- Chapter 1

GENERAL INTRODUCTION

EXPERTISE IN SPORT

Since the seminal work by de Groot (1965) on expertise in chess, there has been an increasing interest in examining expert performance in various domains such as aviation (e.g., Wiggins & O’Hare, 1995), driving (e.g., Hosking, Liu, & Bayly, 2010; Underwood, 2007), music (e.g., Ericsson, Krampe, & Tesch-Römer, 1993), and sport (for a recent overview, see Baker & Farrow, 2015). Figure 1.1 nicely illustrates the rapidly increasing interest in expertise research, and more specifically sport expertise research over the last 30 years.

- FIGURE 1.1. Number of articles between 1985 and 2014 on expertise research (upper graph) and sport expertise research (bottom graph) found in a Web of Science search on the topics “expertise”, and “expertise” and “sport”, respectively.
When it comes to sport, expertise can be defined as the consistent superior athletic performance over a prolonged period of time (Starkes & Ericsson, 2003). Different characteristics can make up a sport expert: physiological (e.g., Wilmore & Costill, 1999) and motor excellence (e.g., Ericsson & Lehmann, 1996; Fitts & Posner, 1967) as well as emotional (Tenenbaum & Eklund, 2007) and cognitive superior performance (Starkes & Ericsson, 2003; A. M. Williams & Hodges, 2004). The domain of cognitive expertise itself may be divided into two further subdomains: strategic (or tactical) skills and perceptual-cognitive skills (that inform decision-making). Firstly, strategic skills involve the ability to resolve what strategy may be most relevant for a certain situation and whether this strategy may also be successfully performed within the constraints of the necessary movements (e.g., Passos, Araújo, Davids, & Shuttleworth, 2008). Secondly, perceptual-cognitive skills involve the ability to identify and acquire environmental information, for integration with existing knowledge, to facilitate the selection of an appropriate response to be performed (e.g., Williams & Ericsson, 2005; Williams & Ford, 2008). A growing body of evidence has highlighted the importance of perceptual-cognitive skills in sport expertise (Broadbent, Causer, Williams, & Ford, 2014; D. T. Y. Mann, Williams, Ward, & Janelle, 2007; A. M. Williams & Ericsson, 2005; A. M. Williams, Ford, Eccles, & Ward, 2011; A. M. Williams & Ford, 2008), one of the most consistent findings of this research being that experts also perceptually outperform lesser skilled athletes across different sports (e.g., Williams & Ford, 2008). For example, experts demonstrate superior visual search behaviour, detect meaningful patterns of information in the performance environment, and are better able to predict situational probabilities resulting in superior decision making skills (e.g., Williams & Ward, 2003). Perceptual-cognitive expertise in sport is key because (successful) perceptual information pick-up informs and guides action, and hence is of utmost important to successful performance and development of expertise (e.g., Williams & Ericsson, 2005).

PERCEPTUAL-COGNITIVE EXPERTISE

A pioneer in this field of research on perceptual-cognitive expertise was the Dutch psychologist de Groot (1965). He examined differences in short-term memory between chess masters (i.e., experts) and less skilled chess players. Master chess players were better able to memorise and reproduce chess configurations when structured chess positions were revealed for a couple of seconds; yet, this supremacy disappeared when random chess configurations were displayed. Expert performance of chess masters therefore seems to depend on the ability to immediately perceive structure in the chess positions and encode this in so-called chunks (i.e., perceptual encoding of several chess pieces). Chase and Simon (1973) replicated the work of de Groot
and argued that in chess perceptual (and memory) expertise is task-specific, and not a general ability. Chase and Simon concluded that chess expertise depends on the relationship between memorising meaningful perceptual chunks and generating relevant relocations of these chess pieces (i.e., effective problem solving). The meaningful chunks relate to logic configurations that high skilled chess players are acquainted with, approximately 50k-100k chunks.

Moving from chess to interactive sports that include gross motor behaviour, innovative work on perceptual-cognitive expertise stems from Abernethy et al. (e.g., Abernethy & Russell, 1984, 1987a, 1987b). They examined how temporal and spatial occlusion of different cues influenced anticipation skills of high skilled and less skilled badminton players. By varying the duration of the stroke sequence that was visible in the presented badminton video clips, referred to as the temporal occlusion paradigm, they found that experts were more efficient in using information presented earlier in the visual display than novices (see also Abernethy & Russell, 1987a). Furthermore, these studies also indicated that spatial occlusion of critical information (such as the arm and racket in badminton) deteriorated experts’ prediction accuracy, while novices were not or less affected (for similar findings, see e.g., Huys et al., 2009). Thus far, researchers have identified a range of perceptual and cognitive characteristics of sport expertise (A. M. Williams & Ward, 2003). To briefly summarise the main findings of research on expertise in sports, when compared with their less skilled counterparts, experts:

- have better recall and recognition of sport-specific patterns of play (e.g., recalling players’ positions in small-sided games in soccer; van Maarseveen, Oudejans, & Savelsbergh, 2015);
- detect and recognise relevant objects (e.g., a volleyball) faster in the visual field (Allard & Starkes, 1980);
- demonstrate more efficient visual search behaviours (e.g., soccer players showing fewer fixations of longer duration during different offensive, defensive and unstructured situations; Cañal-Bruland, Lotz, Hagemann, Schorer, & Strauss, 2011);
- have better anticipatory skills by, for instance, picking up advance visual information (e.g., for goalkeepers in soccer: the non-kicking leg during a penalty kick; Savelsbergh, Williams, van der Kamp, & Ward, 2002)
- have more stable perceptual processes when confronted with changes in emotional state, such as anxiety (for an example in climbing, see Nieuwenhuys, Pijpers, Oudejans, & Bakker, 2008; Oudejans & Nieuwenhuys, 2009).

This summary of findings gives an indication of the main focus of perceptual expertise in sports thus far: it has been mainly directed toward visual perception.
VISUAL PERCEPTION

Indeed, vision plays a crucial role in sports and therefore many researchers have studied athletes’ visual perception both from a theoretical and applied perspective in sports such as soccer (e.g., Savelsbergh, van der Kamp, Williams, & Ward, 2005; Savelsbergh et al., 2002; van Maarseveen et al., 2015), cricket (e.g., Müller et al., 2009), tennis (Huys et al., 2009) and beach volleyball (e.g., Cañal-Bruland, Mooren, & Savelsbergh, 2011). To accurately perceive the environment, athletes produce meaningful eye, head and body movements to put visual information with maximum visual acuity upon the fovea (i.e., a small depression in the retina of the eye). Gaze control consists of eye movements to bring objects of interest onto the fovea (e.g., ballistic eye movements – saccades) and to keep this information steady so that detail can be derived (e.g., fixations and pursuit tracking). For example, fixations refer to keeping the gaze steady to allow visual information pick-up from a specific location; it typically ranges from one to three degrees of visual angle for about 80-150 ms (Vickers, 2007). A fixation allows attention to be directed to specific details in the performance environment. To examine measures like (predictive) saccades and fixations, researchers often measure visual search behaviour of experts and novices using eye-tracking devices (for recent overviews on visual search and eye-tracking, see D. L. Mann & Savelsbergh, 2015; Panchuk, Vine, & Vickers, 2015). Eye-tracking studies have already been conducted in the 1970s (e.g., Bard & Fleury, 1976). Most studies suggest a superior attunement to relevant visual cues among experts as suggested by their visual search behaviour (e.g., D. T. Y. Mann et al., 2007). Reliable differences have been identified between experts and novices regarding gaze measures such as fixation locations, fixation duration, and search patterns (for a special class of fixation - the ‘quiet eye’, see Vickers, 1996). These findings are by and large in agreement with findings of occlusion studies (e.g., Abernethy & Russell, 1987b; A. M. Williams, Davids, & Williams, 1999).

To give an example, Oudejans et al. (2002) investigated experts’ visual search while executing basketball jump shots under different viewing conditions using a temporal occlusion paradigm (similar to Abernethy & Russell, 1987a), showing that late vision shooting appeared to be as good as full vision shooting. These results imply that the final shooting movements were controlled by the continuous use of visual information until the ball was released. Additionally, Oudejans (2012) successfully trained the visual control of high skilled basketball players during three-point shots using special goggles to temporally occlude visual information. These results demonstrate the potential advantage of training perceptual-cognitive skills for better performance. Recent technological advancements make it possible to address the issues and questions relating to the design, implementation and evaluation of perceptual training methods (for examples...
in badminton and soccer, see Hagemann, Strauss, & Cañal-Bruland, 2008; Savelsbergh, van Gastel, & van Kampen, 2010).

As regards studies examining attention, the execution of motor skills has been shown to benefit from an external focus of attention (i.e., to movement effects) relative to an internal focus of attention (i.e., to body movements) (e.g., Wulf & Prinz, 2001; Wulf, 2007b). For example, basketball players shooting free throws can focus- either on their wrist motion (internal focus) or the rim of the basket (external focus). This benefit from an external focus of attention seems to hold true for motor skills ranging from simple tasks (e.g., balancing on a stabilometer) to more complex tasks (e.g., hitting a baseball) (e.g., Gray, 2004; McNevin, Shea, & Wulf, 2003). These skills can be classified on the open/closed skill continuum. For example, golf putting, dart throwing, and basketball shooting are rather closed skills on the open/closed skill continuum. Closed skills take place in stable, predictable environments and athletes’ actions follow set patterns, are often self-paced, with a clear beginning and end. Despite the growing knowledge on the role of attentional focus during more closed skills in relation to expert performance, it remains to be determined to what degree attentional focus plays a role in more open skills (Schmidt & Lee, 2011), including complex body movements and unpredictable environments (e.g., Raab, 2007).

In summary, an external focus of attention seems beneficial for many closed skills (e.g., Wulf, 2007), however more research is necessary to underpin the effects of attentional focus during more open skills (e.g., Raab, 2007). Attentional focus and visual search behaviour can be trained in order to improve performance (e.g., Oudejans, 2012). Therefore, researchers frequently use temporal occlusion paradigms and eye tracking devices to measure variables such as fixations and saccades to understand and check the visual perception of experts and their less skilled counterparts. In addition to the role of visual perception on expert performance, recent research (e.g., Gray, 2008) highlighted that information picked-up via other senses – and the integration of this information, coined multisensory integration – may also account for expert-novice differences. Therefore, it is important to first examine the individual contributions of the various senses in relation to expertise effects.

CUTANEOUS PERCEPTION

For many complex motor actions, perceptual information is available from different senses, such as vision, touch, the auditory and the vestibular systems (for more information on multisensory integration and cross modal correspondence, see Spence, Shore, & Klein, 2001; Spence, 2011). Gray (2008) argued that performers in multiple domains (e.g., aviation, sports, and driving) use
information from multiple senses to guide their actions and hence performance. And indeed, concerning experts’ perceptual-cognitive superiority there is abundant evidence that expertise effects exist for various sensory modalities. Experts do not only demonstrate better visual skills (e.g., D. T. Y. Mann et al., 2007), but also outperform less skilled performers when, for instance, listening to music (e.g., Koelsch, Schröger, & Tervaniemi, 1999), or identifying and recognising wine odours (e.g., Parr, Heatherbell, & White, 2002). However, relatively little is known about expertise effects in haptic perception, more specifically, cutaneous perception by means of the touch receptors in the skin (Lederman & Klatzky, 2009). On that account, research on cutaneous perception has mainly focused on developing haptic interfaces (e.g., Kulkarni, Fisher, Pardyjak, Minor, & Hollerbach, 2009) or the underlying mechanisms, for instance, the cutaneous perception of pain (e.g., Sheffield, Biles, Orom, Maixner, & Sheps, 2000) and heat (e.g., Casey, Minoshima, Morrow, & Koepe, 1996).

Given the paucity of expertise research on some sensory modalities, such as cutaneous perception, it seems mandatory to first study the individual contributions of these senses to expert performance in well-controlled experiments in the lab. On the other hand, given the long history of expertise research on visual perception that has dramatically enriched our understanding of perceptual-cognitive expertise and that was mainly conducted in laboratory settings (for an exception, see for instance Dicks, Button, & Davids, 2010), a fruitful and promising next step in this line of research rather is to capture and understand expert performance in more representative task designs (Araújo, Davids, & Passos, 2007; Pinder, Davids, Renshaw, & Araújo, 2011; van der Kamp, Rivas, van Doorn, & Savelsbergh, 2008). It follows that both approaches, lab and transfer studies in the field, are much needed to ultimately help us capture and understand perceptual-cognitive expertise in sport.

**CAPTURING AND UNDERSTANDING EXPERTISE**

Capturing and understanding expertise in sport can be difficult, particularly given the typically complex competition environment in which athletes perform (for an overview on this matter, see D. L. Mann & Savelsbergh, 2015; Pinder et al., 2015; Renshaw & Gorman, 2015). Whereas early work focused on specific components of expertise, more recent research (e.g., Dicks et al., 2010; D. L. Mann, Abernethy, Farrow, Davis, & Spratford, 2010; Müller et al., 2009) starts to examine the relationship between perception and action. For example, Dicks et al. (2010) indicated that goalkeepers’ visual search behaviour, while stopping penalty kicks in soccer, significantly varied between video simulation and in-situ conditions. If the aim of researchers is to inform or translate findings into practice, then experiments should replicate the
perception-action coupling in an unrestricted manner in order to understand expertise differences in sport (i.e., a representative task design, see Pinder et al., 2011).

For example, athletes should have full visual information and the opportunity to perceive, process and respond to stimuli without constraints with the opportunity to demonstrate functional responses (e.g., Travassos et al., 2013). Recent expertise studies have demonstrated that an expert’s superiority is most effective under conditions that more closely replicate the performance environment (e.g., D. L. Mann, Abernethy, & Farrow, 2010; Müller et al., 2009). Fortunately, the advances in technology have made this more achievable. From a methodological point of view, various aspects deserve attention when trying to set-up and run transfer studies examining sport-specific tasks in representative environments, such as: fidelity of stimuli, type of response, and environmental factors that could affect performance or behaviour (i.e., experimental control) (see also Pinder et al., 2015). These issues apply to a range of research fields in sports science, such as talent identification and development, coaching science and sport technology. In this thesis, we strived to capture, understand and predict expertise in sailing, more specifically, perceptual-cognitive skills and motor performance, using recent technological advancements and keeping these methodological issues in mind.

**STUDY AIMS**

In sailing, it is relatively unknown to what degree perceptual-cognitive skills contribute to decision-making and expert performance. Furthermore, the Dutch Olympic Committee (NOC*NSF) categorised sailing as one of the eight priority sports resulting in extra financial and technical support, at least, for the Olympics 2016 and 2020. Both from a scientific and practical point of view, sailing offers a unique opportunity to assess and predict perceptual-motor expertise (e.g., based on the suggestions by Raab, 2007). Sailors have to deal with environmental conditions such as wind shifts, waves, tides, and fellow opponents. The fastest route to the finish is always variable, since wind direction, speed and wave height change along the course. Furthermore, a sailor’s ability to ‘trim’ the boat settings is essential but difficult, adding to the perceptual-motor complexity (Schmidt & Lee, 2011). So far, some sailing studies concentrated on tasks in a laboratory setting (e.g., Araújo et al., 2006, 2005; Callewaert, Boone, Celie, de Clercq, & Bourgois, 2014; Manzanoa, Menayo, Segado, Salmerón, & Cano, 2014), whereas others were executed on the water (e.g., Araújo et al., 2015, 2010). For example, Araújo et al. (2005) examined sailors’ expert performance using a computer-simulation including different phases of a regatta. They measured different information sources using verbal protocols, namely: opponents’ actions, space ahead on the racecourse, number of manoeuvres, and wind direction...
and speed. Participants (i.e., three groups of sailors: experts, skilled sailors, intermediates; and one group of non-sailors) also used keyboard responses for technical actions. Results, operationalised by final ranking and total time to finish the regatta, revealed expertise differences between non-sailors and higher levels of expertise. That is, in general, non-sailors performed more manoeuvres than sailors (for more details, see Araújo et al., 2005). These results support the notion that sailing may further fuel our understanding of perceptual-cognitive expertise in a rather unpredictable environment. More recently, Araújo et al. (2015) emphasised that sailors should act according to contextual demands rather than solely act on the basis of memorised behaviour and ignoring relevant information. In their study, they observed and studied decision-making processes of young sailors during the regatta start, resulting in practical guidelines for coaches. For example, coaches are advised to manipulate the starting line or regatta course (by changing marks) in relation to the wind direction, adding or removing the presence of opponents, or the time to start. Related to these practical guidelines, in close collaboration with the Dutch Netherlands Yachting Federation and national sailing innovation lab in The Hague (InnoSportNL), a major aim of the current thesis was to translate sport scientific knowledge on sailors’ perceptual-cognitive expertise into practical guidelines for coaches and athletes, in terms of informing instruction and feedback, developing training methods, and talent identification and development.

Keeping this aim close in mind, this thesis comprises six Chapters. Following this Introduction, Chapter 2 continues with presenting an approach of how to translate key methodological issues into technological advancements when running in-situ experiments in sailing. It describes how we use a representative performance environment – together with fidelity of stimuli and type of response – to set-up field research on sailing expertise. In Chapters 3 and 4, two studies are reported that examine the impact of sailors’ visual perception and focus of attention on performance during representative tasks. That is, in search of key performance indicators and potential implications for practice, we examined visual search, movement behaviour and boat control while rounding the windward mark, a decisive event in sailing – in particular the first windward mark after the start (Chapter 3). Next, Chapter 4 examines whether an external focus of attention is beneficial in open skills such as upwind sailing. In the same study we tested and validated the practical use of action sport cameras to quantify visual focus of attention instead of using eye-tracking devices. Athletes and coaches might benefit from this validation since these cameras are relatively low-cost and technologically advanced. For the purpose of these two experiments (Chapter 3 and 4), all measurements were conducted in the same boat type – a one-person laser dinghy. In the final experimental Chapter (Chapter 5), the role of cutaneous perception on expert performance is examined in a lab setting. In a wind simulator, sailors and non-sailors were presented wind stimuli from different wind directions.
and speeds – without having access to visual or auditory information – in order to understand the individual contribution of cutaneous perception in relation to expertise in sailing. After reporting and discussing these experiments, in Chapter 6, the experimental findings are summarised and – turning back to the representative task design presented in this introduction and Chapter 2 – provide suggestions and directions of future research. In addition, practical, evidence-based implications will be discussed on how coaches and athletes may improve their sailing performance.