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## Reading the game

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## Epilogue

Team sports offer a unique, dynamic, and time-constrained environment in which the ability to pick up visual information to decide upon an appropriate course of action is key to high-level performance (Williams & Ericsson, 2005; Williams, Ford, Eccles, & Ward, 2011). As these decisions are regularly made under time pressure, players need to quickly recognize the pattern of play, anticipate future events, and make fast and accurate decisions. This ability to 'read the game' is an important factor of team sport performance and it distinguishes skilled from less skilled players (Williams, 2000). The aim of this thesis was to examine how tactical skills in team sports can be measured reliably and objectively, and to gain more insight into tactical skills and their underlying mechanisms in order to examine how tactical skills can be developed. This epilogue first summarizes the previous research chapters, followed by the main conclusions. Next, theoretical and methodological implications and some limitations will be discussed as well as suggestions for future research. Finally, practical implications will be given for coaches and athletes on how to measure and improve tactical skills in team sports.

## Summary

Skilled athletes are consistently found to be superior on a variety of perceptual-cognitive tasks, including those designed to test anticipation, pattern recall and decision making. These skills have typically been measured using simplified video-based tests in which participants do not move but instead indicate their preferred action or response verbally or by way of a button press. Although these tests offer a significant advantage in terms of their methodological rigour and control, there has been increasing criticism on how well these tests accurately represent the on-field performance they are designed to sample (Mann & Savelsbergh, 2015; Pinder, Headrick, & Oudejans, 2015; Williams & Ericsson, 2005). For example, in traditional pattern recall tests participants watch video clips of specific sport situations and directly afterwards they are required to recall the positions of the players as accurately as possible by using the computer mouse or pen and paper. In calculating the recall accuracy, the 2D perspective of the video images of the actual 3D situations may cause a perspective bias. As in most video clips the defenders were further away from the camera than the attackers, similar errors in pixel coordinates for the defenders and attackers would result in larger actual errors for the defenders.

To eliminate this perspective bias we introduced two new methods to analyse pattern recall accuracy in Chapter 2: (i) instead of pixel coordinates we calculated pattern recall accuracy in real-world coordinates, and (ii) instead of absolute positions of separate players we analysed player positions relative to each other as we hypothesised that for pattern recall the characteristics of the patterns were more important than the absolute position of each single player. Using both the traditional analysis method and our two

new analysis methods, we examined the differences in pattern recall performance within a group of talented female soccer players and we explored the role of gaze behaviour in recalling patterns of play. Gaze behaviour analyses revealed no differences in search rate, fixation duration, fixation order or fixation location between trials that resulted in good or poor pattern recall accuracy. Therefore, 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 earlier findings of Gorman, Abernethy, and Farrow (2013a). The results also showed that the differences in recall accuracy between the defensive and offensive elements were not consistent across the methods of analysis, which confirmed that the perspective in the video clips introduced a bias and that this should be taken into account in further research. Irrespective of the method of analysis, the participants encoded the pattern significantly further in advance of the actual finishing point of the video clip. This means that although the participants were instructed to recall the positions as last seen in the video clip, they intuitively predicted the next likely state of the pattern of play. This finding is consistent with previous research on pattern recall and pattern recognition (Didierjean & Marmeche, 2005; Gorman, Abernethy, & Farrow, 2011, 2012, 2013b), and provides support for the idea that pattern recall serves an anticipatory function, it allows expert players to predict future situations based on the current configuration of players and thereby helps to decide upon the best course of action (Farrow, McCrae, Gross, & Abernethy, 2010; Gorman et al., 2012, 2013b; Williams & Davids, 1995).

The degree to which different perceptual-cognitive skills are related is a significant issue (Farrow et al., 2010), as it helps to reveal whether pattern recall, anticipation, and decision making are independent skills that should be acquired separately, or whether they are all related and underpinned by similar cognitive processes (Gorman, Abernethy, & Farrow, 2015; North, Williams, Hodges, Ward, & Ericsson, 2009). One possible way to gain insight into these underlying mechanisms or processes is through the examination of gaze behaviour. Differences in gaze behaviour when performing various perceptual-cognitive skill tests means that different processes underpin these perceptual-cognitive skills (North et al., 2009). To determine the degree to which the three tests of perceptual-cognitive skill are related we examined the correlations between the tests and the similarity of the gaze of skilled soccer players when performing those tasks in Chapter 4. The results revealed that there were no significant correlations between the level of performance on any of the three tests, suggesting that anticipation, pattern recall, and decision making are all three unique skills. The analysis of gaze behaviour revealed significant differences in search rate, fixation duration, fixation order, gaze entropy, and percentage viewing time towards the areas of interest when performing the test of pattern recall compared to the way that the tests of anticipation and/or decision making were performed. This provided strong evidence for the unique characteristics of pattern

recall, but with no significant differences between any of the measures of gaze behaviour when performing the tests of anticipation and decision making, the underlying processes responsible for anticipation and decision making might be much less distinct. However, the lack of correlation between the test scores for anticipation and decision making, and the fact that the participants chose the same response in these two tests in only 65% of cases (likelihood of identical answers was 25% by chance), implies that the participants approached the tests of anticipation and decision making differently. Altogether, the results indicated that anticipation, pattern recall, and decision making seem to be independent skills that are not underpinned by one underlying skill or identical cognitive processes. Therefore, it could be that some perceptual-cognitive skills are more related to actual performance on the field than others, and this could depend on how well the separate tests reflect the processes that are needed for actual actions on the field.

An important topic in recent literature is whether a relationship exists between performance on those tests of perceptual-cognitive skill and actual on-field performance (Mann & Savelsbergh, 2015; Pinder et al., 2015; Williams & Ericsson, 2005). Previous studies have used the expert-novice comparison to examine differences in perceptual-cognitive skill between skill levels, and assumed that the perceptual-cognitive skills for which there are differences must comprise an important element of expertise. However, this expert-novice approach does not provide direct evidence that performance on those tests is related to on-field performance. For that purpose in situ performance of participants should be directly related to their performance on video-based tests of perceptual-cognitive skill. To do so, an objective and reliable assessment tool for on-field performance must be developed first, since earlier developed performance assessment instruments for team sports only examine the player in possession of the ball and not the other players involved in the game, or contain a high level of subjectivity as the observer has to evaluate the appropriateness of the player's actions. We therefore developed an objective and detailed notational analysis system with which the performance of all players involved in a small-sided game can be assessed, and we examined the validity and reliability of it in Chapter 3. In this system, at any one point in time each player has one of three roles: attacker with ball, attacker without ball, and defender. Possible actions and outcomes as well as the a priori determined number of points a player earns when performing that action (and the consequent outcome) were determined by two experts with over 25 year of experience in coaching soccer at the national and international level. For example, a player earns two points when he/she passes the ball in forward direction to a teammate and this teammate successfully receives the ball. All actions and the consequent outcomes were registered for each player on the field by analysing video footage of in situ games frame-by-frame. Performance scores for each role are subsequently calculated as the average number of points a player earns per trial in that role. The notational analysis system was tested on 3 vs. 2 + GK small-sided games played

by 19 highly talented female soccer players. Besides high content and ecological validity, the results showed significant concurrent validity (i.e., significant correlations between the performance scores attained with the notational system and judgments of the head coach), construct validity (i.e., significant differences in performance scores between high- and low-skilled players), and reasonably good intra- and inter-observer reliability.

Using this notational analysis system the in situ performance of skilled soccer players was assessed and related to their performance on separate tests of anticipation, pattern recall, and decision making in Chapter 4 in order to examine how well these tests accurately represent the on-field performance they are designed to sample. The results revealed that on-field performance could not be predicted on the basis of performance on the perceptual-cognitive tests. This indicates that the traditional video-based tests of anticipation, pattern recall, and decision making may not be as strong a determinant of actual performance as has been previously been assumed, and that caution is warranted when using these video-based tests for talent identification or to evaluate the effectiveness of interventions. To accurately capture perceptual-motor skills of athletes, in situ research designs should be used so that the task constraints and response mode represent as accurately as possible the actual skill and context in which the athlete is engaged. However, so far hardly any studies have been conducted on the direct relationship between decision making and gaze behaviour using an in situ design, which is exactly what we did in Chapter 5.

To gain insight into the visual information that players use to make decisions and control their actions, we studied the decision-making skills and gaze behaviour of skilled basketball players in situ in Chapter 5. The participants played as ball carrier in a specific 3 vs. 3 basketball play on both the left and right side of the court and facing three different types of defence. The ball carrier had to decide upon and perform one of four options: shoot, drive, or pass to one of two teammates, while concurrently wearing a mobile eye tracking device in part of the trials. The findings comparing the trials with and without eye tracking device revealed no differences in the decisions of the players nor in the quality of the decisions. This shows that using eye tracking in in situ research designs does not (necessarily) interfere with task execution and performance, indicating that eye tracking provides a powerful tool to investigate the relationship between perception and action in complex in situ sport settings. The findings also showed that the players mainly relied on central vision to execute a perceptual-motor action, whereas for decision making peripheral vision seemed to play an important role. As expected the players primarily fixated on the option they chose at the end of the trial, but prior to fixating on this eventually chosen option the players spent most time fixating on central locations. They may have used a point in this area as an anchor point and detected information about the developing situation using both central and peripheral vision, which is in accordance with the findings of Ryu, Abernethy, Mann, and Poolton (2015); Ryu,

Abernethy, Mann, Poolton, and Gorman (2013). The results revealed that correct decisions were accompanied by fixation transitions between the central fixation locations whereas fixation transitions from more remote fixation locations were associated with incorrect decisions. This underlines the importance of peripheral vision in decision making. Using solely the traditional gaze measures like search rate, fixation duration and percentage viewing time no differences were found in visual search strategies across the different chosen options. However, using more advanced gaze analysis methods differences in visual search strategies across the chosen options were found. The scan paths and time series analysis revealed that visual search strategies were more diverse and resulted in later fixations on the chosen option when passing than when shooting or driving (i.e., individual actions). This underlines the need for developing and using newer and more informative methods to analyse gaze than the traditionally used gaze variables. Finally, the results also showed that handling the ball with the dominant or non-dominant hand influenced the decisions that were made. When dribbling with the dominant hand, the participants more often chose to shoot or to pass to a risky but advantageous option compared to when dribbling with the non-dominant hand. This shows that the action (i.e., dribbling with dominant or non-dominant hand) reflects different constraints (and thus different action possibilities or affordances) leading to different decisions, which is in support of the embodied choice framework (Lepora & Pezzulo, 2015).

After these studies focusing on capturing expert performance in team sports reliably and objectively and identifying underlying mechanisms, the final experimental chapter (Chapter 6) of this thesis concerned the third stage of the expert performance approach (Ericsson & Smith, 1991) which is aimed at the development of tactical skills. Research has demonstrated that allowing learners to control (some) features of their own learning process enhances motor skill acquisition, especially self-controlled feedback has been proven to be effective in a variety of individual tasks (Aiken, Fairbrother, & Post, 2012; Chiviakowsky & Wulf, 2002; Chiviakowsky, Wulf, de Medeiros, Kaefer, & Tani, 2008; Post, Aiken, Laughlin, & Fairbrother, 2016; Ste-Marie, Vertes, Law, & Rymal, 2013). However, in contrast to the effects on individual tasks, the effectiveness of self-controlled feedback on complex skills that involve multiple persons was unknown before the present study. We examined the effects of self-controlled video feedback on tactical skills in 3 vs. 2 small-sided soccer games, and were particularly interested in the preferences of the players for how often and when to receive video feedback and whether self-controlled video feedback stimulates the learners' involvement in their own learning process, as this latter has been suggested to be a possible explanation for the beneficial effects of self-controlled learning (Ferrari, 1996; Janelle, Barba, Frehlich, Tennant, & Cauraugh, 1997; Wulf, Clauss, Shea, & Whitacre, 2001). To that end, highly talented youth soccer players were assigned to a self-control or yoked group and received video feedback on their offensive performance in the small-sided games. The three attackers and the coach

collectively watched the video and their conversations were videotaped, transcribed and analysed. One of the most interesting findings of this study was that the participants of the self-control group showed a preference for receiving feedback after relatively good trials, though, analyses of the conversations around the video feedback showed that the participants and coach discussed both positive and negative aspects of the trial and how to improve it. Thus, the video feedback was being used to confirm success (Chiviakowsky & Wulf, 2002) and to correct errors (Salmoni, Schmidt, & Walter, 1984). The analyses of the conversations also showed that although the coach had a major role in the conversations, the participants of the self-control group spoke more and showed more initiative in comparison to the participants of the yoked group. Therefore, the ability to control video feedback seems to have a positive effect on the involvement of the players in their own learning process. The findings further revealed no significant differences between the self-control and yoked group in performance scores as awarded by the coach or by the players themselves. Therefore, this study could not reveal a direct beneficial effect of self-controlled video feedback on performance in small-sided soccer games, as was found earlier in individual tasks, but it suggests that the effects of self-controlled feedback on tasks involving multiple persons are more indirect (i.e., more active involvement in learning process).

## Main conclusions

In sum, this thesis aimed at studying how experts perform and learn tactical skills. Based on the expert performance approach (Ericsson & Smith, 1991), we first examined how performance in team sports can be captured in a reliable and objective manner. The current thesis shows that to this end, the traditionally used video-based tests of anticipation, pattern recall, and decision making are not such strong determinants of actual performance as has been previously assumed, since on-field performance could not be predicted on the basis of performance on the perceptual-cognitive tests (Chapter 4). Specifically, projecting 3D visual information onto a 2D display causes a perspective bias in pattern recall tests that cannot be ignored but should be corrected for (Chapter 2). Using such a correction, we showed that there were no significant correlations between the level of performance on any of the tests of anticipation, pattern recall and decision making, which suggests that these tests are measuring unique skills that are not strongly related to each other, and it could be that performance on these perceptual-cognitive skill tests is a by-product rather than a characteristic of expertise (Chapter 4). To accurately capture performance in team sports in situ research designs should be used in which the task constraints replicate as accurately as possible the actual skill and context in which the athlete is engaged, because even an action itself (for example playing with

the dominant or non-dominant hand) influences the decisions that are made (Chapter 5). In order to do so, we developed an objective and detailed notational analysis system specific for small-sided soccer games with which the performance of all the players involved in the game can be assessed, and this system showed to have high validity and reasonably good reliability (Chapter 3).

With regard to the second phase of the expert performance approach, which is to determine the processes and mechanisms that underlie performance in team sports, we showed that eye tracking devices can successfully be used in complex in situ sport settings and that these provide a powerful tool to investigate the relationship between perception and action (Chapter 5). Using eye tracking we found that basketball players mainly rely on central vision to execute perceptual-motor actions and that for decision making peripheral vision seems to play an important role (Chapter 5). We also showed that insight into visual search strategies is limited when only using traditional gaze variables like search rate, fixation duration, and percentage viewing time; using more advanced gaze analysis methods like scan paths or time series analyses yields more informative results (Chapter 5).

The aim of the final stage of the expert performance approach is to examine the acquisition of the identified characteristics of expertise. To this end, we examined the effects of self-controlled video feedback in small-sided soccer games. Although the participants of the self-control group showed a preference for receiving feedback after relatively good trials, we could not find a direct beneficial effect on performance. Instead the effects seem to be more indirect: participants of the self-control group spoke more about the video footage and showed more initiative in the discussions around the video than the participants of the yoked group. Therefore, the ability to control video feedback seems to have a positive effect on the involvement of the players in their own learning process (Chapter 6). Furthermore, we showed that the video feedback was used to both confirm success and to correct errors (Chapter 6).

## General discussion and suggestions for future research

### Research design

One of the main conclusions of this thesis is that in situ research designs should be used to accurately capture performance in team sports, as we have shown that the traditionally used video-based tests of anticipation, pattern recall, and decision making could not be used to predict on-field performance. A disadvantage however of using in situ research designs is that its methodological rigour and control is less than in simulation studies. The popularity of video-based laboratory tasks to examine performance and expertise in sport seems plausible

given the important advantage of video that it enables the reproducibility of situations in a consistent manner from trial to trial, and thus provides an objective method to evaluate performance. However, this is outweighed by the fact that video-based laboratory tasks fail to adequately replicate the natural performance setting in which the athlete is engaged. The visual stimulus in video clips is a less than veridical simulation of the actual performance environment, and this has been shown to result in different movement and gaze behaviours of athletes compared to in situ conditions (Dicks, Button, & Davids, 2010; Mann, Williams, Ward, & Janelle, 2007; Travassos et al., 2013). Requiring participants to respond to the video clips verbally or by using button-presses or simplified movements, changes their behaviour (Dicks et al., 2010; Mann et al., 2007; Travassos et al., 2013) as the natural perception-action coupling is absent and only the role of ventral "vision-for-perception" system is examined whereas the contribution of the dorsal "vision-for-action" system is overlooked (two-visual system model of Milner and Goodale (1995); Van der Kamp, Rivas, Van Doorn, & Savelsbergh, 2008). Furthermore, a study of Ryu et al. (2015) showed that even static response slides on itself could contain sufficient information to influence response selection to better-than-chance levels in a video-based decision making task. Thus video-based tests seem to be inadequate for both the stimulus and the response mode. Therefore, task constraints selected for empirical investigation should be as representative as possible for accurate testing, and in situ research designs fulfil these criteria. Nevertheless, a precondition for successfully measuring performance in team sports in situ is that the method of assessing performance on the field is objective and reliable.

A good first step in this direction was taken by developing a detailed notational analysis system (Chapter 3) with which the performance of players involved in small-sided soccer games can be assessed. However, we have to admit that until now this system is only suitable for soccer and adaptations should be made to the system to make it appropriate for other team sports as well. Furthermore, on the one hand the detailed character of the notation analysis system is one of its strengths as it reveals a great deal of specific information about the players, but on the other hand it also makes using the notational analysis system very labour-intensive and consequently possibly less attractive to use in science or in practice. Upcoming technical advances should make it possible to automatize the notational analysis system in the near future by using specialised cameras and software that can track the positions of the players and ball in combination with specially designed algorithms. This would be time-saving and could possibly also improve the reliability of the system. Possible next steps would be to validate the notational analysis system on a larger group of male and female players of varying age and skill levels, and to apply the notational analysis system on full matches, which would be of both scientific and practical relevance as it is the most representative method of assessing performance of team sport athletes. Subsequently coaches can use the information to follow the development of their players and to inform their game strategy.

Another suggestion for future research is to use virtual reality, as it seems to be a promising compromise between ecological validity and methodological control. Current technologies enable the creation of virtual reality simulations that are reasonably representative for the actual performance setting, and at the same time, enable trial to trial reproducibility (Bideau et al., 2010; Correia, Araujo, Cummins, & Craig, 2012). Using these immersive and interactive simulations, studies examining tactical skills and performance in team sports can be conducted, and probably temporal or spatial occlusion paradigms can be applied to further study what visual information athletes use to inform their decision making or the role of peripheral vision in dynamic sport settings. However, for a really realistic virtual environment, some technological improvements should be made in terms of better graphics and reducing the delay between motion and visual simulation. Then athletes' feeling of being immersed in the situation (i.e., presence) will improve and potential problems of nausea when using virtual reality for extended periods of time will be diminished. As Gray (2009) showed that visual, auditory, and tactile information are collectively used in the control of complex motor actions, it would also be interesting to attempt to add tactile information to the virtual reality simulations that until now only exist of visual and at times auditory information.

Furthermore, the majority of studies of expertise or visual search behaviour in sport have compared the performance of participants who possess very different levels of skill. Using this approach clear differences have been found between experts and novices in perceptual-cognitive skills and gaze behaviour (e.g., Savelsbergh, Williams, Van der Kamp, & Ward, 2002; Williams & Ward, 2007). However, when examining tactical skills of team sport players one has to acknowledge that not all expert players are expert decision makers, since performance in team sports is multifactorial and depends on physiological, technical, psychological and tactical skills. Weaknesses in one aspect could be compensated by strengths in other aspects. Therefore, in this thesis we examined the differences between successful and less-successful performers within a group (Chapter 3 and 4) and between successful and less-successful trials (Chapter 2 and 5). Such comparisons are aimed at revealing the more subtle differences in skill or gaze behaviour and thus may help to disclose the determinants of successful performance that otherwise may have remained unknown when only using studies that rely on expert-novice comparisons. A precondition is though, that the tests need to be highly sensitive to be able to differentiate performance or gaze behaviour of successful and less-successful participants, and this might be the cause of some of the null-findings.

### Gaze behaviour

Although we showed in Chapter 5 that mobile eye tracking systems can be used successfully to measure gaze behaviour of athletes in dynamic sport settings such as basketball, more research in various team sports is needed to investigate the direct relationship between perception and action. Moreover, despite technological advances there are some substantial limitations of eye tracking techniques that require caution when interpreting gaze behaviour. As also mentioned in the General introduction of this thesis, eye registration devices measure foveal fixations but these are not necessarily directly related to information extraction or attentional focus. First, when a person directs his gaze towards a certain location, this is not an assurance that he/she picks up information from that location (Ryu et al., 2013; Williams & Davids, 1998; Williams, Janelle, & Davids, 2004). This difference between 'looking' and 'seeing' was also reported in Chapter 2, as trials that resulted in good and poor pattern recall accuracy scores were accompanied by similar visual search strategies, thus the differences in pattern recall score were caused by differences in processing or interpreting visual information instead of the employed visual search strategy itself. Second, attention can also be relocated in the visual field without making distinctive eye movements to change the point of fixation (Ryu et al., 2013; Williams & Davids, 1998; Williams et al., 2004). This means that knowing the line-of-gaze of someone does not tell where the person's attention is at that time. The fixation location could reflect one's attention via central vision, or the fixation location could be used as an anchor point to extract information from the visual periphery. Peripheral vision seems to be specifically important for decision making in team sports (Chapter 5; Ryu et al., 2015; Ryu et al., 2013; Williams & Davids, 1998). More research including manipulations of central and peripheral vision in situ is needed to gain further insight into the role of peripheral vision in team sports.

Another issue in using eye tracking techniques that warrants attention is the context-specificity of visual search strategies. Watching the same video clips for the purposes of anticipation, decision making and pattern recall results in differences in visual search strategies, as shown in Chapter 4 and other studies (Gorman et al., 2015; North et al., 2009). Moreover, Williams and Davids (1998) and Vaeyens, Lenoir, Williams, Mazyn, and Philippaerts (2007) have shown that gaze behaviour also depends on task constraints such as the number of players displayed in video-based presentations. This means that in addition to performance athletes' visual search strategies vary under different experimental designs, and consequently it seems incorrect to assume understanding of the visual information used by athletes in sport settings when assessed with video simulation tasks and different task constraints. Therefore, attention should be paid to the task constraints when comparing results of multiple visual search studies and when measuring gaze behaviour in general. Especially, caution is needed when visual search strategies of experts are being identified to develop visual attention training. Event-



related visual occlusion goggles (Mann, Abernethy, & Farrow, 2010; Oudejans, 2012; Oudejans, van de Langenberg, & Hutter, 2002) appear to be a good tool to train vision during perceptual-motor tasks, as it enables the use of representative task constraints and preserves the natural perception-action coupling.

Finally, gaze behaviour measurements of players in dynamic team sport settings contain a potential wealth of information, however it appears to be difficult to reduce that into the traditionally used dependent variables like search rate and fixation duration (Chapter 5; Mann, Farrow, Shuttleworth, & Hopwood, 2009). The use of time series graphs and scan paths (Chapter 5) is a good first step to enhance our understanding of visual search, but other advanced gaze analysis methods should be explored as well in future research. By averaging data across trials and participants for statistical analyses, important individual differences may have been disguised as this assumes that there exists an optimal or universal visual search strategy for all participants (Dicks et al., 2010; Withagen & Chemero, 2009). In future research it may be more informative to examine gaze behaviour of participants at an individual level in order to thoroughly examine the direct relation between perception and action in dynamic sport settings. In addition to the most obvious source of perceptual information (i.e., vision), it would also be interesting for future studies to examine how athletes use auditory or tactile information or integrate multisensory information to inform their decision making.

### Video feedback

The indirect beneficial effects of self-controlled feedback on performance in small-sided soccer games (i.e., more active involvement of the players in their own learning process; Chapter 6) could be due to the multifactorial nature of performance in small-sided games, as well as to the design of the study. The limited number of training sessions employed in the study may have been too low to induce a significant performance effect. It could be that the participants had not maximized their possible learning benefits by the end of the intervention period, and thus our findings may not completely reflect the complete extent of the benefits of self-controlled video feedback. Empirical work with longer intervention periods is required to verify this.

Participants of the self-control group preferred to receive feedback after good trials. Post training questionnaires, however, showed that only three out of seven participants from the self-control group indicated that they intended to request feedback after they thought they had a good trial. This discrepancy may be explained by the complexity of the trials in the small-sided game; the trials were too complicated to label as either good or bad. Some aspects of the performance might have been good while other aspects were not. This was also supported by the finding that although the participants requested feedback more often after relatively good trials, in the conversations around the video feedback both positive and negative aspects of the trial were discussed. To gain more

insight into how participants use self-controlled feedback to enhance the learning of a complex task, future research should involve the effects of self-controlled feedback and the feedback preferences of the learner in relation to the specific aspect of performance the individual is focusing on or the specific goal the individual set for him/herself.

Another interesting direction for future research is the necessity of attentional guidance by a coach or expert when using self-controlled video feedback. Due to the information-richness of video footage, it has been suggested that video feedback is most beneficial for learning when attentional cues are provided to direct the learner's attention to the critical information in the video (Janelle, Champenoy, Coombes, & Mousseau, 2003; Landin, 1994; Rothstein & Arnold, 1976). However, if players get the opportunity to decide themselves when they want to receive video feedback or which parts of a filmed match or training session they want to see, they probably have a reason for their decision to request or not to request video feedback. It could be that this reason is enough to direct the learner's attention to certain aspects in the video footage and that attentional cues from an expert will not provide added value. Future research could examine this by presenting self-controlled video feedback on a complex skill with and without attentional guidance of an expert.

## Practical implications

The results of the current thesis have a wide range of practical implications. First of all, to accurately measure performance in team sports we recommend selecting test situations in which the task constraints replicate the actual performance environment of the athlete as precisely as possible (i.e., in situ research designs; Chapter 4). This means that the assessment of performance should take place on the field in game play and not using video-based skill tests of anticipation, decision making or pattern recall. The performance of the players should be evaluated in all roles of the game, that is, on-the-ball and off-the-ball, and in offense and defence. This can be achieved using our developed notational analysis system (Chapter 3). Team sport players participate in small-sided games and video footage of the games will be thoroughly analysed afterwards. In this way, the criteria for a representative environment are met, and furthermore participants will hardly notice that their performance is being assessed and the assessment session can easily be implemented into a regular training session. Although up to now using the notational analysis system is very labour-intensive, upcoming technological advances will make it possible to automatize the notational analysis system in the near future.

The notational analysis system can serve several purposes in team sports as we have also shown in Chapter 3. In addition to the commonly used judgments of scouts, the notational analysis system can be used to determine the quality of players for talent



identification or to select team members. It also enables to follow the development of players during a season or over years, and to set and evaluate individual goals with the players. After creating a large benchmark of male and female players of varying age and skill levels, the notation system can also be used to create player profiles to identify the individual strengths and weaknesses of the players, and to use the system as talent identification tool as players can easily be compared. Also, coaches can use the information of the notational analysis system to screen opponents or to compare players within their team and to use this information to select a more offensively or defensively competing player according to their preferred game strategy. With some slight modifications it should also be possible to incorporate team strategies into the system, so that the system reveals even more specific information to the coaches and players.

Mobile eye tracking devices can be used in dynamic sport settings to measure gaze behaviour of players during in situ game play (Chapter 5). This can be done to gain insight into where players are looking while performing on the field, and consequently if needed to set up training interventions to improve their visual search behaviour. For example, we showed that when players make an incorrect decision, on most occasions they have not fixated on the correct option (Chapter 5). Thus, these incorrect decisions could be caused by fixating too much on less-informative locations in the environment, and thus missing out on the more relevant visual information. This suggests that players may benefit from learning where to look to pick up more relevant information to make better decisions. Event-related visual occlusion goggles (Mann et al., 2010; Oudejans, 2012; Oudejans et al., 2002) offer a good tool to train visual skills on the field, as they enable the use of representative task constraints and preserves the natural perception-action coupling. Earlier research on visual attention training in more isolated sport skills, for example the basketball jump shot, has revealed that it can improve perceptual-motor performance (e.g., Oudejans, 2012; Oudejans, Koedijker, Bleijendaal, & Bakker, 2005).

In the commonly used way of video feedback in sport practice, the coach generally selects moments of the video footage to show to their players, and often these are fragments of game situations in which incorrect decisions were made or the game situation was otherwise not well executed. The coach then points out what went wrong and how this can be improved. However, this contrasts with the revealed preference of players to receive feedback after good attempts (Chapter 6). Furthermore, feedback after relatively good trials has been shown to be more effective than after relatively poor trials (Badami, Vaez-Mousavi, Wulf, & Namazizadeh, 2012; Chiviacowsky & Wulf, 2007; Saemi, Porter, Ghotbi-Varzaneh, Zarghami, & Maleki, 2012). Therefore, it is recommended to select video clips of game situations more often that are performed well. This may create a larger success experience for the learner, which increases motivation which in turn can enhance learning. Selecting video clips of good attempts does not necessarily mean

that only positive aspects of performance can or should be discussed. We showed that although the players in our study more often chose to watch video feedback of good attempts, they still were critical about their own performance and discussed both positive and negative aspects and how to improve their performance. Thus, the players and coach used video feedback to both correct errors and to confirm success. Furthermore, it is recommended to give players the possibility to choose when to receive video feedback, as it results in more active involvement of the players in their own learning process (Chapter 6), which is especially valuable for talent development programs.