Quantifying the role of anticipation in badminton during competition; the impact of situational constraints, game format, match stage and outcome of match

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Introduction

Expert performance requires athletes to consistently produce superior *motor* and *perceptual-cognitive* performance over an extended period of time (Starkes, 1993; Alder et al., 2014). Perceptual-cognitive skill is defined as the ability to locate, identify and process environmental information so as to incorporate with pre-existing knowledge structures and action capabilities in order to select and execute appropriate responses (Broadbent et al., 2015b). Elite sport contains dynamic, uncertain and ever changing situations in which severe temporal demands are placed upon athletes (Williams & Ericsson, 2005). Therefore the ability to predict or anticipate the actions of opponents is essential to allow maximal time to select and execute appropriate responses (Alder et al., 2016). Through extended periods of deliberate practice (Ericsson, 2008), expert performers enhance anticipatory behaviours by developing the ability to identify early cues arising from an opponent's postural movements (Jones & Miles, 1978; Williams et al., 2002b) and integrate this with contextual information such as opponents action tendencies, patterns of play and situational probabilities (Canal-Bruland & Mann, 2015).

A significant bank of work has shown how high level anticipatory skill distinguishes between elite and sub-elite athletes in a range of racket sport contexts including; table tennis (Williams et al., 2002a), tennis (Broadbent et al., 2015a; Shim et al., 2005; Smeeton et al., 2005; Williams et al., 2002b), squash (Abernethy, 1990; James & Bradley, 2004) and badminton (Alder et al., 2014; 2016; Abernethy & Kawi, 2007; Abernethy & Russell, 1987). The majority of the aforementioned work utilised the method of examining anticipatory skill through a temporal occlusion paradigm in which athletes are shown representative video clips of their sport which have been occluded at different time points around key events within the actions of an opponent (i.e. around shuttle-racket contact in badminton as per Alder et al., 2014). Athletes are then required to complete either a verbal and/or physical response in relation to the outcome of the occluded video (i.e. complete a shadow shot as per Alder et al., 2014). Although this method consistently demonstrates an expertise effect in relation to anticipatory skills, it has been suggested that the method is limited in terms of ecological validity as a result of the lack of task representativeness (Araujo, Davids, Passos, 2007). This is primarily due to the video being displayed on a 2 dimensional screen thus lacking the potential cues that are available during the real-world version of the event (Broadbent et al., 2015b). Further critics of the technique argue there is a lack of information-action coupling due to the observed video and the subsequent action being disconnected (Pinder et al., 2011). As a result of these limitations a number of studies have examined anticipatory actions "in-situ" (Dicks et al., 2010). For example Alder et al. (2016) tasked Olympic standard athletes with physically anticipating live serves from an international player on court. Participants were instructed to move as quickly and accurately as possible and to return the shuttle as they would do in match. Authors report how on successful anticipation judgements athletes were able to extract key postural cue information through efficient visual search strategies. Although this method addresses the limitations related to representative task design and information-action coupling, it has methodological issues of its own. The method is described as "in-situ" (Alder et al., 2016), however contextual information such as score, fatigue level, game format, momentum and anxiety are all missing. Therefore it is unclear as to whether the information relating to anticipatory behaviours collected through this "in-situ" method transfer to the actual performance environment of the sport (i.e. competition) in which contextual information is available.

Recent work in tennis competition however has begun to answer the question of whether anticipatory behaviours are influenced in competition by contextual factors that are not present in the traditional temporal occlusion or in-situ methodologies. Triolet et al. (2013) used performance analysis techniques to code 3000 situations involving top ranked tennis players during actual competition. The study identified how different types of anticipatory behaviour take place within competition depending on a range of situational constraints. Specifically, authors identified the transition from *reactive behaviours* to *anticipatory behaviours* as any action when movement is initiated prior to 160ms after ball-racket contact point. Furthermore the findings showed that when players were in a defensive or unfavourable position there was a greater need to anticipate upcoming opponent actions prior to racket-ball contact compared to offensive or favourable positions. This adapted methodology therefore highlights the need to examine anticipatory behaviour in competition to truly understand the demands placed upon elite athletes. Such knowledge is currently not available on elite level badminton which is surprising given its potential importance for training and talent identification. Furthermore the effects of other constraints on anticipatory behaviour such as different formats of the game and the stage of the match, or the relationship between match outcome and anticipatory behaviour have not been examined and could allow for a greater understanding of the mechanisms involved in anticipation in badminton.

The current project aimed to identify: (a) the average response time of elite level badminton players, (b) the frequency of anticipatory behaviours which occur in elite level badminton and (c) how contextual factors such as format of the game (i.e. women's, men's, singles and doubles matches), the outcome of the match (i.e. win, lose), and the stage of the match (i.e. set 1, set 2) impact on both average response time and frequency of anticipatory behaviours.

Method

Participants: Analysis was based on video recordings of matches played during the 2015 SuperSeries events involving athletes ranked in the top 20 according to the BWF ranking. Altogether six matches per format (men's singles, women's singles, men's doubles, and women's doubles) were analysed. The observed players from the men's singles (*M* age = 26 years, SD = 5), women's singles (*M* age = 23 years, SD = 2), men's doubles (*M* age = 28 years, SD = 3), and women's doubles (*M* age = 26 years, SD = 3) had played badminton at a professional level for an average of 10 years (± 3) and all had reached the world top twenty in the ranking established by the BWF.

Video coding process: The recordings were analysed using Dartfish 4.5.2.0 (Dartfish, Fribourg, Switzerland) Software with a frequency of 50 Hz providing an accuracy of 40ms/frame. For each observed situation, the delay between the opponent striking the shuttle (t = 0) and the observable beginning of a response from the other player was measured. This time period, termed the response time, was either positive (i.e. movement after shuttle contact by the opponent) or negative (i.e. movement before shuttle contact by the opponent). In total approximately 2000 points were analysed which translated to approximately 21,000 situations. The set number, outcome of match and format type were each used as dependent variables to analyse the data.

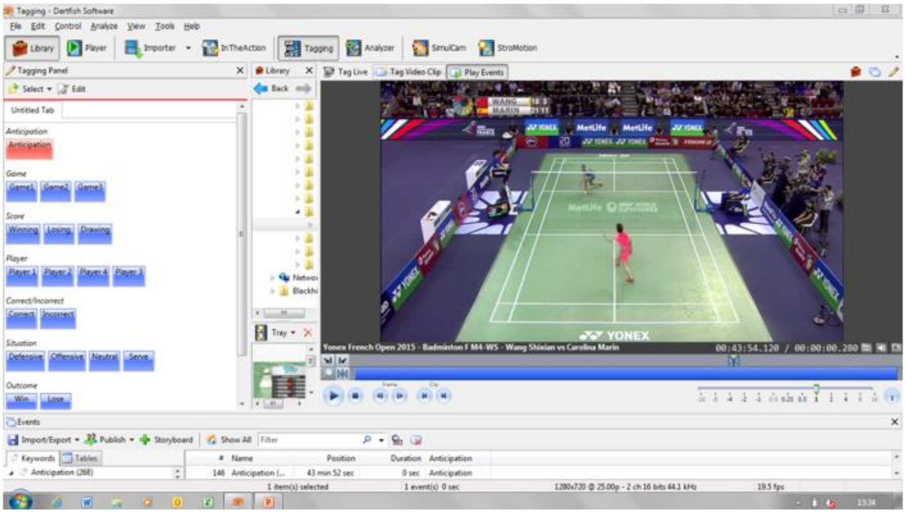

Figure 1. A screenshot of the data collection method through Dartfish software. On the left hand side is the code window designed specifically for this experiment.

Data analyses: The data were presented in two ways. Firstly the mean response time was calculated and descriptive comparisons were made between the different formats, the set, and between the winner and loser of the matches. Secondly the frequency and distribution of response times were presented to allow for a profile of each format to be displayed and an understanding of the percentage of anticipatory behaviours which occurred in each format.

Results

Mean Response Time: Figure 2 shows the mean response time of all the formats combined and also broken down to show the mean response time in the men's singles, women's singles, men's doubles and women doubles competitions. The mean response time combined was 262 ms (*SD* =101). Analysis of mean response time as a function of match format revealed men's singles had the lowest response time (*M* = 239 ms, *SD* = 87) followed by women's doubles (*M* = 251 ms, *SD* = 89), women's singles (*M* = 267 ms, *SD* = 88) and men's doubles (*M* = 287 ms, *SD* = 124).

Figure 3 shows the mean response time across the different formats as a function of (a) Set (Set 1, Set 2), (b) match outcome (Winner, Loser) and (c) Set and match outcome (Set 1 Winner, Set 1 Loser, Set 2 Winner, Set 2 Loser). Overall no difference was found between response time in Set 1 (*M* = 262 ms, *SD* = 102) and Set 2 (*M* = 261 ms, *SD* = 100) or between the 'Winners' (*M* = 262 ms, *SD*= 102) and 'Losers' (*M* = 262 ms, *SD* = 101) mean response time although these variables did seem to interact with the format of the game which is discussed in more detail in the discussion section.

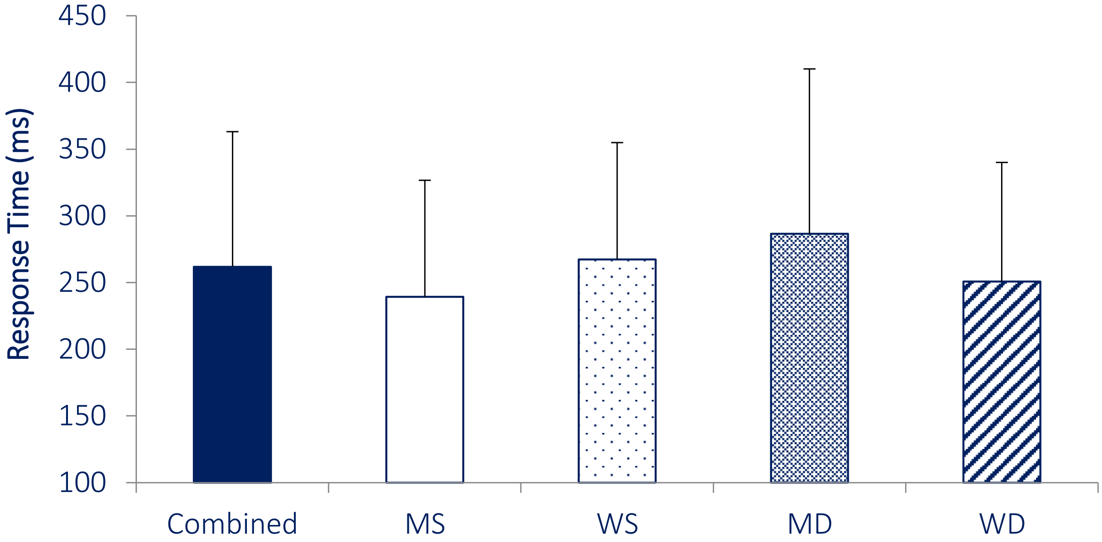

Figure 2. Mean response time over all formats (combined) and broken down in to men's singles (MS), women's singles (WS), men's doubles (MD) and women doubles (WD) competitions.

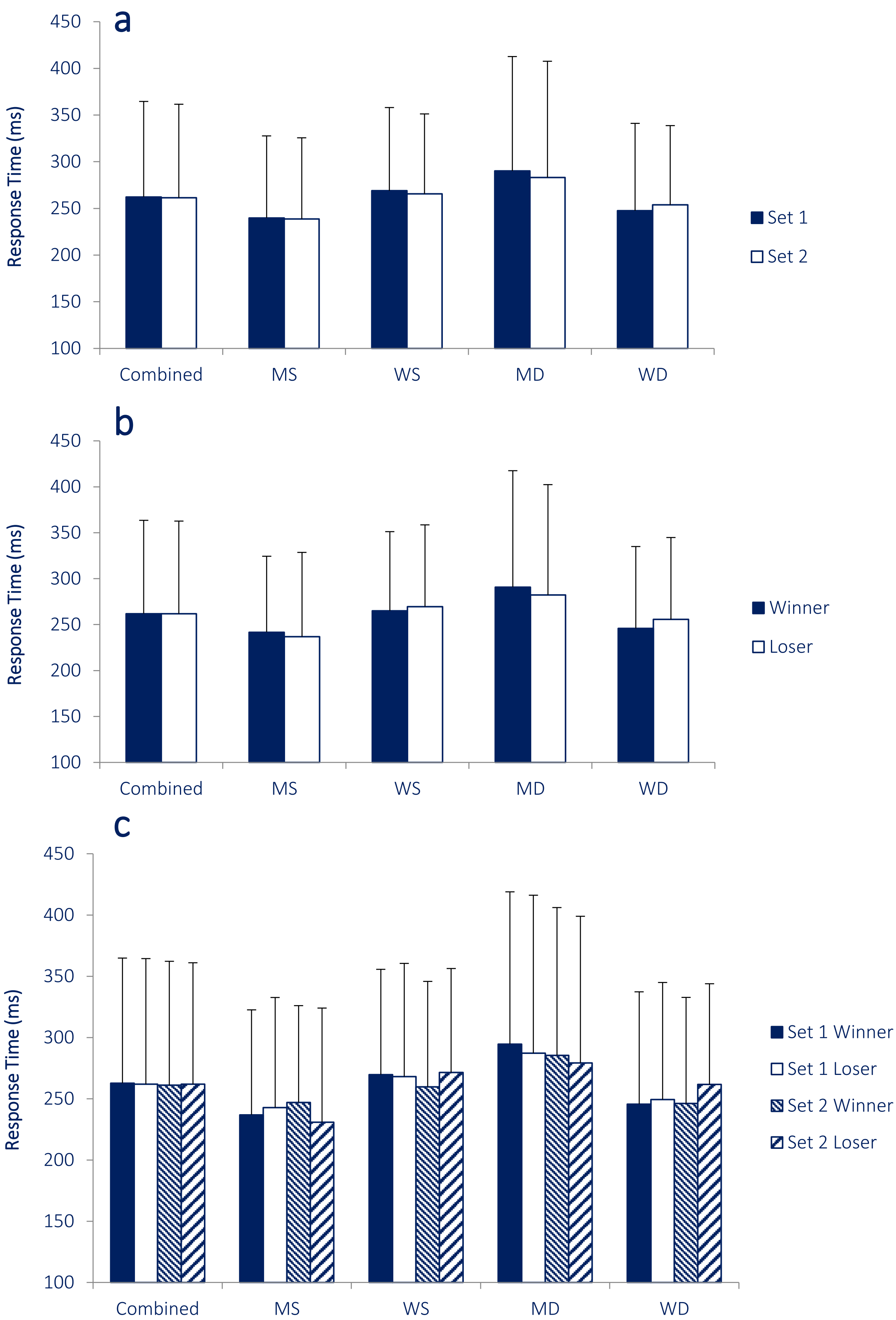

Figure 3. Mean response time across the different formats as a function of (a) Set (Set 1, Set 2), (b) match outcome (Winner, Loser) and (c) Set and match outcome (Set 1 Winner, Set 1 Loser, Set 2 Winner, Set 2 Loser)

Frequency and Distribution of Response Times: Figure 4 shows the frequency of shots at each response time for (a) all the formats combined (b) men's singles, (c) women's singles, (d) men's doubles, and (e) women doubles competitions. The mode response time over all was 240 ms and this was the same for the separate formats of the game except for in women's singles where the mode was 280 ms. However, the percentage of shots at the mode differed between the formats. Men's singles had the greatest percentage of shots at the mode (28.09%), followed by women's doubles (22.42%), men's doubles (20.86%), and women's singles (18.62%).

Based on the research by Triolet et al. (2013) initial movements which occurred prior to 160 ms after ball-shuttle contact point were deemed to be anticipatory behaviours. Analysis revealed that 14.03 % of all shots (*N* = 2921 shots) were classed as anticipatory behaviours. Differences across formats were also found. The greatest percentage of anticipatory behaviours was found in women's doubles (16.34 %) followed by women's singles (15.52 %), men's singles (14.31%) and men's doubles (10.50%). Based on the average rally length for each format (MS = 9.54 shots per rally; WS = 8.76 shots per rally; MD = 11.23 shots per rally; WD = 13.78 shots per rally) it is suggested that around 1-2 shots per rally require anticipatory behaviour (MS = 1.50 anticipatory behaviours per rally; WS = 1.77 anticipatory behaviours per rally; MD = .93 anticipatory behaviours per rally; WD = 1.19 anticipatory behaviours per rally).

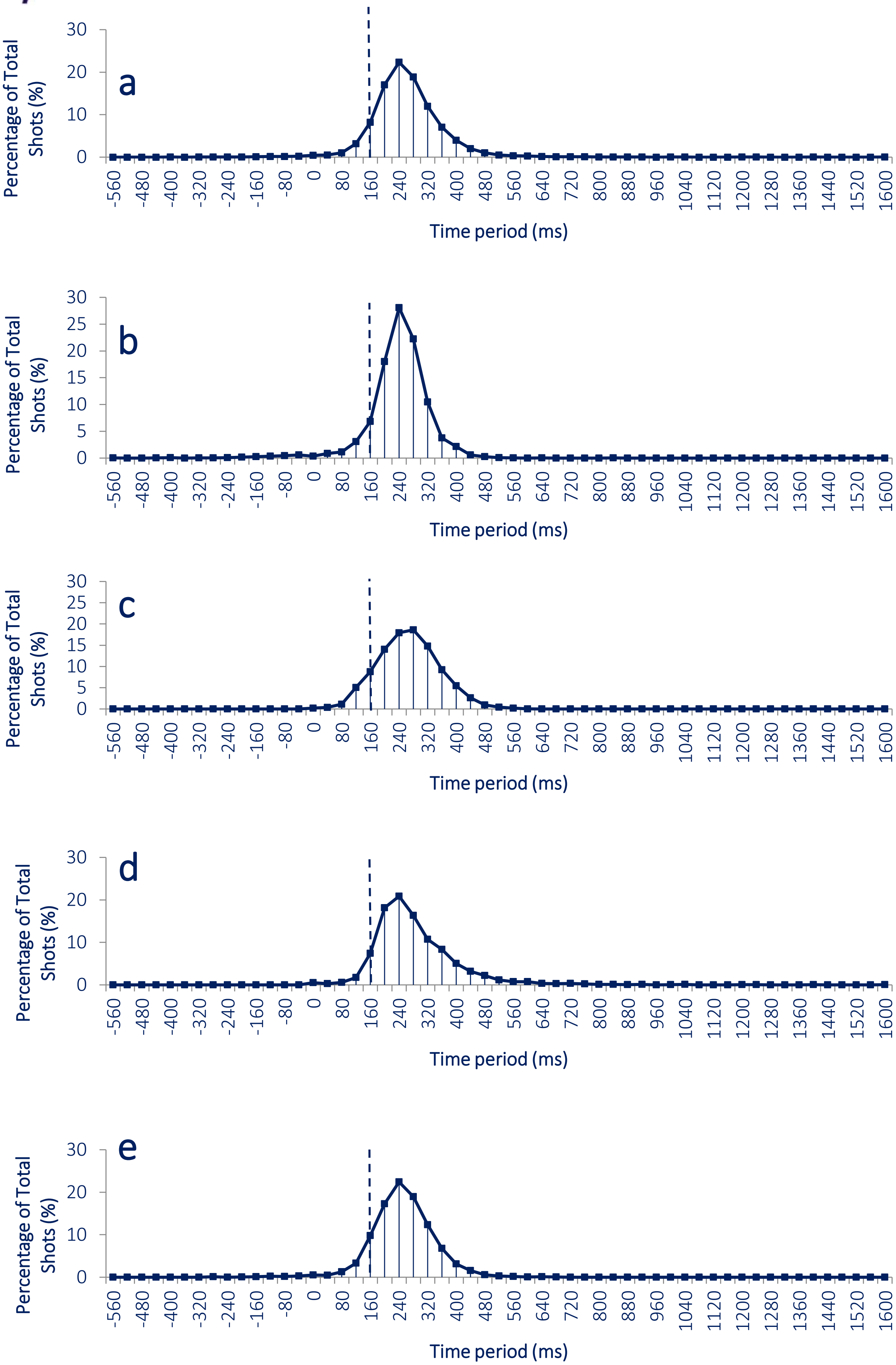

Figure 4. Percentage of shot frequency at each response time for (a) all the formats combined (b) men's singles, (c) women's singles, (d) men's doubles, and (e) women's doubles competitions.

Discussion

Research examining anticipatory behaviour in sport has tended to use representative tasks to simulate the performance environment either through video simulations (for example, Broadbent et al., 2015a) or 'in situ' scenarios (for example, Alder et al., 2016). Using performance analysis techniques the current project examined badminton matches involving top ranked players in the world in order to quantify the frequency of anticipatory behaviour in actual competition and provide comparisons to previous research in this area. A total of 21,000 situations were coded and certain situational factors were analysed to provide contextual information and to build upon the video-based analysis work completed in tennis (Triolet et al., 2013). We examined how contextual factors such as the format of the game (i.e. women's, men's, singles and doubles matches), the outcome of the match (i.e. win, lose), and the stage of the match (i.e. set 1, set 2) impacted on both average response time and the frequency of anticipatory behaviours.

We found a mean response time of 262ms. To our knowledge there is no previous research examining mean response time in elite level, or even less skilled, badminton players with the focus being on response accuracy (Abernethy & Russell, 1987; Abernethy & Kawi, 2007; Alder et al., 2014; 2016). The current finding was comparable to findings in squash (James & Bradley, 2004; 270 ms) although this paper did attempt to control and eliminate the use of tactical information which would affect the mean response time of the athletes. Substantial research examining response time has been completed in tennis but with mixed findings due to the type of representative task used. Research using video simulation techniques (Smeeton et al., 2005; 195 ms) or against a ball machine (Shim et al., 2005; 179 ms) have found similar response times. Research in tennis using in situ scenarios have found similar response times to those using lab-based settings (Broadbent et al., 2015; 168 ms) but also quicker (Shim et al., 2005; 129 ms) and slower response times (Smeeton et al., 2005; 229 ms). This highlights the difficulty for researchers to create consistent and reliable ecologically valid scenarios in order to examine anticipatory behaviour. However, research conducted on actual tennis matches between top ranked athletes found an average response time of 183 ms (Triolet et al., 2013). When comparing this 'gold standard' response time to the previous research conducted in tennis it is evident that lab-based settings do provide a somewhat comparable practice format to the performance environment and allow for athletes to experience repetition of key information in a consistent and reliable manner.

Current findings highlight similarities and differences when compared to previous work using video-based analysis on elite athletes (i.e. Triolet et al., 2013). With regards to mean response time, the findings suggest that elite level badminton players (*M* = 262 ms) have longer response times compared to elite level tennis players (*M* = 183 ms). This is most likely down to the speed and types of shots that occur in the different sports. Strokes such as a 'net lift' and a 'clear' are common strokes in badminton which spend a long time in the air so as to push the opponent back and allow time for the player playing the stroke to recover their court position. In comparison, the main stroke in tennis is the groundstroke which is most often played at speed and with a relatively low trajectory which reduces the time available between racket-ball contact point and the opponent's movement initiation. A further possible explanation as to the differences between sports may be the nature of the required response. When compared to traditional tennis shots (smash, forehand, backhand) badminton shots typically contain more fine movements and recruit smaller and less groups of muscles to complete (i.e. drop shot). Therefore in tennis participants may have to initiate movements earlier in order to execute the shot appropriately. However, analysis concerning the frequency of response times found similar mode response times in both badminton (240ms) and tennis (200ms). This suggests that the majority of response times in the two sports are similar but in badminton the response times are skewed to the right (i.e. slower) compared to tennis which is skewed to the left (i.e. quicker). An argument could be made that the difference between the two sports may be due to the increase in research focusing on anticipatory behaviour in tennis, and importantly on training these skills (Broadbent et al., 2015b), which has impacted the applied field. This speculation is made tentatively but an increase in research will improve understanding the role of anticipation and decision making in badminton and allow for the design and implementation of training protocols and techniques (for example, Alder et al., 2016) which may potentially facilitate a shift in response time to an average which is quicker than the mode as in tennis.

With regards to anticipatory behaviour in badminton, which was defined as any initial movement that occurred prior to 160ms after ball-shuttle contact point (Triolet et al., 2013), analysis revealed that 14.03% of all shots were classed as anticipatory behaviours. This was very similar to the findings in tennis which revealed that 13.42% of shots could be classed as anticipatory behaviours. Given the importance that research has placed upon anticipatory behaviours in underpinning sporting expertise, this may appear to be quite a low percentage (Williams et al., 2002). However, based on the average rally length in the badminton matches analysed it is suggested that around 1-2 shots per rally require anticipatory behaviour and it is possible that these shots are often the most critical in the rally, when the individual is under most time constraints and is forced in to an early movement or lose the point (Triolet et al., 2013). A limitation of the video based analysis method is that we are only able to code *observable* anticipatory behaviours when actually anticipation is a cognitive task and the players are likely to be continually engaging in cognitive processes prior to making an observable movement in one direction or another (Van der Kamp et al., 2008). Moreover, in a sport like badminton it is not the case that *the faster the better* when having to respond to an opponent's shot. For the athletes there will be a constant balancing act between the benefits of earlier anticipatory behaviours but the costs involved in anticipating incorrectly. The benefits associated with waiting longer in a more conservative manner may lead to a greater opportunity to ensure a correct response, especially when facing deceptive movements, but the costs of waiting too long may result in an athlete not being able to react and recover the shuttlecock (Canal-Bruland & Schmidt, 2009). This process creates an optimum time window for an initial movement to be made in response to an opponent's shot. In situations such as responding to a defensive clear stroke there is sufficient time for the player to wait and view a large portion of ball flight so as to be sure of initiating a correct movement. In situations such as responding to an attacking smash shot the time constraints the individual will be under will force them to 'gamble' and move earlier than they would ideally like otherwise they will not have enough time to move and recover the shuttlecock. It is when facing these offensive strokes that anticipatory behaviour is critical to performance (Triolet et al., 2013). Furthermore an argument could be made that the elite badminton players which were in the current experiment are physically able to react very quickly and can cover the court quickly, negating the need to initiate an early movement (Bottoms et al., 2012; Dicks et al., 2010). Further work comparing intermediate and novice badminton players in their performance environment may find that in order to reach the shuttlecock and play a return stroke earlier response times are required due to physical attributes.

The current research also built on previous research by examining how certain contextual factors impacted on both average response time and frequency of anticipatory behaviours. First a comparison was made between the different match format; men's singles, women's singles, men's doubles, women's doubles. Analysis of mean response time as a function of match format revealed men's singles had the lowest response time (M = 239 ms) followed by women's doubles (M = 251 ms), women's singles (M = 267 ms) and men's doubles (M = 287 ms). The mode response time was 240 ms for all the separate formats of the game except for in women's singles where the mode was 280 ms. However, the percentage of anticipatory behaviours differed between the formats. The greatest percentage of anticipatory behaviours was found in women's doubles (16.34 %) followed by women's singles (15.52 %), men's singles (14.31%) and men's doubles (10.50%). The fact that differences were found between the men's singles and double format was expected with men's singles revealing a greater percentage of anticipatory behaviours and faster response times compared to men's doubles. In the singles format of the game the individuals will have more areas of the court they have to cover and therefore have to initiate movements quicker to be able to retrieve the shuttlecock and play a return stroke (Liddle et al., 1996). However, the percentage of anticipatory behaviours and average response times were similar between women's doubles and women's singles. The women's singles average rally length was approximately 9 shots, whereas in women's doubles the average shots per rally were 14. This suggests that perhaps the anticipatory behaviour in the women's singles format adopted a conservative approach by waiting longer to insure the initial movement was correct but this was at the cost of not being able to retrieve the shuttlecock and continue the rally. It also appears that gender differences occur but these are not the same in the different formats. Men's singles has a quicker average response time compared to women's singles but the percentage of anticipatory behaviour is very similar. In comparison Women's doubles has a lower average response time and greater percentage of anticipatory behaviour compared to the men's doubles format of the game. Future research is required to understand these differences in more detail by examining tactical differences between the formats.

Finally the stage of the match (i.e. set 1, set 2) and the outcome of the match (i.e. win, lose) was analysed with regards to their impact on average response time. No difference was found between response time in Set 1 and Set 2 suggesting stage of the match may not influence response time. Moreover no difference was found between the 'Winners' and 'Losers' mean response time suggesting that faster average response times does not dictate whether an individual is successful or not. However, analysis of response time separated in to the different formats of the game as a function of Set and Outcome revealed a trend in the data. In women's singles and women's doubles format the response time of the Winner was quicker compared to the Loser but only in Set 2 indicating perhaps an impact of fatigue on response time and outcome of the match (Casanova et al., 2013). This trend in the data did not occur in either of the men's formats. Further research should look to examine how physiological attributes in the different formats of the game impact on anticipatory behaviours to help explain the current findings.

Conclusion

In summary, this research project was the first to quantify the role of anticipatory behaviour in badminton and provide video-based analysis of elite level athletes across a range of formats in the sport. The findings show that anticipatory behaviour is critical in badminton with an average of 1-2 shots per rally suggested to require initial movements prior to shuttle flight information being available. This demonstrates that coaches and athletes should look to integrate some form of perceptual-cognitive skills training in to their programmes in order to maximise the potential of athletes' development across all stages of learning. Furthermore the findings suggest that situational factors such as the format of the game and the stage of the match do appear to impact on anticipatory behaviour but much more research is required on this before recommendations can be made. While the current findings, emphasise the importance of anticipatory behaviour in badminton, the current lack of research in to perceptual-cognitive skills in badminton means that much has to be done by academics and practitioners before a full of understanding of how elite level athletes locate, identify and process environmental information efficiently and incorporate this with pre-existing knowledge and action capabilities in order to select and execute appropriate responses.

References

Abernethy, B. (1990). Expertise, visual search and information pick-up in squash. *Perception, 19*, 63-77.

Abernethy, B., & Zawi, K. (2007). Pickup of essential kinematics underpins expert perception of movement patterns. *Journal of motor behavior*, *39*(5), 353-367.

Abernethy, B., & Russell, D.G. (1987). The relationship between expertise and visual search strategy in a racquet sport. *Human Movement Science, 5*, 283-319.

Alder, D., Ford, P. R., Causer, J., & Williams, A. M. (2014). The coupling between gaze behaviour and opponent kinematics during anticipation of badminton shots. *Human movement science*, *37*, 167-179.

Alder, D. B., Ford, P. R., Williams, A. M., & Causer, J. (2016). The Effects of High-and Low-Anxiety Training on the Anticipation Judgments of Elite Performers. *Journal of Sport and Exercise Psychology*, *38*, 93-104.

Araujo, D., Davids, K., & Passos, P. (2007). Ecological validity, representative design, and correspondence between experimental task constraints and behavioural setting: Comment on Rogers, Kadar, and Costall (2005). *Ecological Psychology, 19(*1), 69-78.

Bottoms, L., Sinclair, J., Taylor, K., Polman, R., & Fewtrell, D. (2012). The effects of carbohydrate ingestion on the badminton serve after fatiguing exercise. *Journal of Sports Sciences*, 30, 285-293.

Broadbent, D. P., Causer, J., Ford, P. R., & Williams, A. M. (2015a). Contextual interference effect on perceptual-cognitive skills training. *Medicine and Science in Sports and Exercise*, *47*, 1243–1250.

Broadbent, D. P., Causer, J., Williams, A. M., & Ford, P. R. (2015b). Perceptual-cognitive skill training and its transfer to expert performance in the field: Future research directions. *European journal of sport science*, *15*(4), 322-331.

Cañal-Bruland, R., & Mann, D. L. (2015). Time to broaden the scope of research on anticipatory behavior: a case for the role of probabilistic information. *Frontiers in psychology*, *6*.

Cañal-Bruland, R., & Schmidt, M. (2009). Response bias in judging deceptive movements. *Acta psychologica*, *130*(3), 235-240.

Casanova, F., Garganta, J., Silva, G., Alves, A., Oliveira, J. O. S. E., & Williams, A. M. (2013). Effects of prolonged intermittent exercise on perceptual-cognitive processes. *Med Sci Sports Exerc*, *45*(8), 1610-1617.

Dicks, M., Button, C., & Davids, K. (2010). Examination of gaze behaviours under in situ and video simulation task constraints reveals differences in information pickup for perception and action. *Attention, Perception, & Psychophysics, 72*, 706-720.

Ericsson, K. A. (2008). Deliberate practice and acquisition of expert performance: a general overview. *Academic emergency medicine: official journal of the Society for Academic Emergency Medicine*, *15*(11), 988-994.

James, N., & Bradley, C. (2004). Disguising ones intentions: The availability of visual cues and situational probabilities when playing against an international level squash player. In A. Lees, J.-F. Kahn, & I.W. Maynard (Eds.), Science and Racket Sports III (pp. 247–252). Abingdon, Oxfordshire: Routledge.

Jones, C. M., & Miles, T. R. (1978). Use of advance cues in predicting the flight of a lawn tennis ball. *Journal of human movement studies*, *4*(4), 231-235.

Liddle, S. D., Murphy, M. H., & Bleakley, W. (1996). A comparison of the physiological demands of singles and doubles badminton: a heart rate and time/motion analysis. *Journal of Human Movement Studies*, 30, 159-176.

Pinder, R. A., Davids, K., Renshaw, I., & Araujo, D. (2011). Representative learning design and functionality of research and practice in sport. *Journal of Sport & Exercise Psychology*, *33*, 146-155.

Shim, J., Carlton, L. G., Chow, J. W., & Chae, W. S. (2005). The use of anticipatory visual cues by highly skilled tennis players. *Journal of motor behavior*, *37*(2), 164-175.

Smeeton, N. J., Williams, A. M., Hodges, N. J., & Ward, P. (2005). The relative effectiveness of various instructional approaches in developing anticipation skill. *Journal of Experimental Psychology: Applied*, 11, 98.

Starkes, J. L. (1993). Motor experts: Opening thoughts. *Advances in psychology*, *102*, 3-16.

Triolet, C., Benguigui, N., Le Runigo, C., & Williams, A. M. (2013). Quantifying the nature of anticipation in professional tennis. *Journal of Sports Sciences*, *31*(8), 820-830

Van der Kamp, J., Rivas, F., Van Doorn, H., & Savelsbergh, G. (2008). Ventral and dorsal system contributions to visual anticipation in fast ball sports. *International Journal of Sport Psychology, 39*, 100.

Williams, A. M., & Ericsson, K. A. (2005). Perceptual-cognitive expertise in sport: Some considerations when applying the expert performance approach. *Human Movement Science*, *24*, 283-307.

Williams, A. M., Vickers, J. N., Rodrigues, S., & Hillis, F. (2002a) Anxiety and performance in Table tennis: a test of Eysenck and Calvo's processing efficiency theory. *Journal of Sport and Exercise Psychology, 24, 438-455*.

Williams, A. M., Ward, P., Knowles, J. M., & Smeeton, N. J. (2002b). Anticipation skill in a real-world task: measurement, training, and transfer in tennis. *Journal of Experimental Psychology: Applied*, *8*(4), 259.