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SPORT AND EXERCISE PSYCHOLOGY

Scanning is associated with better performance in professional ice hockey

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ABSTRACT

Although active exploration of environmental information is essential for specifying one's action opportunities in team sports, knowledge about the relationship between visual exploratory behaviour and successful actions in ice hockey is scarce. The purpose of this study was to investigate whether scanning prior to pass reception was associated with a higher probability of a successful outcome of the following action among professional ice hockey players. A total of 43 male and 45 female ice hockey players participated in the study. Observations from 22 filmed ice hockey matches from the top Swedish male and female Hockey League (SHL and SDHL, respectively) were included in the study, generating a total of 2,545 actions that were included for analyses. In line with previous research on elite soccer players, the results showed that scanning before receiving a pass increased the probability of a successful subsequent action ($\beta = 0.12$, 95% CI = [0.07, 0.17]). Neither gender nor position moderated the relationship between scanning and the probability of a successful outcome. We suggest it is important to acknowledge the benefits of scanning within player education, while also providing concrete training methods so that players can develop their ability to scan before receiving the puck.

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Ice hockey; visual scanning; expertise; perception

Introduction

In dynamic team sports with strict spatiotemporal constraints, such as ice hockey, players' ability to acquire relevant visual information from the environment, and then successfully execute appropriate actions based on the information gathered, is a significant marker of expertise (Mann et al., 2019). Drawing on concepts from ecological frameworks of perception and action, research has been focused on how athletes move their body and head to *scan* the visual environment and prospectively guide their actions during actual game play (e.g., Aksum et al., 2021; Jordet, 2005a; Jordet et al., 2020). While this research has predominantly been conducted on male soccer players, the use of such in situ scanning behaviours among professional male and female ice hockey players is yet to be explored. Such research could extend the knowledge about scanning behaviours and individual performance of professional male and female ice hockey players in real-world competitive settings.

As summarised in the Gibsonian maxim "We must perceive in order to move, but we must also move in order to perceive" (Gibson, 1979, p. 223)' ecological psychology holds that perception and action is a cyclical process involving active bodily movements to obtain environmental information, which helps specifying one's opportunities for action (Gibson, 1979). Yet, most research on how athletes acquire and use environmental information during performance has been conducted using video-based paradigms under highly controlled laboratory conditions (Mann et al., 2019). By means of online eye-movement recordings (e.g., Roca et al., 2018), retrospective verbal reports (e.g., Natsuhara et al., 2020), and systematic manipulations of the visual scene (e.g., Ryu et al., 2015), this research affords valuable insights into how athletes of different skill-levels use foveal and peripheral vision during performance. However, a problem with such video-based protocols is that the complexity of the performance environment is being reduced to visual information projected on a screen in front of the participant. This neglect of the multifaceted nature of the information present under naturalistic performance conditions – especially those of invasive team sports, where opportunities for action rapidly evolve 360° around the player – may limit the transferability of findings to real-world competitive settings (Dicks et al., 2010, 2019; van der Kamp et al., 2008).

Another, more naturalistic, approach that has been adapted to study the relation between visual exploration and performance in soccer focuses on the scanning actions (e.g., turning the head) that the players perform to update their visual field during actual game play. Jordet (2005a) used high-zoom video cameras to film professional soccer players during live games to examine the players' scanning behaviours before receiving the ball. The results indicated that, for midfielders, successive scanning of areas of the field behind one's back was necessary to perceive and successfully act upon information in these areas. Furthermore, by analysing 1,279 game situations with 118 professional midfielders and forwards in soccer, Jordet et al.

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(2013) demonstrated that players who had received prestigious awards (e.g., FIFA World Player of the Year) exhibited a higher scanning frequency than non-award-winning players and that scanning frequency was positively correlated with pass completion. Using similar data collection approaches, the positive relation between scanning prior to ball reception and the success of subsequent action outcomes has been replicated in several studies on elite soccer players (e.g., Aksum et al., 2021; Caso et al., 2023; Feist et al., 2024; Jordet et al., 2020; Phatak & Gruber, 2019). Moreover, it is suggested that the scanning behaviours exhibited by players may vary with the type of action performed following ball reception, as well as several contextual factors, such as positional role, field location, game state, and opponent pressure (Aksum et al., 2021; Jordet et al., 2020).

Ice hockey shares the dynamic and temporally constrained nature of soccer, where players must actively search for action-specifying information, such as the spatial relations between teammates and opponents, in an ever-changing performance environment. Thus, it would be expected that the positive association between scanning and performance reported in soccer also would apply in professional ice hockey. However, the reported influence of action type and contextual factors on scanning behaviour in soccer – factors that naturally differ between soccer and ice hockey – calls for further exploration of the relation between scanning behaviours and performance in professional ice hockey. For example, in soccer, central midfield and defensive playing positions are associated with higher scanning frequencies than positions closer to the opponent's goal (Caso et al., 2023; Feist et al., 2024; Jordet et al., 2020) and positions wider in the field, and players tend to scan more often prior to passing the ball, compared to dribbling and shooting (Feist et al., 2024; Jordet et al., 2020). As the positional roles within a team as well as the technical aspects of the game actions performed following ball/puck reception differ across sports, findings regarding the influence of contextual factors on the relationship between scanning and performance in soccer may not be applicable within the game of ice hockey. Furthermore, protective head equipment, such as the helmet and visor used in ice hockey, may result in reduced visual field (Wilkins et al., 2019), decreased eye-hand coordination (Kramer et al., 2021), and decreased responsiveness to visual stimuli (Kramer et al., 2017). Thus, differences in equipment constraints between soccer and ice hockey may also influence the relationship between scanning and performance during the game.

Another aspect that must be considered when studying the processes of utilising visual information is the potential influence of gender differences in basic perceptual and cognitive performance, such as visual motion processing (Murray et al., 2018). Therefore, the aim of this study was to explore how professional male and female ice hockey players in different positional roles use scanning behaviours in real competitive games. More specifically, we examined the relation between scanning prior to pass reception and the probability of a successful outcome of the following action, and whether this relation was moderated by gender and positional role.

Methods

Data and participants

Participants were 88 professional ice hockey players aged 16–36, representing five teams. The teams were randomly selected by representatives from the Swedish Ice Hockey Association. Among the participants, 43 were male players (*M*age = 28.57, *SD* = 4.20) competing in SHL (Svenska Hockeyligan) and 45 (*M*age = 22.32, *SD* = 3.94) were female players competing in SDHL (Svenska Damhockeyligan). The data consisted of 2545 individual players' puck possessions and were retrieved from publicly available TV broadcasts of 22 official league games; hence, no written consent was necessary.

Procedures

TV broadcasts of entire matches were obtained by the Swedish Ice Hockey Association (SIHA). Matches were imported into and hand-tagged using the video analysis software program Dartfish 10. A tagging panel was created intending to identify scanning, performance, context, and player-related variables. All sequences were analysed frame-by-frame to allow for the accurate evaluation of the abovementioned factors.

Coding was initiated by tagging every pass reception (by players belonging to the team included in the study) in each period of a game, which automatically produced a new sequence starting 5 s before the pass reception. This time interval was set based on previous studies with a similar setup carried out on soccer (Jordet et al., 2020) where an interval of 10 s before receiving a pass was used to detect scans. Research has, however, shown differences in pace between soccer and ice hockey. National Hockey League (NHL) players spend, for example, approximately 50% of the total distance above the high intensity skating threshold (>17.0 km/h; Lignell et al., 2018). Soccer players, on the other hand, cover most of their total distance with moderate intensity with only ~10% of the total distance above the high-intensity threshold (>19.8 km/h) (Dolci et al., 2020; Oliva-Lozano et al., 2021). After considering these statistics and consulting SIHA, we decided that an interval of 5 s was more appropriate, as the game situations change at a much higher pace in ice hockey than in soccer. In contact with SIHA, the head of education and the video coach of the national team were asked to provide their opinion about the sufficient time frame.

The sequences were then analysed based on predetermined inclusion criteria, where sequences that did not meet these criteria were excluded from further analysis. Sequences were excluded if: (a) the receiving player was not in the picture during the 5 s before receiving the puck; (b) the receiving player's team was not in possession of the puck during all of the five seconds before receiving the puck; (c) the receiving player had already had the puck within the five seconds before receiving it; (d) the image clarity was too low (i.e., the quality of the recording made it impossible to determine if a scan was performed within the frame-by-frame review; cf. Caso et al., 2023), or when the sight was covered (e.g., when the receiving player was blocked by another player) so that it could not be

determined with certainty when the puck reception took place or if scanning occurred.

For all sequences that met the inclusion criteria, continued coding was carried out. The coding followed a set flow, with the first tag set by specifying the player ID and game time of the pass reception. This was followed by specifying if scanning occurred before receiving the pass and if the player was pressed by an opponent. The coding was finalised by specifying the action performed after receiving the pass, the action outcome, and if there was subsequent body contact with an opponent.

To develop an efficient working procedure and to ensure an acceptable level of agreement between all coders (A.B, J.M, A.J. & L.S.), several tests of the tagging procedure were carried out before data collection began. In the test phase, six periods were coded independently by two pairs of coders, after which the results for the variables were compared for each period. In this phase, a total of 1487 sequences were coded, representing ~58% of the total sequences analysed (cf. 10% in Aksum et al., 2021; 10% in; Caso et al., 2023; 8% in; Jordet et al., 2020). Based on these comparisons, the tagging protocol was revised and refined to minimise the risk of interpretation differences. Individual coding and data collection commences when a stable agreement within the pairs of coders of at least 80% was achieved for all variables (e.g., Hrycaiko & Martin, 1996). Within the test phase, the agreement between the two pairs of coders was 86% and 88%, respectively. During the individual coding phase, sequences where there was any uncertainty about the coding of the number of scans were jointly reviewed before the sequence was approved and added to the data set. More specifically, the sequence was only included after the coders had agreed on the number of scans within a sequence. Sequences that could not be elucidated were discarded.

Scanning

A scan was defined as a clear head movement in which the player's face, and thus the direction of gaze, was temporarily turned away from the position of the puck/puck holder, with the implied purpose of gathering information about the positions of teammates and opponents (cf. Jordet, 2005b). To be counted, scanning was required to take place in at least 20 hundredths (5 frames). If such behaviour was observed during the 5 s before receiving a pass, this was coded as a scanning behaviour (cf. Jordet et al., 2020). Initially, we coded the frequency of scanning behaviours. Given that most sequences (71%) only included none or one scan we decided to use a dichotomous variable (scanning vs. no scanning). An additional reason for treating the data as a dichotomous variable was the large skewness of the variable (Skewness *z*-score = 13.86). This procedure has been performed also in other studies (Eldridge et al., 2013).

Game time

Game time was determined by the period of the match (1st, 2nd, or 3rd) in which the pass reception took place. In addition, the following time interval (1–4) within the period was logged for each pass reception: 1 = 00:01–04:59, 2 = 05:00–9:59, 3 = 10:00–14:59, 4 = 15:00–20:00.

Positional role

The positional roles the players receiving the puck were categorised as defenceman, centre forward, and wing forward. This categorisation was based on the respective team's official match line up. No consideration was given to where the player was positioned when receiving the puck.

Opponent pressure

By coding the variable opponent pressure with yes/no, it was noted whether the player was exposed to pressure from one or more opponents at any time from receiving the puck until the subsequent action was performed. Pressure was defined as having one or more opponents within a stick-length distance at any time during the 5-s time frame.

Close combat

Close combat was defined as the player receiving the puck and an opponent having body contact at some point in connection with reception/possession of the puck or the following action.

Performance

In the current study, a successful outcome of the following action, after receiving the puck, was determined based on the following criteria, formulated in consultation with SIHA:

- Passing – playing the puck to a teammate with enough precision for him/her to receive it.
- Shooting – a shot fired with the direction of the opponent's goal net,
- Stick handling – shifting to a new position while maintaining control of the puck for at least three seconds
- Deflecting – redirecting the course of the puck after it has been shot by a teammate with the purpose of scoring a goal.
- Shielding the puck – preventing opponents from gaining control of the puck by placing himself/herself between the puck and the opponent for at least 3 s after receiving it.
- Dump and chase – dumping the puck to a part of the rink where no player is at the time but resulting in a teammate regaining control of it within 5 s.

In the statistical analyses all these actions presented above was collapsed into one variable. The reason for this decision was to increase the statistical power of the analyses.

Statistical analyses

To investigate the relation between scanning and probability of a successful outcome of the following action, we applied a Bayesian two-level logistic regression model using Mplus, version 8.3. The relation between scanning and the probability of a successful outcome of the following action was specified at the within-person level (Level 1), which also included game time, close combat, and opponent pressure as covariates. Gender and positional roles were included as moderators of

the relation between scanning and probability of a successful outcome of the following action at the between-person level (Level 2).

We applied the Bayesian framework for all statistical analyses. One main difference between the Bayesian statistical approach and the more traditional frequentist approach is that they are based on different statistical assumptions (e.g., Stenling et al., 2015). In comparison to the frequentist approach one of the advantages with the Bayesian approach is that it has an increased likelihood of producing reliable estimates with small sample sizes (Song & Lee, 2012). More specifically, due to the less restrictive distributional assumptions the normality assumption is not needed to be fulfilled to perform the analyses within the Bayesian approach (Yuan & MacKinnon, 2009).

We used the Markov Chain Monte Carlo simulation procedures with a Gibbs sampler and performed 200,000 iterations and a potential scale reduction factor around 1 was considered as an indicator of convergence (Kaplan & Depaoli, 2012).

We estimated a credibility interval (CI) for all parameters within the models. In comparison to the more traditional confidence interval, the credibility interval indicates the probability (e.g., 95%) that the parameter of interest, given the observed data, lies between the two values. The recommendations from Zyphur and Oswald (2015) were followed, meaning that we rejected the null hypothesis if the 95% CI did not include zero.

Results

On average, the players in the study performed 1.48 scans (±1.01) in the last 5 s before receiving the puck. Of the 2545 sequences analysed, ≥1 scans were recorded in 61% of cases. Females performed 1.55 scans/5 seconds (±0.76) while males performed 1.39 scans/5 s (±1.24). Also, defensive players performed, on average, more scans ($M = 1.60 \pm 0.82$) compared to offensive players ($M = 1.43 \pm 1.00$).

The distribution regarding successful/unsuccessful actions was 1,916 (75%)/629 (25%). The proportion of unsuccessful actions was slightly higher for female players (26.1%) in comparison to male players (21.6%). When the participants scanned before receiving the puck, the success rate was 78.8%. In comparison, the success rate for the sequences without scanning was 70.1%, indicating a difference between the two types of sequences of 8.7% (95% CI = [5.3%, 12.1%]).

The two-level regression analysis showed that scanning was, at the within-person level, associated with a higher probability of a successful outcome of the following action ($\beta = 0.12$, 95% CI = [0.07, 0.17]). It was also a higher probability of a successful outcome of the following action in sequences where: (a) the player did not have any opponent pressure ($\beta = -0.11$, 95% CI = [−0.16, −0.06), and (b) there was no close combat with an opponent ($\beta = -0.18$, 95% CI = [−0.22, −0.13). There was no association between the time the sequence was obtained in the game and the probability of a successful outcome of the following action ($\beta = 0.03$, 95% CI = [−0.02, 0.08]).

At the between-person level, there were no moderating effects of gender ($\beta = 0.09$, 95% CI = [−0.56, 0.61]) or player position ($\beta = -0.31$, 95% CI = [−0.90, 0.32]) on the relation between scanning and the probability of a successful outcome of the following action.

Discussion

The purpose of this study was to investigate the relation between scanning prior to pass reception and the probability of a successful outcome of the following action during competitive games in professional ice hockey, when controlling for opponent pressure, close combat, and time in the game. Additionally, we examined the moderating effects of gender and positional role on this relation.

The results showed that the probability of a successful outcome of the following action increased when the player performed at least one scan prior to pass reception. This finding aligns with the positive association between scanning prior to ball reception and performance of subsequent ball actions observed among elite soccer players (e.g., Aksum et al., 2021; Jordet et al., 2020; Phatak & Gruber, 2019). While ice hockey and soccer differ in several aspects (e.g., positional roles, technical demands, and equipment requirements), both sports share an ever-changing and fast-paced performance environment. In accordance with the ecological view of a cyclical relationship between perception and action, where opportunities for action constantly evolve with the momentary changes in environmental information inherent in the game, it makes sense that engaging in extensive visual exploration through scanning facilitates the regulation of prospective actions during the game (Fajen et al., 2008). In other words, turning the head to discover pertinent environmental properties (e.g., an emerging gap between a teammate and an opponent) before receiving the puck likely helps the player to successfully act upon this information (e.g., perform an accurate pass to the teammate in a timely manner).

Positional role did not moderate the positive relation between scanning and performance, suggesting that the performance benefit of scanning prior to pass receptions is not contingent on whether the player is lined up as defenceman, centre forward, or wing forward. In soccer, it has been shown that central defenders and midfielders exhibit more scanning actions, compared to wing players and central forwards (Aksum et al., 2021; Caso et al., 2023; Feist et al., 2024; Jordet et al., 2020). Aksum et al. (2021) argued that these position related difference may be explained by the fact that wing players typically operate under more restricted space constraints (i.e., near the sidelines, where they do not have to scan for information in all directions; see also Jordet et al., 2020) and the fact that defenders, generally, have more time with the ball upon reception, which enables them to engage in more extensive visual exploration, compared to players in more time-pressured situations higher up in the field (see also Eldridge et al., 2013). However, due to fewer players and a smaller field of play, where all players often operate in all three zones of the ice hockey rink, it is possible that the spatial and temporal constraints do not differ as much across positional roles in ice hockey and, as such, scanning prior to pass reception is equally advantageous regardless of the positional role of the player.

Neither did gender moderate the relationship between scanning and the probability of a successful outcome of the following action among the players, which suggests that scanning prior to pass reception in professional ice hockey is equally beneficial for males and females. While gender differences have been detected on basic perceptual and cognitive tasks, such as faster visual motion processing among males than females (Murray et al., 2018), our findings imply that any such differences do not seem to influence the positive association between scanning and the probability of a successful outcome of the following action in professional ice hockey.

Limitations

There are several limitations important to acknowledge in relation to the study. First, scanning behaviour was registered during a 5-s interval before receiving a pass, while no track of the time between the reception of the pass and the subsequent action was considered. The time between scanning and the pass reception as well as the subsequent action could therefore vary from situation to situation. More specifically, players in different situations had varying possibilities to scan their surroundings after receiving the pass, which in turn could influence the outcome of the action. Furthermore, passes were all registered as one homogeneous action, regardless of difficulty related factors such as direction and length of the pass, which potentially could affect the probability of a successful outcome. Future studies should therefore further explore the association between scanning and the probability of successful actions while taking into consideration the effects of the proximity between scanning, the pass reception, and the subsequent action, as well as the difficulty of the pass.

Second, in our analysis, scanning was registered as a dichotomous variable (yes or no). The reason for this decision was that a large majority of the sequences only contained one scan. This means that we cannot say whether a higher scanning frequency would be more beneficial compared to a lower one.

Third, games were played at different venues where tv-productions varied in terms of camera position in relation to the ice. Camera changes, zoom-ins, and camera panning used to cover game actions meant that players went in and out of the picture during the game. As a result, sequences in which the receiving player was not in the picture during all the 5 s before receiving the pass could not be used for analysis.

Practical implications

The result from the study indicates that scanning is beneficial for in-game performance. It is therefore important for coaches to underline the importance of such behaviours, both in practice and in games. Based on the results we recommend that, because scanning is a deliberate behaviour, coaches should emphasise this within regular practice by, for example, design practice activities where such behaviours are warranted. From an ecological psychology perspective, such activities should be characterised by representative task designs that place dynamically interlinked demands on the player's perceptual, technical, and tactical abilities during task performance. Furthermore, previous studies within soccer have shown that scanning behaviour might be increased using relatively short imagery training interventions (e.g., Jordet, 2005b; Pocock et al., 2019). It is, therefore, suggested to implement training methods aimed to improve scanning behaviours from a relatively young age to increase the chances of successful scanning behaviour.

Conclusions

This study affords novel insights into the relation between scanning and performance during competitive games in professional ice hockey. Specifically, we provide the first empirical evidence that scanning prior to pass reception is associated with a higher probability of a successful outcome of the following action with the puck. Furthermore, we show that neither gender nor positional role seems to moderate this positive relationship between scanning and the probability of a successful outcome of the following action. We suggest that it is important to acknowledge the role of scanning in coach and player education; both by providing information about the benefits of scanning, as well as by creating training methods through which players can develop their ability to scan before receiving the puck. To overcome the limitations of using TV broadcasts for gathering behavioural data from players during a match (e.g., poor image clarity, the receiving player being outside the visual display, or the receiving player being blocked by others), future studies should employ recording solutions that are tailored to the purpose of the study. These solutions include on-site recordings operated by the research team (see Aksum et al., 2021; Jordet et al., 2020).

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Data availability statement

The data presented in this study are available on request from the corresponding author.

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