# Gaze Control DURING the hitting phase in Tennis: a Preliminary Study

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**Abstract**
***The present study is an examination of the head position in tennis during the hitting phase as revealed in recent observations of professional tennis players. The comparison of head position during the hitting phase is based on top tennis players' photos recorded whilst they performed during competition. The photo analysis revealed that the head position during the stroke execution distinguished significantly elite players from other professional players especially after impact. Elites show a characteristic head fixation in the direction of the contact zone at impact and during the follow-through. This finding suggests significant differences in gaze behaviour (coupled eyes and head movement) among professional players.***

**Keywords**: Tennis; Head; Gaze control; Contact; Fixation

## 1. Introduction

We've all heard the phrase "Watch the ball!" many times, probably the most used instruction ever given in tennis (Gallwey, 1974). Indeed, it is often assumed that, at the very best, everyone can keep their eyes on the ball until the moment of contact. Thus, player was told to keep his eye on the ball at the moment of impact and keep it there after the impact. Some players even claim they can watch the ball almost to the point of impact. In fact, one of the most important tennis skills is one the players often take for granted, vision (Williams, 2000). Looking in the right place at the right time is particularly important in tennis in which a player needs to determine the future trajectory of the ball and the timing of contact with it (Land and McLeod, 2000).

However, the players can never see impact – that is, the ball striking the strings of the racquet (Brabenec and Stojan, 2006). Singer et al. (1998) studied the gaze behaviour of tennis players and showed that neither elites nor near-elites are able to track the ball to contact, supporting other studies on baseball (Bahill and Laritz, 1984), table tennis (Ripoll and Fleurance, 1988) and cricket (Land and McLeod, 2000). This is due to limitations in our ability to track fast approaching objects. That is the great visual delusion of tennis is that one can see the ball at all times and keep it in focus. Stein and Slatt (1981) recognized that some players can definitely follow the ball longer than others. They argued that is not productive to track the ball close to the racquet when dealing with a fast ball. It will come as something of a shock since all players have been taught from the first day they ever took a tennis lesson, "Watch the ball hit your strings."

Though, over the last century, tennis has been dominated by an old paradigm that posited ball-tracking as the guiding model for hitting excellence. Hence, it is customary

for coaches and teacher in tennis to tell their players to hold their gaze on the ball. This advice is given because intuitively, one would think there is a direct link between the ability to maintain fixation on the ball and hitting accuracy. Thus, to watch the ball throughout its entire flight is remained a key coaching point.
However, recent evidence found by tennis coaches and specialists has shown this traditional thinking of ball-tracking to be contrary to the visual patterns of elite level tennis players. In particular, recent studies noted the especial hitting sequence shown by Roger Federer who keeps his head still and oriented toward the contact zone at impact during both backhand and forehand follow-through (Yandell, 2005; Ranney, 2006; Murphy, 2007; Lafont, 2007a,b).

The origin of the present study lies in these observations which call the concept of gaze control in sport. Schmidt (1991) defined gaze as “the absolute position of the eyes in space and depends on both eye position in orbit and head position in space.” Usually, the term “gaze behaviour” is used when the subject’s head and eye system moves naturally, unlike eye movement recordings where the head is often fixed (Vickers, 1996a, 1996b). Thus, gaze control involves movements of eyes, head and trunk. These are coordinated in a way that allows for both flexibility and movement and stability of gaze (Land, 2006).

In a context where most of studies did not account for head position or head motion, this study only focused on one component of the gaze: the head position which has been captured from high-speed photos. From the previous definition of gaze control, the head behaviour is defined here as the manner in which athletes move their heads while hitting the ball. Hence, the main aim of this study was to have a more precise idea of the head behaviour of professional tennis players during the hitting phase with the purpose to serve as basis for future gaze studies in tennis.

## 2. Research on gaze control

A considerable amount of research has focused on gaze control during the performance of sport skills. Several characteristics of performance have been investigated, including visual search (Bahill and LaRitz, 1984; Haywood, 1984; Abernethy, 1990, 1991) or eye-head-arm coordination (Carnahan and Marteniuk, 1991, 1994; Carnahan, 1992). Also, from a methodological perspective, researchers have progressed from static slide (Bard and Fleury, 1976, 1981) to dynamics film (Helsen and Pauwels, 1993; Williams et al., 1994; Williams and Davids, 1998) and field-based protocols (Vickers, 1992, 1996a; Singer et al., 1998; Land and McLeod, 2000). The collection of data in situ represents an important evolution, since the gaze and motor characteristics observed under laboratory conditions may not provide an accurate reflection of participants’ natural behaviour (Williams and Davids, 1998). Moreover, in situ investigations have revealed important mechanisms and strategies involved in the acquisition of visual information. In general, dynamic studies on gaze behaviours have found significant differences in the frequency, duration, and location of gaze of experts and non experts, highly skilled subjects displaying a greater economy of gaze behaviours recording longer duration on critical locations in the targeting space (Helsen and Pauwels, 1993; Ripoll et al., 1985; Ripoll et al., 1986; Vickers, 1992). One of the earliest and most noticeable studies in the field setting was undertaken by Ripoll and Fleurance (1988), who showed that expert table tennis did not track the ball throughout its entire flight path.

In tennis, few works has been devoted to visual skills and visual strategy, which is yet of first interest. Nevertheless, the above-mentioned eye movement and gaze control studies in motor skills have shed some light on the visual behaviour of tennis players. More specifically, research has shown that different head and eye movement strategies are used depending on the timing constraints in tennis (Flotat and Keller, 2004). The eye movement of athletes have been measured to determine visual search strategies, especially for the anticipation phase (Mester and von Marees, 1982; Goulet et al., 1989; Goulet et al., 1998) and selective attention (Singer et al., 1996; Cauraugh et al., 1996). However, although these studies have identified important components of performance, eye movement research in tennis is still rather limited and suffers of a lack of on-court studies.

In addition, past research has mainly tried to identify the gaze pattern associated to expert and non-expert, but few works were focused on the differences among experts themselves. Only one noticeable study on visual strategy during the hitting phase in tennis was made by Stein and Slatt (1981) who looked at photos of all the major professionals and revealed that players never had their eyes on the ball. Since, this problem has never been covered in depth and the recent observations of Roger Federer call into question their conclusion. Therefore, there is a need for sound methodological and experimental studies dedicated to the hitting phase of professional players. More specifically, the idea motivating this study is that any elite players seem to achieve a sort of head control during the hitting phase. Thus, the main objective is to highlight the head behaviour of top tennis players. To this end, photos of elite players will be analysed in the following sections and compared to less-skilled professional players.

## 3. Method

This study is placed in the context of qualitative analysis in tennis, i.e. the subjective observation of player movement (Reid et al., 2003), especially head movement and position among elite and near-elite tennis players. Qualitative analysis is the most common stroke analysis tool for tennis coaches with the purpose of providing the most appropriate intervention to improve performance (Knudson and Morrison, 2002). Usually, it involves direct observation as well as photo or video analysis. Here, the analysis is based on photos of professional tennis players in the perspective of identifying the head position during the last part of the stroke execution.

Of course, it is not possible to carry out research on gaze using photos alone; continuous gaze and motor data is necessary coupled precisely in time. Measurements must be taken of the coupled gaze and motor data that are continuous and accurate. Nevertheless, as a first step, photos can reveal important information on the head component of the gaze, i.e. the head position in space. Indeed, since the ball is on the strings only four to six milliseconds (Plagenhoef, 1979; Brody, 1987; Brabenec and Stojan, 2006) that is essentially impossible for a human eye in the same time to see the ball on the strings and the actual head position. Hence, only photography can freeze the instant of impact. In particular, by using high-speed photo operating with shutter speed from 1/2000 to 1/5000, it is possible to gain information about the position and direction of the head and to limit blurring effects. The information about head position was gained from photos of the groundstrokes of top 100 ATP and WTA players during competition constituting a relatively large dataset. The photos come from professional photographs operating on the tennis tour with the vast majority of photos provided by Advantage Tennis (Mike McCarron). The data are taken at different location and time therefore the scenes are confined to neither specific location nor time of the year. A minimum of 20 photos per player have been used to determinate each player head behaviour both at impact and during the immediate post-impact phase. Thus, more than 5000 photos were analysed by three tennis specialists regarding the head position and direction. The specialists were three certified tennis pros from France and USA with many years of experience both in teaching and training.

## 4. Elite player observations

The impact and post-impact photos allowed to described the head position of two current elite tennis players. To date, the reference study is the photo analysis by Stein and Slatt (1981), who demonstrated that top player's eyes invariably didn't follow the ball until impact. They highlighted that tracking the ball as close as possible to the impact zone is not feasible or desirable for most people. They underlined that professional players such as John McEnroe or Jimmy Connors never had their eyes on the ball at impact.

However, since this study several observations tend to go in favour of a special head and eye movements by elite players, especially revealed by Roger Federer's ability to always keep his head still during the hitting phase (Yandell, 2005; Murphy, 2007). Indeed, it was initially expected that elite players use a continuous ball-tracking strategy. That was not what it was revealed by high-speed photo observation. Roger Federer's head position is highlighted in Figure1 to Figure 3. He is ideally balanced with his head consistently aligned with his current hitting direction and then contacts the ball well (Figure 1). Additionally, what contrasts with previous studies and the current hitting model is that Federer and Nadal (Figure 4) not only keep their head still at impact, but after impact their head remain oriented toward the contact zone (Riewald and Lubbers, 2004; Lafont, 2007a, 2007b; Murphy, 2007). From high-speed video analysis, Yandell (2005) highlighted this special head position of Roger Federer, especially how far sideways his head is turned at contact and how long it stays that way after he hits the ball. More precisely, he showed that Federer keeps his head still for around 1/10th of a second after the hit (to compare to one second for the ball to travel between the rackets). An important point is also revealed by photos of Nadal on Figure 4 showing that the lifting motion is not a limitation for proper head control. Even in open stance position, his head doesn't throw up and back when he hits – his body remaining in balance at impact. It should be noted that Federer also maintains a fairly consistent head movement control in approach and volley which require the most effective response – a similar behaviour also revealed for Pete Sampras (Saviano, 2000).

Figure 1. Federer's backhand at impact. His head is oriented toward the contact zone (with permission of Advantage-Tennis.com).

Figure 2. Backhand after impact. Federer keeps his head still in the direction of the hitting zone (with permission of Advantage-Tennis.com).

Figure 3. Federer’s post-impact forehand. His head pointed in the direction of the contact zone (with permission of Advantage-Tennis.com).

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Figure 4. Lifting motion and head control. Notice how the head pointes in the direction of the contact zone – the key characteristic of elite players (with permission of Advantage-Tennis.com).

Figure 5. Example of top player head behaviour at impact. His head and eyes are directed ahead (with permission of Advantage-Tennis.com).

Figure 6. Example of player showing a partial fixation. After impact his eyes and head are directed toward the contact zone- not the ball - but only on the backhand side.

**5. Comparison of top player's behaviours**

The head beahviour of professional tennis players was then analysed in relation to that which has been found for elite players. In photography shots in which thousands hitting actions were examined, there was a profound disparity in the head behaviour as compared to previous champions. A representative example of tennis player is presented on Fig.5 where the large discrepancy between the position of the head and the position of the impact is evident. The player doesn't follow the ball and his head is directed in front of the ball and not on contact. His eyes were straight ahead when the ball was at his side, almost to the racquet. He gets his head still but in the direction ahead of the contact zone. This zone of loss of the ball is often named the fog zone – a concept introduced by Stein and Slatt (1981), who argued that it tends to increase as the level of expertise decreases. This behaviour is representative of the vast majority of pros hitting with their eyes focused out ahead of the ball.

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More broadly, significant differences were found for head position during the hitting phase both between elite and near-elite players and among professional players. While making contact with the ball, most of them have their head oriented out ahead of the racket. Moreover, after contact, their head either remain oriented where the ball was last seen clearly or already directed toward the opponent's court. Thus, a more mobile head during the hitting phase and a lesser head rotation characterises the near-elite players. Moreover, players most often pull their head up before the ball even reaches the racket. It is especially evident for the forehand side. At impact, they turn their head as they want to immediately follow the beginning of the ball trajectory as they want to see if it well directs toward the target.

Nevertheless, despite this photo-analysis illustrates no fixation in mostly professional players, some of them have been noted to achieve the fixation stage either on backhand or forehand side. It can be seen as an intermediate behaviour between fixation and no fixation. For example the Fig.6 shows a top player turning his head to the side after impact. It should be noted these players usually show the fixation on their backhand side, whereas, for the forehand, the head movement seems often associated to a « loss of the gaze» in the fog zone. It could be related to the twist of the upper body and shoulder housing the hitting arm which sweeps along the head in the impact direction; the shoulder movement maintains the head toward the ball during the hitting process.

Thus, three types of hitting profiles emerge from the observations: (1) total fixation, (2) partial fixation and (3) no fixation, all of them corresponding to a certain level of expertise among professional players. More specifically, the total fixation was defined when more than 85% of the photos showed fixation both for backhand and forehand; the partial fixation was defined either when the photos showed total fixation between 5% and 85%, either only on one side (backhand or forehand); finally the no-fixation case is defined when less than 5% of the photos showed fixation. When applying this classification to the top 100 men ranking, it was found 10 players with a total fixation (with 7 among these 10 players ranked in the top 25). Moreover, 34 players show a partial fixation with dominancy on the backhand side, most of time associated with high rankings.

In a similar study made in the top 100 women ranking, it emerges that only one player is currently showing a total fixation (Justine Henin) as confirmed by the observations of Saviano (2001) and Teltscher (2003) who noted that Justine Henin’s head remains still for a long period of time after contact. In addition, 18 players show a partial fixation, the rest of the player having a classical follow-through without fixation stage. So, further study is needed to understand this large gender difference in the hitting phase, in particular the difference in fixation occurrence.

In this comparison we can find the key elements of this article. Indeed, if there is not a lot of difference in players in term of their physical abilities (Weinberg, 2002), they differ greatly in their head movement and position.

From this preliminary investigation, elite players show a common characteristic maintaining fixation on the contact zone as they complete the hitting action. It can be noted that similar observations can be made in hitting sports such as baseball or squash, where only the best athletes seem to exhibit such fixation of the contact zone after the impact. So, the evidence is for head movement control as a decisive characteristic of elite players. In addition, the distribution of the fixation pattern among the players suggests a close relationship between head-eye stabilization and level of skill expertise; hypothesis reinforced by the analysis of the former number ones and Grand Slam men winners since 1999 showing the presence of the fixation pattern – at least partial fixation – for most of them (Lafont, 2007a).

## 6. Discussion

A common idea is that, there is very little difference in the stroke capabilities of the top players, the only difference would lie therefore in their mental strength. However, if it's true that most players are highly trained athletes, the above observations show that at the professional level, all the players are not equally talented in terms of technical skill especially with regard to head movement control. Indeed, it is apparent that what is seen in the top 100 players' ranking will be vastly different than what it is observed in the elites: elite players don't just execute stroke better, they do it differently. Indeed, what departs from all the above-mentioned studies on gaze control is really the fixation during the post-impact phase. Elite players look steadily at the ball and let their gaze stay there even after the ball is hit. A similar behaviour can be found in golf, where Vickers (1992, 2004) showed almost all novices follow the ball with their eyes after they hit it whereas the good player maintains fixation on the same location at the point of impact through the swing, forward swing, contact and for almost half a second after the ball is hit.

Some studies in racket sports have ever reported that experts watch the ball differently. They differ from novices in eye fixation patterns and perceptual strategies (Mester and von Marees, 1982; Murray, 1999), analyse few information but focus only on the most pertinent information (Tenenbaum et al., 1996; La Rue and Ripoll, 2004) and show faster information processing and decision times (Day, 1980). But the main finding of the present study is that elite players move their head differently too and the fixation pattern is their trademark.

It is not the first time that different forms of gaze control are observed among highly skilled athletes but most of studies focused on the early ball flight. Indeed, the hitting sequence is a complex skill that requires the integration of visual information mainly gained in the first part of the ball trajectory. Ripoll and Fleurance (1988) and Land and McLeod (2000) showed that this period is important in providing information on the ball's trajectory and likely location of bounce and in planning the ensuing motor response. Thus, athletes kept their eyes on the ball at crucial moment during its flight: early in flight but not during the final portion of its trajectory (Bahill and LaRitz, 1984; Ripoll and Fleurance, 1988; Vickers and Adolphe, 1997; Land and McLeod, 2000).

It should be noted that several studies have shown athletes maintained a stable gaze on a location in advance of the ball (cf. Ripoll et al., 1986; Ripoll and Fleurance, 1988; Land and McLeod, 2000). The head and eyes were stabilised (i.e. the eyes are stable and aligned with head orientation) on the area of contact before the ball's arrival. They suggested this eye-head stabilisation may facilitate the extraction of information from the final portion of the ball's flight (between the final ball bounce and the strike). For elite tennis players, the previous observations suggested this head stabilisation is extended during the fixation stage which begins prior to impact and extends during the follow-through when players keep the head in the direction of the contact zone.

A direct consequence of such fixation is the players probably don't watch the ball during the end of the stroke movement. Overall, elite player's performances suggest that there are certainly fundamental benefits in adopting this strategy during the follow-through. However, there is neither systematic comparative biomechanical research on the variety of follow-throughs used in tennis (Knudson, 2006), neither study on the visual process during the follow-through. Nevertheless, despite the preliminary nature of the present study only based on one of the gaze components (the head), several hypotheses can be made on the function of the observed fixation.

This fixed, straight-ahead gaze moved toward the contact zone suggests that elite players are following a form of gaze already reported in golf putting and often named “dead-eye” gaze (Mangum, 2007). The theory is that spatial analysis for voluntary goal-directed movement like hitting is only partially a matter of vision and is more importantly related to the connection between vision, vestibular processes and proprioceptive body-sense of the state and location of the body in relation to the ball (Jeannerod, 1997). This dead-eye gaze pattern would generates visual and other spatial-analysis cues in a synergistic fashion that takes advantage of the underlying neurophysiological processes more effectively than the common gaze pattern. In addition, this visual pattern would eliminate variable signaling during hitting occasioned by the brain having to account for shifting eye positions as well as variable head motions (Bach-y-Rita et al., 1971; Howard and Templeton, 1966; Senders et al., 1978; Wurtz and Goldberg, 1989). Hence, this “dead-eye” would maintain a steady relation between the eyes and the head at all times. Thus, as suggested by Williams et al. (1999), perhaps the recommendation “keep your eye on the ball” may be more to do with maintaining a stable head and body position during skill execution than with the need to extract operational information from the ball.

In all cases, Roger Federer demonstrates that the strategy which consists of focusing on the contact zone is an efficient way to use the eyes in a fast-moving ball sport such as tennis. The elite’s fixation may prevent the intake of interfering information from the moving ball in the visual field. In particular, it would eliminates the source of input errors present in the classical visual pattern, i.e. focusing on the ball, and generated by the numerous fixations as the ball traverses along its flight path (continuous refocusing) (Ford et al., 2002). Thus, contrary to near-elites who have to control their racket, arm, head and gaze, as they hit the elites who use the fixation do not have to control as many systems. By maintaining their head oriented toward the contact zone, they let each system specialize in turn, the visual first (before the ball enters the fog zone), followed by the motor system (impact and follow-through). In this way the complexity of hitting task is alleviated and effective can hitting occurs. Practically this assumption has not always being corroborated by the research findings in tennis. This is an important point and merits further development.

At this time, it can be only hypothesized the information on the ball trajectory is gathered during the first part of the ball flight, then the fixation stage would allow a better integration of the information in order to provide in turn better motor response finally contributing to superior motor skill execution exhibits by experts (McPherson and Vickers, 2004).

Clearly, as underlined by Williams et al. (1999), further innovative research is required to increase our understanding of the complex relationship between head, body and eye movements in sport contexts. For example, since the head, body and oculomotor control system (especially the vestibular-ocular system) function as one closely coupled system during skilled performance (Guitton and Volle, 1987), it would be interesting to examine how variations in follow-throughs between classical and fixation pattern modify the motor response. Understanding these complex relations could give us insights for teaching players how to adjust their upper body posture, pick up and select visual information during tennis performance.

## 7. Conclusions

If any one theme emerges from this study, it is that the professional tennis players are not as individual in the way they deal with the head control in tennis as they are in the way they stroke the ball. It is significantly illustrated in the modern game by Roger Federer who gives us a new model for the head movement control during the hitting phase (Lafont, 2007c). Indeed, a comparison of the head movement characteristics among the top 100 shows few high-level performers follow a typical process of head movement control. Through observations and comparison of impact and follow-through process among elite and near-elite tennis players these studies revealed a key mechanical feature of elite tennis players: they differ significantly from near elites in having a fixation of long duration on the contact zone during the follow through. Hence, what is emphasized in this study - and what maybe you don’t immediately notice when you watch tennis - is that the special hitting sequence of Roger Federer is more than an isolated phenomenon. His head behaviour consisting to a specific fixation stage with head stabilization on the contact zone is a common characteristic among elite tennis players and may have a strong influence on the success of hitting. Hence, a new paradigm is emerging dominated by the potential benefits produced by this fixation stage on the contact zone which really departs from the conventional instruction and goes against the traditional way the player learn to track the ball in tennis.

However, the observations based on photos doing little to validate a scientific evaluation of fixation technique and nothing to clarify the supposed advantages and disadvantages of each head position/orientation during the hitting phase. Even if a weight of evidence is beginning to favour the contact zone focus as relevant visual strategy during the hitting process, the photo analysis highlights the head position but does not provide sufficient accuracy to give the gaze location and duration. Thus, there is a need for quantitative analysis which involves the measurement and interpretation of key variables related to the fixation stage. Here, by focusing on the head position this preliminary study provides the general guidelines for more completed studies on gaze behaviour, i.e. combined measurement of eyes and head movements. The main perspective of this study is therefore to serve as basis for future quantitative analysis of the two part of top players’ gaze behaviours, i.e. combined measurements of eye and head movements. Now, technology allows research in dynamic conditions with lightweight eye trackers, small enough to be worn without affecting a player's performance (see Vickers, 2007). Essentially, an eye tracker monitors the movement of the eye and head, i.e. the gaze, in order to track where athletes look during play and provide his visual strategy (for a tennis application see Mester and Von Marees, 1982; Flotat and Keller, 2004). Information on gaze behaviour may, therefore indicate which parts of ball flight are important (Land and McLeod, 2000). Since knowing “where” and “when” to look are important aspects of skilled performance in sport (Williams et al., 1999), by drawing upon current pattern of head behaviour, this study can serve as background to deeper studies on the area of visual strategy in tennis.

Finally, this work opens important mental perspectives. As suggested by Ford et al. (2002), a contact zone focus could promote flow and peak performance. As majority of elite players shows the same characteristics, the fixation pattern could be what gives them higher efficiency especially through better attentional focus, therefore may contribute to the thin separation between elite and near-elite players. So, more should be made to evaluate the mental benefits of such special focus during the stroke execution (Lafont, 2008).

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