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Article

A pilot study on the use of dynamic-contextual and kinematic information in the anticipation of tennis shots

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Abstract – The goal of this study was to examine how expert and novice tennis players can use kinematic from the opponent and dynamic contextual information (*i.e.*, the relative position of players on the tennis court) to anticipate tennis shots. Participants viewed film sequences under four different conditions that included low *versus* high contextual information and early *versus* late occlusion providing more or less kinematic information. Only experts significantly improved their response accuracy when more kinematic information was added (*i.e.*, late occlusion). Findings show that experts and novices can use dynamic contextual information to anticipate, but only experts can anticipate based on low contextual information. Finally, experts are better able to use both types of information. Further studies should take into account the type and relevance of the information given to the participants to better understand the anticipation process.

Keywords: perceptual-cognitive skill, expertise, context-specific information, postural cues

Résumé – Une étude pilote sur l'utilisation d'informations contextuelles dynamiques et cinématiques lors de l'anticipation des frappes en tennis. L'objectif de cette étude a été d'examiner comment les joueurs de tennis experts et les novices peuvent utiliser des informations sur l'action de frappe adverse et sur un contexte dynamique (*i.e.*, la position relative des joueurs sur le court de tennis). Des séquences filmées ont été projetées aux participants selon quatre conditions différentes : information contextuelle pauvre *versus* riche et occlusion tôt *versus* tard permettant d'obtenir plus ou moins d'information sur la préparation de la frappe adverse. Seuls les experts ont amélioré la précision de leur réponse avec l'ajout de l'information sur la gestuelle adverse (*i.e.*, occlusion tardive). Ces résultats montrent que les experts et les novices peuvent utiliser de l'information contextuelle pour anticiper, mais que les experts ont une capacité à anticiper même dans des situations tactiques moins riches. Finalement, les experts arrivent mieux à utiliser les deux types d'informations. Les études futures devront prendre en compte le type et la pertinence de l'information donnée aux participants pour mieux comprendre les processus d'anticipation.

Mots clés : habileté perceptivo-cognitive, expertise, information contextuelle spécifique, signaux posturaux

Introduction

With increased training time and physical preparation and also with material innovations (*e.g.*, Crespo, Botella-Carrubi, & Jabaloyes, 2021), the speed of play in fast ball sports such as tennis has significantly increased over recent decades. Consequently, the anticipation of the opponent action can be a useful strategy specifically when space and time constraints are high to get more time to organise a response (Triolet, Benguigui, Le Runigo, & Williams, 2013; Wilson, Dicks, Milligan, Poolton, & Alder, 2018). This ability which is based on information available early in the action sequence is presumed to be one of the key attributes of expertise in fast ball sports (Williams, Ford, Eccles, & Ward, 2011). For example, in a recent experiment presenting frozen pictures before the opponent stroke (*i.e.*, either at landing time of the ball before the stroke or 80 ms before the stroke) Shangguan and Che (2018) showed a better anticipation accuracy for professional tennis players compared to second-grade athletes.

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Published reports highlight that several perceptual-cognitive skills underpin anticipation *(e.g.*, Williams & Jackson, 2019) such as the recognition of sport-specific patterns *(e.g.*, North, Williams, Hodges, Ward, & Ericsson, 2009), the ability to pick up and use precontact information available from the context *(e.g.*, Abernethy, Gill, Parks, & Packer, 2001) and/or the opponent's kinematic or biological-motion (*e.g.*, Ramsey *et al.*, 2020). Runswick, Roca, Williams, Bezodis, and North (2018a) differentiated situation-specific from non-situation-specific context. They referred to situation-specific context as information that is unique to the event such as the score *(e.g.*, Farrow & Reid, 2012), the sequence in which information is displayed *(i.e.*, previous actions of the match; *e.g.*, Loffing, Stern, & Hagemann, 2015) or the position of opponents and team-mate *(e.g.*, Paull & Glencross, 1997). Non-situation-specific context relates to past performances and opponent preferences *(e.g.*, McRobert, Ward, Eccles, & Williams, 2011). Contextual information can also be divided into two groups (Williams & Jackson, 2019): it may be stable, remaining unchanged during the action, such as opponent preferences or the score; or it may be dynamic, unfolding during the action such as the opponent's position on the tennis court.

Kinematic information can be perceived from the opponent's postural and action cues. For instance, Williams, Ward, Knowles, and Smeeton (2002, experiment 1) showed that expert tennis players fixed their gaze on the head, shoulder, trunk and racket in order to pick up information about the intention of the opponent, whereas novices looked mostly at the racket.

Scientists have demonstrated consistently that kinematic information can be used by experts when attempting to anticipate (*e.g.*, Farrow & Abernethy, 2003), whereas experiments examining the link between level of expertise and use of contextual information have presented mixed results depending of the type of contextual information used in experiments. Runswick, Roca, Williams and North (2020) emphasized there is a need for researchers to clearly define the different sources of context that can be controlled experimentally in order to avoid confusion of such an all-compassing term. In the same time, very little is known about the respective use of kinematic and contextual information.

Regarding contextual information, it seems that the use of the various sources of information are expertise-dependent. Farrow and Reid (2012) showed that only experts could use tactical consistency in relation to the score in the game as a cue to better anticipate, whereas Paull and Glencross (1997) reported that intermediate baseball players needed players positioning information in addition to the score to accurately anticipate.

In addition researches presenting similar dynamic situation-specific contextual information (*i.e.*, the relative position of players during the point) also showed contradictory results. Abernethy *et al.* (2001) reported that only squash experts could anticipate accurately using this information, whereas Murphy *et al.* (2016) showed that even novices were able to use these sources of information in tennis.

To explain this difference, the relevance of the information given to participants could be questioned. For example, in racket sports, when watching a rally where one player is located on the far side of the court, it sounds logical to anticipate that the opponent will play the following stroke to the opposite side of the court. The dynamic situation-specific context information presented in this case can be considered as a high contextual information useful to anticipate whatever the level of the player. This finding could explain why Murphy *et al.* (2016) showed that novices could also use this kind of information. Conversely, in a rally where players are in the center of the court, we might need to use specific knowledge to properly anticipate the opponent's likely action. A suggestion is that low-level or more subtle contextual information could only be used by experts, as proposed by Abernethy *et al.* (2001).

Finally, an important question relates to how these various sources of information are integrated to facilitate superior anticipation. There are only few researches analyzing the combined use of kinematic and contextual information. These researches have mainly used stable contextual information prior action such as the score or the position of players before the action (*e.g.*, Runswick, Roca, Williams, McRobert, & North, 2018b) or opponent preferences (*e.g.*, Gray & Cañal-Bruland, 2018; Gredin, Bishop, Williams, & Broadbent, 2021). Regarding the interaction between kinematic and dynamic contextual information, Loffing, Sölter, Hagemann, and Strauss (2016) used an occlusion paradigm associated with two different on-court positions. They found that tennis players' response selection was mostly affected by an opponent's on-court position, particularly at an early stage of a hitting movement. Indeed, they found an interaction between contextual and kinematic information for experts but not for novices. However, it is important to underline that the position of the player hitting the ball was defined by the investigator prior to the action and the experiment did not take place in an *in situ* situation with players trying to win the rally.

All together, these studies suggested that an interaction could exist between the richness and the type of the contextual information available, the presence of kinematic information and the expertise of the player, specially in real situations of matches.

In order to address this issue, we ran an experiment examining the use of high *versus* low dynamic situation-specific-contextual and kinematic information in the anticipation of tennis shots from real tennis rallies. The goal was to determine whether both sources of information can be used by experts and non-experts. We hypothesized that high contextual sources of information could be used by experts and non-experts, but only experts should be able to use low contextual information. Additionnally, only experts should be able to take advantage of the combined use of contextual and kinematic information.

Materials and methods

Participants

An *a priori* power analysis was conducted with G*Power 3.1 (Faul, Erdfelder, Lang, & Buchner, 2007). Among the relevant published studies reporting interaction between skill level and manipulation of anticipatory information, Runswick, Roca, Williams, McRobert, and North (2019) reported an effect size of $\eta_p^2 = 0.69$, while Abernethy and Zawi (2007) reported an effect size of $\eta_p^2 = 0.24$. When only looking at manipulating contextual or kinematics information, effects size ranged from $\eta_p^2 = 0.49$ (McRobert *et al.*, 2011) to $\eta_p^2 = 0.72$ for Runswick *et al.* (2019) up to $\eta_p^2 = 0.92$ for Abernethy and Zawi (2007). Based on these effect sizes, an alpha of 0.05 and 80% power, analyses indicated sample sizes ranging from six participants to 30 participants per group, with a mean sample size of 13 participants. Based on these analyses, we decide to recruit at least 13 participants with a maximum of 18 participants to achieve 95% power.

The expert group was composed of 14 male professional players (mean age of 23.86 years old [±6.85]) who had reached the ATP ranking (rank ranged between 1600 and 37) and practiced tennis for 16.71 years (±6.49) on average. The novice group included 14 male participants (mean age of 30.21 years old [±14.01]) who had never played tennis. Participants had normal or corrected-to-normal vision. Participants took part voluntarily in the experiment and written and informed consents were obtained. The research received ethical approval from the lead institution in accordance with the Declaration of Helsinki.

Test film

We based this study on the use of video clips from professional matches. With the goal of inferring the information content of these situations, we proceeded in a pre-test to select the video clips for the experimental task according to the relevance of contextual information. We sought 13 professional tennis coaches (coaching experience of 9 years [±6.65] on average for 29 hours a week [±13.15]) for a session of one hour. The video clips used were recorded from broadcast tennis matches from Grand slam tournaments involving 10 male players (nine right-handed and one left-handed) who reached the top 12 of the ATP ranking, filmed in the longitudinal axis of the court. Each clip ended with a winning shot delivered by the player filmed at the top of the screen from a front-on perspective. These shots could be forehand or backhand groundstrokes but also volley or smashes and correspond to very unfavourable situations which required an anticipation to get a chance to stay in the rally (Triolet *et al.*, 2013). The winning shot occurred on the sixth stroke of the rally to provide enough time to the participants to get contextual information. The occlusion moment was set early before the contact ball/racket (*i.e.*, −340 ms) in order to avoid providing participants with kinematic information related to the execution of the shot (Farrow & Abernethy, 2003).

The aim of this procedure was to discriminate video clips providing high contextual information from others that contained lower contextual information. Coaches had to respond to 10 series of 10 clips presented in a random order on a laptop using a program created with E-Prime® (Psychology Software Tools, Inc.). Response accuracy (right/left) for each clip was recorded to obtain the mean of correct responses for each game sequence in order to estimate the difficulty of the clips and select them for the experiment. At the end, 40 video clips were selected from this pre study:

20 clips with a mean response accuracy around 80% (M = 81% [±6%]), considered as game sequences supplying high contextual information (HCI);

20 clips with a mean response accuracy around 50% (M = 49% [±4%]), corresponding to chance level, considered as game sequences with low contextual information (LCI).

Procedure

For the experimental test, each selected clip was presented either with an early occlusion 340 ms before the stroke (no kinematic information), or with a later occlusion 20 ms before the stroke to add kinematic information. Participants watched only one condition of the clip (early or late occlusion). The video clips were presented on a Dell 17” laptop and tennis players sat in front of a 40 cm laptop screen. Each trial began with a countdown from 3 to 1 before starting with a freeze frame of the first image for two seconds. Then the video began 200 ms before the first stroke of the sequence and ended either 340 ms or 20 ms before the sixth stroke of the player at the top of the screen. To avoid participants being influenced by the behaviour of the player at the bottom of the screen (*i.e.*, player to whom the participant had to substitute himself), the player was hidden by a black rectangle 200 ms after his last stroke.

The experiment began with a familiarization session containing eight trials (four clips with early occlusion and four with late occlusion). After this, the participant had to respond to five blocks of eight clips presented in a randomized order. Each block lasted approximatively two minutes and contained four clips with high contextual information (two cut 340 ms and two cut 20 ms before the stroke) and four clips with low contextual information (two cut 340 ms and two cut 20 ms before the stroke) which were also randomized within the block. The total duration of the experiment was approximately 15 minutes.

When occlusion occurred, the screen turned black and the participant was asked to answer as fast as possible by indicating on an AZERTY keyboard if the opponent played a winner directed on the right by pressing the key “P” or on the left side of the court by pressing the key “A”. A maximum of two seconds was allowed to provide the response in order to get quick responses (see Shangguan & Che, 2018 for a similar procedure). Note that no trial has exceeded this time. A new trial began immediately after the response. At the end of each block, feedback relating to the percentage of correct responses for each block was provided to keep the participant’s motivation in the test.

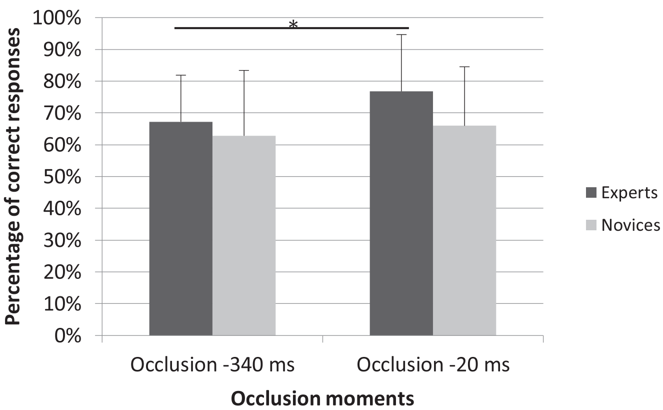

Fig. 1. Percentages of correct responses according to the occlusion moments for experts and novices.

Data analysis

For each participant, the percentage of correct responses was recorded and served as dependant variables.

The data were analyzed using a three-way factorial ANOVA with expertise (experts *versus* novices) as a between-participants factor and occlusion (early occlusion *versus* late occlusion) and contextual information (low contextual information [LCI] *versus* high contextual information [HCI]) as within-participants factors. We normalized the obtained percentage of correct responses using an Arc-sine transformation of the square root of the data (Legendre & Legendre, 1998) in order to run regression analysis, ANOVA and one-sample Student-t tests to compare response accuracies with chance level.

Results

ANOVA on mean percentage of correct responses revealed separate main effects for expertise, ($F(1.26) = 4.335$, $P < 0.05$, $\eta^2 = 0.143$), occlusion ($F(1.26) = 13.732$, $P < 0.05$, $\eta^2 = 0.346$), and contextual information ($F(1.26) = 37.216$, $P < 0.05$, $\eta^2 = 0.589$), as well as an interaction effect between occlusion and expertise ($F(1.26) = 5.726$, $P < 0.05$, $\eta^2 = 0.180$). The percentage of correct responses was higher for experts than for novices (72% [±6.5%] *versus* 64.4% [±6.5%]), higher for late (71.4% ± 18.9%) compared with early occlusion (65% ± 17.8%) and higher for HCI clips (78.9% ± 14.7%) than for LCI clips (57.5% ± 15.6%). Newman-Keuls *post hoc* tests on the interaction showed that only the experts significantly improved their accuracy percentage when kinematic information was added (*i.e.*, scores improved between early occlusion and late occlusion, $P < 0.05$, $m = 9.55\% \pm 13.8\%$) (Fig. 1).

Table 1 presents the percentage of correct responses for experts and novices in the different experimental conditions.

Student-t tests showed that the expert percentage of correct responses was significantly higher than chance level in all conditions (LCI and early occlusion, $t = 2.45$, $P < 0.05$; HCI and early occlusion, $t = 8.2$, $P < 0.05$; LCI and late occlusion, $t = 3.232$, $P < 0.05$; HCI and late occlusion, $t = 9.12$, $P < 0.05$) while this was only the case in the HCI conditions (for both occlusions) for novices (HCI and early occlusion, $t = 4.913$, $P < 0.05$; HCI and late occlusion, $t = 4.470$, $P < 0.05$).

Discussion

In this study, we examined how contextual and kinematic information could be used by expert and novice tennis players. Our second aim was to analyze which possible interactions between these sources of information would be more useful according to the relevance of the contextual information and expertise.

First, there were no differences between experts and novices for early occlusions. This result contrasts with Shangguan and Che (2018) who showed that differences between experts and less expert tennis players occurred even for information provided at the moment of the landing of the ball on the ground before the stroke which is several hundred milliseconds before the stroke. However, in this experiment, static images were used which may have provided experts a better opportunity to extract predictive information. Moreover, contextual information was not quantified and it is not possible to determine what type of information was provided and used. In contrast, only the expert players were able to significantly improve their accuracy by 9.55% when kinematic information became. Our findings support those of Farrow and Abernethy (2003) who showed that only experts are able to use pre-contact kinematic information. It is also interesting to note that there are strong inter-individual differences in this improvement, which means that even for experts the use of such information is not systematic. As the performance in tennis is multifactorial, this is not surprising that athletes could have variable strengths and weaknesses in the various factors of performance.

This result highlights that experts can use kinematic cues in addition to contextual information and are able to combine both sources of information as suggested by Runswick *et al.* (2018b). One possible explanation of the superiority of experts in extracting information from the opponent action is the experience of such actions of the observer. Calvo-Merino, Glaser, Grèzes, Passingham, and Haggard (2005) suggested that the brain's response to seeing an action is determined by the acquired motor skills and level of the observer.

Second, as no change in gain of response accuracy in the presence of kinematic information was reported between the two levels of relevance of contextual information, it appears that the use of kinematic information is not linked to the relevance of the dynamic situation-specific-contextual information.

Thirdly, our findings support the hypothesis that both experts and novices can use high sources of contextual information to anticipate the opponent action, while the experts' superiority over novices only emerged when the contextual information was lower. In the latter condition, only expert players recorded accuracy levels higher than chance level. It can be noted that experts were more

Table 1. Percentage of correct responses for experts and novices according to the experimental conditions.

	Early occlusion		Late occlusion	
	LCI	HCI	LCI	HCI
Experts	61.6% (±17.2)*	72.9% (±9.1)*	65.1% (±17.2)*	88.4% (±8.8)*
Novices	47.8% (±10.6)	77.9% (±16.7)*	55.5% (±12.2)	76.4% (±18.2)*

LCI: low contextual information; HCI: high contextual information. The * indicates the significant differences with a score of chance of 50%.

accurate than coaches in this situation. Our findings suggest the ability of experts to extract more subtle information in low contextual situations and that their current activity as players compared to the coaches can be an advantage. We propose that using more subtle information in low contextual information requires a long learning process that seems more efficient when playing (like professional players) rather than when only watching it like coaches. We can suggest based on the study of McPherson and MacMahon (2008) that low contextual situations require access to domain-specific knowledge of the processes or constraints involved in tennis interaction. These results could also modulate Runswick *et al.* (2018b) conclusions suggesting that skill level underpinned the use of contextual information. Indeed, our results suggest that the access to contextual information according to skill level is mainly dependant of the richness of the contextual information.

In sum, our results enhance understanding of how expertise may impact the use of dynamic situation-specific-contextual and kinematic information based. We showed that while both experts and novices can use high contextual information only experts seemed to employ both kinematic information and low, more subtle, contextual information. Moreover, only experts were able to take advantage of the combined use of contextual and kinematic information.

Before concluding on work perspectives, it seems important to discuss some limitations of the present study. Firstly, a vision of the scene in the third person for the participant does not correspond to the situation the players can experience. However, the better scores of experts even when compared to the coaches could mean that this point of view allows the discrimination of expert anticipation. Secondly, if the use of very different groups of participants is classic in the literature on the determinants of expertise, this can be considered as a first step in the study and understanding of anticipation (see the perspectives below). Thirdly, as we have selected clips that contained more or less relevant contextual information, we have not really manipulated this information. Therefore, we do not really know what increases the relevance of contextual information.

In future, further researches are required to determine more precisely what type of information is used by experts to anticipate efficiently. Moreover, a second step after this pilot study should test and compare different levels of expertise to better understand the access to low contextual and kinematic information and to discriminate different levels among experts and also individual differences. In future experiments, one goal could be to better control the different types of dynamic situation-specific contextual information based on how much they are, or are not, specific to the activity itself. Moreover, further empirical work is needed to evaluate how contextual and kinematic information can be combined to improve the anticipation accuracy in order to enhance understanding of the mechanisms underpinning superior performance (*e.g.*, Gredin *et al.*, 2021). Is any type of information more relevant in specific situations or can players use both types of information indifferently? The use of virtual reality as proposed by Le Noury, Buszard, Reid, and Farrow (2021) could be the better way to achieve this deeper analyze of tennis anticipation mechanisms with the possibility to manipulate and control specifically the various sources of information.

Conflicts of interest

The authors declare that they have no conflicts of interest in relation to this article.

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