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Review

Do expert tennis players actually demonstrate anticipatory behavior when returning a first serve under representative conditions? A systematic review including quality assessment and methodological recommendations

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ABSTRACT

Objectives: The present article aims to (i) critically review and classify the studies on the tennis serve return by the degree of representativeness of the experimental task design, (ii) assess the quality of the studies classified with a high degree of representativeness, (iii) analyze to what extent expert tennis players demonstrate anticipatory behavior when actually performing a first serve return.

Design and method: Searches were performed in Web of Science and Scopus up to 31st December 2017. The main search term tennis was combined with four groups of key words: anticipation, perception and action, response time and serve return. Researchers selected 62 studies after applying the inclusion criteria. Subsequently, they were screened by degree of experimental task design representativeness through 6 further criteria.

Results: Fifty-four studies were found with a medium to low degree of representativeness (87%) and only 8 studies with a high degree of representativeness (13%). Among those eight studies, only one attained the best methodological quality in terms of variables analyzed and information reported. Also, some methodological recommendations were outlined for future research.

Conclusions: After 40 years of research, evidence has not yet been found that expert tennis players move to either side before the ball is hit in representative task conditions. Hence, players do not demonstrate observable anticipatory behavior towards the ball direction on the first serve in tennis, but guide their actions upon the information unfolding around the server's action and first moments of the ball flight.

1. Introduction

The evolution of modern tennis has converted the serve into one of the most critical aspects of the game, forcing players to develop an effective return if aiming to maintain their chances of success (Elliot & Saviano, 2001; Gullikson & MacCurdy, 2017). When comparing the percentages of points won with the first serve and the return of serve, it is apparent that the advantage is with the server (Cui, Gómez, Gonçalves, & Sampaio, 2018; Gillet, Leroy, Thouvarecq, & Stein, 2009). Consequently, the coaches of top level players program specific training sessions to improve the return (Elliot, Reid, & Crespo, 2009).

Moreover, as the first serve in tennis is an explosive action, the returning action has to be executed within pressuring temporal (less than a second) and spatial (whole of the service box) limits. Therefore, considering that this challenge is so determinant and that it represents an extremely demanding situation for tennis players, researchers have taken pains to discover what anticipatory mechanisms (Jackson & Mogan, 2007; Jones & Miles, 1978) and other aspects related to the timing of the actions, underlie the success of tennis players when facing a first serve (Avilés, Ruiz, Sanz, & Navia, 2014).

In this regard, several techniques have been used to identify the perceptual-motor and cognitive expertise of athletes, including temporal and spatial occlusion, the reaction time paradigm, liquid crystal glasses, eye movement recording, high-speed film analysis, qualitative interview methodology, etc. (e.g., Müller, Brenton, & Rosalie, 2015; Williams, Davids, & Williams, 1999). Results of sound research projects have suggested that skilled tennis players anticipate the direction of the ball to a greater extent than their lower skilled counterparts. For instance, expert players have been found to extract information from the opponent's movement (e.g., Murray & Hunfalvay, 2017), from the context (e.g., Farrow & Reid, 2012) or both (e.g., Vernon, Farrow, & Reid, 2018) prior to the server's stroke. Then, expertise is believed to be characterized by the ability to extract and *make use* of that advance information (Jackson & Mogan, 2007; Reid, 2003). This idea of the use of information then refers to the ability of tennis players to anticipate, that is, to buy time by *moving* in the (foreseen) *direction of the ball* before the opponent's shot, in order to counteract the unfavorable constraints. In fact, coaches have indicated that expert players base their game to a

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great extent on anticipation, and that they frequently need to anticipate during the competition to be able to move and take up a position that gives them a chance of success (Crespo & Miley, 1998).

Yet the fact that the expert tennis players can successfully predict the future direction of the ball above chance level does not necessarily mean that they actually demonstrate anticipatory behavior –which is no wonder since expert servers are true masters at hiding their intentions, being able to change shot directions with very slight kinematic differences (Elliot et al., 2009)-. Without denying that anticipation is a term that may entail mental preparation, predictions and expectations, we consider that an athlete demonstrates anticipatory behavior when showing observable behavior before the occurrence of a certain event (e.g. see Buckolz, Prapavesis, & Fairs, 1988). In the case of first serve returning, anticipatory behavior denotes the tennis player's lateral movements on court prior to the server's stroke (c.f. Cañal-Bruland & Mann, 2015; Triolet, Benguigi, Le Runigo, & Williams, 2013).

Hence, the idea that anticipatory behavior is imperative and a hallmark of experts is being questioned, as recent indications point to the fact that skilled athletes may actually wait as long as possible to initiate their actions (see review on Navia, Avilés, López, & Ruiz, 2018). In this respect, regardless of the informational variables that players exploit to control their actions (i.e., perceptual, contextual information) the behavior of the expert athletes *in situ* does not support the idea that they evenly demonstrate anticipatory behavior regarding the direction of the server by moving to either side prior to the server's stroke (Shim, Carlton, Chow, & Chae, 2005; Triolet, Benguigui, Le Runigo, & Williams, 2013; van der Kamp & Renshaw, 2015). In short, whereas there is a body of research suggesting anticipatory behavior as a key factor when facing tennis serves, other studies point out that anticipatory actions may not actually represent an optimal response when reacting to a first serve. An explanation of this apparent contradiction could be found in the experimental design employed.

1.1. Representative task designs

In 1979 there was already a lot of interest in studying natural vision and carrying out experimental tests with greater behavioral realism, Gibson himself stated: “It is not true that ‘the laboratory can never be like life.’ The laboratory *must* be like life!” (Gibson, 1986, p. 3). At the same time, Martens urged researchers to develop more applied field research with greater external validity, without neglecting basic laboratory studies which imply greater experimental control (Martens, 1979).

In the last decade, concern has grown among researchers about the effect of representativeness in the experimental task on the results. To be precise, the scientific community has questioned the generalization of the results of studies wherein the experimental tasks do not adequately reproduce the specific conditions of play actions (Araújo, Davids, & Passos, 2007; Müller et al., 2015; Pinder, Davids, Renshaw, & Araújo, 2011; Travassos, et al., 2013; van der Kamp, Rivas, Van Doorn, & Savelsbergh, 2008). The specific conditions of the activity in representative task designs refer to different aspects like:

a) The type of stimulus: varying from observing a light, a complete video, sequences with point-light displays, a video with temporal or spatial occlusion, sequences of virtual reality, a ball shot from a machine or a real opponent.
b) The type of response: written, verbal, unspecific tennis hand movements (pressing a key or button, moving a joystick and others), restricted or limited body movement (e.g. stationary split step), a simulated shot (without contact) or a real tennis shot.
c) The moment of response: delayed in time, induced or provoked (e.g. as soon as possible after observing the stimulus) or concurrent.
d) The information on the response: body segment or the racket used to codify the beginning of the response (e.g. movement of the foot, trunk, the whole body, the racquet head, etc.).

In this line of thought, van der Kamp et al. (2008) argued that temporal occlusion studies, with delayed verbal or written responses, triggered different perceptive-neurological processes from those produced by actual responses against a real opponent. For instance, it has been reported that the perception (visual patterns) of goalkeepers in football when facing a penalty kick varied as a function of the type of stimulus (video vs. real opponent) and the type of response (verbal vs. restricted vs. a real save) (Dicks, Button, & Davids, 2010). Other studies state that the conditions of task representativeness in the experimental design can influence response accuracy (i.e., percentage of successes in judging the direction of the ball; Farrow & Abernethy, 2003) as well as the timing of the movements of interceptive actions (Pinder, Renshaw, & Davids, 2009). In fact, evidence indicates that expert performance is constrained by requisite response behaviors (Travassos et al., 2013).

Another important factor that shapes the anticipatory behavior of returners is the ranking of the participants, as the degree of the server's expertise modulates the speed and accuracy of the first serves. Findings confirm that the accuracy and efficacy of the return decreases when the speed of the serve increases (Avilés, Ruiz, & Benguigui, 2006; Haake, Rose, & Kotze, 2000). Yet, very few studies have managed to reproduce speeds similar to those seen in top competition (Gillet, Leroy, Thouvarecq, Mégrot, & Stein, 2010), as it is not often that research can count on expert servers and returners at the highest level in the taxonomy of expertise (Swann, Moran, & Piggott, 2015).

In short, research suggests that the representativeness of the experimental task designs could influence the performance of the expert tennis players in the return action, either in the timing of the return and/or in the percentage of response accuracy. Therefore, in order to ascertain whether tennis players actually demonstrate anticipatory behavior when facing a first serve, we first should examine the conditions under which players in different reported studies performed. This subject to date has not been systematically reviewed for the case of the tennis first serve return. Hence, the present article aims to (i) critically review and classify the studies on the tennis serve return by the degree of representativeness of the experimental task design, (ii) assess the quality of the studies classified with a high degree of representativeness, (iii) analyze to what extent expert tennis players demonstrate anticipatory behavior when actually performing a first serve return.

2. Method

2.1. Search process and selection of studies

As depicted in Figure 1, the PRISMA methodology for systematic reviews was followed (Moher, Liberati, Tetzlaff, & Altman, 2009). Bibliographic searches were carried out in the following databases: Web of Science and Scopus. The reference lists of the full-text article selection were also reviewed manually to find additional records. There were no time restrictions to begin the search for the studies as the purpose was to collect all available sources within the topic. The search finished on the 31st December 2017. The main search term “tennis” was combined with four groups of key words: a) tennis AND anticipation; b) tennis AND perception AND action; c) tennis AND response time; d) tennis AND (serve return OR returner).

The following inclusion criteria were taken into account for study selection:

1) The study could be published in English, French or Spanish.
2) It had to be an original full-length paper, review, conference paper or book chapter.

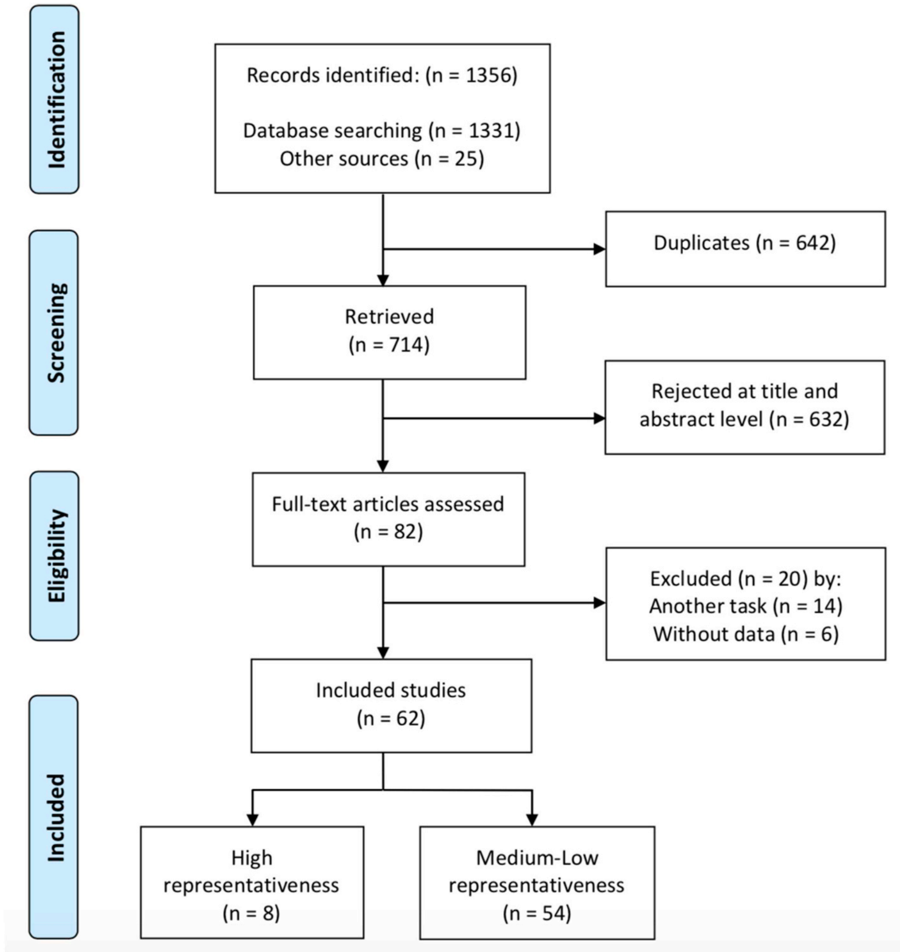

Fig 1. Preferred reporting items for systematic reviews flow diagram.

3) It had to focus on the task of return of serve in tennis. This also included simulation tasks of return of serve, phases of the split step, data on the movements and characteristics of the returner's shot.
4) The study had to provide quantitative data on the aforementioned task.

Therefore, researchers excluded studies about other tasks similar to the return of serve in tennis (e.g. return in volleyball or table tennis serve, split step in paddle tennis or squash, return of a ground stroke in tennis, etc). They also excluded studies which only had a published abstract and did not present the complete contents of the research. Two researchers (Authors 1 and 2) independently reviewed the titles and abstracts of the retrieved studies. If the information in the title and abstract was insufficient, the full text of the study was reviewed to ascertain if it fulfilled the four selection criteria.

2.2. Inclusion criteria for studies on the first serve return with a high representative task design

Once the eligible studies were identified for the review, the next step was to choose those works with a high degree of representativeness relative to experimental task design. Following (and adapting) some of the methodological considerations by Müller et al. (2015), researchers agreed to consider 6 inclusion criteria:

1) To ensure the true expertise of the players, the study had to include at least one returner of level 1 (out of 10 rating categories) of the International Tennis Number. This top performance level is applicable to a player that “holds or is capable of holding an ATP/WTA ranking” (International Tennis Federation, 2004, p. 13).
2) The serves had to cause spatial uncertainty for the returner. That is, serves had to vary in terms of service box aiming location and be unpredictable for the returner.
3) The registered average speed of the first serves had to be above 160 and 130 km/h for men and women, respectively.[1] In the case that the speed data were not reported, the serves had to be made in competition by international or professional tennis players.
4) The server could perform flat, slice or spin first serves, providing that they fulfilled the aforementioned second and third criteria.
5) The returner could observe all the information on the serve, including the server's action (movements prior to and after the impact) as well as the complete ball flight.
6) The returner could perform their habitual technical gesture, without any kind restriction. This includes all the initial preparatory movements (i.e., the split step), a concurrent response in real time, and the shot to return the ball towards the opposite side of the court.

[1] First serve average speed among expert tennis players is around 185 ± 10 km/h in men and 155 ± 10 km/h in women, as well as 150 ± 10 and 130 ± 10 km/h for the second serve, respectively (Cui, Gómez, Gonzçalves, Liu & Sampaio, 2017; Elliot et al., 2009; Haake et al., 2000; Reid, Morgan, & Whiteside, 2016; Ruiz & Cabrera, 2004; Vaverka & Cernosek, 2016). The threshold of 160 for men and 130 km/h for women allows a certain margin (i.e., 2.5 times SD) below first serve speeds and, at the same time, remains above second serve speed average.

Table 1
Studies on the return of serve in tennis with a medium-low degree of representativeness.

Study	Type of stimulus	Type of response	Moment of response	Main findings
Jones and Miles (1978)	TOV	W	IIP	The coaches had better predictions than the undergraduate students in the number of correct responses.
Hennemann and Keller (1983)	RO	H	C	The returners move forward and then jump at different moments.
Isaacs and Finch (1983)	TOV	W	D	The intermediate players achieved better predictions than the beginners in the percentage of correct responses.
Keller (1985)	ROWO, RO	RBM, H	C	The information on the toss phase of the server is used by the returner. When the server carries out the serving movement without hitting the ball (Condition 1), the returner does not modify the initiation of their response.
Goulet et al. (1988)	TOV	V,	I	The expert players detect the type of serve better than the non-experts.
Goulet, Bard, and Fleury (1989)	TOV	V,	I	The experts decided more quickly and with more accuracy than the novices.
Hennemann (1989)	TOV	IIP	D	The participants guessed the direction in 61% of the cases when there was occlusion at the moment of impact.
Goulet, Bard, and Fleury (1992)	VWO, S	V, UTMM	I	Mean RT in both groups: DT experts = 5154 ms DT novices = 5391 ms RT to sound experts = 203 ms RT to sound novices = 183 ms RT in the dual-task = 387 ms
Singer et al. (1994)	VWO, L, VOT, RO	V, SHM, MMIT, G	I, C	Foot RT in the Post-test: Women = 290 ms and Men = 306 ms
Singer, Cauraugh, Chen, Steinberg, and Frehlich (1996)	VWO, L	MMIT, SHM	I	Foot RT Advanced = 275 ms Foot RT Novices = 323 ms
Farrow, Chivers, Hardingham, and Sachse (1998)	TOV	SHM	I	The perceptual training group was the fastest in deciding and the most accurate in responding.
Moreno and Oña (1998)	RO	NR	NR	The crucial information on the server that the returners could use prior to the hit are: the trajectory of the ball, the movement of the edge of the racket and the angle of the shoulders.
Scott, Scott, and Howe (1998)	RO, TOV	H, V, SHM	C, D	The participants improved their scores in the service return.
Singer et al. (1998)	RO	H	C	The quality of participants' server return ranged from 7.6 to 5.3 (1–10 Likert scale)
Williams, Singer, and Weigelt (1998)	RO	H	C	Time of start of the response of the participants: from 216 to 352 ms.
Haake et al. (2000)	BTM	H	C	Increase in speed: decreases the number of good returns and also increases the number of aces.
Tenenbaum, Sar-El, and Bar-Eli (2000)	TOV	W	I	In the oldest group of players, the differences in anticipation between the players of a greater or lesser skill-level were greater at −240 ms.
Pollick, Fidopiastis, and Braden (2001)	TOVWA	UTMM	IIP	Accuracy in recognizing the type of serve improves with the increase in the modification of the information.
Avilés, Benguigui, Beaudoin, and Godard (2002) Study 1	RO	H	C	Mean of both groups in the split step: take off: −40 ms and landing: +160 ms.
Farrow and Abernethy (2002)	RO, VWO, TOV, ROWO	H, SHM, V	C and I	The implicit learning group improved the accuracy of their predictions. However, this effect dissipated after the retention test.
Moreno, Oña and Martinez (2002)	VWO	UTMM	C	Mean RT of the 6 players: At the beginning of the training 337 ms At the end of the training 229 ms
Farrow and Abernethy (2003)	ROWO	SHM, V	C and I	The increase in the percentage of prediction accuracy of the returners depends on three factors: 1) the crucial information on the flight of the ball, 2) being able to perceive the whole action 3) the level of expertise.
Moreno, Reina, Luis, Damas, and Sabido (2003) On court study	RO	UTMM	IIP	Response accuracy 90%. The RT increases against left-handed opponents.
Jackson and Gudgeon (2004)	RO	H	C	Response time (estimated): with random serves: Coaches 320 ms and Club players 385 ms.
Reina, Luis, Moreno, and Sanz (2004)	VWO	UTMM	C and I	The tennis players watched the ball a high percentage of the time.
Reina, et al. (2004)	RO, VWO	UTMM	C and I	The laterality of the server (right or left-handed) influenced the pick-up of information by the participants.
Williams, Ward, Smeeton, and Allen (2004)	RO	H	C	Response Initiation Time in the post-test: Perception-action group = 999 ms Perception-only group = 1164 ms Technical group = 1361 ms
Farrow, Abernethy, and Jackson (2005)	TOV, ROWO	SHM	D, C	The results show that the laboratory-based progressive temporal occlusion paradigm is suitable for studying perceptual expertise.
Reina, Moreno, Sanz, Damas, and Luis (2006)	VWO, RO	UTMM	C	Before opponents in a biped position: Mean RT = 287 ms Mean MT = 161 ms Mean Total response time = 447 ms
Jackson and Mogan (2007)	SOV, VOT	V, SHM	D	The results indicate that the predictive ability of the participants depends on the crucial information of the ball toss and the arm + racquet region.

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Table 1 (*continued*)

Study	Type of stimulus	Type of response	Moment of response	Main findings
Robin et al. (2007)	IM, RO	H	C	Internal visual imagery contributes to improving motor performance in the return of serve task.
Wright and Jackson (2007)	TOV	UTMM	I	The percentage of correct responses increases considerably when the information on the flight of the ball is available.
Fukuhara, Ida, Kusubori, and Ishii (2009)	TOV, TOVWA	V	I	The participants were more accurate in their predictions when they observed video images rather than computer graphics animations.
Gillet, Leroy, Thouvarecq, Mégrot and Stein (2009)	VSO	EM, SHM	C	Beginning of the racquet lateral movement = 254 ms. Maximum rise of the center of gravity (CG) = 459 ms.
Jackson, Abernethy, and Wernhart (2009)	TOV	V	D	A significant interaction between anticipation and display blurring effect was found.
Uzu, Shinya, and Oda (2009)	L	RBM	C	Lateral step time: No-split condition = 580 ms Split condition = 450 ms
Zawadzki and Roca (2010)	RO	NR	NR	The returner can predict the depth of the serve when they detect the information on the ball toss of the server.
Ida, Fukuhara, Kusubori, and Ishii (2011)	TOVWA	IIP	D	The returners are sensitive to the motion modulation of the server.
Ida, Fukuhara, Sawada, and Ishii (2011)	TOVWA	IIP	D	Skilled players were more sensitive than the novices to the modulations.
Mecheri, Gillet, Thouvarecq, and Leroy (2011)	SOV	ITMM	I	The removal technique affected the performance of the participants.
Farrow and Reid (2012)	TOV	UTMM	I	The older players were able to detect the situational probability information responding in −1300 ms before the impact.
Ida, Fukuhara, and Ishii (2012)	TOVWA	IIP	D	The perceptive ability of the experienced players was better than that of the novices.
Zawadzki and Roca I Balasch (2012)	RO	NR	NR	The main speed perceptual cues were the elbow and shoulder.
Ida, Fukuhara, Ishii, and Inoue (2013)	TOVWA, SOV	IIP	D	Type of stimuli differently influenced performance across groups (tennis vs. soft-tennis).
Nieminen, Piirainen, Salmi, and Linnamo (2014)	L	RBM	I	Response time: With split step = 240 ms Without split step = 350 ms
Zawadzki (2013)	RO	NR	NR	Some relevant perceptual cues were found that precede the arm-racquet element of the server.
Avilés et al. (2014)	RO	H	C	The data on the take-off and landing indicate that participants began their actions before the server's impact. The response times were higher than 160 ms.
Balser et al. (2014)	TOV	UTMM	D, I	The expert tennis players obtained 65% of correct responses and a quite long response time of 513 ms.
Cacioppo et al. (2014)	TOV	IIP	I	When the server knows beforehand where he has to serve, the predictions of the observers are more accurate reaching a 64% success rate.
Carboch, Süss, and Kocib (2014)	RO, BTM	H	C	Movement initiation: Group facing ball machine = 370 ms. Group facing server = 420 ms.
Carboch and Süss (2015)	RO	NR	NR	Ball toss differences across the type of the serve were found. This information can be used to accurately anticipate.
Zawadzki (2016)	RO	NR	NR	The technical pattern of the left-handed servers is more predictable than that of the right-handed servers.
Liu et al. (2017)	TOVWA	UTMM	I	Response accuracy of varsity players was 61%. According to the experimental condition the RT varied from 405 to 567 ms.
Luis and Espino (2017)	VWO	SHM	I	Viewing perspective influences RT and shot accuracy of players.

Types of stimulus: IM – imagined; L – light; S – sound; VWO – video without occlusion; TOV – temporal occlusion video; SOV – spatial occlusion video; TOVWA – temporal occlusion video with animation or in 3D; BTM – ball thrown by a machine; ROWO – real opponent with occlusion or manipulated movement; RO – real opponent.

Type or responses: V – verbal; W – written; UTMM – unspecific tennis manual movements (click on or release a key, button, move a joystick, others); RBM – restricted or limited body movement; SHM – simulated hitting movement (shadow); H – hitting; IIP – insufficient information provided; NR – No response.

Moment of response: D – delayed or deferred for a few seconds; I – induced, provoked or forced (demand to respond quickly: just after, as soon as possible); C – concurrent or coinciding; IIP – insufficient information provided; NR – No response.

Main result: RT – reaction time; DT – decision time; MT – movement time.

Table 2
Studies on the return of the first serve with a high degree of representativeness.

Study	Criterion for the codification of the beginning of the motor response.	Recording frequency	Serve velocity and total response time	Number and level of expertise of the returners	Analysis of the lateral movement of the returner's body or racquet	Time analysis of the split step	Analysis of the response time (RT) and/or movement time (MT)	Findings regarding anticipatory behavior
Pizzinato (1989)	Spatial location of returner on the court until the moment of server's impact: fixed position and body movement.	IIP (camera VHS Sony 3000S)	IIP	(N = 16) International players ranked from 13 to 385 in the ATP ranking	Some players change position more frequently in the second serve returns. These movements are more frequently forward.	Not performed	Not performed	The statistical analyses indicate the absence of a risk-taking strategy to anticipate the direction of the first and second serve. However, in some second serve returns lateral movements are observed.
Kleinöder and Mester (2000)	Resultant segment velocities for forehand and backhand returns	200 fps	160 and 117 km/h 841 and 1010 ms (1st and 2nd serve)	(N = 4) International players at the World Team Cup in Düsseldorf	Not performed	Not performed	Not performed	The players have more time to respond when returning the second serve. This is reflected in a high racquet velocity at the moment of impact. Data supporting an anticipatory behavior are not found.
Avilés et al. (2002) Study 2	Moment of the landing in the split step in relation to the server's impact	IIP	170 km/h	(N = 3): 1 International (12th in the ATP ranking). 1 National and 1 Regional player	Not performed	Take-off and landing International: −5 and 130 ms National: −28 and 160 ms Regional: Take-off: +25 and −50 ms Landing: 190 and 142 ms	Not performed	The international player and the national player take off some milliseconds before the impact. No data found regarding response time towards the ball, but necessarily after landing (around 130 and 160 ms respectively).
Vaverka et al. (2003)	Beginning of body movement towards the ball.	200 and 50 fps	700 ms	(N = 23) International players among the top 100 in the ATP	Performed to obtain response time	Not performed	Response time: 240 ms Movement time: 460 ms	The time to the start of the movement towards the ball was long suggesting that there was no anticipatory behavior.
Avilés et al. (2006)	Timing analysis of the support - feet of the returner every 5 ms. Moment of the take off and the landing of the split step.	200 fps	130 and 170 km/h (slow and fast)	(N = 19) 9 Experts (1 professional and eight 2nd series French players) and 10 intermediate level	Not performed	Experts and intermediate level Take-off times: −28 and −32 vs. −6 and −41 ms Landing times: 122 and 125 vs. 145 and 124 ms.	Not performed	The height variations in the server's ball toss (high and low) affected the timing of the take-off and landing of the intermediate players. No data regarding response time towards the ball.
Gillet et al. (2010)	Time of lateral movement of center of gravity (CG). Time of initiation of lateral movement of racquet. Latency time corresponds to the time elapsed between the moment of maximal GC rise and the beginning of the lateral movement of the racquet.	200 and 50 fps	184 km/h	(N = 1) Participant was ranked number 7 in the ATP	There was a delayed beginning of the lateral movement of the CG and a long time for initiating the lateral movement of the racquet.	The player initiated a lateral racquet movement before the landing of the split-step. The lateral CG movement coincided with the first foot contact on the floor. Backhand and forehand began just before the landing of the split step.	Initiation of racquet lateral movement (ms): Reprogramming strokes: 360 Forehand: 287 Backhands: 285. Very short latency times were recorded: Reprogramming strokes: 298 Forehand: 133 Backhands: 157	There was no evident anticipatory behavior considering the delayed beginning of the lateral movement of the CG and the long delay before racquet lateral movement.

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Table 2 (*continued*)

Study	Criterion for the codification of the beginning of the motor response.	Recording frequency	Serve velocity and total response time	Number and level of expertise of the returners	Analysis of the lateral movement of the returner's body or racquet	Time analysis of the split step	Analysis of the response time (RT) and/or movement time (MT)	Findings regarding anticipatory behavior
Triolet et al. (2013)	Beginning of the lateral movement of the returner's racquet or body (hips, shoulder or feet) towards the future location.	50 fps	IIP	(*N* = 10) Internationals who had been in the top 10 ATP positions	In the first serve returns there was no anticipation, as the players always moved after the server's impact (only in windows 4 and 3)	No timing data reported on the split step.	The percentage of occurrences (distribution of responses) was presented for the returns with regard to 4 different time windows.	The professional returners demonstrated anticipatory behaviors in a very low percentage, and only in second serve returns. In general, they systematically showed a "conservative" strategy of waiting longer.
Filipcic et al. (2017)	Split step timing was used: "Time between the impact point of the opponent's shot and the moment the player performed a split step" (p. 99).	25 fps	IIP	(*N* = 28) 7 ATP players (mean ranking 380), 11 boys and 10 girls at the national junior level.	Not performed	The split step marked the beginning of the response time.	*M* of the response time for 1st and 2nd serves: ATP = 335 ms Boys = 343 ms Girls = 292 ms	The response times were very long in the first and second serve returns (330 and 307 ms, respectively). The results suggest that the returners waited at least 300 ms after impact to move laterally.

Note that total response time represents the time elapsed between the server's stroke and the returner's stroke. IIP – insufficient information provided

Taking these criteria into account, two researchers (Authors 1 and 3) reviewed the contents of the 62 studies and constructed the tables with the data.

3. Results

From the initial 62 studies, 54 (87%) were classified into a medium-low degree of representativeness group (Table 1) and only 8 studies (13%) were found to hold a high degree of representativeness (Table 2).

3.1. *Studies on the return of serve in tennis with a medium-low degree of experimental representativeness*

Table 1 presents the studies related to the serve return in tennis which did not fulfill all the established criteria for being included in the group with a high degree of representativeness. This table presents the descriptions of the experimental task design employed (type of study, type of response and moment of response; see Table 1 footnotes for details) as well as the main findings of the included studies. Other process-tracing measures registered in some studies (i.e., imaginary movements, heart rate, electroencephalogram, fMRI, and eye-movements) were not included as response measures of anticipatory behavior. Studies listed in Table 1 are ordered chronologically.

Studies present a great disparity in the techniques employed (see Supplementary Table 1 for more information). With regard to the stimuli, ten different types or categories have been identified; note that one study might employ more than one technique so that the sum of the frequency (and percentage) is above the actual number of studies (and 100%). From among the 54 studies which comprise this group, 22 (41%) used a real opponent, followed by 18 (33%) wherein temporal occlusion videos were used. Ten studies (19%) employed videos without occlusion, 7 (13%) temporal occlusion videos with animation or in 3D, 4 (7%) light, 4 (7%) a real opponent with occlusion or manipulated movement, 3 (6%) a spatial occlusion video, 2 (4%) balls thrown by a machine, 1 (2%) imagined and 1 (2%) used sound as stimuli.

The results also indicate that the type of response varied. Response was recorded using unspecific tennis hand movements in 14 studies (26%), equal to when participants hit the ball (14, 26%). Verbal responses and simulated hitting movements were used in 10 studies (19%), respectively. In 6 studies (11%) insufficient information was provided, the same as studies wherein the experimental design had no response (6 cases, 11%). Written responses were used in 4 studies (7%) and responses with restricted or limited body movements in 2 (4%).

With regard to the moment of the response, the concurrent (22 cases, 41%) and the induced responses (20, 37%) were the most frequent, while the participants responded in a delayed manner in 10 of the studies (19%). Five studies (9%) had no response, whereas insufficient information was provided in 3 works (6%).

3.2. *Studies on the return of the first serve in tennis with a high degree of experimental representativeness*

3.2.1. *Quality assessment of studies on the return of the first serve in tennis with a high degree of representativeness*

Studies with high representative task designs (i.e., that fulfilled all the inclusion criteria detailed in section 2.2) are chronologically listed in Table 2. Features of the experiments in terms of the variables of the experiment, sample, and main findings can be found throughout the table. All the studies were carried out *in situ* on the tennis court. Note that the publications do not generally provide all the information to the reader on the variables analyzed (see Table 3). Only the work by Gillet et al. (2010) presents the best methodological quality, whereas four publications reach 5 criteria (Avilés et al., 2006; Filipcic, Leskosek, & Filipcic, 2017; Triolet et al., 2013; Vaverka, Stromsik, & Zhanel, 2003). The works by Avilés et al. (2002, Study 2) and Kleinöder and Mester

Table 3
Quality assessment in regards to analyzed and reported variables in studies on the return of the first serve in tennis with a high degree of experimental task representativeness.

Study	Information about								
	CC	Frec.	Speed	Partic.	Mov.	S-S	RT-MT	Total	Anticipatory behavior
Pizzinato (1989)	+			+	+			3	NO
Kleinöder and Mester (2000)	+	+	+	+				4	NO
Avilés et al. (2002) Study 2	+		+	+		+		4	NO
Vaverka et al. (2003)	+	+		+	+		+	5	NO
Avilés et al. (2006)	+	+	+	+		+		5	NO
Gillet et al. (2010)	+	+	+	+	+	+	+	7	NO
Triolet et al. (2013)	+	+		+	+		+	5	NO
Filipcic et al. (2017)	+	+		+		+	+	5	NO
N Total	8	6	4	8	4	4	4		
% Total	100	75	50	100	50	50	50		

Note: CC – coding criterion of response; Frec – recording frequency (fps); Speed – Speed of the serve; Partic. – level of expertise of the returners; Mov. – lateral movement analysis; S-S – time analysis of split-step; RT-MT – analysis of response time and/or movement time

(2000) depict 4 variables, and the experiment by Pizzinato (1989) reports 3 variables out of 7.

3.2.2. *Temporal analysis (criterion, split step and response time)*

We found a lack of unanimity regarding the criterion followed to consider the beginning of the motor response (Table 2). This methodological difference undoubtedly influenced the data and interpretation of the measurements obtained. These differences in times are evident when comparing some studies wherein expert players were recorded. For instance, Avilés et al. (2002) considered the moment of landing from the split step (around 130 ms) as the beginning of the movement towards the ball. The same criterion was used by Filipcic et al. (2017), finding considerably longer times (335 ms). In contrast, Gillet et al. (2010) took the initiation of racquet lateral movement with respect to the server's impact as movement onset (around 286 ms). They also reported very short latency times for returners (133 and 157 ms), but with respect to the moment of maximal gravity center vertical rise instead (Gillet et al., 2010). Furthermore, other researchers like Vaverka et al. (2003) did not consider a specific segment of the body, but rather the whole movement of the returner's body as the initiation of return action (240 ms).

3.2.3. *Recording frequency*

As found in the previous point, the sampling frequency does not follow common guidelines. Some studies do not specify the sampling frequency (Avilés et al., 2002; Pizzinato, 1989), while others captured the actions at very low (Filipcic et al., 2017), or low frequencies (Triolet et al., 2013) of 25 and 50 fps, respectively. In contrast, a select group of studies used devices with a higher frequency or high-speed recordings (200–250 fps) which provide much better chronometric accuracy for establishing the exact beginning and the detailed trajectories of the tennis players (Avilés et al., 2006; Gillet et al., 2010; Kleinöder & Mester, 2000; Vaverka et al., 2003).

3.2.4. *Serve velocity and level of expertise*

The serve velocity in the experimental design is of utmost importance as it dictates the spatio-temporal pressure of the action. That is, the speed of the serve defines the time available for the returners to regulate their actions. From among the studies which report the serve velocity, we found values between 160 km/h (Kleinöder & Mester, 2000) and 184 km/h (Gillet et al., 2010) in men; confirming the temporal constraints of the task. In part, the velocity of the serve is influenced by the experimental conditions and the different recording devices, but undoubtedly the level of expertise of the servers is the most decisive factor (Cui et al., 2017; Ruiz & Cabrera, 2004). Regarding returners, all eight studies included at least one expert player of an international level as defined in the first inclusion criterion (Avilés et al., 2002; Avilés et al., 2006; Filipcic et al., 2017; Gillet et al., 2010; Kleinöder & Mester, 2000; Pizzinato, 1989; Triolet et al., 2013; Vaverka et al., 2003).

4. Discussion

The main aim of the present paper was to elucidate whether expert tennis players actually demonstrate anticipatory behavior when responding to a first serve. To this end, we carried out a systematic review through data bases to collect all published studies on this topic. In order to provide accurate and realistic conclusions, we filtered studies by the degree of representativeness of the experimental designs employed (including the sample's level of expertise).

4.1. *Experimental task design and anticipatory behavior*

As per other sports actions, the serve and return action in tennis have been widely studied. Thanks to the pioneers in this area like C. Goulet, R. N. Singer, A. M. Williams or D. Farrow among others, the scientific community has progressively gained knowledge about the tennis players' behavior when responding to a first serve. For instance, lab-based designs found that expert tennis players correctly guess the direction of the ball well over chance level when they have access to information on the body or movements of the server up to the moment of impact (e.g., Farrow et al., 2005). Similarly, it is apparent that they are able to predict the direction of the ball in advance when they have access to situational information (Farrow & Reid, 2012).

Nonetheless, today we are obliged to raise methodological standards to provide new insights into this sport action. Thus, we established relatively strict inclusion criteria in order to separate studies with experimental designs that either failed in preserving in a realistic manner the spatio-temporal constraints of the task and the natural interactions between performers, or employed non-experts as the sample. After selection, only 8 out of 62 studies were considered as highly representative. As mentioned in the introduction, counting on true experts as participants for research has rarely been feasible. Moreover, lab-based designs allow for greater experimental control, whereas collecting data while manipulating conditions *in situ* is still challenging even today.

Even so, we encourage adoption of scenarios as representative as possible when capturing returner's actions (see forthcoming section 4.3 for details), as a growing number of studies suggest that insufficient experimental task design representativeness may bias the athletes' behavior (van der Kamp et al., 2008; Pinder et al., 2009; Travassos et al., 2013). In this regard, success and time records obtained in lab-based designs may not represent the actual performance that would happen on court. For instance, among temporal occlusion studies, it is common to find relatively low percentages of successful decisions, with a success rate from 61% to 78% when information is occluded at the moment of impact (Balser et al., 2014; Cacioppo et al., 2014; Farrow et al., 2005; Liu et al., 2017). Similarly, whilst some studies in that group (Table 1) suggested tennis players anticipate the serve direction (Farrow & Abernethy, 2003; Farrow & Reid, 2012; Jackson et al., 2009) actually few of them analyzed the timing of preparatory movements (i.e., split-step) due to the constrained unusual response of the players (see Avilés et al, 2014; Uzu et al., 2009 for exceptions).

At this point, it is tempting to both compare the performance results of the medium to low degree of representativeness studies (Table 1) with high representative ones (Table 2), and associate anticipatory behavior to the former and non-anticipatory behavior to the latter. Even though when admitting that studies supporting anticipative behavior in the returners have been carried out under medium to low representative conditions (e.g., Farrow & Reid, 2012), both the association and the comparison would be difficult to make and sustain. First, studies within the medium to low representative group differ among them in terms of focus of interest, design, sample expertise, as well as in general findings. Moreover, the design restrictions in terms of type of stimulus (e.g., light), type of response (e.g., verbal), or moment of response (e.g., delayed) do not provide similar records as *in situ* designs to be effectively compared.

4.2. Do expert players demonstrate anticipatory behavior when responding under representative conditions?

To answer, we focus on those studies categorized with a high degree of representativeness (Table 2). In none of the eight works with a high degree of representativeness (Tables 2 and 3) were data found that indicate that the tennis players demonstrate anticipatory behavior regarding the direction of the first serve (i.e. that they move laterally before the server's racquet-ball contact). In fact, the expert tennis players move laterally above +160 ms after the impact in more than 90% of cases (Triolet et al., 2013). Only in two representative studies (Pizzinato, 1989; Triolet et al., 2013), is a spatial anticipation of the returners mentioned, remarking that such instances represent a marginal percentage, *and* only during the second service.

It has also been observed that players carry out *neutral* preparatory movements (with no lateral direction) before the impact, generally upwards and forwards (i.e., the split step). Findings indicate that expert players perform the split step take-off close to the server's impact of the ball (within 30 ms prior to racquet-ball contact; Avilés et al., 2002; Avilés et al, 2006), whereas the lateral displacement towards the ball is initiated around 200 ms after racquet-ball contact (Triolet et al., 2013; Vaverka et al., 2003). Hence, expert returners seem to wait for the server's impact and first moments of ball flight before moving to either side, which may indicate that they calibrate their actions to the evolution of the informational variables (temporal and spatial information) provided by the kinematics of the server and the trajectory of the ball (Fajen, Riley, & Turvey, 2009). Yet, we cannot ignore the existence of some influential factors on returning performance such as types of court surface (Cui et al., 2018), the speed of the serve (Haake et al., 2000), the situational probabilistic information (Farrow & Reid, 2012), the returner's past experience (Vernon et al., 2018) or the player's own capability (Dicks, Davids, & Button, 2010). Then, a question for future research is to further understand how those aforementioned factors might shape the expert tennis player's temporalization of actions.

4.3. Methodological recommendations for future research

Firstly, the recommendations to be applied into new experimental designs aiming to preserve a high degree of representativeness and to accurately report the findings are derived from the inclusion criteria used for the present article as well as the quality assessment (Tables 2 and 3). In addition, we outline some aspects to be considered in future research:

- To analyze the timing of several unfolding movements of the returner using a wide time-scale, from the early preparatory movements, to the split step, until the regulation of the return shot itself.
- To record with a frequency equal to or higher than 200 Hz to not compromise timing accuracy. In general, normal videos record at a rate of 30 frames per second (fps), resulting in a lapse of 33.3 ms between one frame and the next one. Taking into account that the response time is found in time windows of 160–200 ms approximately, it seems somewhat imprecise to analyze the movement in 33.3 ms intervals. Even more so in the case of analyzing early adjustments such as landing (i.e., timing differences in feet-ground contact).
- To consider as co-variable the speed of the serve in the case that there are considerable differences between trials, both between (different servers) and within participants (first and second serve).
- To register the anticipatory behavior (times, percentage of the cases) and opponent-related measures (1st or 2nd serve, type of serve, etc.) in such instances where the returner actually moves laterally before the server's impact.
- To compare the magnitude of the response time in the successful returns, unsuccessful returns and aces.

5. Conclusions

Research on tennis anticipation, particularly on the timing of returning a first serve, has been a subject of interest over the past 40 years. This paper aimed to assess to what extent expert tennis players demonstrate anticipatory behavior during the first serve return action by moving towards either side *before* the server's stroke. Since the literature has demonstrated that the degree of representativeness of the experiential task design affect the performance of the players (Pinder et al., 2009; Travassos et al., 2013; van der Kamp et al., 2008), we first filtered and categorized the studies by the degree of representativeness of the experimental task design employed. The systematic review revealed that most of the published works (54 out of 62) have been carried out under experimental conditions which do not adequately represent the real scenario of the return action, and/or use a sample with an insufficient level of expertise. Thus, data derived from these studies (i.e., timing, success) should be considered with a certain amount of caution when transferring those findings into training.

In order to answer the manuscript title's question, we then considered those studies (8 out of 62) with a high degree of representativeness. The comprehensive analysis allows us to state that expert returners perform the split-step around the time the servers impact the ball, followed by a lateral displacement towards the direction of the ball. That is, expert tennis players in representative conditions *do not demonstrate observable anticipatory behavior* about the direction of the serve. In other words, the findings suggest that expert tennis players do not try to spatially anticipate the first serve but rather regulate their actions upon the unfolding information regarding the kinematics of the server and the first moments of ball flight.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.psychsport.2018.12.015.

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