The influence of expertise on anticipation of badminton single serves

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Abstract

Badminton is a fast racket sport and requires players to develop highly advanced anticipation skills. Research has identified differences in the way that experts badminton players fixate their gaze during play. Investigating eye movement patterns in badminton players, may help to understand how expertise is associated with better anticipation abilities. All previous research on the return of a badminton serve has been solely made up of laboratory-based components and consequently it is arguable as to whether athletic skills are transferable from real-life settings. This study investigated the return of a badminton serve in a game setting. Expertise and type of serve acted as the independent variables when investigating between-group differences during fixation development. The experts (N=23) and novices (N=11) were asked to return forehand serves, whilst wearing a mobile eye tracker, for recording eye movement data for refixations, first visual intake duration and dwell time. The results demonstrated that both experts and novices targeted similar fixation sites. However, during the short serve, experts were found to make more fixations and longer fixation durations, suggesting that experts may use their pre-existing knowledge about badminton in anticipating serve returns.

Keywords: *Badminton, Expertise, Fixation development, Eye movements, Anticipation*

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Introduction

Badminton has been an Olympic sport since the 1992 Olympic Games and is generally considered the world's fastest racket sport. The sport demands players to have exceptionally quick responses, as shuttles reach speeds of over 400 km/h (Maæka & Cych, 2011). The world record for the fastest smash of 419 km/h is currently held by Viktor Axelsen (Axelsen smashede sig til rekord i All England-finalen: 419 km/t, 2019).

The high shuttle speed, means that badminton players are limited in their ability to track it before it reaches what is known as the point of interception (Müller & Abernethy, 2012), i.e. the moment when the racket touches the shuttle. Research has compared data between experts and novices to understand the naturally occurring behaviours in badminton players prior to this point. Rudin and Sharipan (2016) examined badminton players in relation to non-badminton players, by asking them to follow an alternated light fixation in order to measure eye movement differences between the two groups. They reported that badminton players produce saccadic eye movements that were more accurate than non-badminton players.

Sport research has explored the topic of gaze in sports and has defined gaze as a means of gaining information for the purpose of avoiding making mistakes (Najemnik & Geisler, 2005). Gaze may therefore be another word for target fixation (Vickers, 1996). Being able to anticipate an opponent's movement accordingly is a skill highly valued in badminton, as players only have a very short amount of time to adjust a stroke once the movement has commenced (Müller & Abernethy, 2012). Badminton players may use information provided by the opponent towards completing accurate and appropriate countermoves when responding to the moves of the opponent. There may therefore be some points on the opponent's body that provide more information than other points. We refer to these points as fixation sites or areas of interest (AOI), as this is where the badminton player chooses to fixate their eye movements.

To the knowledge of the authors, four studies have considered the influence of AOI during badminton games. The first, that by Abernethy and Russell (1987), investigated expert and novice badminton players and the ability to predict, i.e. anticipate, the shuttle end location. Participants viewed videos of badminton serves and marked the end location of a shuttle on a piece of paper (Abernethy & Russell, 1987). The results showed that experts were able to make use of the information available earlier (167 s before the shuttle made contact with the racket), in comparison to the novices (83 s before shuttle-racket contact) when anticipating the direction of the shuttle (Abernethy & Russell, 1987). A more recent badminton study was completed by Abernethy and Zawi (2007). They replicated the video-viewing procedures by Abernethy and Russell (1987) in expert and novice badminton players but added the component of occlusion. The videos were edited to display either only the racket and the shuttle, only the arm and the shuttle, only the upper body and the shuttle or only the lower body and the shuttle. They reported that both experts and novices were able to correctly anticipate the direction of the shuttle regardless of whether or not information was concealed from them (Abernethy & Zawi, 2007). What set the groups apart however, was that experts were found to extract more information provided by the racket and lower body of the opponent, in comparison to novices who derived the most information from the arm of the opponent. The data may be more transferable to real-life scenarios if participants were asked to physically respond to the shot shown in the video, as opposed to noting down the direction of the shuttle on paper. Alder, Ford, Causer and Williams (2014) further investigated a badminton player's ability to anticipate the landing of a badminton shot. They asked expert and novice badminton players to physically (by moving towards the place they thought the shuttle would land) and verbally respond to a serve they viewed on a life-sized screen. Eye movements were recorded in both the experts and novice observers. The results were in agreement with the two previous studies (Abernethy & Russell, 1987; Abernethy & Zawi, 2007), proposing that experts show greater anticipation skills than novices (Alder et al., 2014). Experts were again found to fixate most on the racket, in correct trials, and the novices were found to fixate most on the wrist of the opponent, for incorrect trials (Alder et al., 2014). However, similar to the two previous studies, the players were still asked to pretend to respond and it may be questioned whether they experienced true match like feelings and thus produced reliable data.

The only study to measure eye movements while players were actually on court was recently published by Chia, Burns, Barrett and Chow (2017). The researchers examined visual behaviours by eye tracking badminton single players whilst they served. They reported that experts had a longer preparation stage than novices when serving and because of this, they made more and longer fixations and fixated on a wider range of locations in comparison to novices (Chia et al., 2017). All four studies mentioned above have appropriately investigated badminton player's ability to anticipate and make fixations for high level badminton games. However, the studies are lacking both data transferrable to real-life badminton games and eye movement data on the return of a badminton serve.

Studies in sport examining the allocation of attention towards anticipation are limited by the need to ask participants to look for a certain object or at a certain point of interest (Kibele, 2006). This links closely to the idea of a coach telling a player what to do, or where to look. In the well-known experiment by Simons and Chabris (1999), the researchers investigated the concept of inattentional blindness and found that participants failed to notice other important information if they were asked to search for something specific. In other words, asking participants to fixate their vision towards a specific point may hinder the development of the natural fixations that are used in a real-life game of badminton. Hence, real-life experiments investigating the relation between perception, anticipation and oculomotor strategy and movements are required.

This study examines the eye movement patterns made by expert and novice badminton players returning serves on a badminton court. Based on the literature review provided we hypothesise that experts will, in comparison to novices, make a greater number of refixations, longer fixation durations and they will fixate on different AOI.

Methods

Participants

The study contained a total of 34 badminton players, after two were excluded (one beginner and one national player) due to lack of data. They were beginners (five females and six males, M= 11.73 years of age, SD= 0.91 years), youth coaches (seven females and two males, M= 17.33 years, SD= 2.60 years), college players (three females and seven males, M= 17.8 years, SD= 1.23 years) and lastly national players (one female and three males, M= 21.50 years, SD= 4.43 years). The coaches, college players and the national players were grouped as experts because they had a minimum of three years of experience competing in badminton. The beginners had no experience in competitive badminton. All players, except for one male badminton college player, were right-handed and no significant injuries were present in the players. All participants had reported normal vision.

Ethics

The researcher passed the safeguarding check (the Disclosure and Barring Service) before the study, as some of the participants were under the age of 18. Guardians were asked to sign consent forms on the behalf of participants under the age of 18 and participants were debriefed together with their guardian. The study was approved by the Research Ethics Committee of the Faculty of Arts and Human Sciences at Kingston University, London.

Material

SMI mobile eye tracking glasses (SMI ETG 2w, SensoMotoric Instruments, Teltow, Germany) were used in the study as they examine accurate representations of eye movement patterns in real-life settings. The mobile eye trackers permitted participants complete mobility with the lightweight glasses (47 g) and they further supplied high resolution (1280x960) videos and 60 Hz binocular tracking data. The glasses are attached to a recording box via a cable. The recording box was placed around the waist of the badminton player using a normal waist belt and the cable was placed on the back of the player away from their arms. All participants were fitted with the belt accordingly and instructed to warm up while wearing the belt and eye tracker to familiarise themselves with the possible obstructions from the device. No participants expressed discomfort nor feeling restricted by the belt nor wearing the glasses.

Calibration of the eye tracker was necessary for accurate measurements. While wearing the eye trackers, participants were asked to focus on a point roughly 1.5 m away from where they were standing. The researcher used the recording device to allocate point of gaze to the point on which the participants were fixating. The experiment commenced after calibration had been successfully completed.

Procedure

Prior to the experiment, participants were informed that they would be returning a variety of single serves during a badminton single match. Consent forms were either signed by the participants themselves or by a guardian, if the participant was under the age of 18 years old. The experiment required an opponent, i.e. a server, to serve the required serves to the participants. The server was either an expert badminton player, with a minimum of three years of either competition experience, or a coach, with a minimum of three years of coaching experience, and was therefore deemed capable of completing technically correct badminton serves. Each trial of the study followed a procedure created to stimulate a match-like environment and the standard badminton serve rules applied in the experiment. Overall, the participants returned 40 serves, whereof the first 20 consisted of long forehand serves and the last 20 were short forehand serves, and the trials followed the pattern of: serve-return-hit-hit. The data analysis concerned only the eye movement patterns produced by the participant during the return of the serve, but the remaining hits were vital as they simulated realistic badminton scenarios. The serve return phase, in which eye movements were recorded, took place from when the server started the motion until the point of interception. Any incorrect serves or incorrect serve returns were replayed until 20 correct trials had been recorded by the eye tracker for each serve type condition. Breaks were introduced as required. The experiment took a total of 20-30 min per participant and concluded with debriefing. Participants under 18 years old were debriefed along with their guardian.

Data Analysis

The study followed a between-groups design with refixations (the number of times participants returned to one of the fixation sites), first visual intake durations (the amount of time the participants spent looking in the area of interest at the first glance) and dwell times (total time spent looking at the one of the areas of interest) as the dependent variables; and type of serve condition (long forehand serve and short forehand serve) and expertise level (experts and beginners) as independent variables.

The areas of interest (AOI) used in the analysis originated from previous studies on eye tracking of badminton players. A total of 11 AOI were considered of importance for serve returns: the shuttle, the racket, wrists, elbows, arms, shoulders, head, belly, hips, legs, feet (see Figure 1). All data were evaluated for normality using the Shaphiro-Wilk's test at $p<0.05$, and the Mann-Whitney U test was chosen to test for differences between independent variables (part1) with a significance level of $p<0.05$.

Subsequently (part 2), the AOI were grouped into three general sites: upper body fixation sites (elbow, arm, shoulder, head, belly), lower body fixation sites (hips, legs, feet) and fixation sites that were located on areas away from the main part of the body of the opponent (shuttle, racket head, wrist). This was because coaches, when coaching badminton techniques, separate upper body motions from lower body motions. The number of refixations, first visual intake durations and dwell times were used to indicate the level of importance of the AOI to the participants' attentional behaviour. It is assumed that one AOI is considered more important than another AOI if participants either return frequently (i.e. make more refixations) to the AOI or devote longer fixation durations (i.e. longer first visual intake durations and longer dwell times) towards the AOI.

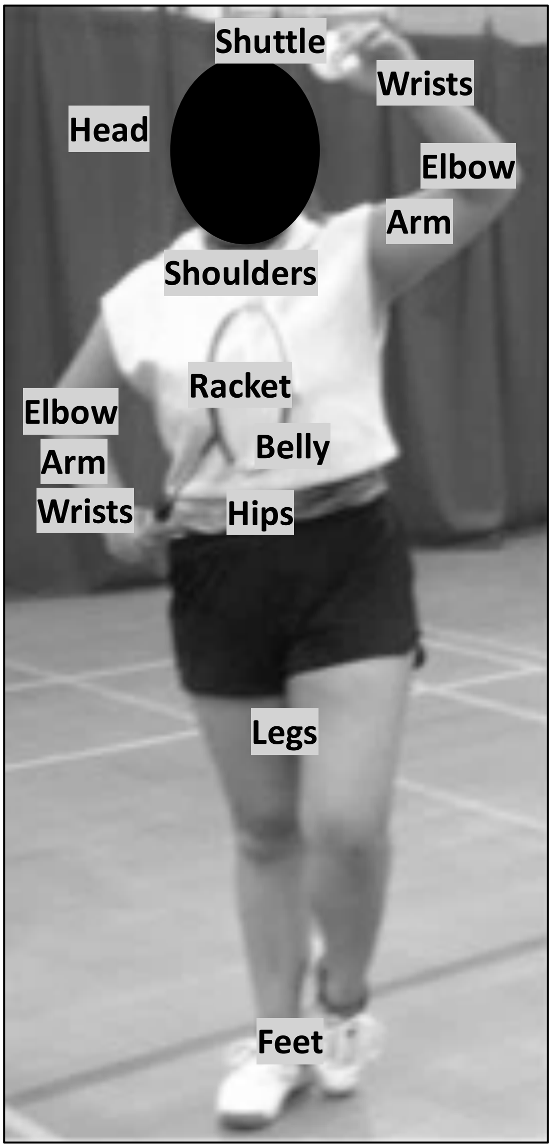

Figure 1. The 11 areas of interest (AOI) analysed.

Results

Part 1

The mean values for refixations (Figure 2), first visual intake durations (Figure 3) and dwell time (Figure 4) are all higher for the experts in comparison to the novices. For refixations, the exception is found for the AOI located on the legs for the long serve and the elbow and arm for the short serve. For first visual intake durations, the exception is the shuttle, racket head and the feet for the long serve and the wrist for the short serve. For dwell time, the exception is the shuttle, racket head and the feet for the long serve and the wrist for the short serve. Qualitatively, the experts are found to show higher mean values for the head during the long serve and for the shoulder during the short serve (see Figure 2, Figure 3 and Figure 4). The novices, in comparison, show higher mean values for the legs (see Figure 2 and Figure 4) and the shuttle (see Figure 3) during the long serve condition and, similarly to the experts, the shoulder (see Figure 2, Figure 3 and Figure 4) during the short serve condition.

Furthermore, the experts appeared to show no fixation patterns for the feet (see Figure 2 and Figure 4) or low fixation patterns for the feet (see Figure 3) for the long serve condition and low fixation patterns for the feet (see Figure 2 and Figure 4) and the wrist (see Figure 3) for the short serve condition. Lastly, the novices show no fixation patterns for the shuttle and the wrist (see Figure 2 and Figure 4) and low fixation patterns for the wrist (see Figure 3) for the long serve condition and no fixation patterns for the racket head, wrist, head or feet (see Figure 2) and low fixation patterns for the elbow, arm and head (see Figure 3) and the feet, head and racket head (see Figure 4).

The data were found to be non-normally distributed. The Mann-Whitney U test revealed significant differences between levels of expertise for the short serve (see highlighted in bold below in Table 1), but not for the long serve condition. The analysis therefore only examined the short serve and found experts favoured the arm and shoulder for refixations, the elbow, shoulder, head, belly and legs for first visual intake durations and the shuttle, shoulder, head, belly and legs for dwell times. Overall, the shoulder was the only AOI found to show a significant main effect across all measurements.

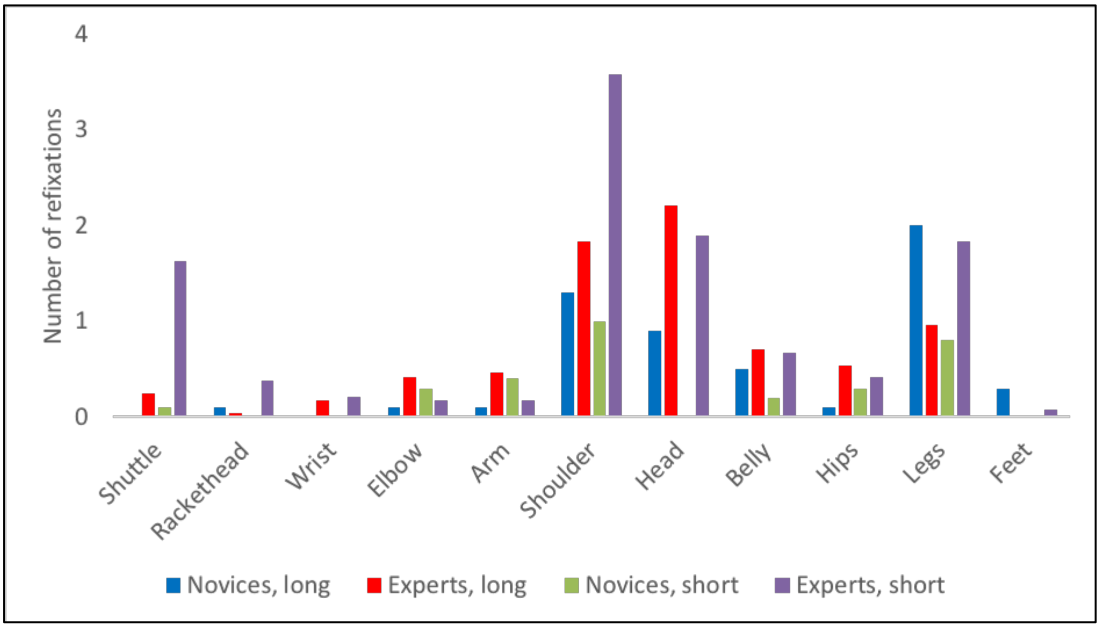

Figure 2. The mean number of refixations for novices (shown in blue for the long serve and green for the short serve) and experts (shown in red for the long serve and purple for the short serve, for the 11 AOI.

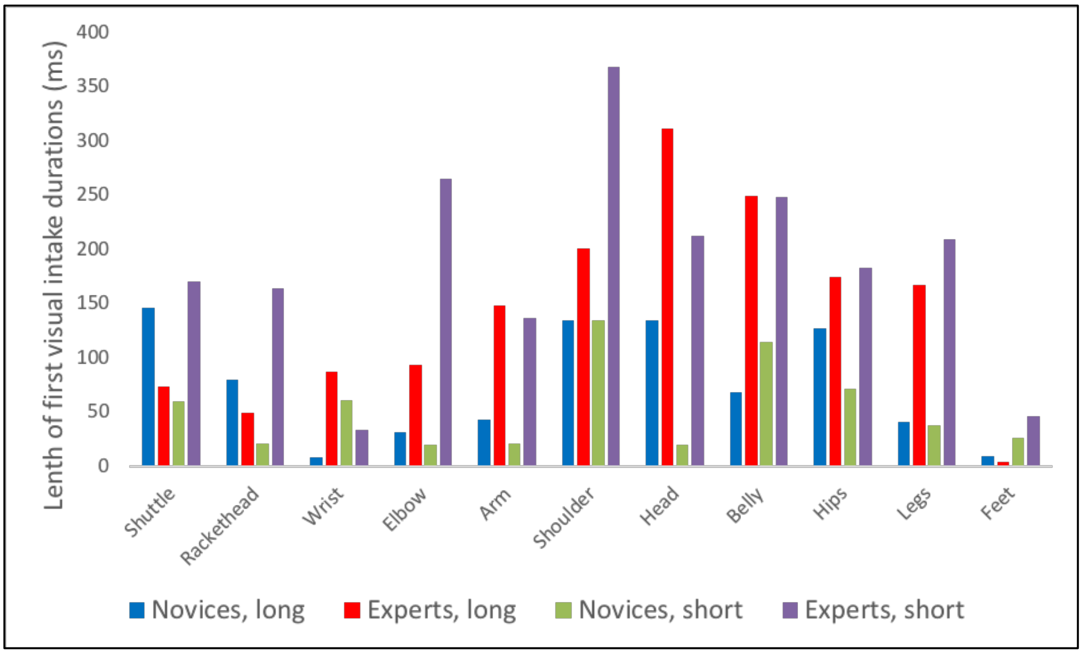

Figure 3. The mean values of first visual intake duration for novices (shown in blue for the long serve and green for the short serve) and experts (shown in red for the long serve and purple for the short serve, for the 11 AOI.

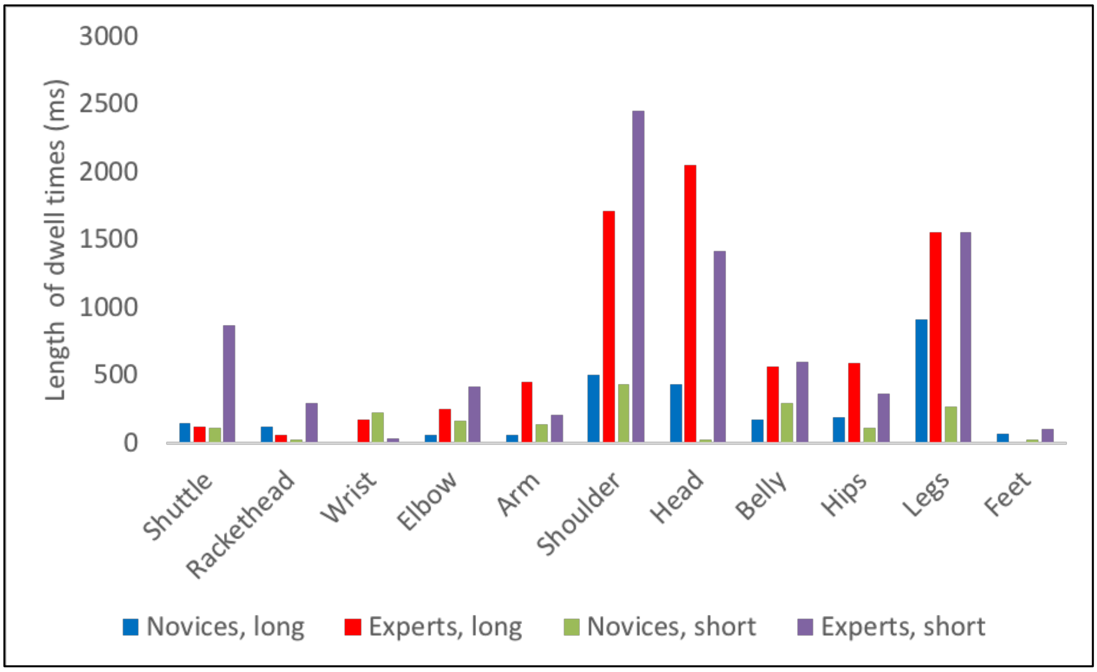

Figure 4. The mean values of dwell time for novices (shown in blue for the long serve and green for the short serve) and experts (shown in red for the long serve and purple for the short serve, for the 11 AOI.

Table 1.
The Mann-Whitney U test values and significance levels for refixations, first visual intake duration and dwell time between levels of expertise for the short serve condition.

AOI	Refixations	First visual intake duration	Dwell time
Shuttle	U=79.00, p>0.05	U=68.50, p>0.07	**U=60.00, p<0.03**
Racket	U=100.00, p>0.05	U=69.00, p>0.07	U=67.00, p>0.06
Wrist	U=115.00, p>0.73	U=104.00, p>0.69	U=102.00, p>0.63
Elbow	U=124.00, p>0.99	**U=60.00, p<0.03**	U=71.00, p>0.09
Arm	**U=124.00, p<0.03**	U=85.50, p>0.25	U=109.50, p>0.83
Shoulder	**U=65.00, p<0.03**	**U=47.00, p<0.01**	**U=43.00, p<0.01**
Head	U=90.00, p>0.21	**U=63.50, p<0.04**	**U=60.00, p<0.03**
Belly	U=98.50, p>0.34	**U=62.50, p<0.04**	**U=63.50, p<0.04**
Hips	U=119.50, p>0.34	U=94.00, p>0.43	U=92.50, p>0.38
Legs	U=94.00, p>0.27	**U=64.50, p<0.05**	**U=64.50, p<0.05**
Feet	U=120.00, p>0.87	U=103.00, p>0.66	U=102.00, p>0.63

Part 2

To further understand the use of gaze during return of badminton single serves, the 11 AOI were grouped into three general sites; upper body, lower body and areas away from the opponent's body. The mean values formed by the experts and novices during refixations, first visual intake durations and dwell times were computed. The mean values for refixations (Figure 5), first visual intake durations (Figure 6) and dwell time (Figure 7) all indicate higher mean values for the experts compared to the novices. The only exceptions are found in the long serve condition. For refixations, the exception is found for the AOI located on the lower body and, for the first visual intake durations the exception is AOI located on the away from the body. Both experts and novices showed higher mean values for the upper body during both the long serve condition and the short serve condition (see Figure 5, Figure 6 and Figure 7).

The Shapiro-Wilk's test found data to be both normally and non-normally distributed so the Mann-Whitney U test was used to test for differences between experts and novices. For refixations, the Mann-Whitney U test revealed a significant main effect for around the body (U=431.00, p<0.05), but was non-significant for either the upper body (U=551.00, p>0.05) nor lower body (U=501.50, p>0.05). For first visual intake durations, the test was non-significant for the around the body (U=408.50, p>0.05), the upper body (U=515.00, p>0.05) and the lower body (U=496.50, p>0.05). Lastly, for dwell time, a significant main effect was discovered for around the body (U=382.00, p<0.05), but not for either the upper body (U=539.50, p>0.05) nor lower body (U=503.50, p>0.05).

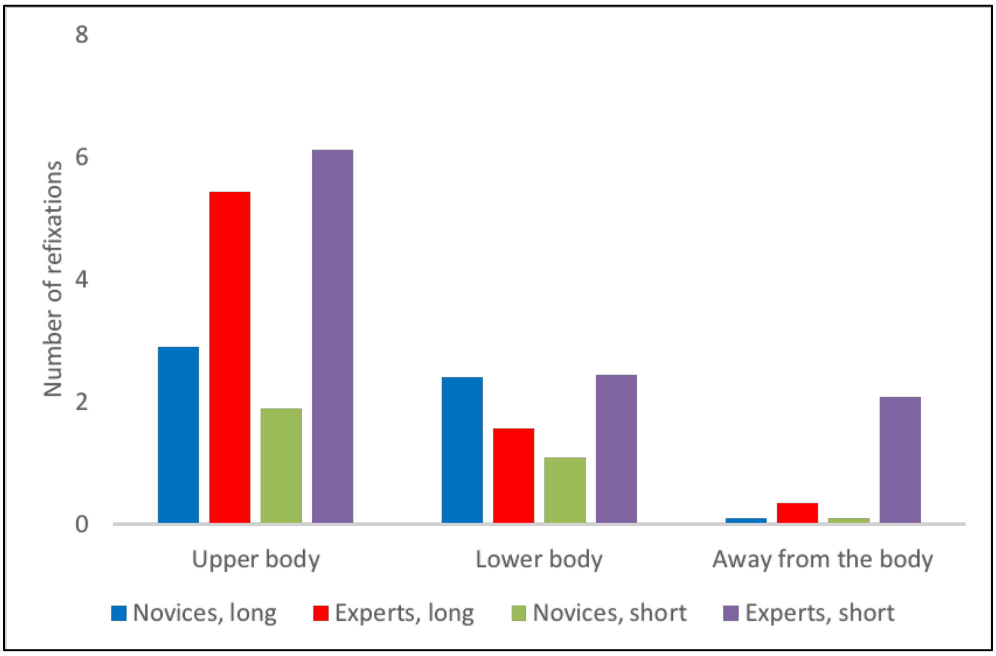

Figure 5. The mean values of refixations for novices (shown in blue for the long serve and green for the short serve) and experts (shown in red for the long serve and purple for the short serve, for the three AOI.

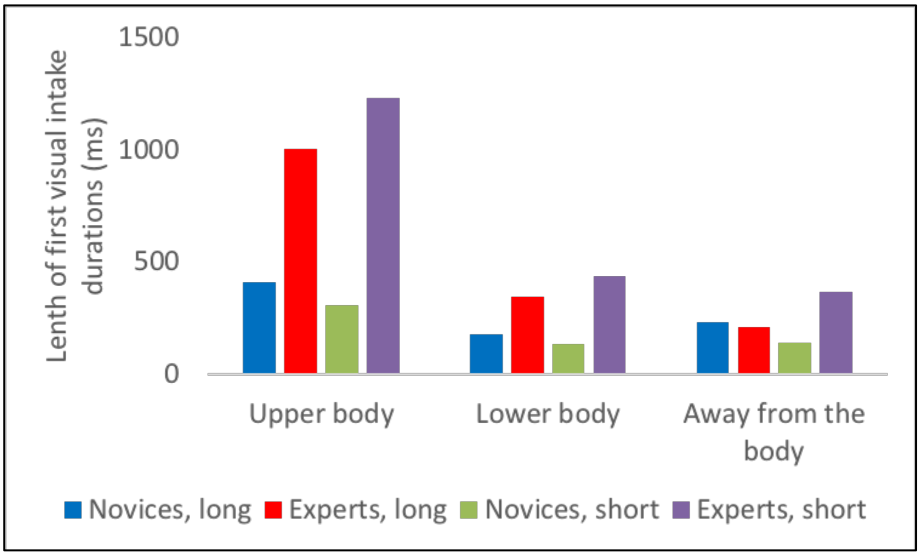

Figure 6. The mean values of first visual intake duration for novices (shown in blue for the long serve and green for the short serve) and experts (shown in red for the long serve and purple for the short serve, for the three AOI.

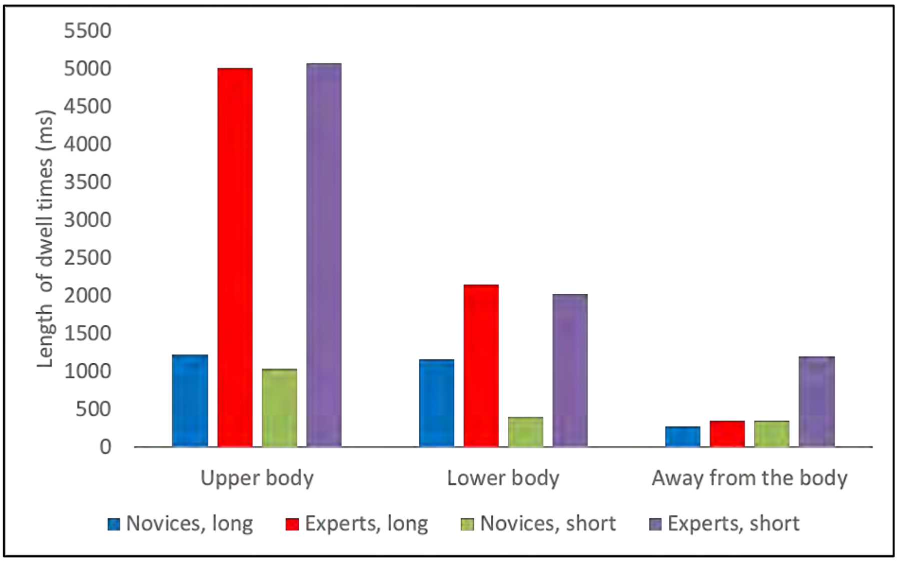

Figure 7. The mean values of dwell time for novices (shown in blue for the long serve and green for the short serve) and experts (shown in red for the long serve and purple for the short serve, for the three AOI.

Discussion

To our knowledge, this is the first study to investigate eye movement patterns in badminton singles players during the returns of forehand serves in real-life situations. The study sought to investigate the development of fixation sites during serve retrieval without asking the participants to look at specific points. It was recognised that naturalistic behaviours would be compromised by asking participants to focus on points and thus eliminate the real-life aspect of the study. The analysis assumes that the more often participants returns to an AOI (refixations), and the longer they spend looking at the AOI (first visual intake and dwell time), the more important that AOI is for correct serve returns.

Badminton players may use information provided from the environment to their advantages during matches. The studies by Abernethy and Zawi (2007) revealed that experts use the racket and lower body of the opponent in anticipating the direction of a shuttle whereas the novices are inclined to use the arm of the opponent. Our current study supports this statement through the analysis of the 11 AOI. Alder et al. (2014) further found that the experts favoured fixations on the racket and the novices favoured fixations on the wrist. These results were not replicated in this study, possibly due to only comparing results on correct trials. Further research may consider comparing eye movement patterns completed during correct serve returns to those completed during incorrect serve returns. The final relevant badminton study is that of Chia et al. (2017). Their results found that expertise lead to longer preparation stages and more fixations. The longer preparation stage might be needed to complete a technically correct serve or a serve that will throw the opponent off their game. This is also the only opportunity athletes have time to slow down and breathe. Hence the badminton players may take longer preparation stages due to the experienced pressure from the opponent or due to tiredness and the need for a break.

It was hypothesised that experts would score higher on refixations, first visual intake durations and dwell time because of their level of expertise and ability to respond quickly. It was also expected that the data would replicate the findings of previous studies showing that experts would favour AOI on the lower body. The results support the hypotheses that experts make more refixations and longer fixation durations. However, the eye movement patterns for both types of serves demonstrate skill related differences in eye movement strategy with experts paying more attention to salient features on the upper body of the opponent.

Abernethy and Zawi (2007) proposed from their findings that experts form AOI towards the racket and lower body of the opponent. In support, both experts and novices were found to fixate on the racket and lower body but our study found that badminton players made fixations on other places as well.

It is foreseeable that the badminton players, regardless of experience, may display fixation patterns towards the 11 AOI due to the physical actions taking place during a serve. Simply put, a right-handed dominant badminton player will serve holding the racket in the right hand and the shuttle in the left hand in front of them. The original serve position is produced by standing sideways with the left arm opposite the net, placing the feet on the ground with the weight onto the left foot, which is stood in front of the right foot as if it had taken a small step forward. The racket or shuttle cannot be held above the level of the hips of the player. The player will start the serve cycle by moving the right *shoulder*, *elbow* and *arm* forwards, in sync with the right *hip* and turning the *belly* towards the net (as commonly seen in other striking sports as well, such as golf). The player will then shift the position of their *legs* by moving their weight from the left leg onto the right leg, i.e. the right *foot* takes a step forward. The cycle ends with the flick of the *wrist* and the *racket* when finally hitting the *shuttle* and placing all the weight from the left foot onto the right dominant foot. All of this takes place in a quick smooth motion. It can be reasoned that it is the movement of the arm that provides the most information towards whether the serve will be a long or a short serve. A long serve requires more of a swing-like motion created by the arm and a short serve is recognised with a more distinct wrist flicking action and less of the arm swing.

Experienced servers will try to deceive their opponents by inhibiting these cues and thereby hiding their intentions for either a long or a short serve from their opponent. However experienced serve returners may also use this knowledge to anticipate the intentions of the opponent and therefore strategically make more and longer fixation sites towards these areas in correctly anticipating which serve is about to take place. This prediction is supported by our study which found significantly greater dwell times on the shuttle, the elbow, the shoulder, the head, the belly and the legs (see Figure

4). Future studies investigating the relationship between successful and non-successful serve returns may further explain the importance of fixating on specific locations.

The long serve may be easier to anticipate than the short serve because it requires a bigger action than the short serve. This is supported by the data showing that experts made more fixations and longer fixation durations for the short serve than the long serve, i.e. experts make more fixations to validate the correct serve taking place. Furthermore, the data found very small variations in the average of fixations made by the novices for the different locations for the long and the short serve, indicating their inexperience and thereby supporting the notion that experts fixate in a more discriminating manner as a result of their greater anticipation.

The strength of the study remains its naturalistic design. We were able to extract reliable eye tracking data by exposing the participants to an environment that resembles natural match situations. Overall, the results are found to support the hypotheses: the experts, in comparison to the novices, showed higher scores of refixations and longer fixation durations. Future studies should therefore aim to continue the development of real-life investigations to further the literature and the understanding on the use of eye movements during badminton.

Conclusion

Badminton players use fixation sites when responding to countermoves from their opponent and some of these fixation sites have been found to be of more importance than others. The fixation sites considered in this study are located on the shuttle, racket, wrist, elbow, arm, shoulder, head, belly, hips, legs and the feet of the opponent. Experts have been found to complete different eye movement patterns in comparison to novices, suggesting that expertise influences the pattern of eye movements in relation to anticipation skills taking place in badminton.

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