Pattern recall skills of talented soccer players: two new methods applied

Abstract

In this study we analyzed the pattern recall skills of talented soccer players by means of two innovative methods of analysis and gaze behavior data. Twenty-two young female soccer players watched video clips of 3 vs. 3 small-sided games and, after occlusion, had to reproduce the positions of the players. Recall performance was measured by calculating the spatial error of the recalled player positions at the moment of occlusion and at consecutive 33 ms increments. We analyzed player positions relative to each other, by assessing geometric pattern features in terms of angles between players, and we transformed the data into real-world coordinates to exclude the effects of the 2D perspective in the video clips. The results showed that the participants anticipated the movements of the patterns. In real-world coordinates, the more experienced players anticipated the pattern further in advance than the less experienced players and demonstrated a higher search rate, a shorter fixation duration and a higher fixation order. The differences in recall accuracy between the defensive and offensive elements were not consistent across the methods of analysis and, therefore, we propose that perspective effects of the video clip should be taken into account in further research.

Key words
Pattern recall
Anticipation
Expertise
Gaze behaviour
Methods of analysis

Introduction

It has been well established that skilled athletes possess better perceptual-cognitive skills than their less skilled counterparts (Helsen & Starkes, 1999; Vaeyens, Lenoir, Williams, Mazyn, & Philippaerts, 2007; Vaeyens, Lenoir, Williams, & Philippaerts, 2007; Williams & Grant, 1993; Williams, Ward, Knowles, & Smeeton, 2002). Those skills include the ability to pick up advance information from an opponent's postural orientation prior to a key event such as racquet-ball or foot-ball contact (Savelsbergh, Van der Kamp, Williams, & Ward, 2005; Ward, Williams, & Bennett, 2002; Williams & Burwitz, 1993), enhanced knowledge of situational probabilities (Ward & Williams, 2003; Williams, 2000), more effective and efficient visual search strategies (Helsen & Starkes, 1999; Savelsbergh, Haans, Kooijman, & van Kampen, 2010; Williams & Davids, 1998) and better abilities to recognize or recall patterns of play (Gorman, Abernethy, & Farrow, 2011, 2012; Williams, Davids, Burwitz, & Williams, 1993). For example, in the study of Williams et al. (1993) experienced and inexperienced soccer players had to recall the positions of the players after viewing video clips of structured and unstructured soccer game situations by pressing the mouse key on the correct locations in a computer-generated image of a soccer field. The findings showed that the experienced soccer players recalled the positions of the players more accurately than the novices, but only for the structured trials.

A question that is often raised is what the purpose is of recalling patterns after watching video footage, since this task is rarely directly required in the sport domain (Williams & Ericsson, 2005). One answer is that the ability to recall the locations of teammates and opponents in ball games assists players to predict the next likely situation and thereby helps to decide upon the best response. For example, the player in possession of the ball uses the information about the positions of the other players to predict the movements of these players and to decide whether to dribble, pass or shoot (Gorman et al., 2013b). Thus, pattern recall may serve an anticipatory function, it allows expert players to predict future situations based on the current configuration of players. Accordingly, De Groot (1965) reported that when expert chess players viewed structured chess board configurations and made mistakes in recalling the positions of the chess pieces, they incorrectly placed the pieces in positions that were possible.
subsequent moves. Therefore, De Groot (1965) concluded that pattern perception may involve the encoding of the spatial and functional relationships between the elements.

Direct evidence for the anticipatory function of pattern recall has been found by Gorman et al. (2012, 2013b; see also Didierjean & Marmèche, 2005; Gorman et al., 2011). In their studies, expert and novice basketball players watched static images and moving video clips of structured basketball game situations. Directly afterwards, the video clips were occluded and replaced with an image of a blank basketball court. The participants had to reproduce the last seen positions of the players by dragging Xs and Os (representing defenders and attackers, respectively) onto the image of the court. Gorman et al. (2012, 2013b) compared the pixel coordinates (in percentage of screen size) of the response patterns entered by the participants with the coordinates of the actual player locations both at the final frame presented (i.e., traditional recall score) and at 50 successive 40 ms increments thereafter. The closest match between the entered and actual patterns was identified for each participant and indicated the anticipatory recall score. The moment at which the closest match occurred was named “advance” and measured in ms. The findings revealed that experts were more accurate than novices, but more interesting was that the response patterns of the participants had closer matches with the actual patterns in successive frames of the final frame than with the final frame itself, that is, the anticipatory recall scores were better than the traditional recall scores. The average advance score of expert basketball players on dynamic video clips was 185 ms and was higher than that of the novices. Gorman et al. (2012) concluded that experts use an anticipatory encoding process and therefore suggested that many previous studies may have underestimated the pattern recall accuracy of experts and that anticipatory encoding is likely to play an important functional role in decision making in the complex and time-stressed environment of team ball sports.

An important issue in the studies on pattern recall skills in sports lies in how the pattern recall accuracy was calculated. In previous literature, pixel coordinates of the 2D video image were used (Gorman et al., 2011, 2012, 2013a, 2013b; Williams et al., 1993), but the 2D perspective of the video images of the actual 3D situations may have affected the results. When analyzing in pixel coordinates, spatial errors close to the camera (i.e., low in the image) yield similar inaccuracies as spatial errors further away from the camera (i.e., high in the image), while in the real-world the actual error further away from the camera is much larger (see Figure 2.2). In other words, a one pixel error in the near field may reflect an actual spatial error of 5 cm, while a one pixel error far away in the field may actually reflect a spatial error of 50 cm (numbers are just examples). In their study on recall performances of soccer players, Williams et al. (1993) found that both experienced and inexperienced soccer players made smaller vertical errors than horizontal errors. They argued that this was due to the fact that the 2D film display compressed the playing area in the vertical field and thus minimized the possibilities of recall errors. In this study we wanted to correct for this perspective bias and therefore introduced two new methods of analysis.

The aims of the current study were to replicate the findings of Gorman et al. (2012) with soccer players by using both the traditional and anticipatory method of analyzing pattern recall accuracy, to apply our new methods of analysis, and to examine whether differences among a group of talented soccer players could be determined. We wanted to extend the research by also including gaze behaviour measurements to examine differences in visual search strategies.

One method we introduced to analyze pattern recall accuracy is to analyze player positions relative to each other instead of in absolute positions of the separate players, because these relations among players may be more important for pattern recall skills than the exact positions of the individual elements. If, for example, a participant reproduced the positions of all players 5 cm to the left, the former ways to analyze pattern recall accuracy (as used by Gorman et al., 2012) would result in an inaccuracy score, however, the pattern of the players was actually correct. In our new innovative method, we calculated the angles between the attackers and defenders separately and the angle between the attacking pattern and the defensive pattern, and in this way the accuracy of the geometric features of the patterns are assessed and the effects of translation, rotation and scaling were ignored.

The second new method concerned computing real-world coordinates instead of pixel coordinates in percentage of screen size (as done by Gorman et al., 2012), since we hypothesized that the 2D perspective of the video images of the actual 3D situations may have affected the results. We wanted to correct for this perspective bias and therefore, transformed the data into real-world coordinates in the current study, using a Direct Linear Transformation (Abdel-Aziz & Karara, 1971) and used these new real-world coordinates to examine pattern recall accuracy.

Using the old and new methods of analysis, we compared the first years of the talent program with the players who participated longer in the talent program (i.e., second and third years). Their difference in experience was one or two years, and is very small compared to the mostly used expert-novice paradigm (Williams et al., 2002). Gorman et al. (2011, 2012, 2013b) compared the pattern recall skills of experts and novices and found that expert basketball players were more accurate in recalling the patterns of play and encoded the patterns further in advance of their actual finishing point than did novices. In the current study no large differences were expected between the two experience groups, because all players are part of a quite homogenous group of highly talented soccer players (otherwise they would not be selected for the talent program). However, the analyses we did in the current study may reveal more subtle differences that otherwise may have remained hidden in studies that relied only on expert vs. novice comparisons.
Finally, we examined gaze behavior during the pattern recall task. In contrast to anticipation and decision making tasks, in which clear differences in visual search strategies have been found between skilled and less-skilled athletes (e.g., Savelsbergh et al., 2010; Vaeyens, Lenoir, Williams, & Philippaerts, 2007; Williams, Davids, Burwitz, & Williams, 1994), in pattern recall tasks visual search strategies have hardly been analyzed. The only exception, to our knowledge, is the study of Gorman et al. (2013a) in which differences in attention on the attacking or defending pattern of play were examined on pattern recall performances. Gorman et al. (2013a) found no significant differences in fixation locations between experts and novices and suggested that the better recall performances of the experts were likely to be the result of better utilization of the visual information than differences in visual search strategies. In the current study, we compared the gaze behavior of the less and more experienced players of the talent program and in addition, we investigated whether the demonstrated visual search strategies differ between trials that resulted in good pattern recall scores and trials that resulted in bad pattern recall scores to ignore the within participant variations.

In sum, we replicated the study of Gorman et al. (2012) on soccer players and expected to find a similar anticipatory effect on pattern recall in soccer players as Gorman et al. (2012) found for basketball players. We introduced two new methods of analysis and hypothesized that these new methods would give more realistic representations of the pattern recall skills of the participants than the former used method of analysis. With these new methods, we compared the more and less experienced players within a talent program and although all the players are part of the same talent program, we expected to find subtle differences between the two experience groups. We measured the gaze behaviour of the participants to examine the differences in visual search strategies between the more and less experienced players and between the good and bad trials. Based on the previous study of Gorman et al. (2013a), we hypothesized to find no significant differences between the more and less experienced players, but differences in visual search strategies between good and bad trials would be indicators of possible preconditions for pattern recall accuracy.

Figure 2.1. Examples of (A) the final frame from a test clip and (B) the corresponding response pattern in which Xs indicate defenders (or goalkeeper), Os indicate attackers and the little star indicates the ball.
Method

Participants
A total of twenty-two talented female soccer players participated in the experiment. All participated in the national soccer talent program in which players train about fifteen to twenty hours a week and play in a high level male competition for players under 14 years of age. Participants had a mean age of 16.4 years (SD = 1.14) and 9.8 years experience of playing in competition (SD = 2.27). The players who just entered the talent program (less experienced group) had a mean age of 15.6 years (SD = 1.19) and 8.4 years of soccer experience (SD = 1.95), whereas the players who participated in the talent program for the second (or more) year (more experienced group) had a mean age of 16.9 years (SD = 0.79) and 10.8 years of soccer experience (SD = 2.04). Independent t-tests revealed that the players of the more experienced group were significantly older and had more soccer experience than the players of the less experienced group, t(21) = 2.930, p < .05, r = .57 and t(21) = 2.525, p < .05, r = .52, respectively. The experiment was approved by the ethics committee of the local research institute and all participants gave their written informed consent prior to the experiment; parental consent was provided for players younger than 18 years.

Stimulus materials
The test footage was captured during three training sessions in which 3 vs. 3 small games were played (i.e., three attackers vs. two defenders and a goalkeeper); we chose to use small sided games since these are the basics of the soccer game according to the Dutch Royal Soccer Association (Dokter, 1993). The playing field measured 40 m in length and 25 m width, the attackers wore red shirts and the defenders wore blue shirts. The six players were instructed to start at specific locations and to play according to the official soccer rules, including offside. The video images were recorded with a Go-Pro Hero 3 camera (Black Edition, resolution 1920 x 1080, 30 Hz; Go-Pro, USA) that was fixed on a 2.5 m high platform (Showtec LTB-200/6 Lifting Tower, The Netherlands) behind the goal of the attacking team. The elevated filming position was used to give a good overview of the situation and to help the participants in perceiving depth. The recordings were cut into video clips of five to ten seconds, and all ended at a decisive moment in the game (i.e., the onset of a shot, pass or dribble). The area outside the playing field was made black in order to mask irrelevant distracting features (e.g., other players who waited for their turn). The video editing was done with Adobe Premiere Elements 9. The level of structure of the pattern of players in all video clips was rated by two highly experienced soccer coaches on a 10-point Likert-type scale. To ensure that the video clips contained representative structured game play, only clips with scores 7 or higher were selected (cf. Gorman et al., 2012, 2013b; North & Williams, 2008; North, Williams, Hodges, Ward, & Ericsson, 2009). Two clips were used as familiarization trials prior to the test and fourteen clips were selected as test stimuli; the test clips were displayed in random order across participants.

Procedure
The procedure that was applied to examine pattern recall accuracy was similar to that described by Gorman et al. (2012, 2013b). Participants did the test while seated in front of a large screen (i.e., the distance between the participant and the screen was about 2.5 m). A projector (ASK Proxima C175, resolution 1024 x 768) projected the video clips on the screen so that the image subtended a viewing angle of approximately 23° horizontally and 18° vertically.

The participants were fitted with the SensoMotoric Instruments (SMI; Teltow, Germany) Eye Tracking Glasses, a binocular eye tracking device that recorded eye movements at 24 Hz. A one-point calibration on a little cross in the center of the screen was performed before starting the experiment.

After instruction and the two familiarization trials, each test clip was displayed and immediately afterwards replaced with an image of a blank playing field. This image contained the exact same features as the test clip, only the players were erased from view and at the bottom of the screen three Xs, three Os and a little star were lined up, representing defenders, attackers and the ball, respectively. The task of the participant was to recall the last seen positions of the players by dragging the Xs and Os to the correct locations on the projected field. The participants were instructed to place the bottom of the symbols at the position of the feet of the players. The participants were free to adjust the locations of the symbols as many times as needed to reproduce the positions of the players. In addition, the position of the ball was reproduced by dragging the little star to the correct position. An example of a correctly reproduced playing pattern can be seen in Figure 2.1B. To avoid a possible speed-accuracy trade off, no instructions were given about the speed of response and consequently, no analysis was done on the speed of response.

Data analysis
Performance on pattern recall test was determined in a traditional and anticipatory way with a similar method as described by Gorman et al. (2012, 2013b). The dependent variable was response accuracy and measured in pixel coordinates, expressed as percentage of screen size. The responses of the participants were registered with E-prime 2.0.

Traditional recall accuracy
To assess the traditional recall accuracy score, the answers of the participants were compared to the correct values as indicated by an answer template. The pixel
provided the attack–defense pattern feature score. The attacking pattern feature score, other. The difference in the angle of the participant's response and the answer template resulted in a defending pattern feature score. The overall recall accuracy score was calculated as the average of the attacking and defending pattern. The lower the recall accuracy score, the better the participant recalled the positions of the players; a recall accuracy score of zero indicated a perfect match with the answer template. Trials in which the participant forgot to reproduce the position of one of the players were excluded from analysis (i.e., 2% of the trials).

Anticipatory recall accuracy
To examine whether and to which extent the participants anticipated the movement of the players, the anticipatory recall accuracy was calculated. Answer templates were created of the positions of the players in 60 subsequent frames after the final frame displayed (i.e., 33 ms increments), that is, two seconds following the occlusion point in the video clip. For each trial, the answers of the participants were compared to all answer templates to indicate the smallest recall score. These scores were then averaged to determine the anticipatory recall accuracy, the corresponding time index was called ‘advance time’ and measured in ms, similar to Gorman et al. (2012, 2013b).

Accuracy of pattern features
In addition to using the position coordinates of the separate players to calculate pattern recall scores, the features of the patterns were analyzed to examine whether the participants were able to recall the characteristics of the patterns. Therefore, the three angles between the three attackers (i.e., \(a_1\), \(a_2\) and \(a_3\) in Figure 2.2) and the three angles between the three defenders (i.e., \(d_1\), \(d_2\) and \(d_3\) in Figure 2.2) were calculated for the answer templates and the participants’ responses. The average difference in angles (i.e., between the participant’s response and the answer template) of the attacking elements resulted in an attacking pattern feature score and the average difference in angles of the defending elements resulted in a defending pattern feature score. The angle between the line through the two defenders (i.e., not the goalkeeper) and the line through the two most outside attackers (i.e., a-d in Figure 2.2), was calculated as a measure of how the defending elements and attacking elements were positioned relative to each other. The difference in the angle of the participant’s response and the answer template provided the attack–defense pattern feature score. The attacking pattern feature score, the defending pattern feature score and the attack–defense pattern feature score were calculated at the moment of video occlusion and for the 60 subsequent frames to assess ‘traditional’ and ‘anticipatory’ scores. In addition, the advance time was calculated to examine to what extent the participants anticipated the pattern features.

Recall accuracy in real-world coordinates
In the above mentioned methods, the coordinates of the positions of the players as indicated by the participants and in the answer templates were calculated as percentage of screen size on the basis of pixel coordinates. To use a more correct perspective we converted these raw pixel coordinates into real-world coordinates using Direct Linear Transformation (DLT method; Abdel-Aziz & Karara, 1971) that was performed with WiNanalyze (Mikromak, Berlin, Germany). Afterwards, a calibration check was done which resulted in an average deviation of the actual positions of the calibration points of 0.20 m (SD = 0.21 m) on a field of 40 x 25 m. The real-world coordinates were then used to re-calculate the traditional and anticipatory recall accuracy scores.

Gaze behavior
Due to malfunctioning of the eye-tracker (e.g., calibration problems), gaze behavior of only 13 participants (i.e., 7 of the less experienced group and 6 of the more experienced group) was available for analysis, varying from three trials up to the maximum of 24 trials per participant, eight participants had nine or more trials. All available gaze behavior data (of 119 trials in total) was analyzed frame-by-frame for the duration of the video clips. A fixation was defined as gaze maintained on any area of the video display for a period equal to or in excess of 251 ms or three sequential frames (cf. Savelbergh, Williams, Van der Kamp, & Ward, 2002; Vaeyens, Lenoir, Williams, Mazyn, et al., 2007; Vaeyens, Lenoir, 

\[
\text{Accuracy of pattern features} = \sqrt{(X_1 - X_2)^2 + (Y_1 - Y_2)^2},
\]

where \(X_1\) and \(Y_1\) were the coordinates of the symbols as positioned by the participant and \(X_2\) and \(Y_2\) were the coordinates of the symbols in the answer template.
Williams, & Philippaerts, 2007; Williams & Davids, 1998). Four dependent variables were assessed: search rate, fixation duration, fixation location and fixation order. Search rate is the number of fixations per second and was calculated for each trial by dividing the number of fixations by the length of the video clip. The mean fixation duration per trial was determined and the fixation location was calculated as the percentage of total viewing time spent on an area of interest. The ten areas of interest were: attacker in possession of the ball (AB), attacker without ball (A), defender (D), goal keeper (GK), ball (B), field/space (F), central spot in field/space (CF), attacker with ball closely marked by defender (AB/D), attacker without ball closely marked by defender (A/D) and other (O). The fixation order referred to the search strategy as used by the participants and was calculated as the number of times per second that participants alternated their gaze between the player in possession of the ball, some other area in the video clip, and back to the player in possession of the ball (cf. Williams & Davids, 1998; Williams et al., 1994). A randomly selected 10% of the trials were analyzed for a second time to assess intra-rater reliability; it was found that $\kappa = 0.93$. A second experimenter independently analyzed 10% of the trials (randomly selected) to determine inter-rater reliability, it was found that $\kappa = 0.80$; both indicate good to almost perfect agreements (Hallgren, 2012).

**Statistical analysis**

For each method of analysis (i.e., former method of analysis, geometric pattern features and realworld coordinates) a mixed design ANOVA was done on the pattern recall scores, in which the between-subject factor was Experience Group (less experienced group vs. more experienced group) and the within-subject factors were Anticipation (Traditional vs. Anticipatory) and Element (Defense vs. Attack). Significant interaction effects were followed up by Bonferroni corrected pairwise comparisons. Only those results that were related to the hypotheses are reported in the results section.

The advance times were analyzed for each method of analysis separately. To determine whether the advance times differed significantly from zero one-tailed $t$-tests were used. To examine the effects of element and experience group on the advance times, an Experience Group (less experienced group vs. more experienced group) x Element (Defense vs. Attack) ANOVA with repeated measures on the last factor was applied. A significant main effect of Element was found, indicating that the participants unknowingly anticipated the movement of the patterns. A significant main effect of Element was found, $F(1, 20) = 21.703, p < .001, \eta^2_p = .520$. The anticipatory recall scores were more accurate than the traditional recall scores, indicating that the participants unknowingly anticipated the movement of the patterns. A significant main effect of Element was found, $F(1, 20) = 102.706, p < .001, \eta^2_p = .837$: the defending elements were better recalled than the attacking elements, so the defense seemed easier to recall than the offense. There was no significant main effect of Experience Group, $F(1, 20) = .874, p = .361$. However, the Experience Group x Element interaction was significant, $F(1, 20) = 9.457, p < .06, \eta^2_p = .321$. Follow-up analyses showed that the anticipatory recall scores of the more experienced group were better than their traditional recall scores for both the defending ($p < .05$) and attacking ($p < .001$) elements. For the less experienced group there was no difference between the anticipatory or traditional recall scores. The defending elements were better recalled than the attacking elements by both groups and in both the traditional and anticipatory approach, all $ps < .001$.

Next, the gaze behavior of the participants was analyzed. The differences in search rate, fixation duration and fixation order between the the two experience groups were analyzed with multiple independent samples $t$-tests. To analyze the differences in fixation locations between the experience groups, a MANOVA was performed in which Experience Group was the fixed factor and the ten Fixation Locations the dependent variables. To examine the effects of different visual search strategies on pattern recall accuracy, the trials that resulted in pattern recall scores in the top half were compared with the trials that resulted in pattern recall scores in the bottom half. Independent samples $t$-tests were used to examine the differences between the good and bad trials for search rate, fixation duration and fixation order. A multivariate ANOVA, in which Trial (good vs. bad) was the fixed factor and the ten Fixation Locations the dependent variables, was used to analyze the fixation locations of the good and bad trials.

**Results**

Mean scores and SDs of the various recall accuracy scores are presented in Table 2.1.

**Former method of analysis**

A repeated measures ANOVA on the pattern recall scores with Experience Group as between-subjects factor and Anticipation and Element as within-subjects factors, revealed a significant main effect of Anticipation, $F(1, 20) = 21.703, p < .001, \eta^2_p = .520$. The anticipatory recall scores were more accurate than the traditional recall scores, indicating that the participants unknowingly anticipated the movement of the patterns. A significant main effect of Element was found, $F(1, 20) = 102.706, p < .001, \eta^2_p = .837$: the defending elements were better recalled than the attacking elements, so the defense seemed easier to recall than the offense. There was no significant main effect of Experience Group, $F(1, 20) = .874, p = .361$. However, the Experience Group x Element interaction was significant, $F(1, 20) = 9.457, p < .06, \eta^2_p = .321$. Follow-up analyses showed that the anticipatory recall scores of the more experienced group were better than their traditional recall scores for both the defending ($p < .05$) and attacking ($p < .001$) elements. For the less experienced group there was no difference between the anticipatory or traditional recall scores. The defending elements were better recalled than the attacking elements by both groups and in both the traditional and anticipatory approach, all $ps < .001$.

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1 An attacker closely marked by a defender was registered if there were no pixels visible between the attacker and the defender. The central spot in field (CF) was indicated if the participant located gaze on the center of the field when no player was situated there. The location ball (B) also indicated ball flight.
Chapter 2

Pattern recall skills of talented soccer players

Advance time

The mean recall accuracy scores by advance time are displayed in Figure 2.3. The advance times (i.e., the moment in time after the moment of occlusion at which the smallest recall accuracy was found) were significantly different from zero (i.e., the moment of occlusion), overall $t(21) = 4.302$, $p < .001$, $r = .68$, attacking elements $t(21) = 4.689$, $p < .001$, $r = .72$, and defending elements $t(21) = 3.364$, $p < .05$, $r = .59$, meaning that the participants anticipated the movement of the players in the video clip. The Experience Group x Element ANOVA on the advance times showed a significant main effect of Element, $F(1, 20) = 4.728$, $p < .05$, $\eta^2_p = .191$. The advance time of the attacking elements was higher than of the defending elements, indicating that the attacking elements were anticipated further in time than the defending elements. There was also a significant main effect of Experience Group, $F(1, 20) = 5.082$, $p < .05$, $\eta^2_p = .203$, which was qualified by a significant Experience Group x Element interaction, $F(1, 20) = 5.472$, $p < .05$, $\eta^2_p = .215$. The more experienced group showed higher advance times on the attacking elements than the less experienced group, $p < .05$, but on the defending elements the advance times of the more and less experienced groups did not differ.

Figure 2.3. Mean recall accuracy scores by advance time for attack and defence and for less and more experienced players. Arrows indicate the advance times of the anticipatory recall score.

Geometric pattern features

Results from the Experience Group x Anticipation x Element ANOVA on the geometric pattern features scores showed a significant main effect of Anticipation, $F(1, 20) = 5.728$, $p < .05$, $\eta^2_p = .215$. The anticipatory recall scores were more accurate than the traditional recall scores. There was also a significant main effect of Element, $F(1, 20) = 21.667$, $p < .05$, $\eta^2_p = .523$. The more experienced group showed higher advance times on the attacking elements than the less experienced group, $p < .05$, but on the defending elements the advance times of the more and less experienced groups did not differ.

Table 2.1. Mean scores and SD of traditional recall accuracy, anticipatory recall accuracy, advance time, real-world recall scores and pattern feature scores.

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Element</th>
<th>Mean</th>
<th>SD</th>
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<td>Defence</td>
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<td>Overall</td>
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<tr>
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<td>Attack</td>
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<td></td>
<td>Attack</td>
<td>3.02</td>
<td>0.42</td>
</tr>
<tr>
<td></td>
<td>Overall</td>
<td>2.98</td>
<td>0.39</td>
</tr>
<tr>
<td>RW advance time (ms)</td>
<td>Defence</td>
<td>100</td>
<td>161</td>
</tr>
<tr>
<td></td>
<td>Attack</td>
<td>94</td>
<td>148</td>
</tr>
<tr>
<td></td>
<td>Overall</td>
<td>74</td>
<td>150</td>
</tr>
</tbody>
</table>

Note. RW = Real-world coordinates.
.001, $\eta^2_p = .520$, the attacking elements were better recalled than the defending elements. No significant main effect of Experience Group was found, $F(1, 20) = .553, p = .466$, but a significant Experience Group x Element interaction, $F(1, 20) = 8.898, p < .05, \eta^2_p = .308$. The less experienced group recalled the attacking elements better than the defending elements, $p < .001$, while the more experienced group did not show a significant difference in the recall score of the attacking or defending elements. Furthermore, the less experienced group recalled the attacking elements better than the more experienced group, $p < .05$, and the more experienced group tended to recall the defending elements better than the less experienced group, $p = .052$. The Anticipation x Element interaction, $F(1, 20) = 4.072, p = .057$, Experience Group x Anticipation interaction, $F(1, 20) = .258, p = .617$, and the Experience Group x Anticipation x Element interaction, $F(1, 20) = .738, p = .400$, were not significant.

**Advance time**
The advance times were significantly different from zero, overall $t(21) = 2.286, p < .05, r = .45$, attack $t(21) = 2.553, p < .05, r = .49$, defense $t(21) = 2.689, p < .05, r = .51$, attack–defense $t(21) = 5.383, p < .001, r = .76$, meaning that the participants anticipated the pattern features. The Experience Group x Element ANOVA on the advance times did not reveal any significant differences, indicating that there were no differences between participants from the less and more experienced groups or between the attacking and defending elements of the pattern of play.

**Real-world coordinates**
The Experience Group x Anticipation x Element ANOVA on the real-world pattern recall scores revealed only a significant main effect of Anticipation, $F(1, 20) = 10.213, p < .05, \eta^2_p = .338$. The anticipatory recall scores were lower and thus better than the traditional recall scores, indicating that the participants anticipated the movements of the pattern of play. The main effects of Experience Group, $F(1, 20) = .620, p = .440$, Element, $F(1, 20) = .827, p = .372$, and the interaction effects were not significant (Anticipation x Element, $F(1, 20) = .195, p = .664$, Experience Group x Anticipation, $F(1, 20) = 3.904, p = .062$, Experience Group x Element, $F(1, 20) = .006, p = .937$, Experience Group x Anticipation x Element, $F(1, 20) = 1.270, p = .273$).

**Advance time**
The advance times were significantly different from zero, overall $t(21) = 2.319, p < .05, r = .45$, attacking elements $t(21) = 2.974, p < .05, r = .54$, and defending elements $t(21) = 2.924, p < .05, r = .54$, meaning that the participants anticipated the movement of the players in the video clip. The Experience Group x Element ANOVA on the advance times only showed a trend for Experience Group, $F(1, 20) = 3.993, p = .059, \eta^2_p = .166$. The more experienced group tended to show higher advance times (thus anticipating further ahead) than the less experienced group. The main effect of Element and the Experience Group x Element interaction effect were not significant, $F(1, 20) = .089, p = .768$ and $F(1, 20) = .089, p = .768$, respectively.

**Gaze behavior**
On average, the participants used 1.6 fixations per second and fixations lasted 717.4 ms. Furthermore, participants switched gaze from the attacker in possession of the ball to another location and back to the attacker in possession of the ball (i.e., fixation order) for 0.13 times per second. The percentage of viewing time spent on the ten fixation locations is displayed in Figure 2.4. The locations most frequently viewed were attacker in possession of ball (AB), attacker without ball (A), defender (D), field/space (F) and central spot in the field (CF).

**Experience groups**
We compared the first years of the talent program with the second or more years of the talent program. Significant differences were found for mean fixation duration, $t(11) = 2.221, p < .05, r = .56$ and fixation order, $t(11) = 3.444, p < .05, r = .72$, both large effects. A trend was found for search rate, $t(11) = -2.035, p = .067, r = .52$, a large effect. Participants of the more experienced group showed more fixations per second (i.e., higher search rate) of shorter duration and a higher fixation order (see Table 2.2). To analyze the differences between the groups regarding fixation locations a MANOVA was performed in which Group was the fixed factor and the ten fixation locations the dependent variables. A mild trend for Group was found, Wilk’s $\Lambda = .018, F(12,10) = 10.615, p = .089, \eta^2_p = .982$. Post-hoc tests revealed that participants of the more experienced group spent more time watching attackers without ball possession (A); more experienced group $M = 29.6\%$, less experienced group $M = 20.6\%$ and spent less time fixating on a central spot in the field (CF); more experienced group $M = 9.1\%$, less experienced group $M = 23.9\%$ when compared to participants of the less experienced group, see Figure 2.5A.
Pattern recall skills of talented soccer players

Chapter 2

locations the dependent variables, yielded no significant effect, *p* > .05. Thus, the visual search strategy did not seem to influence the pattern recall accuracy.

To examine the role of visual search strategies in the pattern recall accuracy, the trials that resulted in high recall accuracy scores (good trials) were compared to the trials that resulted in low recall accuracy scores (bad trials), see Table 2.2 and Figure 2.5B. Independent samples *t*-tests yielded no significant difference between good and bad trials for search rate, fixation duration or fixation order, all *p* s > .05. A multivariate ANOVA, in which trial quality (good vs. bad) was the fixed factor and the ten fixation locations the dependent variables, yielded no significant effect, *p* > .05. Thus, the visual search strategy did not seem to influence the pattern recall accuracy.

For the reported results, the selection of good and bad trials was based on traditional real-world pattern recall scores. However, selecting on anticipatory real-world scores or geometric pattern features scores yielded the same results.
Discussion

The aim of the present study was to examine pattern recall skills of a group of talented soccer players. We used the same traditional and anticipatory methods to analyze pattern recall accuracy as Gorman et al. (2012) and introduced two new methods to calculate pattern recall accuracy. In addition to the separate player positions, we examined player positions relative to each other by assessing geometric pattern features in terms of angles between players, hereby filtering out effects of translation, rotation and scaling. Our second new method of analysis involved the transformation of the pixel coordinates into real-world coordinates, as we hypothesized that the 2D perspective of the video clips may have affected the results. Using the previously used traditional and anticipatory methods and our two new methods to analyze pattern recall accuracy, we investigated the differences in pattern recall performances within a group of talented female soccer players. Defensive elements and attacking elements of the pattern of play were analyzed separately. Furthermore, we measured gaze behavior of the participants to explore the role of gaze behavior in recalling patterns of play.

The results showed that irrespective of the method of analysis, the participants encoded the pattern significantly further in advance of the actual finishing point of the video clip, despite being instructed to recall the positions as last seen in the video clip. This is consistent with previous research using a recall methodology (Gorman et al., 2012, 2013b) or recognition paradigm (Didierjean & Marmeche, 2005; Gorman et al., 2011) and indicate that expert team-sport players intuitively predict the next likely state of the pattern of play when watching a structured video clip from their domain of expertise.

The results also showed that, when using the former traditional and anticipatory approaches (i.e., in pixel coordinates), the defenders were better recalled than the attackers. Similar results were found by Allard et al. (1980), Gorman et al. (2013b, for novices). However, the current study showed that when analyzing the pattern recall accuracy in geometric pattern features, the first years of the talent program (i.e., less experienced group) recalled the attacking players better than the defensive players while the more experienced players recalled the attacking and defensive players to the same degree. Moreover, after transformation into real-world coordinates, no differences were found between the recall accuracy of the offensive and defensive elements for both groups. So, it seems that the 2D perspective in the video clips did have an effect on the results. In pixel coordinates, the magnitude of the spatial errors does not depend on the position in the screen or on the pitch. However, this is incorrect because a spatial error far away from the camera corresponds to a much larger error in real-world coordinates than a spatial error close to the camera. In most cases, the defenders were further away from the camera (i.e., closer to their own goal, which was at the opposite side of the field) than the attackers. Consequently, a similar error for the attackers and defenders in pixel coordinates would result in larger errors for the defenders than for the attackers in real-world coordinates. When analysing geometric pattern features only angles between players are measured and in this way the 2D perspective of the video clips does not distort the results. Also, after transformation into real-world coordinates, the effect of the 2D perspective in the video clips has been ruled out, as we found in the current study. Therefore, in future research, the perspective in the video clips should be taken into account.

Besides introducing two new methods of analysis for pattern recall accuracy, we examined the differences in pattern recall performance among the players of the talent program. In most of the studies the expert–novice paradigm has been used to examine the important characteristics that differentiate the skilled from the less-skilled players (Williams et al., 2002). However, in the current study we examined the differences within a group of talented soccer players. The findings indicated that the more experienced players recalled the defending pattern features better than the less experienced players, who recalled the attacking pattern features better. No differences were found in recall accuracy between the two groups in real-world coordinates or in pixel coordinates. Furthermore, the less experienced players recalled the attacking elements better than the defending element, while the more experienced players did not show a difference in recall accuracy between the attacking and defending elements. It might be that the less experienced players focused more on the attacking elements, whereas the more experienced players distributed their attention more equally over the different elements of the pattern of play. However, the analyses in real-world coordinates did not reveal any differences in recall accuracy between the attacking and defending elements and the gaze behaviour data suggested the opposite, namely: the more experienced players looked more to the attackers without ball than the less experienced players. So, the explanation of the differences in recall accuracy between the attacking and defending elements of both experience groups is still unclear, but it does not seem to have been caused by the visual search strategies.

Furthermore, in real-world coordinates, the more experienced players tended to anticipate both the attacking pattern and defensive pattern further ahead than the less experienced players. Similar results were found by Gorman et al. (2011, 2012), who found that expert basketball players showed larger anticipatory encoding than novices. Thornton and Hayes (2004) showed that novices are able to anticipate the movements of people in everyday scenes, probably because they are able to use their basic understanding of human movement. But, as Gorman et al. (2011) showed, this basic understanding of human motion is not sufficient to apply an anticipatory encoding process on complex patterns from a specific domain of expertise (e.g., basketball or soccer). In their study, only expert and recreational basketball players showed anticipatory encoding, while novices did not. Gorman et al. (2011) argued that anticipatory encoding is likely to occur if the observer has experience in the domain and therewith a better understanding of
the interrelationships among the players within the pattern. Other studies also showed that probabilistic knowledge (Gorman et al., 2013b) and experience in the domain result in larger extents of anticipatory encoding (Jordan & Husinger, 2008; Jordan & Knoblich, 2004). Anyway, the current study showed that the extent to which the participants anticipated the pattern of play in advance, seems to differentiate between the more and less experienced players.

Research on this phenomenon, called 'representational momentum', has also shown that stimuli with higher implied or actual velocities induce larger anticipatory encoding processes (Finke, Freyd, & Shyi, 1986; Freyd & Finke, 1985). Further research should be done to determine whether this is also the case in pattern recall, that is, whether the to be recalled players or (sub-)patterns with higher velocities result in larger advance times. The measurements of gaze behavior in the current study were done to examine the relation between visual search strategies and pattern recall accuracy. The results of the current study indicated that trials that resulted in good and bad pattern recall scores were accompanied by similar visual search strategies, since there were no significant differences for search rate, fixation duration, fixation order or fixation location. So, it seems that the differences in recall accuracy were caused by differences in processing the visual information, rather than differences in visual search strategy, which is consistent with the results of Gorman et al. (2013a).

We also compared the visual search strategies of the more experienced players with the less experienced players of the talent program. The more experienced players spent more time watching the attackers without ball and less time on a central spot in the field than the less experienced players. Furthermore, the more experienced players showed more fixations per second (i.e., higher search rate) of shorter duration and switched their gaze more often from the player in possession of the ball to another location and back to the player in possession of the ball (i.e., fixation order). At first sight, this may seem contradictory to previous research in sport that showed that skilled athletes use fewer fixations of longer duration than their less-skilled counterparts (Abernethy & Russell, 1987; Goulet, Bard, & Fleury, 1989; Helsen & Pauwels, 1993; Ripoll, Kerlirzin, Stein, & Reine, 1995). Theoretically, because saccades are seen as inactive periods of information processing, a more selective and efficient strategy would consist of fewer fixations of longer duration (Williams et al., 1993). However, previous literature showed that the search strategy that is being used seems to be dependent on the task constraints (Roca, Ford, McRobert, & Williams, 2013; Vaeyens, Lenoir, Williams, Mazyn, et al., 2007; Vaeyens, Lenoir, Williams, & Philippaerts, 2007; Williams et al., 1994).

For example, Mann, Farrow, Shuttleworth, and Hopwood (2009) found that visual search behaviour was dependent on the perspective of the video footage. That is, on a decision making task, participants showed a higher search rate and lower fixation duration in the aerial compared to the player perspective, and in the aerial perspective more time was spent fixating on the open space and more fixation transitions were made between the ball carrier and a team mate. Also, Roca et al. (2013) found in an anticipation and decision making study in soccer, that participants made more fixations of shorter duration in situations in which the ball was far away from the participants compared to situations in which the ball was close to the participant. Furthermore, Williams and Davids (1998) argued that game players may use higher search rates when they have to recognize or recall patterns of play, whereas lower search rates may be used in more specific contexts involving a restricted number of players, such as 1 on 1 situations. Similar to the current study, several studies showed higher search rates (Vaeyens, Lenoir, Williams, Mazyn, et al., 2007; Vaeyens, Lenoir, Williams, & Philippaerts, 2007; Williams et al., 1993; Williams et al., 1994) and a higher frequency of alteration of fixation between the player in possession of the ball and any other area (i.e., fixation order; Vaeyens, Lenoir, Williams, Mazyn, et al., 2007; Vaeyens, Lenoir, Williams, & Philippaerts, 2007) for experienced players than for less experienced players. Vaeyens, Lenoir, Williams, and Philippaerts (2007) argued that one should not necessarily interpret the higher search rate and fixation order as a more exhaustive search strategy, but as a more purposeful visual search strategy. Skilled players fixate mainly on the player in possession of the ball and use peripheral vision to track the movements of other players (without ball; cf. Williams & Davids, 1998). When they need more detailed information from these other players, they use a saccade to fixate on that particular area and then make a saccade back to the player in possession of the ball (Vaeyens, Lenoir, Williams, & Philippaerts, 2007). These ‘visual pivots’ have been reported more often in soccer (Vaeyens, Lenoir, Williams, Mazyn, et al., 2007; Williams & Davids, 1998) and other sports (Martell & Vickers, 2004; Ripoll, 1991; Williams & Elliott, 1999) and may be indicative of a more context rather than target control strategy (Tenenbaum & Bar-Eli, 1993) which sounds beneficial for a pattern recall task.

In sum, our results showed that irrespective of the method of analysis, the participants encoded the patterns significantly further in advance of the actual finishing point. So, the participants unknowingly anticipated the movements of the patterns. Furthermore, in real-world coordinates, the more experienced players tended to anticipate both the attacking pattern and defensive pattern further in advance than the less experienced players. The differences in recall accuracy between the defense and offense were not consistent across the methods of analysis. We therefore suggest that the 2D perspective in the video clips distorted the results in the previously used method of analysis, leading to the erroneous conclusion that attack and defensive patterns were recalled with different accuracy. In future research, perspective effects of the video clip should be taken into account. Finally, the good and bad trials were accompanied by similar visual search strategies and thus the perceptual–cognitive capability rather than the visual search strategy seems to define the pattern recall accuracy. Still, the more experienced
players demonstrated a higher search rate, that is more fixations of shorter duration, and switched their gaze more often from the player in possession of the ball towards another area and back to the player with the ball (i.e., higher fixation order) indicating that even within a quite homogenous group of talented soccer players differences in visual search behavior can be found.