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Abstract

BACKGROUND: It has been frequently evidenced that skilled sport performers distinguish themselves from less-skilled based on key temporally constrained perceptual cues in order to anticipate future events. However, the evidence to-date has arguably failed to reflect the true nature of perceptual-cognitive skill in sport, and thus negated any robust suggestions for the assessment and training of athletes. The present study attempts to address this issue by observing measures of anticipation within purely naturalistic match-play.

METHODS: A series of skilled (n=8) and less-skilled (n=8) badminton players undertook regular match-play while an equal number of digital recordings were made of their return-of-serve (n=10). Frame-by-frame analyses were conducted to indicate the moment of initiation and accuracy of initial response selection.

RESULTS: Inter-observer agreement for time (r = .70, p < .00) and accuracy (90.63%) measures were robust. Performance differences between the groups were stark including significant differences for time (*Mdn*: skilled = 184 ms; less-skilled = 322 ms) and accuracy (*Mdn*: skilled = 9; less-skilled = 6) (*ps* < .00).

CONCLUSION: Influence of skill level corresponds with empirically derived suggestions of skilled athletes accessing domain-specific knowledge for the anticipation of future events. Thus, the naturalistic performance setting offers a viable alternative for further examination, while additionally incorporating the invariant features and contextual information that underlie sport performance.

Key words: perceptual-cognitive; anticipation; naturalistic match-play; badminton serves; ecological validity

Introduction

It has been known for many years that the observation of advanced kinematic perceptual cues can discriminate anticipation performance in expert/skilled and novice/less-skilled individuals. Much of this information has been gleaned from the experimental paradigms that prematurely occlude the time-course (*temporal occlusion*) or bodily regions (*spatial occlusion*) of an opponent's play with a view to differentiating performance within- or between-individuals[1,2].

As a result, there have been many studies that have assumed experimentally controlled laboratory settings based on initial frameworks and task situations comprising real-life sport (e.g., estimating the position of serves for return in tennis[3]; goalkeepers estimating the ball location from penalty kicks in soccer[4]). However, there is a growing consensus amongst researchers to more closely envisage the real-life performance setting (*representative task design*[5,6]). Aside from being intuitive, an ecologically valid approach would positively comprise the invariant features that are directly coupled with action[7], as well as the specific sensory-motor parameters that precipitate early learning (i.e., correspondence between prior sensory-motor practice and evaluative performance settings)[8,9,10]. While there have been commendable attempts to enrich experimental settings by incorporating action requirements that involve a pantomimed or gestural response (e. g., [3,11]), they arguably fail to encapsulate the subtle spatio-temporal dynamics underlying sport performance. These discrepancies were highlighted in the neurobiological framework from van der Kamp and colleagues[12], where uncoupled experimentally controlled assessments of perceptual-cognitive skill primarily occupy ventral ("vision-for-perception") visual stream processes that are accustomed to the static detection of object details (e.g., colour, texture). However, real-life sport settings including the requirement for domain-specific responses requires dorsal ("vision-for-action") visual stream processes, which are typically associated with the online visual control of action.

While there have been commendable attempts to explicitly compare anticipation performance in uncoupled simulated and naturalistic performance settings[4,13], performers may treat the perceptual information differently under the confines of an experimental or research-specific setting (e.g., response bias) compared to normal sport performance. For example, performers within a temporal occlusion or presentation paradigm (e.g., [14]) may alter their natural perceptual-cognitive processes based on the knowledge that visual feedback will likely be occluded. Along these lines, there is evidence in golf-putting that performers distribute their quiet eye (i.e., long-duration final fixation known to distinguish skill level) according to the prior knowledge of a period of occlusion (i.e., extending pre-movement quiet eye when vision is occluded after movement onset[15]; see also, [16,17]).

At the same time, the experimental control assumed to-date has primarily focused on the spatial and temporal characteristics of cue utilisation without encompassing the contextual details that may also influence anticipation and decision-making processes[18]. In a similar vein to the above discussion on naturalistic performance settings, there is a growing trend toward investigations of the extraneous factors that coincide with the lower-level spatio-temporal dynamics of cue utilisation. Indeed, it has been shown that skilled performers can use self-discovered probabilistic event information in order to enhance anticipation of squash[19], tennis[20] and soccer penalty[21,22] shots. In addition, there is evidence to suggest that athletes can extract key auditory information in order to infer the shot length[23,24] and power[25], within ball sports, which is not usually available during the muted video-simulations of standard experimental set-ups.

With this in mind, the area of perceptual-cognitive anticipation in sport is potentially becoming more greatly informed by, and veering toward, an ecological approach that goes beyond the intricacies of simulation (e.g., [26]), and coarsely adopts sport performance settings with the objective of capturing perceptual-cognitive skill. At this juncture, we may ask whether anticipation can be manifested and subsequently quantified in a purely naturalistic performance setting devoid of the fore mentioned experimental factors (e.g., video display, visual occlusion, game context, etc)? That is, we address the relatively open matter of measuring anticipation of badminton serves, and the subsequent distinction of skill level, under standard match-play conditions. In line with previous literature, we predict that there will be an advantage served in the time and accuracy of anticipated responses to service in skilled compared to less-skilled individuals. In so doing, we will provide sufficient recourse to measure perceptual-cognitive skills in completely immersed performance environments; not too dissimilar to the field of performance analysis (e.g., [27]).

Materials and Methods

Participants

Sixteen badminton players agreed to take part in the study (*M* age = 20.13 years, *SD* = 1.93, range = 18-25 years; 10 males, 6 females). Skilled participants (n = 8) currently played in the university badminton team with >3 years of competitive playing experience. Less-skilled participants (n = 8) played recreationally with 0.5-3 years playing experience. Informed consent forms were signed by participants prior to the study. The study was approved by the Research Ethics Committee of Liverpool Hope University, and designed and conducted in accordance with the Declaration of Helsinki.

Apparatus, task and procedures

Data collection took place at a university sports complex with standard-sized badminton courts and recordings were taken via two tripod-mounted digital cameras

(Panasonic HC-V250, 10.0 Mega Pixels, 90 X zoom, 25 Hz) located from a lateral and close to birds-eye view (see Figure 1). Participants were instructed to play-out regular competitive games of badminton with a skill- and gender-matched opponent. Prior to the beginning of each point, the participant returning serve raised one of their hands directly above their head in order to explicitly indicate to the experimenters when a trial was about to start for post-study video-coding purposes (see *Dependent Measures and Data Analysis subsection*). The experimenter manually scored the number of successful serves from the opposing player, and subsequent returns of the player located nearest to the cameras. That is, a trial was counted when the serve and return remained in play without hitting the net or reaching the outside of the court boundaries. Once a player accumulated 10 successful return-of-serves, the players would change sides of the court in order for the count to begin for the second player. Once both players had at least 10 successful return-of-serves then the match was suddenly ceased. The responses were scored with respect to the court end nearest the cameras because this end assumed a perceptibly larger angle without interruption of the net. In total, there were 10 trials per participant that were forwarded for further coding (160 trials). Although the score coding scheme dictated match proceedings, the participants were unaware of what was being measured and how the match was being regulated. Thus, the study allowed for robust ecological validity with the matches appearing to proceed as normal until the experimenter told the participants that the game was over. Afterwards, participants were given more detail regarding the true nature and purposes of the recordings.

[Insert Figure 1 about here]

Dependent measures and data analysis

The recordings from the camera that was close to birds-eye view were chosen for further frame-by-frame analysis using Kinovea software (version 0.8.15). The moment the receiver initiated a response in an attempt to return serve was coded to derive measures of initiation time and response accuracy. The initiation time was taken as the time difference between the racket-to-shuttle contact from the server and the initial movement from the receiving player (for similar procedures, see [3],[27]). Meanwhile, response accuracy was taken as the correspondence between the lateral and depth locations of the shuttle in-flight and receiving player. Responses were coded in the context of the entire participant movement meaning a reverse motion of the lower limbs in order to propel in the required direction was considered an accurate response. Thus, it was feasible for participants to indicate an error by initially moving to the incorrect location before possibly amending to return serve. All responses were coded by the second author, and an equal portion of trials for skilled and less-skilled participants (20%) were also coded by an independent coder who remained unaware of the study purposes. There was a significant inter-observer relation for initiation times (r = .70, $p < .00$) and 90.63% agreement[28] for response accuracy scores.

Individual participant mean scores were forwarded to a statistical analysis using IBM SPSS Statistics 24. The assumptions of parametric data were first assessed including whether the data followed a normal distribution (using Shapiro-Wilk) and equal variance of groups (using Levene's test). Providing the assumptions were met, each of the dependent measures for the skilled and less-skilled groups was compared using independent sample t-tests. Alternatively, in the event of a violation, the non-parametric equivalent was adopted in the form of a Mann-Whitney test. Significance was declared at $p < 0.05$ and Cohen's d was adopted as an effect size measure[29].

Results

Because the group frequency distributions appeared to be non-normal, a non-parametric Mann-Whitney test was conducted on each of the dependent measures. For initiation time, there was a significantly shorter time to respond for the skilled compared to less-skilled group, $U = 2.00$, $z = -3.15$, $p < .00$, $ds = 1.92$ (see Table 1). Meanwhile, the response accuracy measure also indicated a significantly higher number of correct responses for the skilled compared to less-skilled group, $U = 1.00$, $z = -3.30$, $p < .00$, $ds = 3.03$.

[Insert Table 1 about here]

Discussion

To-date, the perceptual-cognitive sport skill literature has been fairly steeped in reductionist approach that prioritises the control of spatial-temporal constraints, which typically assume an uncoupled simulated environment. This approach has arguably failed to reflect the invariant stimulus features of performance and the subsequent possibility to couple with actions[6,7]. From a neurobiological perspective, there is also potential neglect of the dorsal visual processes that are well-accustomed to visuomotor control in the real world[12]. As a result, we are beyond the point of recognising the empirical value to adopting a more ecologically valid setting (e.g., [13,14]), as well as the contributing contextual[18] and multisensory (e.g, auditory, proprioceptive, etc)[24] factors that influence anticipation. Instead, the present study provides a relatively coarse account that intends to positively evidence how perceptual-cognitive anticipation may be feasibly measured in real-life match-play, where performers' behaviours can unfold naturally.

The present findings corroborated previous evidence of greater speed and accuracy of anticipatory judgements in badminton for skilled compared to less-skilled individuals (for examples of shot anticipation in racquet sports, see [3,19,30,31,32]). Of interest, the current skill level differences for accuracy (*M* skilled = 89%; *M* less-skilled = 59%) were comparable to those of a similar recent study that also measured anticipation of badminton serves under temporally-constrained video-simulated conditions (*M* skilled = 75%; *M* less-skilled = 54%; [11]). While such cross-study comparisons should be treated with caution based on the vast methodological differences, it is somewhat justified to consider given the similar over-arching implications for sport – domain-specific perceptual-cognitive advantages for skilled/expert vs. less-skilled/novice individuals. In this regard, there is very little lost when it comes to adopting an ecological setting that fully immerses participants in match-play (cf. [13]). If anything, the current approach elaborates on the perceptual-cognitive skill framework by additionally presenting contextual and auditory information that could further differentiate anticipation skill. For example, the inference of a favoured direction of the first serve in tennis has been shown to be more readily detected and anticipated by experienced compared to less experienced elite-level players[20]. Meanwhile, the discrimination of offensive fencing manoeuvres has been shown to be more accurate for competitive compared to novice performers based on auditory, as well as visual, sources of information[33]. With this in mind, it is arguable that alternative experimental approaches to-date have failed to thoroughly portray the domain-specific sources of information, and in so-doing, undermined the extent of the skill-level differences in anticipation[1,2].

Consequently, it may be argued that there is further incentive for researchers and practitioners alike to adopt a similar ecological approach when specifically measuring or training perceptual-cognitive skills in athletes. That is, the present paradigm reflects a similar pattern of results as the previous lab-based controlled experiments, while additionally reflecting the task constraints and contextual information that accompanies real-life sport performance. Herein, the information that is gleaned from such measurements can be positively transferred or framed within the context of actual sport. Similar conclusions can be drawn from the recent analysis of elite tennis matches that highlighted unique anticipation behaviours in the absence of any direct experimental manipulation[24]. However, the present study renders a further possibility of staging performance in order to capture a set time for measurement as per other physical and psychological test batteries (16 players x approx. 30 minutes).

On reflection, the possibility of fully immersing performers into regular match-play in order to infer perceptual-cognitive skill may introduce unknown random variables that operate between- and/or within-performers (e.g., nature of the serve, angle of return, etc) (e.g., [14]). These failings may be restricted by subtle test variants including a range of competitive match-ups (e.g., “round-robin” tournament format) in order for player characteristics to be equally distributed. However, a more fruitful possibility may be to consider registering the characteristics of opposing serves that coincide with subsequent returns. Although beyond the scope of the present study, it is perhaps worthwhile for future assessments to incorporate such analyses with a view to identifying correlates or couplings between perception (observed serve) and action (executed return) (e.g., [11,24]). Herein, we can begin to link the characteristics of opponents’ play and associated kinematics with the speed and accuracy of performers’ anticipatory responses.

Conclusions

The present study reports the measurement of anticipatory performance in athletes during real-life match-play, and consequently corroborates the skill-level differences that have been frequently reported in experimental accounts. Thus, the present study offers one of few attempts to examine perceptual-cognitive skill while engaged in the invariant stimulus and contextual features that guide actual sport performance. Ultimately, the present study does not refute the theoretical value attributed to the previous highly controlled experimental accounts (e.g., temporal/spatial occlusion), although it does suggest more meaningful, sport-specific measures of perceptual-cognitive skill be undertaken. Herein, both researchers and practitioners may greatly benefit from separate, but not mutually exclusive, reductionist and ecological approaches, respectively.

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Notes

Conflicts of interest: The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript

Authors' contributions: James W. ROBERTS contributed to experimental design and writing (primary). Ben KEEN contributed to experimental design and methodological proceedings. Simon KAWYCZ supervised the project and contributed to writing (secondary).

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Table 1. Median (interquartile range) for the initiation times and response accuracy of skilled and less-skilled individuals

Level	**Initiation time (ms)**	**Response accuracy (out of 10)**
Skilled	184 (90)	9 (2.00)
Less-skilled	322 (66)	6 (1.25)

Figure captions

Figure 1. Representative experimental set-up. Two cameras were located at lateral and close to birds-eye views (balcony above the court). The experimenter (*dark grey* figure) roughly assumed the umpire-position next to the net for coding the number of serves received by each player. Only the participant closest to the cameras was coded for analysis (*light grey* figure), while the opposing player was not (*empty black outline* figure).