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Gaze characteristics of elite and near-elite athletes in ice hockey defensive tactics

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Abstract

Traditional visual search experiments, where the researcher pre-selects video-based scenes for the participant to respond to, shows that elite players make more efficient decisions than non-elites, but disagree on how they temporally regulate their gaze. Using the vision-in-action [J.N. Vickers, J. Exp. Psychol.: Human Percept. Perform. 22 (1996) 342] approach, we tested whether the significant gaze that differentiates elite and non-elite athletes occurred either: early in the task and was of more rapid duration [A.M. Williams et al., Res. Quart. Exer. Sport 65 (1994) 127; A.M. Williams and K. Davids, Res. Quart. Exer. Sport 69 (1998) 111], or late in the task and was of longer duration [W. Helsen, J.M. Pauwels, A cognitive approach to visual search in sport, in: D. Brogan, K. Carr (Eds.), Visual Search, vol. II, Taylor and Francis, London, 1992], or whether a more complex gaze control strategy was used that consisted of both early and rapid fixations followed by a late fixation of long duration prior to the final execution. We tested this using a live defensive zone task in ice hockey. Results indicated that athletes temporally regulated their gaze using two different gaze control strategies. First, fixation/tracking (F/T) gaze early in the trial were significantly shorter than the final F/T and confirmed that the elite group fixated the tactical locations more rapidly than the non-elite on successful plays. And secondly, the final F/T prior to critical movement initiation (i.e. F/T-1) was significantly longer for both groups, averaging 30% of the final part of the phase and occurred as the athletes isolated a single object or location to end the play. The results imply that expertise in defensive tactics is defined by a cascade of F/T, which began with the athletes fixating or tracking specific locations for short durations at the beginning of the play, and concluded with a final gaze of long duration to a relatively stable target at the end. The results are discussed

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within the context of gaze research in open and closed skills, as well as theoretical models of long-term memory and decision making in sport.

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1. Introduction

1.1. Eye movements/gaze research in open and closed skills

Extensive research has been carried out to determine the gaze behaviours of sport performers in both closed (Janelle et al., 2000; Ripoll, Bard, & Paillard, 1986; Vickers, 1992, 1996; Williams, Singer, & Frehlich, 2002), and open sport skills (Bahill & LaRitz, 1984; Helsen & Pauwels, 1992; Land & McLeod, 2000; Ripoll & Fleurance, 1988; Rodrigues, Vickers, & Williams, 2002; Vickers & Adolphe, 1997; Williams & Davids, 1998; Williams, Davids, Burwitz, & Williams, 1994). Closed skills are self-paced and executed within stable environments that do not change during performance, while open skills are externally-paced and performed in dynamic environments that vary in terms of speed, direction, and levels of uncertainty (Farrell, 1975; Gentile, Higgins, Miller, & Rosen, 1975; Poultan, 1957). Recently, Gentile (2000) and Magill (2001) have added a new dimension to the open–closed dichotomy and stated that during closed skills the performer interacts with an object that "does not change during performance of a skill", while in open skills performance occurs in environments "where the object or context is in motion during the performance of a skill" (Magill, 2001, p. 7). Given these two definitions, different gaze behaviours should be found that are distinct to each category. In closed skills, since the primary object of interest does not move, a stable gaze should be found due to the unchanging nature of the object, while in open skills a more complex type of gaze control would be required due to the search for objects within the evolving environment.

The aim of this study is to present an empirical investigation of the gaze characteristics of elite ice hockey players as they performed in the open sport of ice hockey. We carried out the research using a mobile eye tracker on ice and as such, this is the first attempt to determine the gaze of athletes in a live tactical setting. Our focus is on the temporal regulation of the gaze, which was recorded during the performance of successful and unsuccessful defensive plays. The research was therefore distinct from film-based studies where the participants typically view scenes from the sport presented on slides, videotapes or by other means and a more limited coupling of the gaze and motor behaviour (e.g. Helsen & Pauwels, 1992; Williams & Davids, 1998; Williams et al., 1994).

Even though the open-closed classification system is one of the oldest in sport, few scientific studies have attempted to ascertain the extent to which the gaze of the performer is dictated by the stability or instability of objects in the playing environment (Brady, 1995; Nougier, Rossi, Alain, & Taddei, 1996). Our aim is therefore to situate the study within the open and closed taxonomy of motor skills and determine how the gaze of the open tactical player is temporally regulated as compared to performers in closed skills where the athlete's stance is relatively stable and the object of interest is not in motion.

1.2. Gaze control research in closed sports

Gaze control research has been carried out in closed skills such as the golf putt (Vickers, 1992), basketball shooting (Ripoll et al., 1986; Vickers, 1996), pistol and rifle shooting (Ripoll, Papin, Guezennec, & Verdy, 1985; Janelle et al., 2000), and billiards (Williams et al., 2002). Performers of these skills orient their gaze to a fixed target or target(s), such as the hole or ball in golf, the hoop in basketball, or the bullseye in shooting. Elite performers have a longer duration of final fixation on the target than near-elites (athletes with lower game statistics), and the duration of this fixation has been shown to be longer on successful than unsuccessful trials. This object-oriented type of gaze control has been termed a "quiet eye" (QE; Vickers, 1996) and expert performers differ from non-experts in having an earlier onset and a longer duration of this gaze suggesting a sustained focus on one location or object is required prior to the initiation of the final movement. Williams et al. (2002) reduced the QE period experimentally in billiards and found that the accuracy of both elites and novice players declined as a function of the amount of reduction in the QE period. Harle and Vickers (2001) trained players to control the onset and duration of QE period in the basketball free throw, and their shooting accuracy improved in both the experimental and competitive setting. The QE period in closed skills has been deemed a perception–action variable, one that specifies the optimal regulation of the gaze relative to a final motor response (Janelle et al., 2000; Vickers, 1996; Williams et al., 2002).

1.3. Gaze control in open skills

Research has also been carried out in interceptive-timing skills and sport tactics where the context is dynamic and influenced to a greater degree by external events than in closed skills. In interceptive timing skills where the flight of the object is predictable, an early onset of pursuit tracking on the object occurs, followed by a long duration of tracking which normally does not occur to contact (Bahill & LaRitz, 1984; Ripoll & Fleurance, 1988; Rodrigues et al., 2002; Shank & Haywood, 1987; Vickers & Adolphe, 1997; Vickers, Rodrigues, & Brown, 2002; Williams & Ward, 2003). However, in skills where the flight of the object is unpredictable, such as in cricket batting, the elite batsman adjusts the gaze to deal with the uncertainty of late flight information. Land and McLeod (2000) found that while both low and high skilled cricket players tracked the ball as the ball was first delivered, only the highly skilled performer used a rapid anticipatory saccade to the bounce point, followed by a brief period of tracking before the ball was struck. In open skills of an interceptive timing nature we therefore see that when the flight of the object is predictable, pursuit tracking is directed early to the object and over the first part of flight, but when the movement of objects is unpredictable then the gaze adapts to deal with late changes in object flight and it is the elite performer who is better at adapting the gaze so that the rapidly changing conditions can be perceived in time to effectively adjust the action.

1.4. Gaze control research in team sport tactics

Studies of gaze control in sport tactics have shown that elite players are faster than non-elite in making decisions and that these decisions are of a higher quality (Helsen & Pauwels, 1992; Williams & Davids, 1998; Williams et al., 1994), but beyond this it is unclear if the superior decision making skills of the elite performer are due to their early detection of cues, and/or their ability to process the fixated information more effectively after it has been fixated. Helsen and Pauwels (1992) examined the gaze characteristics of high and low skilled soccer players as they viewed life-size video simulations of offensive plays. At the appropriate moment, the athletes were required to take a shot, pass the ball, or dribble against the video opponent. They found that the elite players had significantly lower search rates and longer fixation durations than the non-elite, and that the most critical fixations occurred in the latter part of each play. In contrast, Williams et al. (1994) and Williams and Davids (1998) investigated the visual search characteristics of elite and novice soccer players during 11 on 11, 3 on 3, and 1 on 1 soccer plays and found that the elite players had a higher frequency of fixation of shorter duration in the 11 on 11 and 1 on 1 situations, but no significant differences were found in the 3 on 3 plays. The available research in sport tactics therefore supports two different views of the temporal regulation of the gaze in sport tactics. According to Helsen and Pauwels (1992), the elite player has a lower frequency of fixation of longer duration which are directed to critical locations viewed late in the action, while Williams et al. (1994) and Williams and Davids (1998) argue that expertise is dependent on the ability to focus the gaze rapidly on critical locations fixated early in the development of the play.

1.5. Gaze control in ice hockey

Ice hockey is an open sport where the ability to quickly read offensive and defensive play patterns is critical. The ability to quickly read and react in ice hockey has been defined by King (1990) as the perceptual ability to selectively attend to key components of the game and rapidly execute the correct decision. This perception–action relationship ensures that preparatory and attentional factors assist in the production of critical movement decisions, which in turn affects performance. Thorpe and West (1969) suggested the ability to read and react was related to the athlete's game-sense, or game intelligence. This characteristic permits the elite athlete to perceive the structure of the action as "one integrated unit like the game of chess: offensive movements are protected defensively, and defensive movements are potential attacks" (Pelchat, Kostka, Bukac, & Safarik, 1980, p. 13).

Even though the perceptual skill of read and react has been identified as central to expertise in ice hockey, it is not known how athletes with different skill levels temporally regulate their gaze during tactical plays, or the relationship of their gaze control to performance success. In order to explore this problem, we recorded the gaze behaviours of elite (E) and near-elite (NE) players ice hockey players as they defended against opponents on the ice. The E players played at the international Olympic level, while the NE performed at the national level. Our analyses focused on the temporal regulation of their gaze, specifically the onset and duration of fixation and tracking during successful and unsuccessful defensive plays. Given the available evidence on the temporal control of the gaze in open sport tactics, we pursued the following hypotheses. If the fixation or tracking (F/T) gaze that differentiates skill and/or outcome occurs late in the trial and is of longer duration, then this would support the view of Helsen and Pauwels (1992) that expertise in sport tactics is characterized by the late and sustained use of F/T to critical locations at the conclusion of the action. Alternatively, if the F/T behaviour that differentiates skill and/or outcome occurs early in the trial, and consists of rapid F/T of shorter duration, then this would indicate that expertise is dependent on the early detection of cues thus supporting the research of Williams et al. (1994) and Williams and Davids (1998). If both hypotheses are supported, and skill and/or outcome differences are defined by the use of both an early and rapid F/T followed by a long duration F/T at the conclusion of the play, then expertise in team tactics requires the use of a more complex type of gaze control than has been previously described in the literature.

2. Method

2.1. Participants

A total of 12 athletes volunteered for the study. The E participants ($n = 6$) were members of the Canadian Women's team that won the gold medal at the 2002 Olympics (age range 22–34), while the NE ($n = 6$) group consisted of five members of the Canadian women's under-22 (age range 18–22) team that won the Canadian championship in 2001, and a sixth NE participant who was a member of the 1998 Canadian Women's National team but failed to be selected to the 2002 Olympic team. All 12 athletes tried out for the Olympic team, but none of the NE group were successful. The E and NE groups were significantly different in age, $F(1, 10) = 6.94$, $p < 0.03$, with the E group having a mean age of 28.00 ($s = 4.73$) and the NE group a mean age of 21.67 ($s = 3.50$). The E and NE groups also differed significantly in years of formal training, $F(1, 10) = 4.81$, $p < 0.05$ in which subjects practiced and/or participated in three or more coached ice sessions per week. The E group averaged 11.16 ($s = 5.88$) years of formal training and the NE averaged 5.50 ($s = 2.35$). The E and NE groups therefore differed significantly in both age and years of formal training, thereby agreeing with previous research in expertise which has shown that a minimum of ten years of preparation is required for an individual to achieve the level of expert in a given domain (Bloom, 1985; Ericsson, Krampe, & Tesch-Romer, 1993;

Simon & Chase, 1973). Ethics approval was received from the University of Calgary Ethics Board prior to testing.

2.2. Gaze and motor data collection

The vision-in-action system (VIA; Vickers, 1996) was used to record the participant's gaze, movements and ocular behaviours as they performed on ice. The system was comprised of Applied Sciences 501 mobile tracker, which was interfaced to an external video camera (Sony, Model TRV82), two digital video mixers (Videonics, Model MX-1) and a time code generator. The eye tracker was a monocular corneal reflection system that measured eye-line-of-gaze with respect to the helmet. The helmet had a 30-metre cord attached to the waist, connected to the eye control unit, thus permitting near-normal mobility. Miniaturized optics (scene and eye cameras), an illuminator, and visor were mounted on the helmet, for a total weight of 700 g. Three images were captured simultaneously as shown in Fig. 1. The ocular image (A) was recorded by the eye camera on the tracker and shows the participant's (Dp) eye and horizontal and vertical axes of the pupil and CR centroids. The gaze image (B) was recorded by the scene camera (also on the helmet) and shows the participant's gaze (white cursor) within the ice hockey environment (accuracy of 2° of visual angle, precision of 1°). The motor image (C) was recorded by an external camera, which captured the skating and other movements of the participant, teammates, opponents, and puck. A time code generator (not shown in Fig. 1 but an integral part of each frame) simultaneously recorded time in the three images at a rate of 30 frames per second (33.33 ms per frame).

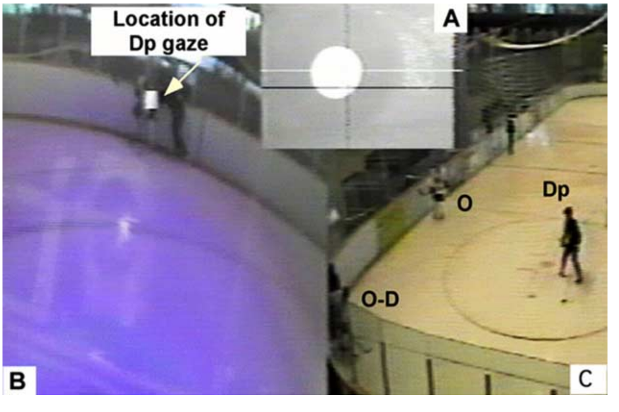

Fig. 1. A frame of vision-in-action data as collected on ice in ice hockey. The eye image (A) shows the eye of the athlete with horizontal and vertical axes at the pupil and corneal reflection centroids. The gaze image (B) shows the field of view in front of the athlete and location of the gaze in the hockey environment as indicated by the white cursor. The width of the cursor represented two degrees of visual angle anywhere in the scene. The motor image (C) shows the movements of the players and puck as recorded by an external camera. All three images were recorded simultaneously, therefore the actions of the participant (Dp), the offensive player (O) and offensive–defensive combination (O–D combo) as shown in image C were coupled in time with Dp's gaze (the white cursor) as shown in image B.

2.3. Experimental task

Two plays were used that are basic to ice hockey (gap, contain). The plays were skated against male hockey players (aged 16–28) who assumed the roles of O1, O2, D1, and Dt. All were members of an elite Junior AA (aged 16–20) team and/or the University of Calgary men's team (aged 20–28). Male players were used as both the E and NE groups trained against male opponents and the use of the male players also provided a consistently high level of skating and competition during the testing. Two training sessions were held in which the plays were practiced and O1, O2, D1, and Dt were instructed to skate at game intensity in terms of speed of entry into the mid-ice and defensive zones.

Fig. 2 presents the location of the players in the contain play, which will be used for demonstration purposes. The participant (Dp) is shown at the beginning of the play (see the pattern recognition, PR phase) standing at center ice ready to defend against the two offensive skaters (O1, O2), while being supported by two defensive teammates (D, Dt), who were positioned trailing the action. Each trial therefore began with the Dp facing two offensive players who had a clear positional advantage, a situation that often occurs during ice hockey games. Dp had to first detect the type of play being skated during the pattern recognition (PR) phase, and then skate rapidly to gain position and control of the situation during the latter two phases (the situation assessment (SA) and final execution (FE) phases).

The three phases (PR, SA, FE) were derived from Klein's (1999) Recognition Primed (RPD) model of decision-making, which is based on his study of experienced decision makers in high stress environments such as firefighting, aviation and medicine. Two variations from the RPD model were used (simple-match, situation assessment) to define the major events of each play. The PR phase was similar to

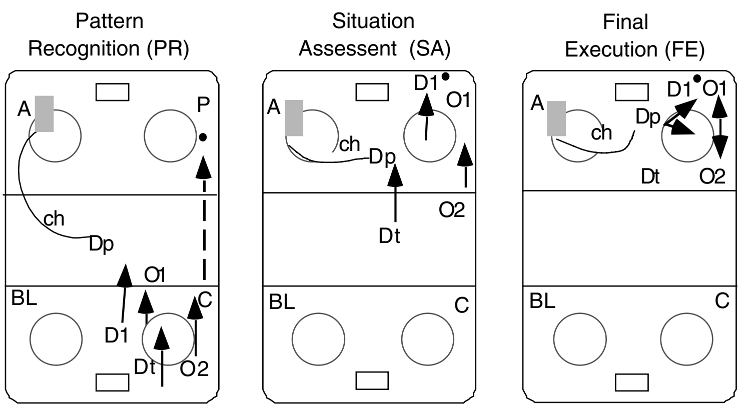

Fig. 2. The three phases of the contain play: pattern recognition (PR), situation assessment (SA) and final execution (FE) showing the positioning of the participant (Dp), the defensive trailer (Dt), offensive player (O) and offensive–defensive combination (O–D combo), as well as the coach (C), the eye tracker system (A), cable holder (CH) and blue line (BL).

Klein's "simple match" variation (p. 25) where perceptual cues are quickly recognized and acted upon by initiating a known course of action. Since both the gap and contain plays were well known to all the players, we expected both groups to quickly recognize the plays and rapidly initiate skating. The trial therefore began with Dp standing with her eyes closed at center-ice in a position to respond to the on-coming rush of O1, O2, D1 and Dt. A whistle from the coach signaled O1, O2, D1 and Dt to begin skating at full speed, while at the same time he shot the puck (P) into the defensive zone. When the first player reached the blue line (BL), a second whistle signaled Dp to open her eyes, read the play, and defend against it in an appropriate manner. The onset of the PR phase therefore coincided with the first appearance of Dp's gaze and offset with the first movement of her skate to defend against the play (see Fig. 1). The SA phase followed and was based on variation two of the RPD model "diagnosing the situation" (Klein, 1999, p. 26). During this variation, both familiar and new information is assessed, but the process ends in a familiar action being taken. In the SA phase, Dp skated rapidly to gain defensive position while at the same time scanning O1, O2, D1, Dt, the puck, and other locations on the ice. During this time both familiar and new information was fixated or tracked, however, given the nature of defensive play in ice hockey, each trial culminated in one action – Dp had to engage one of the offensive players in a 1 on 1 situation. The SA phase therefore ended with Dp's first skating movement to engage the opposing player (O1 or O2) in the 1 on 1 situation. The FE phase followed and ended with Dp's first contact with the offensive player. No shots were permitted on goal (backswing only).

2.4. Protocol

The participants arrived in uniform and after a skating warm-up of 10 minutes were fitted with the eye tracker and calibrated to nine points on the calibration grid. The participants then skated a number of practice trials without opposition in order to become comfortable with the eye tracker and cable holder, who was an elite male player who shadowed Dp's movements. The conditions were counterbalanced in order to prevent guessing. Before and after each trial, calibration was maintained by asking the Dp to fixate specific locations on the ice. A maximum of 24 trials were skated (12 in each condition) which was within the physical capabilities of the skaters. Total testing time took about 60 minutes.

2.5. Data coding

Two independent experts in ice hockey rated each trial as "plus" or "minus" from the videotaped data as shown in Fig. 1. The plus–minus statistic is used in ice hockey to determine defensive skill and records how many goals an athlete is on the ice when their team scores a goal (i.e. plus), minus the number of goals an athlete is on the ice when a goal is scored on their team (i.e. minus). Since there were no shots on goal, the participant's were assessed on their ability to prevent a shot on goal or otherwise interrupt the flow of offensive play. The judges ratings followed pre-set criteria that defined excellent to poor performance in each play. Only those trials where there was 100% agreement between the two experts were retained. An effort was made to include an equal number of trials for each condition and outcome, however, this was not possible for every athlete. A complete skill (E, NE) × outcome (plus, minus) × trials (4, 4) data set would have totaled 96 trials, but five trials were not skated by the E group (4 minus, 1 plus) and four (three plus, one minus) by the NE, leaving a total data set of 87 trials (45.3% of the total skated).

The resultant trials were coded in an editing suite equipped with frame-by-frame shuttle control. Ten gaze locations were initially coded, based on how the athlete's allocated their gaze: the offense–defense combination (O–D combo), negative space, positive space, the puck, the defensive player, and the offensive player's head/shoulders, stick, torso, and legs/skates. In order to reduce the complexity of the analysis, the number of gaze locations were reduced to six by re-labeling the gaze to the offensive player's head/shoulders, stick, torso, legs/skates, and stick as 'offense', a procedure that did not change the duration of any of the gaze. The final six locations were the offense–defense combination (O–D combo), negative space, positive space, the puck, the defensive player and the offensive player.

The O–D combo occurred when no separation existed between O1 and D1 and it could not be determined which player the gaze was directed to. Positive space was defined as the playable ice surface or boards between the players and the puck, while negative space included areas outside of the immediate tactical environment.

Three gaze behaviours (fixation/tracking, saccades, 'other') were coded relative to the gaze locations using minimum duration parameters from the eye movement literature (Carpenter, 1988; Fischer & Weber, 1993; Millodot, 1986). Due to the dynamic nature of ice hockey, no attempt was made to code fixation and pursuit tracking separately. Instead, fixation/tracking (F/T) was coded when the gaze was stable on a stationary or moving player or object for more than 99.9 ms (three or more frames) within 2° of visual angle (the cursor width in Fig. 1). Onset, offset and duration of F/T were coded in reverse order in each phase, that is, the onset of F/T-1 occurred just prior to the offset of each phase. A saccade (Sac) was coded when a rapid shift in gaze occurred between locations, with a minimum duration of 66.66 ms or two frames of video. The 'other' category of data included gaze that was not codeable due to excessive head and body movements, or when the players looked outside the ice surface. Absolute measures of gaze duration (ms) were converted to relative time (Schmidt & Lee, 1999) and calculated as a percent of each phase duration where appropriate code–recode reliability was established using two independent coders. Intra-class correlations were determined for phase durations, F/T onsets, and durations using the procedures outlined in Thomas and Nelson (2001). R-values ranged from 0.80 to 0.99.

2.6. Data analysis

The duration (ms) of the gap and contain plays were analyzed using a skill (E, NE) × condition (gap, contain) × trials ANOVA, with repeated measures on the last two factors. A significant difference was found for condition, $F(1,22) = 20.29$,

$p < 0.001$, but not for skill, or the interaction of skill × condition, or skill × condition × trials, therefore the two plays were collapsed. The data were then analyzed in two levels. In the first part, the objective was to determine how the E and NE groups regulated their gaze (F/T) in terms of frequency, onset, offset and duration, while in the second part, the goal was to determine the location of significant F/T. In order to determine the E and NE group's skating speed, the duration (ms, %) of the phases were analyzed using a skill (E, NE) × outcome (plus, minus) × phase (PR, SA, FE) × trials (4, 4) mixed-model ANOVA, with repeated measures on the last three factors. The frequency of gaze (all combined) was determined in each phase using a similar ANOVA. The temporal onset of F/T was analyzed by phase using a group × F/T factorial ANOVA. In order to determine the interactive effects of skill by outcome on F/T duration, a skill (E, NE) × outcome (plus, minus) × trials (4, 4) mixed-model ANOVA, with repeated measures on the last two factors was used. The analyses were carried out with missing cells and without (using means), and the more conservative missing cells results reported. The Greenhouse–Geisser epsilon was used to deal with any lack of sphericity in repeated measures mixed designs. The final step was to determine the location of the gaze for any significant differences in F/T duration, using descriptive statistics. Effect sizes were calculated for significant main effects, and omega squared (ω^2) when more than two means were involved. Bonferroni adjustments and contract of means were used for multiple comparisons (Maxwell & Delaney, 1990). An alpha level of 0.05 was used for all statistical tests.

3. Results

3.1. Phase durations

Phase durations (ms) were determined using a skill (E, NE) × outcome (plus, minus) × phase (PR, SA, FE) × trials (4, 4) repeated measures ANOVA. A significant difference was found for phase, $F(2,60) = 1363.72$, $p < 0.0001$, $\omega^2 = 0.99$, but not for skill, outcome, or trials. Mean durations of the phases (ms, with standard deviations) are shown in Table 1. The duration of the PR phase was $M = 488.89$ ms ($s = 166.66$), low range 441.75 ms ($s = 129.75$) and high of 547.61 ms ($s = 190.27$). Mean duration of the SA phase was $M = 5806.09$ ms ($s = 1120.81$), range 5560.24 ms ($s = 860.04$) to 6057.13 ms ($s = 1291.18$). The FE phase averaged 705.92 ms ($s = 430.77$), range 557.03 ms ($s = 183.13$) to 883.49 ms ($s = 579.15$).

3.2. Frequency of gaze behaviours

The mean frequency of gaze (combined F/T, sac, 'other') is also shown in Table 1 by phase and were analyzed using a skill (E, NE) × phase (PR, SA, FE) × outcome (plus, minus) × Trials (4, 4) ANOVA, with repeated measures on the last three factors. A significant difference was found for phase $F(1,60) = 241.21$, $p < 0.0001$, $\omega^2 = 0.97$, but not for skill, outcome, or trials, indicating the E and NE groups used similar search rates in each phase. Table 1 shows that during the PR phase, the mean

Table 1
Mean duration (ms, SD) of the three phases (PR, SA, FE) phases during plus and minus plays, along with the frequency of gaze (all combined) in each phase of the elite (E) and near-elite (NE) groups

Outcome:	Plus			Minus		
Phase:	PR	SA	FE	PR	SA	FE
Elite (ms, SD)	466.06 (144.85)	6057.13 (1291.18)	659.11 (414.85)	441.75 (129.34)	5560.24 (860.04)	557.03 (183.13)
Elite (gaze, SD)	2.54 (0.82)	17.71 (5.69)	1.79 (0.82)	2.53 (1.11)	16.19 (5.25)	1.94 (1.18)
Near-elite (ms, SD)	500.10 (184.97)	5687.15 (1077.91)	833.49 (579.60)	547.61 (190.29)	5919.20 (1232.30)	774.01 (456.29)
Near-elite (gaze, SD)	2.75 (0.97)	17.75 (5.59)	2.09 (1.13)	2.87 (1.15)	16.88 (5.23)	2.12 (1.55)

frequency of all gaze was 2.67 ($s = 1.01$), range 2.53 ($s = 1.11$) to 2.87 ($s = 1.15$); in the SA phase, mean frequency was 17.15, range 16.19 ($s = 5.25$) to 17.75 ($s = 5.69$), and in the FE phase the frequency of gaze was 1.95, range 1.79 ($s = 0.82$) to 2.12 ($s = 1.55$). We therefore see that both E and NE used a similar number of gaze in each phase.

3.3. Type of gaze by phase

The frequency of the each type of gaze were analyzed using a skill (E, NE) $\times$ outcome (plus, minus) $\times$ type gaze (F/T, Sac, Other) ANOVA, with repeated measures on the last two factors. Means and standard deviations are shown in Table 2. In the PR phase, a significant difference was found for gaze, $F(1,60) = 29.31$, $p = 0.0001$, $\omega^2 = 0.97$, but not for skill, outcome or trials. Pair-wise comparisons showed that F/T and Sac occurred more than 'other' ($p = 0.001$). In the SA phase, a significant difference was found for gaze, $F(1,60) = 96.45$, $p = 0.0001$, $\omega^2 = 0.94$, but not for skill, outcome or trials. Pair-wise comparisons showed that F/T was used more frequently than saccades ($p = 0.0001$) or 'other' ($p = 0.0001$). In the FE phase, a

Table 2
Mean frequency (with standard deviations) of fixation tracking (F/T), saccades (Sac) and 'other' of the elite and near-elites groups during the pattern recognition (PR), situation assessment (SA), and final execution (FE) phases

Phase:	PR			SA			FE		
Gaze:	F/T	Sac	Other	F/T	Sac	Other	F/T	Sac	Other
Elite (ms, SD)	1.17 (0.48)	1.00 (0.75)	0.43 (0.48)	7.92 (2.59)	6.15 (2.89)	4.49 (1.82)	0.83 (0.77)	0.35 (0.66)	0.57 (0.48)
Near-elite (ms, SD)	1.21 (0.41)	1.23 (0.97)	0.34 (0.46)	8.03 (2.34)	6.22 (3.06)	5.82 (2.65)	1.20 (0.83)	0.52 (0.73)	0.41 (0.53)

significant result was found for gaze, $F(1,60) = 9.87$, $p = 0.001$, $\omega^2 = 0.59$; the pair-wise comparisons showed that F/T was used more often than saccades ($p = 0.0004$), and 'other' ($p = 0.0009$). Overall, the visual search characteristics of the E and NE groups were very similar, with the F/T gaze being most numerous, followed by saccades, and least by the 'other' category.

3.4. F/T gaze

3.4.1. F/T gaze in the PR Phase

Onset, offset and duration of F/T-1 was analyzed, separately, using a skill (E, NE) × outcome (plus, minus) × trials (4, 4) ANOVA, with repeated measures on the last two factors. No significant differences were found indicating the E and NE detected the plays and initiated the first skating movement in similar amounts of time.

3.4.2. F/T gaze in the SA Phase

Table 3 presents the mean frequency of F/T for each athlete in the SA phase. An average of nine were found, with F/T-9 occurring at the onset of the phase and F/T-1 at the offset. Fewer F/T were found at the beginning of the phase (see Table 3) due to the vigorous skating which occurred as the participants accelerated from a standing position to full speed at the onset of the SA phase. The ability to stabilize the gaze on one location varied by athlete, and overall was least from F/T-9 to F/T-7 and most stable from F/T-6 to F/T-1. The frequency data shown in Table 3 was analyzed using a skill (E, NE) × outcome (plus, minus) × F/T (1–9) factorial ANOVA. A significant difference was found for F/T, $F(1,80) = 34.86$, $p = 0.0001$, $\omega^2 = 0.98$, but not for skill, or skill × outcome. Mean number of F/T increased significantly as the SA

Table 3
Number of F/T used for the individual elite (E) and near-elite (NE) athletes in the situation assessment phase (F/T-9 through to F/T-1)

	F/T in SA Phase								
	F/T-9	F/T-8	F/T-7	F/T-6	F/T-5	F/T-4	F/T-3	F/T-2	F/T-1
Subject									
E1	3	4	4	4	4	4	5	5	5
E2	0	2	2	4	4	4	7	8	8
E3	5	6	7	8	8	8	8	8	8
E4	3	4	5	6	7	7	7	7	7
E5	3	3	6	8	8	8	8	8	8
E6	1	1	2	5	6	6	7	7	7
NE1	4	5	7	8	8	8	8	8	8
NE2	7	7	8	8	8	8	8	8	8
NE3	1	1	4	7	7	7	7	7	7
NE4	5	6	7	7	7	7	7	7	7
NE5	3	3	7	7	7	7	7	7	7
NE6	1	3	7	7	7	7	7	7	7
Total	36	45	66	79	81	81	86	87	87

phase progressed from a mean of 3.0 during F/T-9 to a mean of 7.25 at F/T-1 (maximum was 8.0).

3.4.3. F/T onsets from F/T-9 to F/T-1

Fig. 3 shows the mean onsets of F/T-9 to F/T-1 for skill (top) and outcome (bottom). The factorial ANOVA for skill (E, NE) × F/T (1–9) was significant for F/T, $F(1,596) = 142.29$, $p = 0.0001$, $\omega^2 = 0.99$, but not for skill or the interaction of skill × F/T. A similar result was found for outcome, F/T, $F(1,596) = 141.60$, $p = 0.0001$, $\omega^2 = 0.99$. These results show that the E and NE groups scanned the environment using similar temporal onsets of F/T on plus and minus plays.

3.4.4. F/T duration (%) of gaze from F/T-9 to F/T-1

The mean duration (%) of F/T-9 through F/T-1 for skill (top) and outcome (bottom) are shown in Fig. 4. The factorial ANOVA for group (E, NE) × F/T(9–1) was significant for F/T, $F(1,596) = 19.03$, $p = 0.0001$, $\omega^2 = 0.96$, and revealed that the duration increased progressively from a short duration at the beginning of the phase (F/T-9) to longer at the end (F/T-1). The Bonferroni pair wise comparisons showed that the duration of F/T-1 ($M = 18.9\%$, $s = 13.35$) was significantly longer than F/T-2 through F/T-9 (all comparisons, $p = 0.0001$). Similarly, the factorial ANOVA

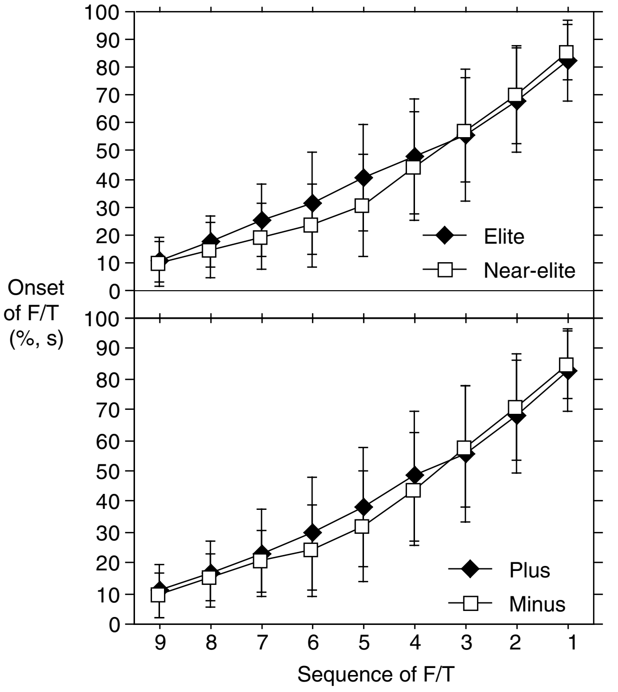

Fig. 3. Temporal onset of F/T in the SA phase. A value of 0% indicated the beginning of the SA phase and 100% the end.

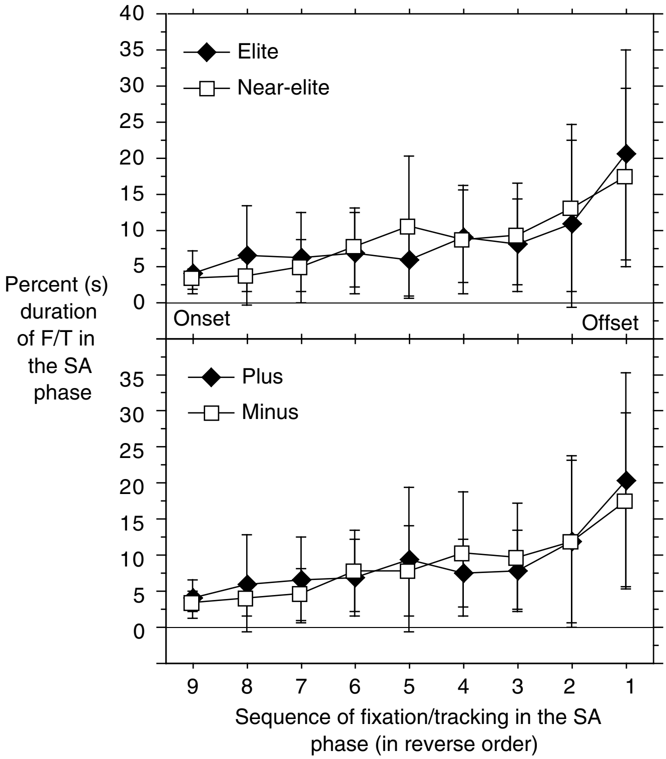

Fig. 4. Mean duration (%) of F/T-9 to F/T-1 in the SA phase for skill (top) and outcome (bottom).

for outcome (plus, minus) × F/T(9–1) was significantly different for F/T, $F(1,596) = 19.23$, $p = 0.0001$, $\omega^2 = 0.97$, and the pair-wise comparisons showed that F/T-1 ($M = 18.9\%$, $s = 13.35$) was significantly longer than all of F/T-2 through F/T-9 (all comparisons, $p = 0.0001$).

3.4.5. F/T duration (%) from F/T-6 to F/T-1

In this analysis the data were analyzed using a repeated measures mixed ANOVA design in order to determine if there were any significant interactions for skill by outcome for F/T duration. The durations of F/T-6 to F/T-1 were analyzed separately, using a skill (E, NE) × outcome (plus, minus) × trials (4, 4) mixed-model ANOVA, with repeated measures on the last three factors. No significant skill or outcome differences were found for F/T-6, but significant differences were found for the interaction of trials × skill, $F(3,11) = 3.16$, $p < 0.04$ (Greenhouse–Geisser epsilon $p > 0.004$) and outcome × skill, $F(3,11) = 3.60$, $p < 0.05$ Greenhouse–Geisser epsilon ($p > 0.001$). F/T-6 duration was lower for the E group than the NE, and this result was more pronounced on plus trials than on minus trials.

These results were mirrored in F/T-5, where significant differences were found for skill, $F(1,16) = 8.84$, $p < 0.01$, ES $= 0.70$, and the interaction of outcome × skill,

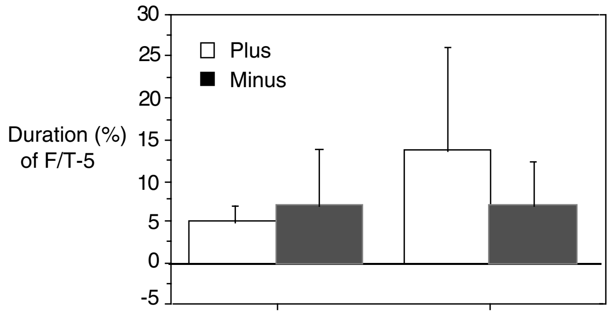

Fig. 5. Mean duration (%) of F/T-5 in the SA phase by skill and outcome.

$F(1, 16) = 5.54$, $p < 0.04$ (Greenhouse–Geisser epsilon $p > 0.009$) The E group had a shorter duration of F/T-5 ($M = 5.83\%$; $s = 5.07$) than the NE ($M = 10.51\%$; $s = 9.80$), indicating they fixated or tracked the available information in a shorter period of time. When expressed in milliseconds, the E mean was 346.74 ms and the NE was 591.59 ms. The significant interaction is presented in Fig. 5 and shows that the E had a shorter duration on plus plays ($M = 4.72\%$; $s = 2.12$; $M = 277.83$ ms; $s = 131.38$) than on minus ($M = 7.01\%$; $s = 6.86$; $M = 419.69$ ms; $s = 444.04$), while the NE were more successful when they took more time on plus trials ($M = 13.58\%$; $s = 12.38$; $M = 770.15$ ms; $s = 750.43$) than on minus ($M = 7.59\%$; $s = 5.38$; $M = 436.32$ ms; $s = 360$). No other significant differences were found in the SA phase.

3.4.6. F/T gaze in the FE phase

No significant differences were found due to skill, outcome, or trials in the mean duration of F/T in the FE phase.

3.4.7. F/T location in the SA phase

The results thus far have concentrated on describing the temporal regulation of F/T during the three phases of the plays. In the following section, the location of F/T was determined for the significant F/T in the SA phase (F/T-6, F/T-5, F/T-1) in order to determine if the E and NE differences were common or unique to the different locations viewed. Table 4 presents the percent of F/T to the different locations and a quick perusal of the percentages shows that the E and NE differed in the locations viewed, and that furthermore the percent of gaze differed as a consequence of the temporal order of F/T.

During F/T-6, 65.6% of the E group's F/T were directed to the O–D combo, followed by positive space (15.4%), the puck (9.7%) and negative space (3.1%). In contrast, the NE group allocated their gaze more evenly, to negative space (32.4%), followed by the O–D combo (27%), positive space (24.3%) and the puck (16.2%). During F/T-5, the E fixated the O–D combo and positive space equally, (28.6%), followed by the puck (22.8%), offense (17/1%) and negative space (2.9%), while the NE fixated the O–D combo (39.5), the puck (25.6%), positive space and negative

Table 4
Percent of F/T directed to different locations during F/T-6, F/T-5, and F/T-1

F/T	Locations	Skill group	
		E%	NE%
F/T-6	Defense	0	0
	O–D combo	65.6	27.0
	Offense	6.2	0
	Neg space	3.1	32.4
	Pos space	15.4	24.3
	Puck	9.7	16.3
F/T-5	Defense	0	0
	O–D combo	28.6	39.5
	Offense	17.1	2.3
	Neg space	2.9	16.3
	Pos space	28.6	16.3
	Puck	22.8	25.6
F/T-1	Defense	0	0
	O–D combo	16.3	6.8
	Offense	34.9	45.5
	Pos space	7.0	4.5
	Negative space	0.0	0.0
	Puck	41.8	43.2

space equally (16.3%) and the offense (2.3%). During F/T-1, both E and NE allocated most of their gaze to only two locations, the offensive player (E = 34.9% and NE = 45.5%) and the puck (E = 41.8% and NE = 43.2%), and fewer gaze to the O–D combo (E = 16.3% and NE = 6.8%), positive space (E = 7.0% and NE = 4.5%). Interestingly, no F/T were directed to the defensive player by either of the groups during F/T-6, F/T-5 or F/T-1.

Recall that during F/T-5, the E differed from the NE in having a lower duration of F/T on successful trials (see Fig. 5). Fig. 6 presents the mean duration of F/T-5 to the

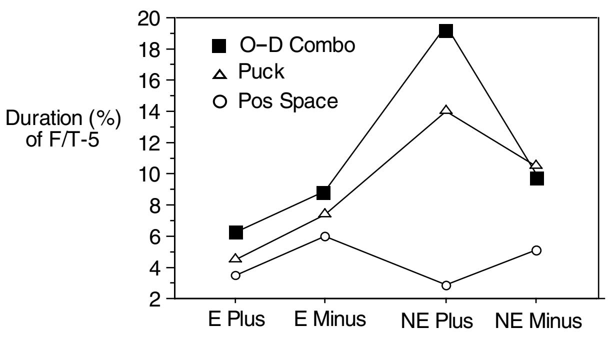

Fig. 6. Mean duration (%) of F/T-5 to the three main locations (the O–D combo, puck, positive space) viewed by skill and outcome.

three principal locations viewed, as shown in Table 4 (O–D combo, puck, positive space). While both groups were similar in the durations they allocated to positive space, the E group had a lower mean duration to the O–D combo and the puck than the NE. These results provide an interesting contrast, in that the E group was more successful when they took less time to fixate the principal locations, and the NE group was more successful when they took more time, suggesting processing differences distinguished the two skill groups at this critical moment during the play.

4. Discussion

Our first objective in this study was to determine how E and NE ice hockey players regulate their gaze when performing successful and unsuccessful defensive plays on the ice. As such this was the first attempt to record the gaze of the tactical player in a live team sport setting. We were interested in determining if the E athletes had a distinct way of temporally regulating their gaze, which in turn may be related to their defensive performance. Based on the literature on expertise in sport tactics, we hypothesized that skill and or accuracy differences would be defined by one of the following three types of gaze control: (a) the E athletes would use rapid F/T of short durations to set locations early in the trial (Williams & Davids, 1998; Williams et al., 1994); or (b) they would use F/T of longer duration later in the trial to specific locations (Helsen & Pauwels, 1992), or (c) they would use a combination of the types of gaze control, specifically, rapid F/T at the beginning of the play followed by a longer duration of F/T on a specific location or object at the conclusion of the play. Our results supported the latter hypothesis, and showed that the E group differed from the NE in directing F/T of shorter duration to specific locations as the play developed early in the SA phase, followed by a longer F/T duration on a relatively stable location during the final 30% of the phase. The ability to excel in defensive team tactics was therefore dependent on the use of two gaze behaviours that occurred in temporal sequence.

Our second objective was to situate the findings within the open and closed skills dichotomy, with is one of the oldest classification systems in sport. Our intent was to determine if empirical support could be provided for Gentile (2000) and Magill's (2001) recent suggestion that while closed skills require the performer to interact with an object that "does not change during performance of a skill", open skills require the perform interact with "objects or contexts [which are] in motion during the performance of a skill" (Magill, 2001, p. 7). Gaze research in closed skills, such as golf, basketball, billiards and rifle shooting has shown that the expert performer selects a single target to which a long duration fixation, or QE, is directed before the initiation of the final action. This type of gaze control is therefore consistent with Gentile (2000) and Magill's (2001) observations about closed skills. The current study shows that in the open skill of ice hockey defensive tactics a different type of gaze control was used that was distinct from that found in closed skills (Williams, Davids, & Williams, 1999). In the following sections, the results are discussed as they relate to the distinctiveness of the gaze control, highlighting the significant skill and outcome differences in F/T behaviours. This is then followed by speculations about the possible theoretical significance of the research, especially as it relates to Ericsson and Kintsch's (1995) long term working memory (LT-WM) theory and Klein's (1999) RPD model of decision-making.

4.1. The temporal regulation of F/T

The PR phase was very brief and included only the time needed to recognize each play. The E and NE groups did not differ in the duration of this phase, indicating a similar amount of time was needed to recognize the play and initiate the skating action. The SA phase followed during which the athletes assessed the play and assumed the defensive positions that could prevent a shot on goal. The E and NE groups did not differ significantly in the duration of the PR, SA, or FE phases, indicating both groups skated the phases at near-equal speeds. No skill or outcome differences were found in F/T onset or duration during the PR or FE phases, but a number of significant differences were found in the SA phase.

During the SA phase nine F/T occurred in temporal order, with F/T-9 occurring at the beginning of the phase and F/T-1 at the conclusion. The onset of the F/T did not differ by skill or outcome, indicating both the E and NE groups scanned the plays at near similar rates. F/T durations were significantly lower for F/T-9 to F/T-2 than for F/T-1, indicating two different types of gaze control were used. During F/T-9 to F/T-2, the gaze moved at the same speed between locations but dwelled for only brief periods at each location. A significant difference was found in the durations of F/T-6 and F/T-5 for skill and/or outcome. Both F/T occurred mid-way through the SA phase and at a time when reading each play was critical. A frame of data is shown in Fig. 1 at this time in the SA phase for the contain play and shows the Dp positioned between the O–D combo and the offensive player, who is located at the top of the screen on the blue line. During this time, Dp is shown fixating the O–D combo while at the same time physically assuming a central position where the other offensive player (O) can be monitored and the shooting lanes covered. Therefore, a tight coupling between perception and action was necessary in order for Dp to control the movements of the opposition and shots in the net prevented. The duration of F/T-6 and F/T-5 were significantly shorter for the E group compared to the NE group, suggesting the E players were able to read the information at each fixated location more quickly and perhaps gain time to position themselves more optimally on the ice. In tactical sports like ice hockey, expertise differences normally emerge when critical levels of temporal pressure and forced choice are reached (Ripoll, 1991). Our results suggest that the NE group was not as able handle the temporal pressure as the E, and were successful only when the play gave them more time to fixate the cues available.

The analysis of F/T locations during the significant F/T-6 and F/T-5 also showed that E and NE fixated different locations (see Table 4), with the E player being more selective in fixating the O–D combination while the NE distributed their gaze more evenly across the locations. F/T-1 was the final F/T in the SA phase and was significantly longer than all previous F/T for both E and NE. Two gaze locations (the offensive player, puck) characterized this final F/T-1 period. The final moments of successful defensive tactics were therefore characterized by a different type of gaze control than what was found in the early part of the play.

Our results therefore agree with the previous work of Helsen and Pauwels (1992), Williams et al. (1994), and Williams and Davids (1998), whose findings appeared to contradict one another. Williams et al. (1994) and Williams and Davids (1998) found that the elite player (in the 3 on 3 situation which was most similar to the current study) used rapid fixations of short duration which occurred early in the play, while Helsen and Pauwels (1992) found that fixations of longer duration were used later in the action. Each of these studies was conducted using film-based protocols where the athletes viewed set plays, unlike the current investigation where each play was skated in a manner similar to that found practices or competition. Therefore, the previous studies were oriented to specific aspects of sport tactics (11 on 11, 3 on 3, 1 on 1, etc.) whereas the live setting used in the current study started with a 2 on 3 situation (see Fig. 2) and evolved to a 1 on 1 situation at the conclusion. The above highlights a potential limitation of the visual search paradigm where the researcher has no choice but to pre-select scenes which by their very nature may limit the responses of the participants. One of the advantages of the vision-in-action approach used here, is that the whole play is performed by the athlete and therefore changes in gaze behaviour can be monitored as changes in context occur over time.

Earlier it was shown that the highly skilled performer has developed the ability to adapt their gaze to rapidly changing conditions that occur late in the action (Land & McLeod, 2000). The current study did not find any adaptive qualities in the athlete's vision late in the action, but this may have been due the opponents not being allowed to take shots on the goal. The adaptive quality of the gaze may be found in conditions where this part of offensive play is allowed.

Our results therefore revealed that two distinct types of gaze control used in sport tactical skills that differed from that reported previously in closed skills, as well as gaze differences which distinguished the E from NE players. The E player is more adept at rapidly fixating or tracking cues early in the play, but both E and NE employed a F/T-1 of long duration to bring the play to an end. The early and rapid F/T agrees with the previous work of Lum, Enns, and Pratt (2002) who found that those who routinely face varying attention-demanding situations develop an ability to decrease attention durations more so than those who are exposed to non-varying attentional demanding tasks. Similar findings have also been found for high skilled over lesser skilled performers in other studies (Anzeneder, Boesel, Kortmann, & Muecke, 1997; Castiello & Ulmita, 1992; Enns & Richards, 1997; Nougier, Azemar, Stein, & Ripoll, 1992; Nougier, Stein, & Azemar, 1990; Nougier et al., 1996).

4.2. Potential theoretical significance of the research

In this section we speculate on the theoretical significance of our results, drawing especially upon Ericsson and Kintsch's (1995) long term working memory (LT-WM), Klein's (1999) RPD model to provide additional insights, as well as the notion of a quiet eye (Vickers, 1996). In open sports like ice hockey, soccer, or basketball, expertise differences normally emerge under critical levels of temporal pressure and forced choice (Ripoll, 1991). Our results suggest that when critical levels of temporal pressure are reached in open tactical environments, the E player is able to efficiently and rapidly encode object-based cues using a series of quick F/T to discrete locations. The ability to read the available cues rapidly during the early part of the play may have contributed to gains in the E's skating time and maintenance of critical object-based information in the final 1 on 1 assignment. In Ericsson and Kintsch's (1995) LT-WM theory, an expert's superior cognitive level of performance is attributed to their ability to rapidly encode and retrieve information from long-term memory (LTM). As skill develops, performers extend traditional short-term memory (STM) limitations by cue-based retrieval mechanisms linked directly to stable memory structures in LTM. Over years of extended practice, these directly accessible episodic memories are quickly re-instated in the focus of attention to ensure a coherent memory representation in building comprehension in task constraints. If the episodic memory is integrated, coherent, and leads to a sense of typicality (Klein & Hoffman, 1993), Ericsson and Kintsch (1995) propose that access to LTM might be performed approximately in a single retrieval operation at speeds comparable to those found in STM. If, however, an individual does not have sufficient task related experience as was the case with the near-experts in the current study, the information-based retrieval mechanism in short term working memory (ST-WM) may be lost as further processing resources from the slower LTM system may be invoked to build situation awareness (Miller & Kintsch, 1980).

According to Ericsson and Kintsch's (1995) if early attention and cognitive processes are interrupted and diverted toward another attention demanding task, the interruption could possibly result in the loss of transfer key object-based information from ST-WM to LT-WM. If however, subjects have extensive experience on the task constraints, information in LT-WM would not become inaccessible and could be retrieved. Ericsson and Delaney (1999), suggest that when a skilled activity is interrupted and is then "successfully resumed later, it strongly suggests that the cognitive state just prior to the interruption can be regenerated – at least in all important aspects – at the time the activity is subsequently resumed" (p. 267). The E groups use of short F/T early in the play may be symptomatic of LT-WM retrieval structures that facilitate typicality early in the decision-making processes.

This process is also central to the characteristics of RPD model (Klein, 1999). In this perception-oriented model, experts are more efficient in recognizing the familiarity in critical cues from LTM and implementing the most appropriate action (Klein, 1999). In the simplest form of the RPD model (variation one or the PR phase of the current study), perceptual cues are quickly recognized and the most obvious solution is quickly implemented (to initiate skating). In more complicated forms of the RPD model (variation two), the decision-maker's continual on-line monitoring of environmental characteristics, called situation assessment, is critical in determining a reasonable course of action. The RPD model assumes that it is the decision-maker's situation assessment ability, rather than their comparative analysis of a number of plausible alternatives, that is critical in understanding typicality and solving the decision problem (Endsley, 1997). The groups did not differ in the number of F/T used and their search rates were very similar, but the E groups significantly faster F/T-6 and F/T-5 durations during successful plays lend credence to this notion. In other words, an expert's decision-making ability is reflected in a tighter coupling between perception and action (Charness, 1981) than the near-experts. Klein and Hoffman (1993) suggested that the ability to judge typicality from object or contextually based cues in naturalistic environments is an acquired skill that separates many experts from non-experts.

> By quickly seeing which goals are feasible, experts can direct their actions and not waste any effort. By recognizing which cues are relevant, experts can avoid information overload. By anticipating what events to expect, experts can rapidly notice if they have misperceived a situation. And by recognizing a typical course of action, experts can respond rapidly. This type of recognitional decision-making enables experts to handle complex cases under time-pressured conditions where analytical methods would not be possible (p. 211).

In ice hockey defensive tactics, the E athlete appears to operate similar to highly experienced decision makers, as reported in other open naturalistic decision making environments. By quickly detecting relevant cues that are critical in framing problems, decision-makers continually build situation awareness until a satisfactory amount of information is obtained to implement an acceptable solution. This 'satisficing' (Simon, 1955) decision strategy, which is not based on an optimizing solution but one that is considered to be good enough as a solution to the current decision problem (Orasanu & Connolly, 1993) permits the E ice hockey player to identify the course of action serially in light of the evidence perceived. If the option is not acceptable, the next best option is then generated as a solution to the problem. The power of this recognition solution process in team tactics is that it gives decision-makers the ability to perform rapid and efficient decision-making processes based on a cue or pattern matching from LTM, an approach similar to Ericsson and Kintsch's (1995) theory of LT-WM.

Our results also showed that the early and rapid F/T-9 to F/T-2 culminated in a final sustained F/T-1. The long duration of F/T-1 at the conclusion of the play had three of the same characteristics of the quiet eye period as reported in closed skills: it was of longer duration; it was directed to a single location (albeit the moving offensive player or puck); and it occurred prior to the final action. F/T-1 was also longer for the E than NE (see Fig. 4), and was longer on plus than on minus plays (but not significantly so). When an athlete is given the task to defend against an opponent (as in the current study) each attempt by the opposition is countered through the use of specific defensive strategies that require each defensive player assume an assigned role relative to a final targeted opponent. We speculate that sport defensive tactics requires the athlete define a single target, and method by which this is done, at least in part, is through the use of a sustained F/T-1, or quiet eye to one location. The earlier a defensive player can correctly isolate the opponent perceptually, then the more this is reflective of good decision making and the sooner is the challenge stopped.

Of the two types of gaze control found, it is tempting to speculate which is the most important in tactical success – the early rapid F/T or the late F/T-1. Given the weight of evidence in the current study, it appears that the early rapid F/T is the greater predictor of expertise in sport tactics, but more research will be needed to confirm this, especially that which allows (for example) shots to be taken on goal. In conclusion, we speculate that a *quick then quiet* cascade of F/T defines expertise in sport tactics, as this combination of gaze behaviours allows the athlete to rapidly access contextual information from LTM (Ericsson & Kintsch's, 1995; Klein, 1999), build an early and 'satisficing' (Simon, 1955) situation assessment, and then use a stable object-oriented quiet eye (Vickers, 1996) to effectively control the opponent at the conclusion of the play.

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