APPLIED COGNITIVE PSYCHOLOGY
Appl. Cognit. Psychol. **19**: 637–649 (2005)
Published online 14 March 2005 in Wiley InterScience
(www.interscience.wiley.com) DOI: 10.1002/acp.1100

Effect of Tactical Initiative on Predicting Passing Shots in Tennis

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SUMMARY

This study aimed to demonstrate that one of the main sources of information that tennis players use to anticipate their opponents' strokes is prior knowledge of the upcoming events likely to develop when the player has the opportunity to impose his or her playing intent. Seventeen experienced male players were faced with simulated on-court situations with three different delivery conditions such that their tactical initiative was high, moderate or weak (reflecting the possibilities of controlling rallies). Each situation finished with a passing shot from the opponent that the participant had to intercept with a volley stroke in the absence of visual information (vision occluded before the opponent's stroke). Analysis of directional responses showed that the participants were more accurate if they were in firm control of the rallies (high level of tactical initiative). Forecasts were also found to be more accurate for down-the-line backhand shots. These findings increase our understanding of anticipation in tennis. Copyright © 2005 John Wiley & Sons, Ltd.

Success in racket sports is generally largely attributed to the ability to anticipate game events effectively (Rowe & McKenna, 2001). For instance, tennis players may find themselves unable to return serve or to intercept a volley if they do not anticipate correctly because their uncertainty may leave them insufficient time to reach the ball. It is therefore important to predict the position at which the ball will arrive well before it comes over the net. According to the cognitive view of motor behaviour, innate talent and exhaustive rehearsals of stroke skills are not the only determinants of anticipation. Players are thought to learn how to use two essential and related sources of information during training that help them to anticipate shots (Abernethy, Gill, Parks, & Packer, 2001; Farrow, 2001). The first source of information is the movement pattern of the opponent. There is considerable evidence that experts anticipate the response of the opponent more accurately than novices, on the basis of advanced visual cues (Abernethy & Russell, 1987; Goulet, Bard, & Fleury, 1989; Tenenbaum, Levy-Kolker, Sade, Liebermann, & Lidor, 1996). The second source of information is prior knowledge of probable upcoming events. Indeed, the strengths and weaknesses of the protagonists, the relative positions of the players and

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Contract/grant sponsor: René Descartes University.

the associated conditions (e.g. weather conditions, court surface) have been identified as contextual cues influencing the opponents' behaviour (Buckolz, Prapavesis, & Fairs, 1988). This information may enable the player to predict events by making it possible to dismiss many events as highly improbable. Without denying the key contribution of the first source of information, we investigated the effect of this second type of information, derived from the overall context of play, on anticipation in tennis players.

Despite its perceived importance, the role of prior knowledge of probable upcoming events has rarely been directly investigated in externally paced sports. One of the first studies to examine the role of such knowledge was undertaken in a host of racket sports by Alain and Proteau (1978). These authors filmed rallies from a normal game, showed players the film and asked them questions relating to their subjective assessment of the probability of the various shots played by the opponent. The initial body displacements of the players in the direction required to return the stroke were recorded to provide an index of anticipatory behaviour. The frequency of anticipatory movements was found to be closely related to the subjective probabilities of the possible events.

However studies on anticipatory skills using film-based tests present significant limitations. For example, Féry and Crognier (2001) have argued that it may be harder to predict the spatiotemporal characteristics of the trajectories of oncoming balls from film clips than in an actual game situation. Furthermore, contextual cues are generally masked in laboratory tasks due to the short duration of the video clips. Williams, Ward, Knowles, and Smeeton (2002) asked participants to hold a tennis racket and to perform simulated tennis strokes in response to near life-size images of opponents playing ground strokes. The 4 s clips included the opponent's preparatory movements and stroke execution but were too short to present the contextual cues relating to previous sequences of shots that might have influenced the participant's predictions. Ripoll (1989) simultaneously explored the visual and motor behaviour of expert table-tennis players. The participants were engaged in realistic situations: they were placed in drill situations (constant repetition of one kind of stroke) and match situations (in which the stroke is less predictable). Ripoll showed that these two situations differed in terms of motor and visual behaviour. Visual processes were more heavily involved in match situations than in drill situations because the players had to reduce the high level of uncertainty. Abernethy et al. (2001) investigated whether such uncertainty is reduced by the contribution to anticipation made by the refined use of situational probabilities. These authors used a visual occlusion method in squash players, during simulated match play. Six experts and six less skilled male players were asked to play against an opponent on a real court and to move in response to sequences of events when their vision was occluded. The experts performed better than the less skilled players in predicting the direction and depth of the opposing player's stroke, as early as 600 ms before the opponent's racket made contact with the ball. The authors concluded that an accurate knowledge of event probabilities may have facilitated successful anticipation even before any significant preparatory movement had been made by the opponent.

These results may be accounted for in two ways. First, the expert's advantage may be maximized by making the participants actually perform the return stroke. Indeed, laboratory studies generally provide little opportunity for participants to be as active as players in a real game. In most cases, the judgments of the participants were evaluated by means of simple verbal (Goulet et al., 1989) or pencil-and-paper responses (Buckolz et al., 1988). For example, Abernethy and Russell (1987) asked elite badminton players to watch a film presenting an opponent's stroke. At the end of the film, the participants had to report the landing position of the shuttlecock on a scaled representation of a badminton court.

Mean errors ranged between 2.7 m for occlusion 167 ms before contact to 1.4 m in conditions of full display. These errors are large given the area of half a badminton court, and may have been due to scaling errors. The mode of action used during actual play should be preserved in experiments investigating anticipation in sports as differences in the frequency, duration, and location of gaze have been reported between expert and novice players in experimental protocols involving physical movement (Helsen & Pauwels, 1993; Ripoll, 1989; Singer, Cauraugh, Chen, Steinberg, & Frehlich, 1996). In squash, no significant differences in visual behaviour were found between the two skill groups if whole-body responses were not assessed (Abernethy, 1990). Farrow and Abernethy (2003) recently used a progressive temporal occlusion paradigm to determine the ability of participants to predict, *in situ*, the direction of an opponent's service. Vision was occluded with PLATO liquid crystal spectacles and participants were instructed to respond by attempting to hit a successful return strike (coupled condition) or by making a verbal prediction of stroke direction (uncoupled condition). Expert tennis players were found to perform better in coupled than in uncoupled response conditions.

However, the findings of Abernethy et al. (2001) may also result from the expert players trying to make their opponents less confident about their decisions during rallies and to reduce the number of possible strokes by varying the direction or the spin of the shots. In tennis, the player in the volley position may voluntarily feign an interceptive movement towards one side of the court to induce the opponent to make a stroke towards the other side, which is therefore easily anticipated. Similarly, by adopting a certain position in which to return serve, the player may force his or her opponent to serve in the expected direction. Moreover, if the player is able to hit a return stroke deep into the opponent's backcourt area, there is a very high probability that the opponent will play a defensive stroke, such as a lob. In other words, if tennis players are able to impose their playing intent, they should be able to reduce the number of options available to their opponent, making it easier to anticipate the opponent's strokes.

For these reasons, it is important to use a live tennis situation when assessing anticipation in experienced players. Given that previous studies have shown that physical movements should be included in experimental protocols to assess anticipation, we investigated whether the anticipation performances of tennis players were best in situations in which they could impose their playing intent. We used an occlusion paradigm, with the participant wearing a pair of liquid crystal spectacles, combined with an original field-based measure of anticipation. We created on-court situations that differed in terms of the degree of control over rallies the participant could impose on the opponent. Each situation finished with a passing shot from the opponent that the participant had to intercept with a volley stroke in the absence of visual signals (the participant's vision was occluded before the opponent played his stroke). We hypothesized that the participants would predict the direction of the opponent's stroke and the location of arrival of the ball more accurately in the situations in which they could control the rallies than in situations in which they had less opportunity to impose their own game.

METHOD

Participants

Seventeen experienced male tennis players (*M*age = 23 years, *SD* = 2.6) agreed to participate in this research. All had normal (uncorrected) vision and gave informed consent. The participants were ranked between −30 and +15 in the system used by the French Tennis Federation.[1] They had on average 15 years ($SD = 4$) of playing experience and had played on average 465 ($SD = 133$) competitive matches. All participants were faced with the same, experienced, right-handed opponent[2] (age = 34 years) who had played 600 competitive matches.

Instrumentation

Passing shot situations were reproduced by the opponent and the participant on an indoor court with a fast surface. Participants wore a pair of liquid crystal spectacles that could be made transparent or opaque. These spectacles were operated by a belt-borne generator (600 g), via a high frequency emitter module (1–10 mW), which transmitted information by amplitude modulation. When the generator received the signal transmitted by the module, the lenses of the spectacles became opaque such that participants could not see through them. The ball was stopped by a flexible protective net (10 m × 2 m) that lay on the ground 1.50 m from the net until the opponent delivered the passing shot (Figure 1). This special net was made of a fine mesh (the same material as the sheet fixed on the fence to protect the tennis court against wind). A rope was used to lift the protective net

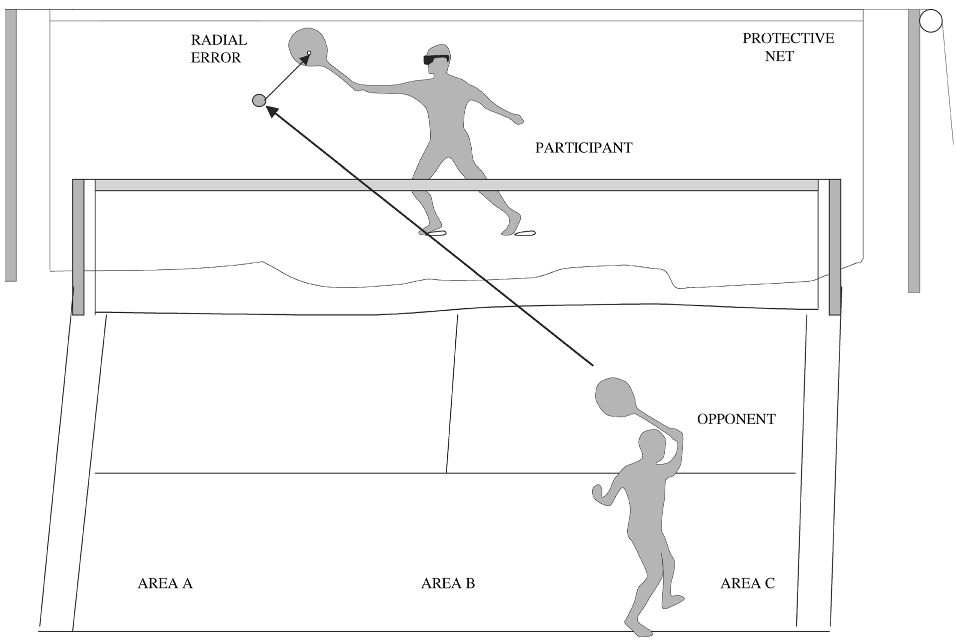

Figure 1. Schematic diagram of the experimental setting

[1]The system used by the French Tennis Federation ranks players in four series. The best 50 male players are classified in the first series, the next 50 best are classified in the second series, and so on. All the participants involved in this study were ranked in the second series. The highest player in our study (ranked −30) was classified among the 100 best French tennis players. The lowest player (ranked +15) had the minimum technical level for certification as a coach in a tennis club.
[2]Importantly, this opponent had faced each of the participants before in several friendly or official matches. Therefore, each participant knew some of the opponent's strengths and weaknesses, potentially providing useful information for prediction of the passing shot.

vertically, with a minimum of effort, and in a mean time of 400 ms. We used the net both to protect the participants against injury and to record the precise location at which the ball arrived. An electronic ultrasound system (measurement accuracy $< 0.5\%$) was used to measure the distance between the racket and the mark made by the ball in the protective net (see *Data collection*).

Procedure

The test procedure was explained to the participant upon his arrival at the tennis court. The participant was equipped with the spectacles and was allowed to habituate himself to playing whilst wearing them. He was then given a series of 10 trials to get used to predicting the location of the ball without sight. Whatever the experimental situation tested (see *Initiative task manipulation*), once the opponent hit the ball and the participant's spectacles had been occluded (see *Control of visual occlusion*), the participant had to move to the position at which he believed the ball would hit the protective net and try to hit the ball, as usual, with a successful volley stroke. The participants were provided with no feedback during the trials and an experimental session took approximately 1.5 h to complete.

Initiative task manipulation

To investigate the effect of prior knowledge on anticipatory decisions in tennis, we needed to compare the accuracy of these decisions in situations in which the participant was able to impose his own game—thereby reducing the number of shots that the opponent could make—with situations in which the participant had fewer or no possibilities to impose his own game. We therefore manipulated the degree of initiative of the participant by creating three on-court experimental situations referred to as HIS (high initiative situation), MIS (moderate initiative situation), and WIS (weak initiative situation).

The HIS situation was set up so that the participant was able to impose his playing intent, increasing the likelihood of correctly speculating that a particular stroke would be more probable than another. Both players started on their own baselines and performed three rallies (i.e. a series of shots interchanged between two players) in which the opponent was asked to let the participant impose his game. The participant was therefore allowed to deliver a firm approach shot at the end of the rallies, placing the opponent on the defensive and reducing his response possibilities. Following this firm shot, the participant had to run to the net and adopt the volley position in a zone 1 m^2 wide located 2 m from the net, in the middle of the court. The approach shot had to be directed at one of the three areas (A, B, or C, see Figure 1) generally targeted in competitive matches (Crespo & Miley, 1999). The opponent then had to deliver a passing shot designed to pass the participant at the net.

In MIS, there were no rallies. The participant was asked to stand in the volley position and to put the ball into play, directing it toward one of the three areas defined for the HIS. The opponent then had to run towards the ball and play the passing shot. The level of tactical initiative was lower for MIS than for HIS because the participant had fewer opportunities to constrain the opponent's stroke. For example, the participant could not deliver a wrong-footing approach shot because the opponent was initially stationary. For such shots, success depends on sending the ball in the direction opposite to that in which the opponent is already moving.

In WIS, the opponent took position in A, B, or C and played the passing shot directly, first dropping the ball as a means of bringing it into play. The participant, holding the tennis racket in the volley position, had to try to intercept the passing shot. The level of tactical initiative was lowest for this situation because the participant had no possible means to constrain the opponent's stroke.

In HIS and MIS, participants were asked to ensure that their approach shots did not land too far from the opponent, to facilitate the delivery of passing shots. In HIS, MIS, and WIS, the direction (i.e. cross-court or down-the-line) and the type of passing shot (i.e. forehand or backhand) to be delivered could be varied at will by the opponent, to preserve the characteristics of live play. Similarly, the opponent was instructed to launch the passing shots as normally as possible. It was therefore not possible to standardize the direction and type of passing shots to be predicted between participants.

The order of the conditions was varied. Five participants were confronted first with the WIS, then with the HIS, and finally with MIS conditions; six others were confronted with the HIS, then the MIS, and the WIS, and the remaining six participants were confronted with the MIS, the WIS, and then the HIS.

Control of visual occlusion

The occlusion of the spectacles worn by the participant was timed so as to prevent the participant from picking up cues from the opponent's stroke movement and the subsequent ball flight. Spectacles were kept transparent, so that the participants could observe the playing sequence, up to the opponent's preparatory movement (i.e. the end of the back-swing, until the racket was drawn behind the body). The participant was therefore unable to see the acceleration of the racket head up to the ball, a phase known as 'critical time'. Indeed, this phase has been identified as the time at which the player is able to extract predictive information from the opponent's movement in badminton (Abernethy & Russell, 1987) and in tennis (Farrow & Abernethy, 2002). For an experienced player, the beginning of this phase is visually detectable because the opponent's movement is at its slowest and the racket is at its farthest point relative to the player's body. The timing of the occlusion was therefore left to an experienced experimenter[3] who underwent special training. One day before the test sessions, the experimenter went through 100 practice trials in which the opponent played 10 sets of 10 alternating backhand and forehand passing shots. This enabled the experimenter to become accurate and reliable in the manual command of spectacle occlusion. This training was videotaped (on a video camera equipped with a timer functioning at 25 Hz), with the spectacles positioned in front of the lens of the camera in such a way that the recording displayed spectacle occlusion and the stroke of the ball. During the last series, all the experimenter's commands for spectacle occlusion occurred 240 ± 40 ms (6 frames $\pm$ 1 frame) before the racket made contact with the ball. During this training phase, backhand and forehand passing shots performed by the opponent were also videotaped. They revealed that a mean time of 760 ± 80 ms elapsed between the occlusion of the spectacles and the arrival of the ball in the protective net. To determine the length of ball trajectory to be predicted, the mean distance covered by the ball was calculated: it was between 13.5 m, for down-the-line shots, and 15.5 m, for cross-court shots.

[3]The experimenter has been playing tennis for 15 years and had played 400 competitive matches at the time of the study.

Data collection

Eighteen trials were performed for the HIS, MIS, and WIS conditions. For each of the 54 trials, the participant was asked to maintain his racket against the protective net for a few seconds after each volley. As the ball made a clearly visible mark at the point of contact in the protective net, the two research assistants could record a) the horizontal and the vertical distance between the impact of the mark made by the ball in the protective net and the impact of the racket, b) the direction and type of passing shot delivered, c) the half of the court (right or left) in which the ball landed in the protective net, and finally d) the half of the court in which the participant played the volley stroke. In the HIS situation, it was more difficult for the opponent to hit the protective net. Trials in which the ball did not end up in the protective net were excluded. This situation applied to 13% of trials for the HIS and 8% for the MIS and the WIS.

Dependent variables

The first dependent variable was the directional response, calculated as a percentage of correct directional responses. In correct directional responses, the participant moved to the half of the court to which the opponent's passing shot was directed. The second dependent variable was the accuracy of prediction of the site at which the ball arrived. This was determined by comparing the distance between the racket and the actual site on the protective net that the ball hit. Horizontal, vertical, and radial errors[4] were calculated as absolute errors (AE). The large number of data to be recorded and the difficulty involved in recording them prevented the assistants from measuring the horizontal precision of the target responses as constant errors (CE): only vertical CE were calculated. Variable errors (VE) were calculated on the basis of the intra-individual reliability of the target responses in terms of AE. Figure 1 illustrates a correct directional response, in which the participant moved in the right direction to intercept the ball.

RESULTS

We used repeated measures multiple analysis of variance (MANOVA) to check that the location at which the ball arrived in the protective net did not differ according to the level of tactical initiative. Directional errors were scored dichotomously and were therefore analysed with Wilcoxon's test. Finally, the location of arrival of the balls was analysed by repeated measures MANOVA, with level of tactical initiative treated as a within-participants factor.

The arrival location of the ball did not affect the participants' responses

We checked that the location at which the ball arrived did not influence the directional response and the location of the ball predicted by the participants. We therefore calculated means for vertical and horizontal coordinates measured from the centre of the protective

[4] For the accurate measurement of radial errors, research assistants calculated the vertical distances between the ball and the ground and between the racket and the ground, and the horizontal distance between the ball and the racket. They also measured the horizontal distance between the ball and the central axis of the protective net. The part of the racket selected for measurement was the 'sweet spot' outlined by a rubber band. The 'sweet spot' is the point of impact on the strings that gives the most efficient stroke.

net. For HIS, MIS, and WIS conditions, mean vertical positions were +27 cm, +24.5 cm, and +29 cm, respectively and mean horizontal positions were 270 cm, 252 cm, and 240 cm, respectively. Scheffé's post-hoc test showed no significant effect of the level of tactical initiative on vertical positions ($p > 0.05$). The same was true for the horizontal positions ($p > 0.05$).

Directional responses

The percentage of incorrect directional responses was 22% in the HIS whereas it was close to 45% in both MIS and WIS conditions. Directional estimation was more accurate in HIS than in MIS conditions, and in HIS than in WIS conditions: $T(N = 17) = 3.32$, $p < 0.05$, and $T(N = 17) = 3.41$, $p < 0.05$, respectively. The accuracy of prediction differed significantly from that due to chance alone (i.e. 50%) only for the HIS: $T(N = 17) = 3.62$, $p < 0.05$. Tactical initiative was therefore found to have a significant effect on directional response. Thus, participants were best able to identify the correct direction in which to move to intercept the ball in HIS conditions.

Location at which the ball arrived

The prediction of ball arrival site was analysed, as AE, by repeated measures MANOVA, with level of tactical initiative treated as a within-participants factor. Analysis of AE indicated no significant effect of tactical initiative level on vertical errors, $F < 1$. However, the level of tactical initiative did have a significant effect on horizontal precision, $F(2, 32) = 9.88$, $p < 0.05$. Analysis of variance (ANOVA) showed that responses obtained were more accurate in HIS than in MIS conditions: $F(1, 16) = 15.48$, $p < 0.05$ or WIS, $F(1, 16) = 12.30$, $p < 0.05$. The level of tactical initiative also had a significant effect on the radial precision of the responses $F(2, 32) = 9.52$, $p < 0.05$. The ANOVA demonstrated that the HIS generated more precise responses than did the MIS and the WIS: $F(1, 16) = 14.58$, $p < 0.05$, $F(1, 16) = 31.37$, $p < 0.05$, respectively. MANOVA also showed no significant effect of tactical initiative for vertical CE or VE, corresponding to the intra-individual reliability of the target responses in AE.

However, the better performances observed for the HIS may result from the higher proportion of displacements in the correct direction. We checked whether this was indeed the case by carrying out MANOVA only for those trials in which the participants moved in the correct direction: no effect of tactical initiative level was observed for vertical, horizontal, and radial errors: $F < 1$, $F(2, 32) = 2.06$, $p > 0.05$ and $F(2, 32) = 2.63$, $p > 0.05$, respectively. MANOVA identified no significant effect of tactical initiative on CE and VE.

We then analysed the data as described by Buckolz et al. (1988), who studied the effect of the two types of passing shot (forehand and backhand) and their directions (cross-court and down-the-line) on the accuracy of ball trajectory predictions. We reordered the data according to level of tactical initiative, type of passing shot and its direction. Data were missing for several participants as we could not standardize the direction and the type of the passing shots to be predicted. We therefore excluded level of tactical initiative. Directional responses as a function of type and direction of passing shots are presented in Figure 2 and were analysed with Wilcoxon's test. We found that cross-court backhands were more difficult to predict than down-the-line backhands. Similarly, cross-court forehands were more difficult to predict than down-the-line forehands:

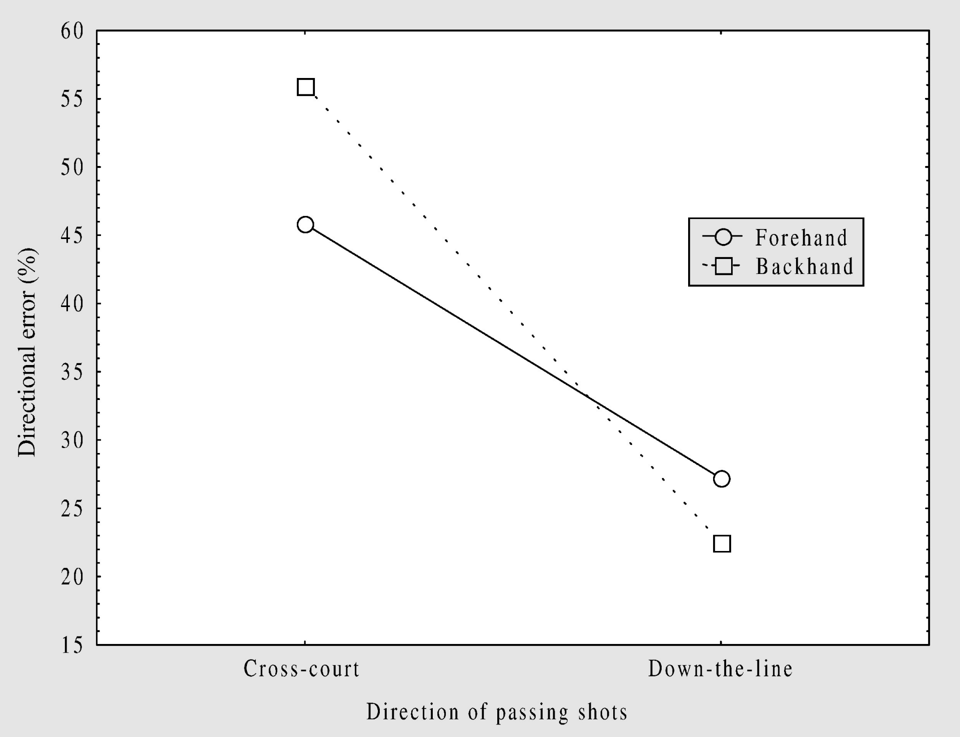

Figure 2. Percentage errors in judging stroke direction (i.e. moving correctly to the left or the right of the court) as a function of type and direction of passing shot

$T(N = 17) = 3.62$, $p < 0.05$, and $T(N = 17) = 2.72$, $p < 0.05$, respectively. Interestingly, the difference between cross-court backhands and cross-court forehands was close to the threshold of statistical significance: $T(N = 17) = 1.86$, $p = 0.061$. None of the other comparisons showed a significant difference.

The precision of horizontal, vertical, and radial responses in terms of AE, for all responses and for correct-direction responses only, were also analysed as a function of type of passing shot and shot direction, by Scheffé's post-hoc procedure. Horizontal and radial precision was found to be significantly higher for down-the-line backhands than for cross-court backhands, $p = 0.035$ and $p = 0.028$, respectively. No difference in vertical errors was observed for CE and no difference in horizontal, vertical, and radial errors was observed for VE.

DISCUSSION

The aim of this study was to examine the influence of tactical initiative on ability to predict the destination of the opponent's passing shot in tennis. Our results indicate that expert tennis players can accurately predict the direction of shots provided that they have controlled the rallies. Indeed, their accuracy in selecting the direction in which to move to intercept the ball was close to 80% for the highest level of tactical initiative (HIS). In contrast, the accuracy of directional responses was markedly lower in situations of lower tactical initiative (MIS and WIS). In the MIS and WIS, predictions were no more accurate than would be expected from chance, suggesting that the direction in which the participant moved was chosen randomly. The choices made by players on the offensive may have influenced the direction of the opponent's strokes: the players were expecting particular solutions as they had initially reduced the opponent's playing possibilities. Interestingly, post-hoc results revealed that down-the-line shots were easier to forecast than cross-court shots and confirmed that anticipatory errors depended on the type of stroke (Tenenbaum et al., 1996; Tenenbaum, Sar-El, & Bar-Eli, 2000). These results also extend those of Buckolz et al. (1988), indicating that cross-court backhands seem to be more difficult to predict than down-the-line backhands. Biomechanical information, such as shoulder and leg rotations, could provide pertinent anticipative cues for down-the-line backhands.

The accuracy of arrival site prediction (in terms of AE) was higher in the HIS than in the MIS or the WIS. The higher proportion of correct directional responses in the HIS accounted for this result. Indeed, the greater accuracy of players in the HIS did not persist if we included only trials involving correct directional responses in the analysis. However, predictions of the arrival locations of the balls were rather imprecise, with a mean radial error of at least 1.50 m. In particular, the participants seemed to find it harder to predict the horizontal than the vertical components of trajectories: location errors of at least 1.4 m were measured in the horizontal plane, whereas errors in the vertical plane were about 0.30 m regardless of the stroke played. Occlusion probably occurred too early for the participants to pick up sufficient information to be accurate. Indeed, interceptive actions, such as hitting and catching, must be continuously adjusted according to visual and temporal information concerning flight path (Peper, Bootsma, Mestre, & Bakker, 1994; Savelsbergh & Bootsma, 1994).

One of the major aims of this study was to investigate recent claims that perception and action should be viewed as mutually interdependent and that studies concerned with the knowledge used in prediction must allow the participants to execute the action concerned (Deakin & Allard, 1991; Williams & Davids, 1995). Our experiment was designed to allow us to investigate the decision processes actually used during the game and to maintain the normal functional coupling between perception and action. There remain substantial differences between the experimental protocol and actual competitive situations, but HIS seems to reflect tactical scenarios accurately. Comparison of the data obtained here with those obtained by traditional, film-based occlusion approaches would be useful, as it would make it possible to determine whether performances are indeed better if coupling is preserved. For instance, in the study by Abernethy and Russell (1987), the mean errors committed by the participants for flight which cannot exceed 13.4 m (the length of the court) were 1.8 m. In our experiment, and for longer possible ball flight paths (i.e. between 13.5 m for the down-the-line shots and 15.5 m for cross-court shots), the horizontal errors for correct directional responses were less than 1 m. This difference confirms that the processes underlying performance depend on the time constraints imposed on participants, and on the task-specificity of responses. Interestingly, our results in the HIS for directional responses were similar to those reported by Abernethy et al. (2001, p. 245), in an in vivo study. Taking into account the periods of occlusion, which were similar to those in our study (between 100 ms and 180 ms before contact), errors in judging stroke direction for the expert group were between 19% and 30%.

The current results also support the conclusion that, in live playing situations rather than in laboratory tasks, experienced players benefit from a prior knowledge of probable upcoming events. Interestingly, no tactical advantage was observed in our previous study investigating whether meaningful situations in tennis preceding the opponent's stroke have a beneficial effect on predicting the rebound of the struck ball (Féry & Crognier, 2001). Experienced participants were instructed to watch two male tennis players executing situations of high, moderate, and low tactical significance but had simply to indicate manually the zone reach by the ball at the moment of its rebound. The discrepancy between the current findings and our previous results highlights the importance of providing a test setting that requires participants to play simulated on-court situations and to make a movement response identical to that they would use in a game. Further research focusing on the knowledge bases underlying skilled perception is needed to confirm this result (Williams & Ward, 2003).

A key limitation of the current experiment, restricting the generalization of the results obtained, is the selection of a single-skill level participant group. It would be desirable to add an expert group (or a less skilled group) to the experimental design, to extend the analysis of contextual and subjective probability. However, we did not use the typical two-group (expert-novice) comparison because the aim of the study was to describe the characteristics of experienced performers rather than to trace the development of expertise. In addition, novices would have had difficulty controlling and targeting their approach shots (especially in the HIS). Given the continuous nature of skill development, and consistent with two recent studies contrasting skilled and less skilled players and examining the mechanisms underlying anticipation in tennis (Ward, Williams, & Bennett, 2002; Williams et al., 2002), we decided to study players who were experienced, but not true 'experts'.

Another potential limitation is the control of occlusion time. Although we took several precautions, it was not possible to control occlusion time perfectly because the variability associated with command time was $\pm$ 40 ms. However, it should be noted that liquid crystal spectacles have been used successfully to achieve temporal occlusion paradigms in real-world tasks (Starkes, Edwards, Dissanayake, & Dunn, 1995) and to examine situational probabilities *in situ*. Furthermore, this variability was random and did not depend on the situation studied. It should therefore have had no significant effect on the results.

Finally, our findings suggest that the kinematic information extracted from the opponent's stroke must be advantageously complemented by tactical information preceding the stroke. Therefore, the advice 'read the play' should be added, in fast-ball games, to the most traditional exhortations of coaches: 'keep your eye on the ball' and 'read the opponent's movements'. In line with the findings of McPherson and Kernodle (2003), our results suggest that tactics, a key attribute of expertise, should not be 'neglected' in tennis training.

AUTHORS' NOTE

Lionel Crognier was working at René Descartes University, UFR Staps Paris 5, Laboratory Cognition and Motor Behavior, UPRES JE 2378, 75015 Paris, at the time of this study.

This research was partly funded by a grant from the René Descartes University. The authors wish to thank Denis Lancelin and Jocelyn Leroy for developing the electronic device and Yves Plard for software design. We thank Jean Keller and Marc Testa from the René Descartes University and Charalambos Papaxanthis from the University of Dijon.

We also thank Vincent Collet, Olivier Ferrand, Timour Griffais, Julien Quillet, Emmanuelle Renart, and Nicolas Veret for assistance with data collection.

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