanced so participants experienced both interventions. Each workshop ran for one-hour and consisted of education around why that element should be considered important, what impact it might have on their performance, and learning the psychological skill. Participants also completed workbooks to provide information on the knowledge of the topic pre- and post-intervention, this was rated on a Likert scale from "1" none at all to "7" excellent. Following all testing, participants took part in a focus group to gain insight into their experiences of the interventions. Results show that the interventions significantly improved shooting performance from baseline ($Z = 2.34$, $p=0.02$), although there was no difference in effectiveness between the interventions ($U = 3$, $p=0.08$). Given the small sample size and missing data, there should be caution around the interpretation of shooting improvement. The qualitative results revealed that prior to the education participants did have some existing gaze behaviour and breathing techniques that they utilised during performance. These were often developed either by the athlete themselves or by the coach, and therefore not evidence based. Prior to the workshops participants had very little knowledge of the interventions (quiet eye = 1, slow paced breathing = 1.7) and following the workshops this significantly increased ($p < 0.05$) (quiet eye = 4.5, slow paced breathing = 5). Following the educational workshops participants reported positive responses to the interventions via the focus groups. For example, participants reported the quiet eye technique helped them to have more control over their gaze behaviour and the paced breathing helped to reduce distractions and increase relaxation. There were some reported barriers to using the interventions, for example contradictions with coaching instruction or an inability to breathe slowly following physical exertion. Overall, there were positive influences on both shooting performance and psychological state as a result of both interventions. The findings, specifically those from the workshops and focus groups, suggest that further education for athletes into the psychophysiological factors which may underpin shooting performance is greatly needed. It is also recommended that coach education surrounding psychological skills for biathletes would be very useful to provide evidence-based guidance in the future.

Keywords: Biathlon, heart rate variability, slow paced breathing, gaze behaviour, quiet eye

Executive summary

Description of research topic

Biathlon is a demanding sport both physically and psychologically where athletes must physically exert themselves skiing and then execute five shots, a fine motor task under pressure and fatigue. Thus, this sport places huge demand on psychophysiological processes (Josefsson et al., 2021), and athletes must successfully regulate themselves to produce effective performances. The investigation of psychophysiological processes in Biathlon is limited and the examination of psychological interventions to promote better psychophysiological states is scarce.

The aim of this research project was to observe how two psychophysiological factors, which have previously been linked to shooting success, interact and affect shooting performance. Further, we also aimed to determine the effectiveness of brief interventions aimed at psychophysiological outcomes. The two psychophysiological factors which will be measured and subsequently trained are gaze behaviour (specifically Quiet Eye[QE]) and cardiac activity (specifically Heart Rate Variability [HRV] via slow paced breathing).

Objectives

The objectives for the study were:

1. To determine the effectiveness of brief psychophysiological interventions on quiet eye duration, heart rate variability and shooting performance
2. To develop practical guidance for practitioners working within elite biathlon
3. To assess athletes' perceptions of brief psychophysiological interventions on shooting performance

Methods

Nine biathletes from the development squad for British Biathlon took part in the study (age: M=18.11, SD=3.01. Six males). A mixed methods approach was used which allowed for a within subject crossover design with a follow-up qualitative focus group to determine the effectiveness and perceptions of the intervention. The study took place over six consecutive days during a snow-based training camp, for a full overview of the procedure please see Figure 1.

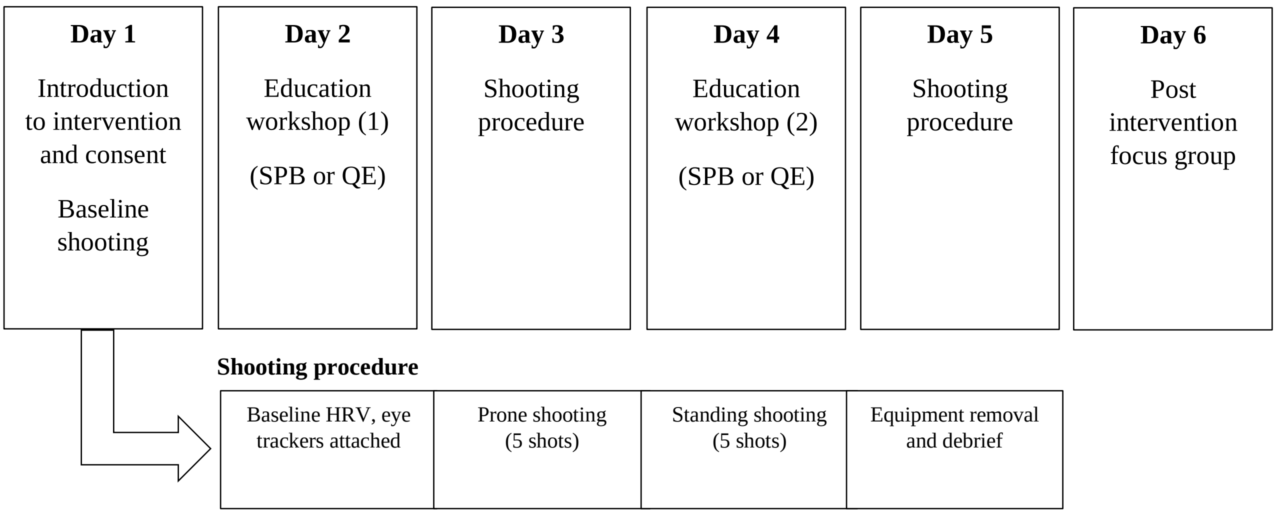

Figure 1: Intervention overview

Data were collected using an eMotion Faros 180° device (to collect HRV data), a Tobii 2 eye-tracking device (to collect gaze behaviour), and a laser rifle (Kiwi Precision Evolution LV1L biathlon laser) and laser target (CTOR10) were set up in an indoor environment and calibrated to a distance of 10m to collect shooting data in both prone and standing positions.

Two, hour-long workshops (one on QE and one on HRV) were run and during these participants completed a workbook to indicate their knowledge of the topic area pre- and post-workshop.

Finally, a post-intervention focus group was run to gain insight into participants experience of the interventions and thoughts on their applicability.

Main findings

Shooting:

Descriptive data can be seen in Table 1, showing the changes in shooting performance from the baseline and following each of the workshops. Statistical analysis using a Wilcoxen Signed Ranks Test showed that there was a significant improvement in shooting performance from baseline to the end of the study when both interventions had been completed ($Z = 2.34$, $p=0.02$).

Table 1: Means and standard deviations of shooting scores (maximum score = 10) at baseline and following each intervention.

Baseline	**Post-QE intervention**	**Post-SPB intervention**	**Post both interventions**
7.22 (1.2)	8.56 (1.13)	8.44 (1.42)	8.78 (1.09)

A Mann Whitney U test was carried out to compare improvements following each intervention and found no significant differences in terms of the improvement they bring ($U = 3$, $p=0.08$).

HRV:

With regards to HRV findings RMSSD is presented as the main variable of interest as this directly reflects cardiac vagal activity and is less influenced by respiration. RMSSD was compared between pre slow paced breathing workshop and post slow paced breathing workshop. By visually inspecting the data a trend emerged for RMSSD reducing from pre to post for both prone shooting and standing shooting. While we would expect to see an increase when athletes have been using slow paced breathing, a possible explanation for this is that athletes were fatigued by the end of the training camp. Therefore, a decrease in RMSSD could be linked to this.

QE:

From the limited data available, it was possible to see an increase in QE duration following the QE workshop. There was also an increase in QE from baseline after the SPB workshop, although this increase was not as great. This suggests that there may be an interaction effect between the two interventions.

Workbooks and focus group:

Of particular interest are the findings of the focus groups and the changes in knowledge reported following the workshops. There was a significant improvement in knowledge related to both breathing and gaze behaviour following the workshops ($p<0.05$). The focus group findings indicate that SPB and QE enhanced performance. Mechanisms were suggested relating to using relaxation, enhancing gaze control, and managing distracting thoughts. Barriers to integrating interventions related to old habits, role models, and practice.

Conclusions

The findings from the quantitative data show us that the combination of both workshops did bring about a significant improvement in shooting performance in biathlon athletes. It is unclear, due to the small number of participants, which intervention may be most beneficial, or whether both are required to bring about improvements.

Based on the outcomes of the workbooks and focus group, we would conclude that education for biathletes is needed around psychophysiological interventions as these are seen as having a positive impact on both knowledge and performance.

Recommendations

Our key recommendations are as follows:

1. Quiet eye and SPB interventions should be considered as part of biathlete education and training
2. Further research should be conducted into the gaze behaviour of Biathletes to inform future quiet eye interventions
3. Further research should be conducted into the use of SPB with Biathletes
4. Coach education surrounding performance enhancing techniques in Biathlon should be delivered

Research topic

Introduction

Biathlon has been described as a complex sport that places huge demand on psychophysiological processes (Josefsson et al., 2021). Athletes will have to manage psychophysiological demand during competition and specifically shooting requires a heavy reliance on mental skills (Coleman, 1980). The pressure to perform well can affect different mechanisms involved in shooting such as gaze (Vickers & Lewinski, 2012; Vickers & Williams, 2007), cardiac activity (Brisinda et al., 2014; Thompson et al., 2015), psychomotor regulation (Konttinen et al., 1998), and gun motion (Causer et al., 2010); which ultimately may result in altered shooting performance. It appears psychophysiological factors are a crucial element of shooting performance – most studies have only observed these factors. Therefore, testing interventions that specifically target psychophysiological factors could be of great importance for biathlon athletes.

There is some evidence for psychophysiological influences on shooting performance. For example, examining gaze behaviour (Vickers and Williams, 2007; Heinrich et al. 2020) or the role of heart rate variability (HRV) which has been shown to be related to shooting performance (Mosley et al., 2018). The focus of these previous studies has been to find links between an athlete's psychophysiological state and their shooting performance, but not specifically biathlon. In addition, limited previous work has attempted to apply psychophysiological interventions to train factors related to shooting performance such as gaze behaviour (e.g. Adolphe et al., 1997; Harle & Vickers, 2001) or HRV (Jimenez Morgan & Molina Mora, 2017; Pagaduan et al., 2020; Pagaduan et al., 2021).

The aim of this research project was to observe how two psychophysiological factors, which have previously been linked to shooting success, interact and affect shooting performance. Further, we also aimed to determine the effectiveness of brief interventions aimed at psychophysiological outcomes. The two psychophysiological factors which will be measured and subsequently trained are gaze behaviour (specifically Quiet Eye[QE]) and cardiac activity (specifically Heart Rate Variability [HRV]).

Heart rate variability and slow paced breathing

Heart rate has long been of interest in shooting sports – however this does not give the whole picture of psychophysiological self-regulation in competition environments. One measure that is gaining momentum is heart rate variability (HRV) due to its links with emotion regulation, attentional control and self-regulation under demand (Thayer et al. 2009). A previous study found that cardiac vagal activity (CVA - measured by HRV) was influenced by shot success (Mosley et al., 2018). A reduction in CVA was seen when shooters scored lower in a pressurised shooting task, suggesting that higher levels of CVA are important for shooting performance. A way of improving CVA is through a technique called slow paced breathing (SPB). Shooting athletes will often use breathing techniques to moderate their physiological response, however there is limited research around how effective these interventions are. One study assessing a year-long intervention with a shooting athlete found that breathing training assisted with stressful scenarios such as target malfunction or missed shots (Gross et al., 2017).

Improving HRV has many benefits which are of interest to sport such given it promotes many positive psychophysiological outcomes such as improving performance, self regulation and wellbeing (Laborde et al., 2022). Slow-paced breathing (SPB) is an easy to administer and accessible relaxation technique which has an increasing effect on the parasympathetic branch of the Autonomic Nervous System (ANS). The output of this can be measured by heart rate variability (HRV, specifically cardiac vagal activity) (Sevoz-Couche and Laborde, 2022). This is because breathing at a specific pace (6 cycles per minute) couples respiration and blood pressure systems which triggers the resonance properties of the cardiovascular system and results in an increase in vagal afferences (Sevoz-Couche and Laborde, 2022).

Previous research using SPB has found that it is effective in the short term with athletes using it as an intervention (Mosley et al., 2023; You et al., 2021) and in the long term with a shooting athlete (Gross et al., 2017). SPB has also been found to increase cardiac vagal activity after a physically fatiguing event (burpees) which subsequently improved executive performance (inhibition) (Laborde et al. 2019). More recently in an applied case reflection practitioners found that slow paced breathing prior to a visual task improved visual performance (Mosley et al., 2022). This evidence suggests that SPB may be an effective way to combat physiological and psychological demand prior to a task needing higher executive control. This could have a direct influence on biathlon performance given physical exertion (skiing) is followed by a task involving the need for psychophysiological regulation (shooting). Therefore, this study will build on previous literature and directly test the effect of SPB on shooting performance.

Gaze behaviour and quiet eye

Quiet Eye (QE) was defined by Vickers (1996) as the final fixation that is located on a specific location or object within 3° of visual angle for a minimum of 100ms. Two previous studies (Vickers and Williams, 2007; Heinrich et al. 2020) have specifically looked at QE in biathlon but have just attempted to measure QE when shooting, rather than training athletes on how to use QE effectively to improve performance.

Research in other sports has shown that skilled performers can be taught to develop more effective QE periods, with subsequent improvements in performance (Adolphe et al, 1997; Harle & Vickers, 2001). This shows that QE is not just a by-product of expertise, but an important mediator of skilled performance. Significantly, Causer et al. (2011) trained international skeet shooters to lengthen their QE and found that this led to earlier onset of QE and an improvement in performance when compared to a control group.

Since QE was first proposed by Vickers (1996), around 100 published articles have utilised it as an objective measure of visuomotor control. Much previous research has focused on the differences in QE between highly skilled performers and their lesser skilled counterparts. There is now a general agreement that QE can differentiate between both expertise and proficiency (within an individual), with experts and successful attempts characterised by longer QE durations (Vickers, 1996). This has been shown in a wide range of aiming sports such as golf putting (Wilson & Pearcey, 2009), rifle shooting (Janelle et al., 2000), shotgun shooting (Causer et al., 2010) and dart throwing (Vickers et al., 2000). Research specifically in biathlon has been limited with only two previous studies investigating QE in this setting.

Vickers and Williams (2007) investigated the effects of high and low pressure and QE on shooting performance in elite biathletes. They found that QE was a significant predictor of accuracy in biathlon shooting, and that increasing the QE duration could prevent choking in high pressure situations. Heinrich at al. (2020) attempted to improve on this initial research by Vickers and Williams by measuring biathlon shooting performance in an environment very similar to competition and by having biathletes shoot in both standing and prone positions. However, their findings were contradictory to nearly all previous QE research as they did not find a correlation between duration of QE and shooting accuracy. They do note that their small sample size may have impacted on their results and some of their other findings are also in conflict with prior research (e.g. deterioration of shooting accuracy with fatigue, Grebot et al., 2003; Ihalainen et al., 2018).

The current study

The proposed study will build on this previous research by drawing on evidence found through other aiming sports that training QE can make targeting skills both more refined (Causer et al, 2011; Vine et al, 2011) and robust under pressure (Vine and Wilson, 2011). Evidence has shown that even a brief (1 hour) QE training intervention can increase QE duration and subsequent performance in a laboratory environment, and that these improvements also transferred to the competitive environment (Vine et al., 2011).

Given both QE and SPB have shown great promise with regards to altering psychophysiological state to help improve performance, it is surprising that there is currently no research examining this in sporting populations. Training QE has been shown to affect similar mechanisms as controlled breathing, yet they have never been studied in a combined intervention programme such as we are proposing. We may find that the QE intervention brings about changes in HRV and vice versa and the cross over design will allow us to potentially observe this. In addition, the focus groups post cross over intervention will allow us to explore participants experiences of the interventions to determine athlete preferences and perceived benefits as well as evaluating the intervention in the real-life context (Sandelowski, 1996).

Objectives

The original objectives for the study were:

1. To examine the influence of physical fatigue on shooting performance and associated psychophysiological factors
2. To determine the effectiveness of brief psychophysiological interventions on quiet eye duration, heart rate variability and shooting performance
3. To develop practical guidance for practitioners working within elite biathlon
4. To assess athletes’ perceptions of brief psychophysiological interventions on shooting performance

However, due to being informed on the evening before testing began that the athletes would not be able to undergo fatigued testing (due to needing to acclimatise to altitude) we were unable to fulfil objective one.

The remaining three objectives were all met.

Methodology

Participants

The participants for this study were 9 biathletes from the development squad for British Biathlon. The group comprised three females and six males ranging in age from 15 to 25 (M=18.11, SD=3.01). All participants gave informed consent before taking part and the study was given ethical approval prior to commencing.

Research Design

A mixed methods approach was used which allowed for a within subject crossover design with a follow-up qualitative focus group to determine the effectiveness and perceptions of the intervention.

Measures

HRV

The eMotion Faros 180° device (Mega Electronics, Finland) was used to collect HRV data. Two disposable ECG electrodes were attached in each right infraclavicular fossa and one electrode aligned with the left 12th rib. The eMotion Faro was attached to the electrodes ready to begin recording. The sampling rate was set to 500hz as this is deemed to be a conservative sampling rate (Laborde et al., 2017).

Eye tracking

The Tobii 2 eye tracking glasses were used to collect eye tracking data. This device consists of a head unit (worn as a pair of glasses) which is connected via a wire to a recording unit which was worn by participants in a small bag around their waist, positioned at the back so it did not interfere when they were in the prone position. The camera on the head unit has a resolution of 1,920 x 1,080 at 25 frames per second.

Shooting performance

A laser rifle (Kiwi Precision Evolution LV1L biathlon laser) and laser target (CTOR10) were set up in an indoor environment and calibrated to a distance of 10m. Performance was measured in number of successful shots (five shots in prone position and five shots in standing position). Time taken for shooting was also measured and was taken from the time the athlete stepped onto the shooting mat to the time they stepped off the shooting mat. The laser rifle was used with a harness which athletes used to put rifle off and on their back which was all included in their shooting time (except for one athlete who had to use a rifle without a harness due to a technical error during data collection).

Workshop knowledge indicators

To assess knowledge pre and post educational workshops, Likert scales were developed. Participants were asked their knowledge of vision and breathing techniques and their knowledge of the specific skills being taught (slow paced breathing and quiet eye). For example, “on the following scale please rate your current knowledge of breathing techniques” which was rated from 1 (none) to 7 (excellent). Other more detailed questions were recorded (written responses) within the workshops for example “do you use any breathing techniques currently” and “if you were to recreate your pre-shot routine what would your vision/gaze look like?”. This is common practice in educational interventions of this nature (Mosley et al., 2023).

Procedure

The study took place over six consecutive days during a snow-based training camp, for a full overview of the procedure please see Figure 1.

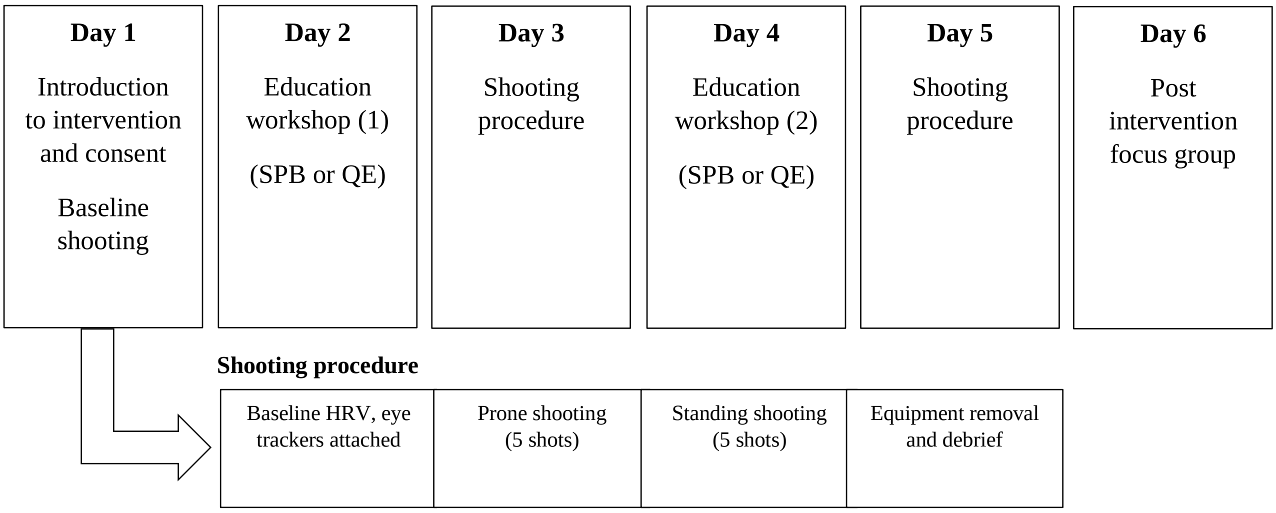

Figure 1: Intervention overview

Day one

Researchers welcomed the participants, coaches and support staff to the camp and explained the outline of the project and gave an overview of the 6 days. Following this, participants all read the information sheet and signed a copy to indicate consent (appendix 1) before taking part in the study. They also completed a pre-screening checklist (appendix 2) to check for any underlying conditions or variables that may influence the testing and intervention procedures i.e. heart conditions. No participants reported any variables that would influence the intervention.

This was followed by the initial shooting test, in which a baseline measure of performance was gained prior to any intervention. Participants were all tested individually and were welcomed to the testing site. The procedure was explained to them in detail, and they had time to ask questions. A pre-testing screening was used to determine the participants current state on the day of testing (see appendix 3).

Once the pre-testing questionnaire was complete, the participants were fitted with the eMotion Faro and a baseline measure of resting HRV was taken. The baseline was taken for a period of two minutes and the participants were instructed to sit comfortably with their eyes closed, and palm of hands facing upwards on their knees. Only the final minute of resting baseline was used in the analysis. Following this, participants were fitted with the Tobii 2 eye tracking glasses. These were then calibrated by having the participant fixate on a circular target for around 20 seconds. All wires and electrodes were taped down to improve comfort for the participant whilst shooting.

Participants then shot using a laser rifle, five shots from the prone position and five shots from the standing position. The time taken (from stepping onto the mat until they stepped off) and success of shots was recorded for each shooting position. Following the shooting, participants had the HRV and eye tracking kit removed and were thanked for their time.

Day two and four

On days two and four, participants were divided into two groups (of four and five) and each took part in a one-hour workshop on either slow-paced breathing (to control heart rate variability) or gaze behaviour (to control Quiet Eye). For a detailed example of similar educational workshops please see Mosley et al. (2023). Both workshops followed a similar structure and were run by an expert in the topic. The workshops started with an introduction to some basic research to show why that element should be considered important in biathlon, and what effect it might have on their performance. They were then given instructions and time to practice the particular skill. All participants completed a workbook pre- and post-workshop to show what they knew about the topic already and any learning that they reported following the workshop (see appendix 4 for an example workbook).

Following the workshop all participants were instructed to practice the skill they had learnt for at least 15 minutes (in three, five-minute bouts) before they were re-tested on their shooting the following day. Those athletes who took part in the slow-paced breathing workshop on day two, then did the gaze behaviour workshop on day four and vice versa. All athletes completed both workshops.

Day three and five

The same protocol as day one was followed on day three and five with the only difference being that on day three and five, they were instructed to try and implement what they had learnt at the workshop they attended on the previous day when shooting.

Day six

On day six, eight of the athletes (one athlete left camp earlier that day so was unable to take part) took part in a focus group which aimed to assess their perceptions of the interventions they had learnt at the workshops and how they felt they had influenced their shooting performance.

Following the focus group, participants were all debriefed and thanked for their participation.

Data analysis

Quantitative data from the measures taken were entered into Microsoft® Excel® and descriptive statistics were calculated. Statistical analysis on the shooting data was carried out using SPSS. As the data were non-parametric, a Wilcoxen Signed Ranks test was performed on the shooting data, followed with Mann-Whitney U test to look for differences between the two interventions.

Descriptive statistics from the HRV data, QE data, and workshop knowledge ratings were visually inspected to determine differences between pre- and post-intervention measures and graphical accounts of the data were created to display the changes over time. This method has been used in similar intervention research examining small sample sizes (Didymus & Fletcher, 2017).

The focus group was audio-recorded and transcribed verbatim. To analyse the focus group content, reflexive thematic analysis was used in line with recommendations from Braun and Clarke (2019). This reflexive approach led to a comprehensive exploration of the data for relevant and meaningful quotes. Quotes were analysed for meaning and organised based on similarities and differences, which led to theme generation. The first and second authors acted as critical friends providing questioning, feedback, and modification regarding assumptions and interpretation of the data. Following a thorough and inclusive review of the developing data, themes that were best thought to represent participant experiences were agreed upon.

Findings

Shooting findings

Descriptive data can be seen in Table 1, showing the changes in shooting performance from the baseline and following each of the workshops. Statistical analysis using a Wilcoxen Signed Ranks Test showed that there was a significant improvement in shooting performance from baseline to the end of the study when both interventions had been completed (Z = 2.34, p=0.02).

Table 1: Means and standard deviations of shooting scores (maximum score = 10) at baseline and following each intervention.

Baseline	Post-QE intervention	Post-SPB intervention	Post both interventions
7.22 (1.2)	8.56 (1.13)	8.44 (1.42)	8.78 (1.09)

Due to the counterbalanced design of the study, some athletes had already experienced one workshop by the time they had the second so it is difficult to work out which intervention had the most impact. In order to investigate this, an improvement score was calculated by subtracting the pre-score from the phase 1 score. This allowed for comparison between the two interventions when only one had been completed, but it did reduce the sample size as it became an independent samples analysis. A Mann Whitney U test was carried out and found no significant different in the interventions in terms of the improvement they bring (U = 3, p=0.08). However, it is worth stating that the descriptive data shows that the QE intervention led to greater improvement than the SPB intervention and this might be worth exploring with more participants, as a single intervention is more easily implemented than two interventions.

HRV findings

With regards to HRV findings RMSSD is presented as the main variable of interest as this directly reflects cardiac vagal activity and is less influenced by respiration. There were 9 data points (out of 27) that were not able to be used due to noise in the data, this may have occurred due to the gun placement in the shoulder where the electrode is situated.

RMSSD was compared between pre slow paced breathing workshop and post slow paced breathing workshop. By visually inspecting the data a trend emerged for RMSSD reducing from pre to post for both prone shooting and standing shooting. While we would expect to see an increase when athletes have been using slow paced breathing, a possible explanation for this is that athletes were fatigued by the end of the training camp. Therefore, a decrease in RMSSD could be linked to this.

It is interesting to observe that across the baseline (resting) RMSSD increase from pre to post educational workshop. It was quite clearly represented in some of the athlete's HRV data that slow paced breathing was being used during the resting baseline (see figure 2). While athletes were not prompted to use slow paced breathing during this time, they may have wanted to use this to prepare for the shooting tasks ahead.

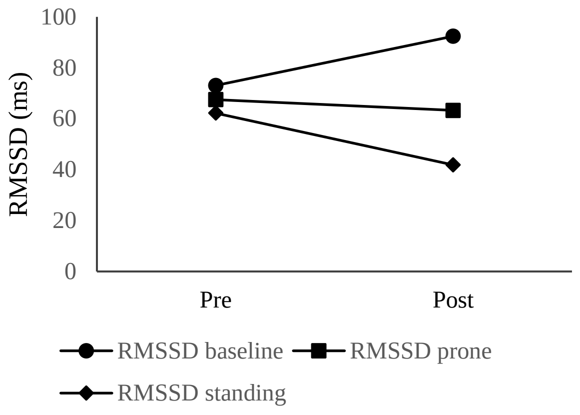

Figure 2: RMSSD changes following SPB workshop

QE findings

With regards to the QE data, we are interested in the length of fixation prior to the trigger being pulled. Unfortunately, only 15 data points were able to be collected (out of a possible 90). This is likely due to the gun blocking the image of the eye obtained via the eye-tracking glasses. However, we did get good data from three participants which allowed for some exploration of the findings.

From the data collected, we could see an increase in QE duration following the QE workshop (see figure 3). There was also an increase in QE from baseline after the SPB workshop, although this increase was not as great. This suggests that there may be an interaction effect between the two interventions.

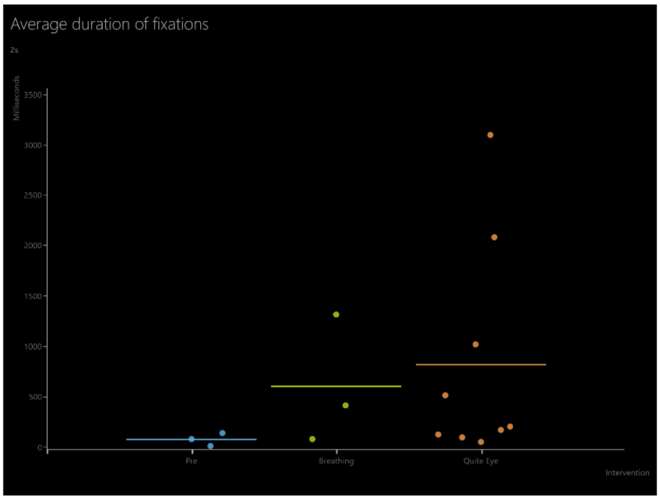

Figure 3: Fixation duration post interventions

Looking closely at the data from one participant, there was an interesting finding whereby pre-intervention, they demonstrated blinking after each shot (see figure 4), but after the QE workshop, they had one fixation for the entire five shot sequence. Although this technically would not count as an elongated QE period (as there is action to pull the trigger for each shot), it is an interesting change to the gaze behaviour, and seemingly successful one as they went from a score of 3 (out of 5) to 5 (out of 5) in their shooting.

Figure 4: Gaps in orange line demonstrate blinks after each shot

Figure 5: Continuous lines show one fixation for all shots

Workshop findings

Pre-workshop

Prior to the first workshop, participants wrote their thoughts and experiences on how they had developed their existing breathing techniques and gaze patterns. They also rated their knowledge on the subject pre- and post-workshop (change scores of perceived knowledge pre- and post-intervention can be seen in figure 6). This allowed for a direct comparison to post-workshop ratings and perceptions. There was a significant improvement in knowledge of all areas from pre- to post-intervention ($P < 0.05$). Pre- and post-education workbook answers and focus group discussions are detailed in turn below.

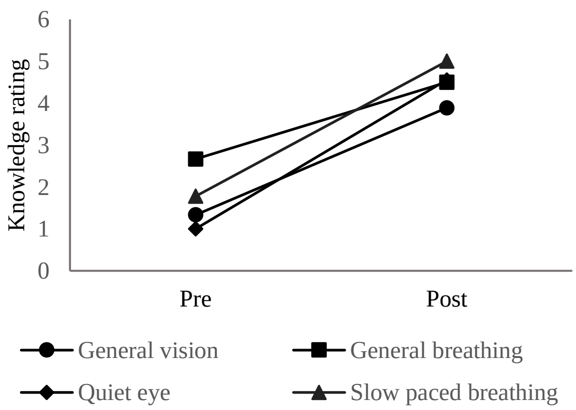

Figure 6: Knowledge ratings pre vs post educational workshops

Breathing workbook (pre-education)

In relation to breathing techniques, participants identified the benefits of using their existing breathing techniques, where in biathlon training and competition these breathing techniques were used and who were the influential figures in developing these techniques.

Participants initially reported several different breathing strategies, consisting of a variety of quick and slow breaths for different parts of biathlon. When transitioning from skiing to shooting, participants generally reported trying to control breathing by slowing the breathing pace down. Breathing techniques during shooting tended to vary the most, with some participants suggesting, “quick, short breaths” and others reporting exhaling in a “quick, quick, slow to align with target” type of breathing routine. Some participants attempted to hold their breath during the shooting period. Interestingly participants did not identify using a slow-paced deep breathing technique during shooting. Although participants recognised a benefit to using breathing techniques, not all participants understood why they were using the specific breathing technique that they were using, but participants were aware that there were benefits for shooting performance and in life beyond biathlon. Overall benefits were reported as being able to switch mindset whilst coming onto the range, reduce the rifle movement during shooting, to reduce stress and increase focus.

Participants had experienced a range of influential individuals who had taught them about breathing techniques. These individuals included national and international level coaches, local gun club coaches, and school coaches. Several participants identified that they had tried various patterns taught to them by a key stakeholder. Participants also highlighted that they had tried several techniques and used trial and error to see which one worked well for them in the different situations.

Breathing focus groups (post-education)

The focus groups followed at the end of the study once participants had practiced SPB on several occasions, both during training in biathlon and away from the training and competing environment. Themes and subthemes (see Table 2) were organised from the data and revolved around participants’ experience of using SPB, when to use it in biathlon, benefits, and potential barriers.

Participants suggested that incorporating SPB was beneficial for performance in several ways. These benefits related to the way SPB influenced performance in terms of focusing thoughts on the breathing allowed participants to be aware of the task at hand rather than on thinking about outcomes or what if’s described as “poisonous thoughts” that might distract them, feeling and being able to relax when it counted both pre-race and during the race. The physical effects of the SPB were also highlighted as a way that SPB was beneficial for performance in that individuals felt able to slow their body down and avoid shaking that often comes with fast and quick breathing.

There were a variety of places that participants felt SPB was beneficial, which included getting over mistakes, during shooting, transitioning from skiing to shooting and outside of biathlon. Participants reported feeling more in control during shooting and enjoying the process of being able to focus on slowing breathing down. Interestingly participants also noted that they thought SPB could be useful the night before a competition while trying to get to sleep and using SPB for additional anxiety-evoking situations.

Although the focus group was overwhelmingly positive in participants’ experiences of using SPB, a number of barriers were highlighted. These barriers related to the difficulty of changing existing patterns that had been used over a period of time. One interesting barrier related to the idea that SPB was not biathlon breathing and this had been handed down by coaches and successful biathletes. Participants felt the influence of this barrier was reduced somewhat by the funding source, “If the IBU funded it then it must be important.”

Table 2: Themes and Subthemes for SPB

Overarching themes	Themes	Subthemes	Representative quote
Using slow paced breathing	Timing	During shooting	Using SPB has changed . . . how I breathe when I get ready for target. I bring the rifle onto the target so that final breath if I know that it is a confident breath it is going to be super steady and then I can release a shot and I feel that I am really in control of the moment.
		Transitioning	I personally would only use the deep breathing when coming onto the range, (not on the range)
		Following a mistake	Say you fall on a tight corner; you can implement some deep breathing it kinda relaxes you and helps stop the negative thoughts the next time that you come around that piece of the track you can think about breathing and not the thoughts.
		Outside of biathlon	The deep breathing, I quite enjoyed it, it was relaxing. I can imagine [it is] something that you can use in day-to-day life.
	Performance improvements/ reasons to change	Relaxation	The slow breathing just sort of relaxes you and takes your mind of it (shooting) and then you focus more on like what needs to be done as if you are just starting from the first shot again. It just makes it easier to be on target to be honest.
		Self-talk	In biathlon we speak a lot about poisonous thoughts, when you get to three out of three on the range and you start to think, “I’m going to get five out of five” . . . so deep breathing . . . really helps to, not necessarily get rid of those poisonous thoughts, but dampen them so that you can really focus and concentrate and then you are likely to be more successful in shooting.
		Focus	When you come into the range, you are tired, you are in pain, your legs are shaking . . . you can only think about big things and if one of those big things is breathing then it means you can’t think about other things. It kinda focuses you.

		Pre-race anxiety	When you think about a race you can get really nervous and think "oh what are the expectations?" But actually, implementing the deep breathing with the visualisation can help slow it down and stay in the moment and this can help visualise how the race will go well.
		Performance improvements	High heart rate shooting is just generally shaky I think the deep breathing helps a little bit with steadying the rifle and that in turn allows you to focus on the target and allows you to be a better shot.
		Existing method not working	If you have the fast breathing it is hard to hold the rifle stable . . . I can feel myself shaking more.
	Barriers	Skepticism	I want to experiment with it a bit more before using it.
		Habit	For the more experienced athletes it's kind of … you have your set method and if it works it is hard to move away from that.
		Too slow for shooting	I wouldn't use the slow-paced breathing when I'm on my mat and lining up to my target cause for me then I'm waiting too long exhaling for 5, 6 seconds that's too long to take a shot for me. I take much quicker sharper breaths.
		Going against coach advice	I've had more of a closed mindset because I have done races before . . . and used what the coaches told me.
		Going against the norm pattern	Biathlon has been set in its ways in the past so it was hard to think about new ways and actually the best in the world aren't using them but I think if the science says it is beneficial . . . actually it could be the new way forward.

Gaze workbook (pre-education)

Participants described several existing gaze strategies that enabled them to shoot including ensuring that their left eye was closed, which was reported to improve sight alignment. This strategy was commonly reported, even though, after testing, several participants were left eye dominant.

Other participants kept both eyes open to enable a better focus on the target, while some participants did not have a specific strategy. Across the group, various methods were reported as enhancing the alignment of sights including centering the foresight in the rear sight, keeping the target central, and gazing at the sights to align them correctly. Benefits of this alignment related to improved performance, clearer vision, and increased confidence to get the timings correct for shooting. A range of individuals had taught these techniques, but the key individual cited was the coach.

Gaze focus groups (post-education)

Several themes were organised from the data relating to using quiet eye techniques. Participants recognised and experienced how using Quiet Eye could improve performance whilst shooting. One of the mechanisms identified by participants to explain why QE influenced performance was similar to that described for SPB as a way to avoid focusing on unhelpful thoughts. Participants suggested that focusing on something else such as the mantra or breathing meant that there was not enough room to focus on unhelpful thoughts, which in turn led to a more controlled focussed performance.

Additional mechanisms were reported as enhancing stability, reduction of strain on the eye via a more efficient focussing pathway. A number of barriers were reported that again were similar to those reported for SPB in that there was initial scepticism because this was not the normal biathlon way taught by coaches but again the validity provided by IBU funding meant that participants tried to be open minded when using QE. One factor that could affect the effectiveness of QE is the ability to practice these techniques.

Table 3: Themes and Subthemes for QE

Overarching themes	Themes	Subthemes	Representative quote
Using quiet eye	Influence on performance	Helpful for performance	It's been really interesting seeing the different types of gaze of your eye, it’s been really helpful for me implementing it into the shooting training we have been doing.
		Improved performance	When I actually started to focus on it [quiet eye] I started to see a difference in my shooting. I think I was more focussed on the gaze instead of just lining them all up.
	Performance improvement mechanisms		
		Mantra and thoughts	I think the mantra could be helpful (to) try not to focus on too many thoughts
		Focus	I can now look at the target but without focussing so it’s not like straining my eyes and when I know when my sights are about to come onto it, I try to get QE and focus and that gives me good timings to pull the trigger
		Stability	While I think the two second period is not huge but if you are already tired coming into the range in an actual

			biathlon it could significantly affect your shooting by affecting your stability
		Efficiency	At the start of the camp . . . I would focus on the sights and wait for them to align with the target, which I felt had a lot of unnecessary eye movement, now I focus on the target and wait for it to align um which has a lot less unnecessary movement
		QE and eye rest	My eyes fatigue quite quickly so it gives you that period of solid concentration and then when you move onto the next target you rest it for those short seconds and then you are ready for solid concentration again.
	Barriers	Equipment	the glasses that you wear, they do impact how you use the rifle to the side so I think that that slightly impaired it.
		Difficulty finding a pattern.	Effectively you are trying to focus on the target but you are trying to focus on having your gun lined up at the target too. The combination of the two made it quite hard to move to fully focus on the target and use the quiet eye.
		Practice	I think it will take some practice especially as like I personally, like… I don't try to hold the target for the whole two seconds before I pull the trigger.
		Scepticism	At first I was quite sceptical, I was like how is this going to work?
		Balance	I need to find a balance [with how long I use QE] because sometimes I've been trying to focus so hard on the QE that I am taking too long to take the shot and then I am starting to lose my balance and stuff

The final point to reflect on relates to the participants thoughts regarding using the interventions in competition or during training. From the focus group, there was a feeling from participants that both interventions would be useful going forward. A general point identified a need for further training with the interventions but also training that replicated the natural setting with one participant suggesting, “more realism in the testing so to include that impact of the natural environment” as a way to develop the effectiveness of the interventions.

Although sceptical at first, having the IBU involved in the project enhanced the buy-in from participants, “If the IBU funded it then it must be important,” participants demonstrated an appreciation for both techniques and felt that the study enabled them to get out of a habit that although may have been used for long periods, may not be effective for this group of aspiring biathletes.

Conclusions

The findings from the quantitative data show us that the combination of both workshops did bring about a significant improvement in shooting performance in biathlon athletes. It is unclear, due to the small number of participants, which intervention may be most beneficial, or whether both are required to bring about improvements.

While the data was limited and some unfortunately missing, there was a promising trend in the resting HRV (RMSSD) data. This increased from pre to post intervention, this suggests that athletes were able to increase their HRV using breathing at a baseline level across a very short intervention period. Participants did also report that they felt relaxed while doing SPB and would use this outside of the sporting environment, therefore perhaps supporting the increased HRV at baseline. While the influence of the shooting intervention on HRV is still unclear, the qualitative results supported the use of SPB either in the preparation for shooting or to help influence other performance distractions e.g., negative thoughts.

The limited data collected via the eye-tracker did give us some interesting results. Perhaps of most relevance was the change in blink rate of one participant from blinking after each shot, to not blinking, and demonstrating one long fixation for the entire five shot sequence. Based on this data, and feedback from the focus groups, this may be an idea gaze pattern for biathlon as athletes did report that having an extended QE between each shot may take up valuable time. Further research should be conducted in this area.

Recommendations

The findings, specifically those from the workshops and focus groups, suggest that further education for athletes into the psychophysiological factors which may underpin shooting performance is greatly needed. The workshops created for this research project can be packaged up for delivery to biathletes and should improve understanding and potentially also performance. They were specifically designed to require minimal access to specialist equipment so they could be rolled out relatively easily and carried out online if required.

However, based on our experiences in conducing this study, we would recommend that further research and/or coach education sessions are delivered prior to attempting any intervention with athletes. Particularly regarding SPB, we found that athletes were actively being taught to breathe in a manner which directly contradicted what was required to influence HRV (fast paced breathing). Previous research into breathing in Biathlon has identified a range of breathing techniques used and with varying results. For example, evidence suggests that increased respiratory rate has a negative impact on accuracy, shooting time, postural control and stability of rifle (Ihalainen et al., 2018; Laaksonen et al., 2018; Pelin et al., 2020; Sattlecker et al, 2017). This is supported by more recent research where shallow or fast paced breathing was suggested to increase sympathetic activity, which may be useful for sports needing high levels of activation (i.e. weightlifting) (Laborde et al., 2022), but may not be suitable for shooting. Despite these potentially negative effects this type of breathing has been recommended for Biathlon performance in the past. Higginson (2002) suggested that biathletes should use rapid, shallow breathing as this decreases heart rate and HRV. However, we promoted the opposite in slow, deep breathing as this helped to decrease heart rate and increase HRV (Laborde, Allen, et al., 2022; Laborde, Allen, et al.; 2021; Sevoz-Couche & Laborde, 2022). This seemed to cause conflict with the athletes as many of them were open to trying the new techniques we were introducing, but they were aware that these were not what they had previously been taught. Further, although the coach encouraged athletes to be open to what we were suggesting, at the training sessions he was running around our intervention, athletes were often being asked to practice techniques that were in direct opposition to what we were suggesting. Therefore, to reduce possible conflict for athletes, and to improve coaches scientific understanding, we strongly recommend running coach education sessions prior to any athlete interventions.

In terms of the understanding around vision and quiet eye, athletes reported having little to no knowledge of this area before the workshop. This was evidenced by the finding that three of the nine participants were found to be left-eye dominant, despite all shooting with their right eye. Eight of the nine participants reported that they did not know about eye dominance prior to the workshop so were all just shooting with their dominant hand and had not considered that they might have greater success with their dominant eye. The concept of eye-dominance had not been introduced to them by the coaching staff at all which again highlights the need for coach education sessions in this area.

Based on the discussion above we have the following recommendations:

1. Quiet eye and SPB interventions should be considered as part of biathlete education and training
2. Further research should be conducted into the gaze behaviour of Biathletes to inform future quiet eye interventions
3. Further research should be conducted into the use of SPB with Biathletes
4. Coach education surrounding performance enhancing techniques in Biathlon should be delivered.

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Appendices

Appendix 1: Information sheet and consent form

AECC University College
Transforming lives through Health Sciences

Research Information Sheet for Participants

I am Dr Zöe Wimshurst and I am a Senior Lecturer at AECC University College leading a research project investigating psychophysiological measures and shooting performance in Biathletes. I am requesting your participation in this study as you have been identified as a high-level biathlete within the British system. The study will involve participants wearing an eye tracker and heart rate monitoring equipment while shooting. You will shoot in both fatigued and non-fatigued states. Following this initial measure of your shooting performance, you will be given the opportunity to learn about how your gaze behaviour and/or breathing rate may be affecting your shooting performance, and you will receive training on how to improve this. After further testing of your shooting performance, you will be given training in the other psychophysiological measure and your shooting performance will be measured again. At a third testing session you will have one final test of your shooting performance and then given the opportunity to participate in a focus group where you will be asked questions about your experience of the interventions you underwent and how you feel they impacted on your performance.

Personal information will not be released to or viewed by anyone other than researchers involved in this project. Results of this study will not include your name or any other identifying characteristics. The anonymity of participants will also be maintained in the published results.

Your participation is voluntary, and you may withdraw your participation at any time up to one week after the end of your data collection. If you decide not to participate there will be no negative implications on your place within the British Biathlon team.

If you consent to take part, you understand that you anonymised data may be stored on file and used in other research at a later date in order to enhance scientific understanding of the psychophysiological factors involved in biathlon.

Please sign below to indicate your consent to participate and also that you understand the following: That you may withdraw your consent and discontinue participation at any time without penalty or loss of benefit to yourself. You understand that data collected as part of this research project will be treated confidentially, and that published results of this research project will maintain anonymity. In signing consent, you are not waiving your legal claims, rights, or remedies. A copy of this information sheet will be offered to you.

If you have any questions please ask them now, or contact me Dr Zöe Wimshurst at zwimshurst@aecc.ac.uk or 07793411648

You understand that if you have questions about your rights as a participant in this research, or if you feel that you have been placed at risk, you can contact: School of Rehabilitation, Sport, and Psychology, Lead on Research, Dr Alyx Taylor (ataylor@aecc.ac.uk)

Please sign and date here to indicate that you understand the information above and that you are willing to participate in this study.

Signature Date

Name

Appendix 2: Pre experiment checklist

Biathlon checklist

Participant number: _____

Date: _____ Time: _____

Please **tick to confirm** that you meet the following conditions:	Yes	No
Have you read the information sheet and consent form, understood it and agree to it?		
Can you confirm you have *no known* heart or respiratory conditions?		
Do you have any blood pressure conditions?		
Can you confirm you have *no known* allergy to electrode gel?		
Are you a smoker? *If yes how many cigarettes do you smoke a day* ___________________________________		
Are you taking any medication (including sleeping tablets)? If yes what medication/s are you taking ____		
For female participants, are you taking a form of oral contraceptive?		
Do you suffer from any mental disorders, for example severe depression or anxiety disorder? If yes are you taking medication for this____		
Are you allergic to plasters?		
Do you have corrected vision? If yes - do you wear contact lenses or glasses (please circle) If glasses - can you use contact lenses or see without (please circle)		

Sex: M/F

Current ranking: _______________

Age: __________________

Height: ______________

Weight: _____________

BMI:________________ (experimenter only)

Thank you. Please hand this sheet back to the experimenter.

Appendix 3: Pre-testing screening

Biathlon pre-experiment checklist

Participant number: _____ **Date: _____ Time: _____**		
Please **tick to confirm** that you meet the following conditions:	**Yes**	**No**
In the past 24 hours have you done any strenuous exercise (*above and beyond what you would normally do*)?		
In the past 24 hours have you consumed alcohol?		
In the past two hours have you smoked?		
In the past two hours have you consumed caffeine?		
In the past two hours have you eaten?		
In the past two hours have had a drink of water? If yes roughly how much? ____		
Did you follow your usual sleep routine last night? Bed Time______________________________ Waking Time______________________________		
Do you need to use the bathroom?		
Have you rushed in order to arrive on time for this experiment?		
Are you feeling fit and well, free of injuries?		

Please hand this back to the experimenter when finished.

Appendix 4: Quiet eye workbook example

Quiet Eye Workshop Workbook

Participant name:

Workshop 1/2

(1) Knowledge of applied vision (pre)

On the following scale please rate your current knowledge of vision techniques:

1 None	2	3	4 Fair	5	6	7 Excellent

Any other comments:

On the following scale please rate your current knowledge of Quiet Eye:

1 None	2	3	4 Fair	5	6	7 Excellent

Any other comments:

(2) What visual techniques do you use when you perform?

Do you use any visual techniques currently?

When do you use them?

Where did you learn this visual technique?

If you were to recreate your pre-shot routine what would your vision/gaze look like?

What benefits do you get from controlling your vision/gaze?

(3) Knowledge of applied vision (post)

On the following scale please rate your current knowledge of vision techniques:

1 None	2	3	4 Fair	5	6	7 Excellent

Any other comments:

On the following scale please rate your current knowledge of Quiet Eye:

1 None	2	3	4 Fair	5	6	7 Excellent

Any other comments: