International Journal of Sports Vision, 2001, 7, 30 - 39

Gaze Behaviours of Elite Ice Hockey Players: A Pilot Study

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Accepted December 05, 2001

Abstract

The purpose of this study was to determine how elite athletes in team sports use fixation and tracking (F/T) gaze to detect critical cues in live tactical plays. Research in tactical sports has found conflicting results, with some studies finding a high frequency and low duration of F/T while others have found the opposite - a low frequency and long duration of F/T. In order to explore this problem, the F/T gaze of expert (E) and near-expert (NE) Team Canada male ice hockey player was recorded as they performed set defensive plays on ice. Irrespective of expertise, the context of the tactical play was a factor in determining the frequency and relative duration of F/T. When the tactical problem was lcoated further from the athlete, then a high frequency and low duration of F/T were found due to the necessity of scanning a wider field of view. As the play progressed, a lower frequency and longer duration of F/T were found due to the decrease in the distance between the participant and opposing players and the more specific 1 on 1 role assumed at the end of each play. Within the limits of a pilot study, these results show that both high frequency/low duration and low frequency/high duration F/T occur in team sports, with the guiding principals being the relative position of the athlete in the tactical setting.

Introduction

In team sports information from the playing environment is obtained through all of the senses, but primarily through vision. In order for a player to efficiently produce skilled movements, he/she must read each situation and react accordingly in a time-pressured environment. The player relies on perceptual and cognitive processes to perceive the environmental situation, make a decision in relation to the play, and execute the appropriate action. Decision-making in fast-based team sports is therefore reliant on the ability to detect and interpret perceptual information and compare internalized memory structures with situational events (Williams, Davids & Williams, 1999). It is currently unclear if the elite performer's superior skill is due to the rapid acquisition of visual cues, as reported by Williams et al, or the economical use of the gaze as reported by Helsen & Pauwels (1992). Different findings by these and other researchers lead to the question - do elite athletes in sports such soccer, basketball, field hockey and ice hockey move their gaze rapidly about the playing environment gaining critical information through the use of a high frequency of fixation or tracking gaze (F/T) of low duration, or do they exhibit an economy of F/T to fewer locations for longer durations?

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Visual search techniques in which the athlete views slides or videotapes have been used to examine the frequency and duration of fixation of expert and non-expert athletes in team and dual sports. In this approach, the eye movements of the athletes are recorded as they view tactical problems critical in their sport while at the same time they are required to make decisions or perform other cognitive tasks relative to the scene viewed. Research using these techniques has yet to produce a consensus on the visual characteristics of elite athlete's (Abernethy & Russell, 1987; Abernethy, 1990; Helsen & Pauwels, 1992; Williams et al, 1994; Williams et al, 1999). Helsen & Pauwels (1992) found that elite soccer players shooting on goal employ an efficient visual search process, consisting of a low frequency of fixations of longer duration than non-elites. Presumably, this economical process assisted in locating and processing relevant information used in decision-making. Williams et al (1994) and Williams and Davids (1998) investigated the gaze behavior of elite soccer players in 1 on 1, 3 on 3, and 11 on 11 tactical situations and found different fixation patterns depending on whether the athlete was performing in a 1 on 1 situation or more complex pattern. Elite players in 11 on 11 situations had a higher frequency of fixation and lower relative duration than non-experts, while in the 1 on 1 and 3 on 3 settings no differences were found.

Insight into the problem of the frequency and duration of F/T has direct consequences for sports vision, sports psychology, coaching and other training areas in sport. If a high frequency of F/T is needed by team players in order to detect the fast action within their sport, then this requires the training of the ability to quickly detect and process critical cues. But, if a lower frequency and longer duration of F/T defines how elite athlete's read the playing environment, then a completely different approach is needed, one that results in the processing of using fewer sources of information in a more economical and efficient manner.

Gaze of Athletes In Open and Closed Sports

In order to explore this problem, the gaze behaviours of Team Canada ice hockey players were recorded using the vision-in-action (VIA) system (Vickers, 1996). The VIA system simultaneously records the athlete's gaze, ocular, and motor behaviors while selected skills or tactics are performed. The VIA method has been adopted by a number of researchers to determine the gaze of athletes performing skills in live sport settings of both a closed and open nature

In closed skills the athlete is not pressured by external events and performs in a self-paced manner. In skills such as the basketball free throw (Vickers, 1996; Harle & Vickers, 2001), billiards (Frehlich, 1997; Frehlich et al, 1999; Williams et al, in press), darts (Vickers, Rodrigues & Edworthy, 2000) and rifle shooting (Janelle et al, 2000), the gaze of elite performers has been found to exhibit a lower frequency of fixation of longer duration to specific objects or events. The final fixation has been called the "quiet eye period" (Vickers, 1996). It has been shown that QE has a consistent onset across different closed skills and is located just prior to the initiation of the final aiming movement.

While a consensus appears to be emerging about the role of QE in closed skills, the picture is not as clear in open skills where events are both unpredictable and time pressured. In skills such as the volleyball serve reception (Vickers & Adolphe, 1997), table tennis return (Rodrigues, Vickers & Williams, 2002), and soccer tactical play (Helsen & Pauwels, 1992; Williams et al, 1994, Williams, et al, 1998) it has yet to be determined when and where the most critical F/T occur. Vickers & Adolphe (1997) found that QE was longer for expert versus non-expert volleyball receivers, while Rodrigues et al found no difference in QE duration of expert and non-expert table tennis players. As is evident, it has been difficult to determine when the most critical fixations occur in tactical plays. Do expert athlete's detect critical cues earlieror later than non-expert performers?

The goal of this pilot study was therefore to determine the F/T of E and NE athletes during defensive plays performed on ice. The frequency, duration, location and temporal sequence of F/T was determined during the execution of successful (plus) and unsuccessful (minus) defeisnive plays which were skated against opponents who played at the same competitive level.

Method

Participants

Two Team Canada male ice hockey players were selected based on their different proficiency in playing defense at the international level in ice hockey. The E player was exceptional in defensive play, while the NE player consistently made decision-making errors in while playing defense. The selection of the two players was based upon each players "plus-minus" statistic in a recent international tournament. The plus-minus score is a standard measure used in ice hockey that is calculated by subtracting the number of goals scored when a player's line is on the ice from the number scored by the opponents. Ice hockey teams are typically organized into three or four lines, with three forwards and two defensive players on each line. Each line stays on the ice for one to two minutes and then is replaced in a constant rotation that goes on throughout the game. If a line is constantly scored against by the opponents then all members of the line are negatively affected in terms of the plus-minus score. The E player had a plus-minus score of plus six in the tournament, meaning his line scored six more goals than the opponents when he was on the ice, while the NE had a plus-minus score of minus five indicating a major deficiency in preventing the other team from scoring when he was on the ice.

Figure 1. A frame of Vision-In-Action data as collected on ice in ice hockey. The eye image (top inset) shows the eye of the athlete with horizontal and vertical axes at the pupil and corneal reflection centroids. The gaze image (left) shows the field of view in front of the athlete and location of the gaze in the hockey environment as indicated by the white cursor. The motor image (right) shows the actions of the players as recorded by an external camera. Time was recorded at 30 frames per second, or 33.33 ms per frame, simultaneously in the three images.

Apparatus

The Vision-in-Action (VIA) system (Vickers, 1996) was used to record the gaze, ocular and motor behaviors of the athletes. Applied Sciences Laboratories (ASL) 501 eye tracker was interfaced to an external video camera and two digital video mixers to produce frames of video data similar to that shown in Figure 1. The eye tracker is a monocular corneal reflection system that measures eye-line-of-gaze with respect to the helmet. The helmet has a 30-metre cord attached to the waist, connected to the eye control unit, thus permitting the athlete near-normal mobility. Miniaturized optics (scene and eye cameras), an illuminator, and visor were mounted on the helmet, with a total weight of 700 g. The VIA system has an accuracy of 2 degrees of visual angle, precision of 1 degree, and an output frequency of 30 Hz (33.33 ms per frame).

Protocol

Data was collected on the Olympic Oval ice hockey rink at the University of Calgary. Each trial was skated against teammates on Team Canada, who assumed the role of defensive teammates or offensive opponents. In order to prevent anticipation of the play, three defensive plays familiar to the players were presented in random order. Five trials were skated of each play, or 15 total. No problems with fatigue were encountered during the execution of this number of plays.

Each play included three temporal phases: pattern recognition (PR), situation assessment (SA) and decision-making (DM). The 'contain' play is shown in Figures 2 for illustration purposes. In the PR phase, the defensive participant (Dp) began with his eyes closed at center-ice in position to respond to the movements of two opponents (O1 and O2) and two team-mates (D1 and Dt). At the onset of each trial, the coach (C) blew a whistle and shot the puck into the defensive zone while at the same time the players skated toward the participant at game speed. When the first player reached the blue line, a second whistle signalled Dp to open his eyes and defend against the play. The SA phase was skated into the defensive zone as shown in Figure 2, culminating in the DM phase. The trial ended when a third whistle was blown signaling the end of the trial. No shots were permitted on goal.

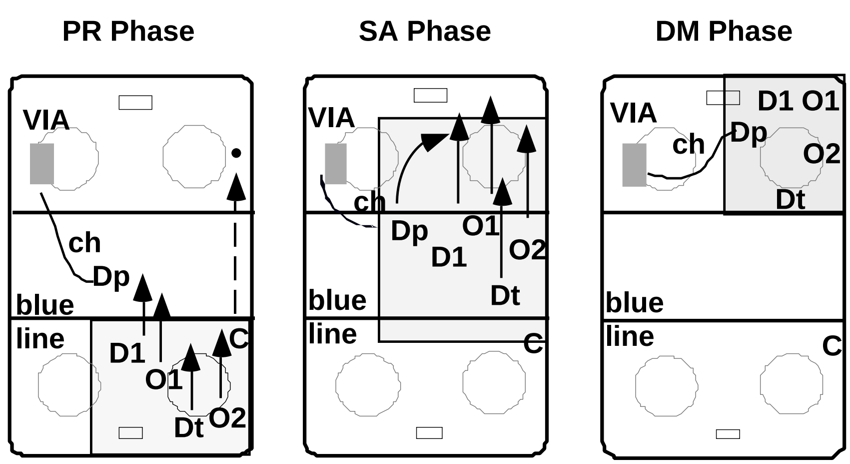

Figure 2. The pattern recognition (PR), situation assessment (SA) and decision-making (DM) phases of the 'contain' play. The defensive participant (Dp) and cable holder (Ch) are shown as well as defensive player one (D1), defensive teammate (Dt), offensive player one (O1), and offensive player two (O2). The location of the VIA system (VIA), coach (C) and path of the puck (dotted line) at the beginning of each trial is shown. The shaded regions show the approximate locations of fixation/tracking gaze in each phase.

The approximate location of F/T on the ice during the PR, SA and DM phases is shown by the shaded portions of Figure 2.

Coding and Analysis of Data

The plus-minus outcome of each play was determined by the coaches of Team Canada in both the live setting and on videotape. The 'contain' play was selected for in-depth analysis due to the E player skating two "plus" trials and the NE two "minus" trials. The VIA data was coded in an editing suite equipped with frame by frame shuttle control. Coding rules were adapted for ice hockey from previous studies (Vickers, 1996; Vickers & Adolphe, 1997; Williams et al, 1999).

The temporal onset and offset of each phase were defined by constant events signalling the transition from the PR to SA to DM phase. The PR phase onset occurred with the first frame showing Dp's gaze and offset when the first skating movement was made to counter the oncoming players. The SA phase offset occurred with Dp's final skating action to counter the play. The DM phase offset occurred when the puck was controlled by offense or defense.

Due to the dynamic nature of ice hockey, no attempt was made to distinguish between fixation and tracking gaze. F/T gaze were defined using minimum duration parameters from the eye movement literature (Carpenter, 1988) and occurred when the gaze was stable on a location, object, player or players for a minimum of 99.9 ms (3 or more frames). Frequency of F/T was determined, as was the relative duration (%) and temporal order of F/T in each phase (F/T1, F/T2...F/Tn). Since the duration of each trial and phase varied, absolute measures of F/T (ms), phase duration (ms) and gaze duration (ms) were converted to relative time (%) in a normalization procedure that expressed each variable as a percent of phase duration. Thus, every trial had its onset transformed to 0% and its offset to 100%, and each point in between a proportion of the total time (Schmidt & Lee, 1999). The location of F/T were identified as: offensive-defensive combinations (O-D combo), offence, defence, open space, puck, and 'other'. The 'other' category included blinks, gaze locations beyond the task area, and gaze that were not codable due to excessive head movements.

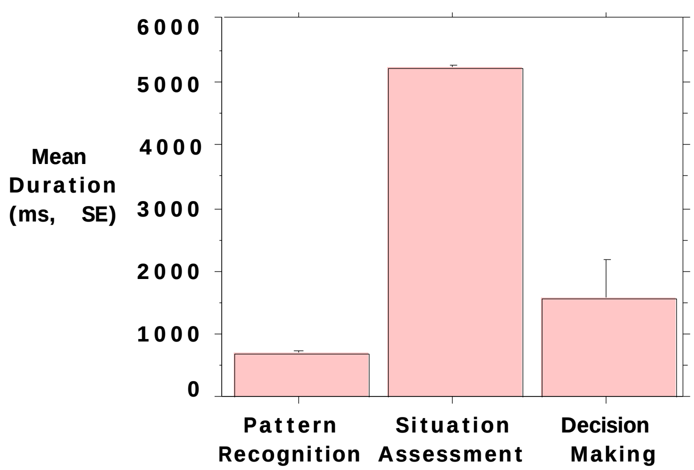

Figure 3. Mean duration (in milliseconds) of the pattern recognition (PR), situation assessment (SA) and decision making (DM) movement phases in ice hockey.

Results

Duration of Movement Phases

The mean duration (ms) of each phase (PR, SA, DM) is shown in Figure 3. In the PR phase, E and NE were similar in the time needed to identify the play averaging 722.95 ms. E and NE did not differ in the SA phase, averaging 5204.22 ms of skating over half the length of the ice. During the SA phase, the athlete's scanned the play and skated against the movements of the offensive players, while at the same time co-ordinating their actions with that of their defensive teammates. The DM phase averaged 1562.45 ms and was similar for E and NE. During this phase, the final cues were detected and final movement made to control the puck.

Frequency and Sequence of F/T

Frequency of F/T did not differ by skill or outcome in the PR phase, with both players averaging one F/T. No results are presented for the DM phase due to F/T in the SA phase extending into the final phase These F/T were therefore analyzed as part of the SA phase

Figure 4 presents the relative percent of F/T in the SA phase for the E on plus plays and NE on minus. The temporal sequence of F/T is shown with F/T 9 occurring at the beginning of the SA phase and F/T 1 at the conclusion. Figure 4 shows that the NE player had a higher frequency of F/T than the E, using nine F/T gaze compared to six for the E. F/T durations were also longer for the E player than the NE. Figure 4 shows that F/T durations were shorter at the beginning of each SA phase than at the end, for both E and NE.

Figure 5 presents the mean duration of F/T at each location for the E on plus trials and NE on minus. The E player allocated more time to each location than the NE, fixating longest on the O-D combinations, followed by open space, offensive opponents, defensive teammates and least on the category 'other'. The NE player's F/T were similar to the E in that the same locations were fixated but for shorter durations. Neither player fixated the puck during any of the trials, indicating both players monitored the movement of the puck using their peripheral or ambient system.

Discussion

In this pilot study we determined the F/T gaze of a highly skilled E and lesser skilled NE Team Canada ice hockey player while performing in a defnsive play. The specific impetus for the study was a lack of clarity in research in attributing differences in F/T gaze to expertise or task characteristics. Recall that Vickers & Adolphe (1997) and Rodrigues et al (2002) found different locations and durations for F/T in open sport settings. Similarly, Helsen and Pauwels (1992) found a lower frequency and longer duration of fixation in a soccer shooting situation on goal, while Williams et al (1994) and Williams et al (1998) found different search rates if players were involved in 1 on 1, 3 on 3, or 11 on 11 plays. Williams et al (1998) suggested the reason for the different search characteristics may lie in the spatial qualities of each play.

Our results support this argument. The participants first skated against a 2 on 3 situation, which evolved to a 1 on 1 at the conclusion of each trial. During the PR and early SA phase, the opposing players were located at a greater distance from the participant, and this required the scanning of a wider field of view, which contributed to the higher frequency and lower relative duration of F/T observed at the beginning of each trial (see Figure 4). A lower duration of F/T was found for both E and NE at the beginning of each trial consistent with

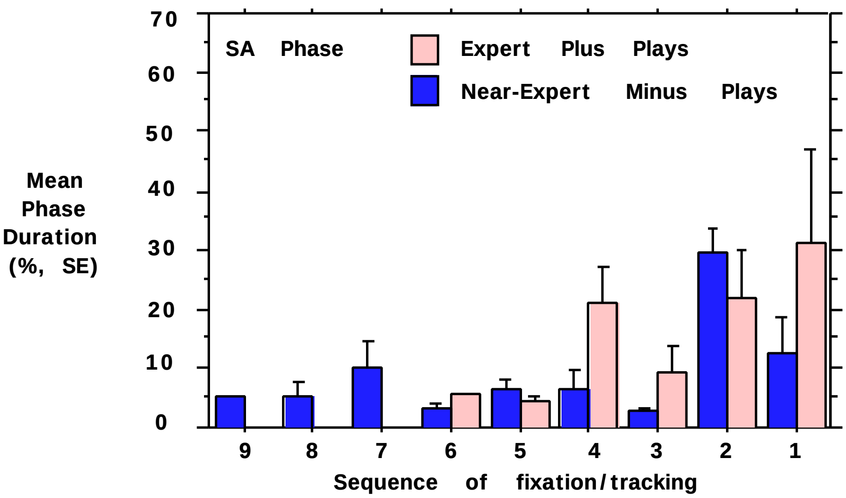

Figure 4. Temporal sequence and relative duration (%) of fixation/tracking (F/T) in the situation phase (SA) for the expert (E) athlete on plus plays and the near-expert (NE) on minus plays F/T 9 occurred at the onset of the SA phase and .F/T1 at the offset.

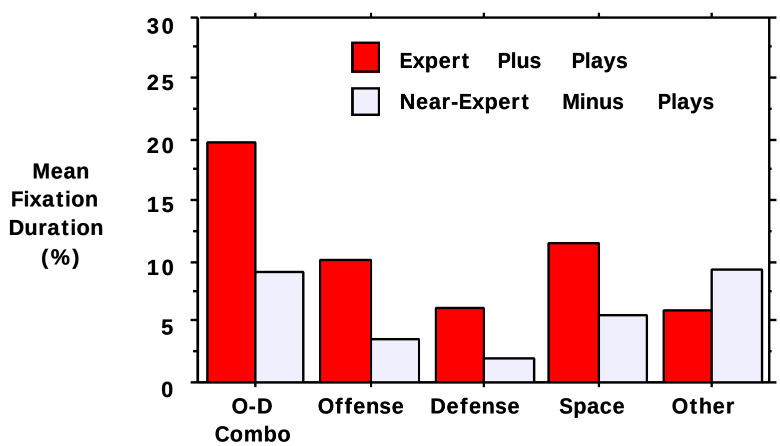

Figure 5. Location and mean relative duration of fixate/tracking (F/T) of the expert and near-expert hockey players in the SA phase. Relative duration of F/T was calculated as a percent of the total SA phase duration. Locations fixated were offensive defensive combinations (O-D combo), the offensive players, defensive, open space and other (blinks, uncodable data, gaze out of ice area).

the need to evaluate an extensive number of perceptual information sources. The field of play was also more complex for the athletes and required a continual assessment of assigned roles. The shorter duration of F/T during the first part of each trial was also due to the greater space within which the opposing players and teammates could skate, thereby requiring a faster shift of gaze at the beginning of the trial and shorter duration of fixation than occurred at the end.

As the tactical situation progressed to the latter SA phase, the perceptual information acquired was dictated by the skill level of the players and also a decrease in the distance between the participants and other players. Overall, the E player was more economical in his use of F/T, using fewer F/T of longer duration compared to the NE. This result was consistent with that of Helsen & Pauwels (1992), as well as that found in closed skills for quiet eye.

Both E and NE players assumed more specific roles during the latter stages of the tactical play. During this time, defensive roles became more defined and time-pressured. The athlete's final role was a 1 on 1 assignment, and in this situation a lower frequency of F/T of longer duration was found in agreement with Williams, Davids & Burwitz (1994) and; Williams et al (1999).

Conclusions

Within the limitations of a pilot investigation, the following conclusions can be made. Earlier it was mentioned that if a high frequency of F/T is needed to detect the fast action typical of team sports, then this would require the use of perceptual training programs that promote the use of a high frequency of F/T of low relative duration. However, if an economical control of F/T defines expertise in tactical settings, then visual attention programs should be used that feature a more economical use

Irrespective of expertise, the team sport athlete uses both high frequency/low duration and low frequency/high duration F/T, with an important guiding principal being the relative location of the athlete within the evolving play. When the tactical problem is located at a distance and includes a large number of opponents and/or teammates, the athlete uses a higher frequency of F/T of lower relative duration to critical locations. As the play nears, the athlete then narrows the focus to fewer locations using a lower frequency and longer duration of F/T in the 1 on 1 setting. The results also show ed that the gaze of the E athlete is more efficient and economical than the NE with fewer F/T directed to critical locations for longer relative durations. Although speculative, the E defensive athlete appears to be able to perceptually "hold " his opponents in his gaze by using fewer F/T of longer duration.

A more extensive study involving members of Canada's Olympic team (Martell, 2002; Martell & Vickers, in progress) has recently been completed and shows that team sport athletes see critical events much earlier than in the closed skills, thus allowing a better anticipation of the defensive play and programming of subsequent movements. The equivalent of QE in open sports appears to be located much earlier in the team sports than what occurs in closed sport setting.

Given these results, the vision trainer, coach or psychologists should not use unidimensional training programs in the team sport setting, but instead conduct a careful assessment of the tactical needs in each sport and develop both near and far F/T gaze training programs. Overall, the training program should emphasize the development of economy in F/T gaze that are knowledge-driven, rather than being ballistic and solely motor driven.

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