NORWEGIAN SCHOOL
OF SPORT SCIENCES

Lars Brotangen

Visual exploratory behavior (VEB) of Norwegian top division midfielders in 11v11 match-play

A Tobii eye tracker analysis

Master thesis in
Department of
Norwegian School of Sport Sciences, 2019

Preface

My entire life has evolved around the game of football. My mother tells a story of when she tried to take the football away from three-year-old me and get me to play in the sandbox instead. She only just made it back into the house before she heard the noise of the ball once again hitting our house wall. As I grew older, I found it difficult to decide what I wanted to do with my life, with football being my only true passion. In lack of better options, at the time, I eventually went to study at the Norwegian School of Sport Sciences.
I never regretted my decision, and during my time there I was introduced to many interesting topics. The football players who always seems to have more time than the others when on the ball have always fascinated me, and during my time at the Norwegian School of Sport Sciences I found the secret to the phenomenon. Geir Jordet introduced me to studies about visual perception in football, providing videos and detailed statistics about how the best players in the world perceive the footballing environment. This caught my full attention, and I had found what I wanted to write my master's thesis about.
Writing this master's thesis has been one of the greatest challenges of my life. With a full-time job and a career as a professional football player, it has taken me longer than I had hoped. However, the challenge of writing this thesis has also proven to be a very useful experience. It has helped me gain a wide array of knowledge on the topic of visual perception in football. It has given me the chance to write and develop my English skills, as well as my skills in SPSS and general statistics. It has put me in contact with many great human beings and it has given me the chance to work with people I look up to. I am fortunate to have had the opportunity to contribute new research to a growing research field on one of the most important skills for modern football players.

Finally, it is with great pride that I now conclude this chapter in my life and look forward to what comes next.

Takk til bidragsytere!

Veileder: Geir Jordet for muligheten til å gjennomføre dette prosjektet. Jeg setter stor pris på din enorme ekspertise, som har vært veldig motiverende og avgjørende for å fortsette når det har vært tungt.

Biveileder: Karl Marius Aksum for uendelig mange gode svar på mine mange spørsmål. Takk for at du har vært tilgjengelig for å hjelpe når jeg har trengt det, og for tydelige tilbakemeldinger.

Daniel Nordheim Pedersen: For hjelp til å sette sammen videofilene denne studien har analysert.

Stian Pettersen: For å ha "gått opp stien" med sin studie på eye tracking i fotball, for hjelp med Tobii Pro-utstyret og gode svar på spørsmål.

Tobii Technology AS! For god veiledning og opplæring av den aller nyeste teknologien innenfor eye tracking.

Mathias Haugaasen: For hjelp med statistikk.

Jørgen Bjørn: For hjelp med interreliabilitetsanalyse.

Familie og venner: Takk for at dere har gitt meg avgjørende avbrekk fra det som til tider har vært veldig tunge arbeidsperioder.

Elise: Takk for at du er den du er ☺

Abstract

The main aim of this study was to learn more about the way elite midfield football players use their eyes during head turns in 11v11 match-play, including how performance is affected by visual exploratory behaviour, how contextual factors affect the visual exploratory behaviour of elite midfield players, the role of fixations, timing of head turn initiation, and the duration of head turns. A field- and observational study was conducted and Gibson's (1979) ecological approach to visual perception applied as a theoretical framework together with the vision-in-action paradigm (Vickers, 1992, 2007, 2009). Four male elite midfield players (M = 20,75 years, SD = 2,87) from the Norwegian top division (Eliteserien) was investigated in 11v11 match-play situations using a mobile eye tracking device as well as an overview video film of the match-play. The content of the participants head turns was registered using the Tobii Pro Glasses 2 (Tobii Technology AB, Sweden). The head turns were analysed frame by frame using Tobii Pro Lab Analyzer and Scratch Play.

Results showed that fixations occur in less than one out of five head turns. Further, fixations occur in one out of three long duration head turns. Most head turns were initiated when the ball travelled between players and when a player had control of the ball without touching it. There were more opponents than teammates visible to the players in their head turns stop phase. A tendency of a positive correlation between the number of head turns performed by players in the final ten seconds before receiving the ball and performance was found, however not statistically significant. In attack most head turns were performed when the ball was within close proximity to the player. A relationship between the distance from the analysed player to the ball and head turn duration was found, as when in close proximity to the ball almost half of all head turns were of short duration.

This study was the first research conducted on 11v11 match-play using a mobile eye tracker, making it an exploratory study. The results indicate that the peripheral vision play an important role in elite midfielders' visual exploratory behaviour and that head turn frequency affect performance positively. The results provided need more research before conclusions can be drawn. Hopefully, the study can generate hypotheses for future research and function as a guide in future research using eye tracking technology to investigate visual perception in football.

1. Introduction

Football is one of the most popular sports in the world. The 2018 FIFA World Cup was watched by 3,572 billion people, and the final itself by 1,12 billion viewers (FIFA, 2018). According to FIFA 270 million people worldwide play the game regularly (2007). Yet only about 0.04 % play the game on a professional level. The game of football is highly competitive and difficult to master (Haugaasen & Jordet, 2012). Football skill has been described as "making appropriate decisions and actions to create and take advantage of situations of play in advantage of your own team." (Bergo, Johansen, Larsen & Morisbak, 2010). The game of football consists of physical, technical, tactical and psychological components, all of which are important to master for experts of the game. However, a growing consensus has emerged that the anthropometrical and physiological attributes are not key in separating the best players from the rest. Williams & Ford (2013) argue that technical abilities like passing and dribbling, psychological abilities like coping with pressure, mental toughness and resilience and tactical abilities like decision making are key attributes discriminating between successful players and less successful players. Further, other researchers argue for the critical role of cognitive processes such as perception (Jordet, Bloomfield & Heijmerikx, 2013), decision making (Ward, Ericsson & Williams, 2013), anticipation (Roca, Ford, McRobert & Williams, 2011) and intention, in high level football performance (Jordet, 2005a). Perceiving what is going on around you is an important skill to master and is essential for any football player on elite level. The ability to "read the game" distinguishes skilled from less skilled players (Williams, 2000), and most of the information is being perceived by players' visual system, consisting of the eyes, head and body (Gibson, 1979). Vision is what gives information to the athlete about when and where to look in order to perform (Erickson, 2007). Brazilian midfielders reported that they used their visual systems to look around on the pitch and then using the perceived information to perform subsequent actions with the ball (Tedesqui & Orlick, 2015). Football players must make decisions based on the information they possess at any given time and in a football match the opposition is constantly trying to minimize time and space. Knowing when and where to look, and then being able to sort this information in a way which eliminates what is less important is essential for elite performance (Mann, Williams, Ward & Janelle, 2007; Panchuk, Vine & Vickers, 2015). Based on this information, perceptual skills are suggested as one of the key abilities for elite performance in football (Jordet et al., 2013; Jordet, 2005a), and have therefore attracted the attention of researchers. Most of the research performed on perception in sports have been conducted within a laboratory setting, ignoring the actual sport context (Vealey, 2006). The lack of appropriate technology has been one important reason for why most research on perceptual-cognitive skills in sports have been conducted in laboratories. Researchers argue that field studies are needed to complement this research area, where you involve investigation of a phenomenon within the context it naturally occurs (Jordet, 2005a). Eye tracking technology like the Tobii Pro Glasses 2 are now available, allowing for eye tracking studies to be performed in the actual sport context.

This study examined the head turns of midfielders in the Norwegian top division (Eliteserien) using a mobile eye tracking device (Tobii Pro Glasses 2). Four central midfield players were analysed in a 11v11 match-play situation. Their eye movements during head turns were registered and analysed using eye-tracking technology and an overview video film. The goal of this study was to build on previous research on perception in football, by providing information from an eye-tracking device in 11v11 match-play. The main aim was to investigate the way elite midfield football players use their eyes during head turns, in order to execute consistent and precise actions. There is no published research using eye tracking in an 11v11 match-play situation, making this an exploratory study. Consequently, this study may prove to be a hypothesis generating study, providing information which may lead to new research questions.

2. Introduction to theory

Extensive research has been conducted on the topic of visual perception in football. Football players are at any given time dependent on perceiving visual information from highly complex, dynamic environments to execute consistent and precise actions (for reviews, see Williams, Davids & Williams, 1999; Williams, Ford, Eccles & Ward, 2011). An important skill for football players is the ability to constantly process and interpret information, and then make decisions on what information is most relevant for elite performance at the time of action. Extensive research has been conducted on the topics of anticipation, decision making and attention (Casanova, Oliveira, Williams, Gargante, 2009; Mann et al., 2007). Research on visual perception and attention in sports has mainly been performed by monitoring athletes' eye movements in laboratory settings (Dicks, Button & Davids, 2010; Savelsbergh, Haans, Koojiman & van Kampen, 2010), and by comparing elite/highly skilled athletes with less-skilled/novice performers (Gorman, Abernethy & Farrow, 2015; Roca, Ford, McRobert &

Williams, 2011, 2013; Savelsbergh, Van der Kamp, Williams & Ward, 2005). A common denominator for most of the research on this topic is that it has been conducted in laboratories, and it belongs within the cognitive field of research. In contrast to this work, Gibson's (1979) ecological approach to visual perception has emphasized the importance of exploring perception in the real world.

2.1 Cognitive approach to perception

Cognitive processes are all processes where sensory input is elaborated, reduced, stored, recovered, transformed and ultimately used (Neisser, 1967). Perception, problem solving, imagery and pattern recognition are some of many aspects or hypothetical stages of cognition (Neisser, 1967). Further, perception is the process in which humans make sense of the world, with athletes perceiving and interpreting stimuli within the environment in order to successfully perform actions (Williams et al., 1999). Humans use their senses in acquiring this information. The visual, auditive and haptic receptors provide most of the sensory input, with vision seen as the most important source of information for most humans (McMorris, 2004). Studies within the cognitive approach to perception, has mostly been conducted by using pictures or videos, examining the athletes' eye movements, giving researchers complete control over what the subjects eyes are fixated on.

The essence in the cognitive approach to perception is that our awareness of the world happens indirectly. Cognitive research has given explanations that are built on structures of knowledge, sequential processing of information and other mental processes (Jordet, 2003). Proponents of the cognitive approach believe that within the perception-action relationship what we perceive is a mental reconstruction of the environment, meaning that perception can be studied separately from action (Williams et al., 1999). The information humans acquire depends on how it is interpreted (McMorris, 2004), and according to Gordon (1989) human senses and sensory input, consciously and unconsciously, must be processed into pictures. Information Processing Theory is one of the leading cognitive perspectives on perception, with the key assumption that perception does not happen immediately, but as a result of processes being carried out over time (Haber & Hershenson, 1974). According to this theory the senses are only to transfer information from the environment to the Central Nervous System, which in turn interprets the information in a way that makes sense. The Central Nervous System's ability to organize and interpret the information is based on previous experiences stored in the long-term working memory (McMorris, 2004). The Long-Term

Working Memory Theory claims that skilled athletes develop domain specific memory structures that facilitates the ability to quickly and precisely be able to code and obtain information from the long-term working memory when needed. This will help them in avoiding the limitations set by the short-term working memory and difficulties in obtaining information from the long-term working memory (Roca et al., 2011).

Signal Detection Theory (Swets, 1964) is another theory involving cognitive processes. According to this theory humans are able to perceive signals based on partial information (McMorris, 2004), because of their ability to recognise patterns. The phenomenon known as *closure* is an important aspect of pattern recognition. *Closure* occurs when we see an object moving towards us, lose it out of sight for a brief period of time, but we are still able to judge when and where it reappears by mentally “filling the gap” in our visual tracking (McMorris, 2004). The best football players in the world exemplify this skill perfectly when looking away from the ball scanning for information when the ball is travelling towards them, and still being able to “fill the gap”, which enables them to control the ball when it arrives at their feet. According to Information Processing Theory, this happens as a result of experience stored in the working memory (McMorris, 2004). To better understand how these processes function among athletes, a few laboratory studies will be presented below.

2.1.1 Laboratory research on perception

The first empirical studies on visual perception in football were performed within the cognitive paradigm in a laboratory setting (for review, see McGuckian, Cole & Pepping, 2017). For the most part, researchers have shown simulations of football related situations to athletes on a big screen using eye-tracking technology to monitor visual fixation-duration, frequency, location and order (Cañal-Bruland, Lotz, Hagemann, Schorer & Strauss, 2011; Helsen & Starkes, 1999; Roca et al., 2011; Roca et al., 2013; Williams & Davids, 1998; Williams, Davids, Burwitz & Williams, 1994). This research has contributed useful and reliable information related to perception of video-simulated situations in sports (Jordet, 2004).

As early as age 9, elite level athletes possess superior perceptual and cognitive skills compared with sub-elite level athletes (Ward & Williams, 2003). Research in football has shown that experts possess more relevant and effective visual search strategies, fewer fixations of longer duration, and the ability to fixate on more informative areas as well as the ability to anticipate future actions (Williams & Davids, 1998; Helsen & Pauwels, 1993).

Further studies have concluded that skilled players are superior when it comes to context specific pattern recognition compared with less skilled players (Abernethy, Baker & Côte, 2005; North, Ward, Ericsson & Williams, 2011; North, Williams, Hodges, Ward & Ericsson, 2009; Williams & Davids, 1995; Williams, Hodges, North & Barton, 2006).

In 1994 the first laboratory study in football where players were exposed to a video simulation of an 11v11 match-play situation was conducted (Williams et al., 1994). The study compared experienced football players with unexperienced players. The players were shown video footage as seen from the perspective of a central defender in a defending situation, having the entire game in front of them. The results showed that the experienced players perform more visual fixations of shorter duration when compared with unexperienced players. This was considered as preferred behaviour for anticipating an opposition players' pass direction. The study also found that the experienced players performed more fixations away from the ball and the player in possession of the ball, which made the researchers suggest that experienced players employ a more relevant and extensive visual search strategy compared with unexperienced players (Williams et al., 1994). Four years later, Williams and Davids (1998) published a study examining visual search strategies in smaller groups of players. They conducted an eye tracking study in 1v1 situations and 3v3 situations, again focusing on the defensive part of football. The results showed a higher visual search frequency, more fixations of shorter duration and longer fixations on the opposition's hip area amongst the experienced players in the 1v1 situations. The results showed no significant differences in search strategies between the two groups in the 3v3 situations, which the researchers attributed to the increasing need for peripheral vision in obtaining task specific information in a more complex situation (Williams & Davids, 1998). The results also showed that experienced players possess superior anticipating abilities (Williams & Davids, 1998), which is supported by more recent research conducted on defensive 11v11 situations (Roca et al., 2011). This research has showed that skilled players employ a visual search strategy with more fixations of shorter duration and more fixations towards information sources away from the ball and player in possession the ball. These studies suggest that experienced players make use of more relevant visual search strategies, which may explain their superior ability to anticipate opponents' actions and their own decision-making (Roca et al., 2011; Williams et al., 1994). Also, experts perform fewer fixations and fixations with longer duration than non-experts (Mann et al., 2007), which has proven to be more expedient when collecting task specific information (Williams, Davids, Burwitz & Williams, 1993a). This is acknowledged by another study finding that skilled decision makers had more fixations with shorter duration than less skilled decision makers (Vaeyens, Lenoir, Williams & Philippaerts, 2007a).

In 2007 a very interesting study was conducted on 87 young, male Belgians. The researchers compared elite youth players (recruited from soccer academies in the top division) with sub-elite youth players (recruited from second or third division teams), players from regional teams and a control group of students who had not participated in team ball sports during the last 5 years (Vaeyens, Lenoir, Williams, Mazyn & Philippaerts, 2007b). Participants were shown videos of attacking sequences designed to represent typical situations these players would experience in a match setting, with researchers monitoring their eye movements with an eye-head integration system. The sequences involved a relatively small number of players, varying from 2v1 to 5v3. Elite youth players focused their vision more centrally than the other participants, thus using their peripheral vision to a larger extent (Vaeyens et al., 2007b). The researchers propose two big advantages with this visual search strategy. Evidence suggest that information can be processed more quickly through peripheral vision than through the fovea, providing an advantage in time constrained situations. Also, using the peripheral vision means fewer eye movements, reducing the number of saccades, which are considered as inactive periods of information processing (Wright & Ward, 1994). The study also found that elite youth players alternate their gaze between the player in possession of the ball and other areas of the display more frequently than the other participants, matching the findings of Williams et al. (1994). Further, football players possessed superior decision-making skills compared to the control group (Vaeyens et al., 2007b). The research of Helsen and Starkes (1999) support this finding. They found perceptual similarities and differences between semi-professional football players and kinesiology students. Their study was based on a multidimensional approach where they exposed their subjects to both pictures and video in offensive simulated situations. Tests were conducted on non-specific tasks, like clarity of sight and the ability to follow a moving object with the results proving no differences between the two groups (Helsen & Starkes, 1999). On the football specific tasks, however, the semi-professional players performed fewer fixations of longer duration and they located more fixations towards free space away from the ball when compared with kinesiology students. They were also able to find the best decisions on the basis of fewer fixations. The researchers attributed this to the football players' previously attained football specific knowledge, which is believed to help them recognise patterns for quicker and more precise decision making (Helsen & Starkes, 1999). Cañal-Bruland et al. (2011) supports these findings, in a study investigating differences between skilled, less-skilled and novice football players. The research group consisted of 56 male participants and they were tested in offensive, defensive and unstructured football situations. This study also found that skilled football players perform significantly fewer fixations of longer duration compared with less skilled players (Cañal-Bruland et al., 2011). An interesting finding in this study, surprising the researchers, is that the skilled players do not use a larger visual span than less skilled players. A larger visual span would mean them being able to process more information from a broader visual area. This finding is in contrast with previously presented research (Vaeyens et al., 2007b; Williams et al., 1994).

Another interesting study was published in 2011, where skilled and less-skilled football players were studied in an 11v11 situation from the perspective of a central defender (Roca et al., 2011). This study showed that skilled players were more accurate than less skilled players at anticipating the intentions of opponents and subsequently deciding on an appropriate course of action. Their visual search strategy involved more fixations of shorter duration in a different sequential order and towards more informative locations in the display than the less skilled players (Roca et al., 2011). This finding is in direct contrast with the findings of other studies, where expert perform significantly fewer fixations of longer duration (Cañal-Bruland et al., 2011; Helsen & Starkes). Roca et al. (2011) argue that the differing results presented on visual search strategies can be attributed to methodical differences. An important thing to consider is the nature of the task playing an important role in which visual search strategies skilled players employ when scanning for information (Williams, 2000). His study showed that visual search strategy differs when comparing 11v11-situations with 4v4-situations and offensive situations with defensive situations (Williams, 2000).

One relatively new addition within the cognitive approach on visual perception in sports is Neuro Tracker (NeuroTracker, 2016). Neuro Tracker is technology based on years of scientific research, designed to optimize perceptual-cognitive performance in sport. A user of the Neuro Tracker will be equipped with a set of 3D goggles, focusing his attention on a specific number of spheres on a screen. Some of the spheres (usually four out of eight) will be highlighted for about one second, before they start moving around on the screen. After a while the spheres will stop moving, and the observer is asked to identify which spheres were highlighted before the session started. If the answer is correct the spheres will move faster in the next session, and if the answer is wrong the speed decreases (Faubert & Sidebottom, 2012). The exercise is built on multiple object tracking (MOT). Classical theories of attention have assumed that attention is single focused, but there are many everyday activities that demand our focus to attend to multiple stimuli at the same time. This was proven by Cavanagh and Alvarez (2005), which found that observers are able to track up to four different targets simultaneously for several seconds. In 2016 a study investigating 3D-MOT in football was published by Romeas, Guldner and Faubert. The researchers wanted to find out if a non-contextual, perceptual-cognitive training exercise could increase football performance. 23 Canadian university-level football players were tested in the skills of passing, dribbling and shooting in small-sided games, before they were split into three groups. The experimental group (n = 9) then performed ten sessions of 3D-MOT training, seven players watched real 3D footage from the 2010 FIFA World Cup and the final seven participants were in a passive control group receiving no particular training outside of regular football practices. The results show no significant improvement in dribbling or shooting, but the experimental group improved their passing accuracy significantly compared with the other groups (Romeas et al., 2016). This led the researchers to conclude that their study presents the first evidence in which a non-contextual, perceptual- cognitive training exercise has a transferred effect onto the football field. These results are to be viewed with caution. The number of participants were limited to 23 Canadian university level footballers, with one of the authors being Chief Science Officer of Cognisens Athletics Inc., the producers of commercial version of the NeuroTracker (Romeas et al., 2016). Also, no inter-observer test was conducted on the data.

2.1.2 Laboratory studies and methodical limitations

Laboratory research has contributed a significant amount of useful and reliable knowledge about perceptual expertise in football (Jordet, 2005a). Still, the game of football is a highly complex team sport, and when you move a highly complex team sport into a laboratory, recreating the competitive environment is challenging. Laboratory research fail to account for things like pressure from opponents, tactics and position on the field (Jordet, 2005a). Moving football into a laboratory fails to fully capture a player's expertise, knowledge and sport-specific movements (Pinder, Headrick & Oudejans, 2015). Skilled football players in a football game are constantly moving their heads and eyes to "look around" the field (Williams & Ford, 2013). This is not recreated in a traditional laboratory set-up. Researchers have claimed that laboratory research in which players receive information from a screen put in front of them, without any simulated motion parallax, may in fact compromise players' perception (Craig & Cummins, 2005). Most laboratory research have a significant limitation in the way that research subjects have been asked to register non-sport-specific movement responses, such as verbal responses (Williams et al., 1994; Roca et al., 2013), moving a computer mouse (Williams et al., 1994), writing with pencil on paper (Ward & Williams, 2003), stepping on response pads (Williams & Davids, 1998), moving a joystick (Savelsbergh et al., 2005) and multiple spheres selection (Romeas et al., 2016). Non-sport-specific responses like the ones mentioned above comes with limited ecological and external validity, and needs to be changed if the goal is to produce knowledge about visual perception in actual match-play situations (Jordet et al., 2013) As previously mentioned, most laboratory research has been conducted without any simulated motion parallax, which may suggest low validity, considering the highly complex, 360-degree competitive environment football players perceive information from in a game (Jordet, 2004; Jordet et al., 2013). Supporting this, research has shown that greater differences are registered between experts and non-experts in field studies than in research using video and pictures (Mann et al., 2007). Research presented have also indicated that the best players only resort to their superior perceptual skills if the situation reflects the dynamic reality that meets the player in a game setting (Cañal-Bruland et al., 2011).

Laboratory research has contributed a significant amount of useful and reliable knowledge about perceptual expertise in football (Jordet, 2005a). Still, research on perception in football needs to increase its ecological and external validity with field research (Araujo, Davids & Hristovski, 2006; Jordet, 2005a; Jordet et al., 2013). Field studies involves investigating a phenomenon in the context in which it naturally occurs (Jordet, 2005a). Field studies are conducted within the ecological framework, where emphasise lies in the perception of the real world and the strong relationship between perception and action (Gibson, 1979). Expert performance is best understood and described using an ecological dynamic framework because of the emphasise this framework puts on the relationship between the performer and the environment (Seifert, Button & Davids, 2013).

2.2 Ecological approach to perception

> Let us remember once again that it is the perception of the environment that we wish to explain. If we were content to explain only the perception of forms or pictures on a surface, of nonsense figures to which meanings must be attached, of discrete stimuli imposed on an observer willy-nilly, in short, the items most often presented to an observer in the laboratory, the traditional theories might prove to be adequate and would not have to be abandoned. (Gibson, 1979, p. 239)

The quote above illustrates quite clearly what Gibson feels is key when researching perception. An extremely dynamic, complex and information rich environment characterize the game of football (Jordet et al., 2013), contrasting strongly with the traditional set-up in laboratory research. Exploratory behaviour provides the link between perception and action (Gibson, 1979). Gibson's ecological theory on visual perception tries to provide an understanding of perception in the real world (Jordet, 2005), making it more suitable for research on perception in football than the cognitive approach. Researchers have emphasised the importance of providing research with high ecological and external validity (Araujo et al., 2006; Jordet, 2005a; Jordet et al., 2013). Following in the footsteps of Aksum (2016), Pedersen (2016) and Pettersen (2018), this thesis will use Gibson's (1979) ecological theory in trying to provide further understanding on the topic of perception in football.
The relationship between information from the environment and individuals' ability to perceive this information has been proposed as the most important variable to study (Jordet, 2005a). In doing so, this thesis will present some key perspectives from Gibson's (1979) ecological theory.

Direct perception refers to actually experiencing and perceiving something in natural surroundings (Gibson, 1979). In the context of football and perception, an optimal example would mean actually being on a football field, with 21 other players, in a 11v11 match-play situation. According to Gibson "we must perceive in order to move, but we must also move in order to perceive" (Gibson, 1979, p. 223). Football players and specifically midfielders and forwards are constantly surrounded by opponents and teammates (Jordet et al., 2013) and skilled players constantly move their heads and eyes around to perceive movements of opponents, teammates and the ball (Williams & Ford, 2013). According to ecological psychologists, all information is available to the observer in what we see, indicating that no prior experience is needed when perceiving the environment (McMorris, 2004). Gibson compares experiencing the Niagara Falls live to seeing a picture of it, in an attempt to explain direct perception (Gibson, 1979). He highlights ambient optic array as important, which has been described as "the structured light in the environment" (Reed, 1996, p. 49). The structure of the ambient light is important to what information we perceive, which is characterised by the specific pattern in the energy fields of the environment, not the organism (Gibson, 1979).

Football players, as well as all other humans, perceive and act on surfaces (e.g. the football pitch), substances (e. g. the smell of grass), places (e.g. the football stadium), objects (e.g. the ball or opposition players) and events (e.g. the football match) in the environment (Araujo et al., 2006), which only an ecological research paradigm can provide. These opportunities or possibilities to act are referred to as affordances. Jordet (2003) exemplify affordances using a ball placed on the ground. A football player will probably experience affordances like kicking the ball or maybe start juggling with it, whilst his or her parent most likely would pick the ball up and put it somewhere safe for her son or daughter to play with the next day. In football, affordances are everywhere, meaning that players need to discover affordances through exploratory behaviour involving movements of eyes, head and body to perceive the 360-degree surrounding environment (Reed, 1996). Fajen, Riley & Turvey (2008) claim that the theory of affordances is the conceptual pillar of the ecological approach to perception and action in sport. Simultaneously, affordances also provide a challenge for ecological psychology. As mentioned earlier, ecological psychologists believe that all information is available to the observer in what we see (McMorris, 2004). In the highly complex, extremely dynamic and information rich environment of professional football (Jordet et al., 2013), this will provide a significant challenge for players. McMorris (2004) claim that players will automatically scan for the most important information in the environment that can help us in reaching our goal. To use an example from football; a central defender put in a 1v1 situation against an attacker, will scan for the most important information helping him stop the attacker. In a situation like this, experience will play an important part, as research show that athletes who acquire expertise gradually attune themselves to affordances that can support them in achieving their performance goals (Davids, Araujo, Seifert & Orth, 2015). This is supported by Vicente and Wang (1998) that experts are more skilled at perceiving the important affordances.

According to the ecological approach to perception all information exist in the environment, specified by affordances that the observer perceive (Reed, 1996). This relationship is one of the strengths with Gibson's ecological approach, as humans base their perception and their actions on what they perceive from the environment (Jordet, 2004). We do not need to break information down into sensory elements and experiences (Gordon, 1989), which directly contest everything the cognitive approach believe. Perception is an activity (Gordon, 1989) and the connection between perceptual information and motoric control occurs when exploring the environment (Gibson, 1979). Gibson has argued that exploratory movements are of a different nature and have a different function compared with movement made to interact and alter the environment (Gibson, 1966). Reed (1996) deemed these interacting movements as performatory, defining them as movements made to compete for resources by using force interacting with the environment. Performatory and exploratory actions often occur at the same time, as exploratory actions do not interfere with the environment like the performatory ones does (Reed, 1996). In the game of football teammates, opponents, free space and the ball are examples of environmental resources that constitute future opportunities for action which the players need to compete for to win (McGuckian, Cole, Chalkley, Jordet & Pepping, 2018a) So, in reference to performatory actions, the environmental resources are constrained, but at the same time they are always available to every player on the pitch in performing exploratory actions.

In 2018 a visual exploration study was conducted to better understand the importance of exploratory action for performatory action in situations where the participants are surrounded by affordances (McGuckian et al., 2018a). The experiment investigated head movements of Australian youth association football players by simulating a game situation in a laboratory setting, measuring head movements using a 9-DOF Intertial Measurement Unity (IMU; SABELSense, Nathan, QLD, Australia). What is unique about this study is the use of an IMU, which is technology strapped to a headband used by the researchers to collect information about VEBs. The study produced two main findings, with the first being that the time constraints of the task influenced the head movements and performatory actions of footballers in their constructed passing task. In situations where the players were afforded only 1 second to explore their environment before receiving the ball, their head turn frequency was higher after receiving the ball compared to when afforded 2 or 3 seconds before receiving the ball. The second finding was that the higher head movement frequency after receiving the ball slowed down the speed of a passing response. To elaborate, players responded with a pass more quickly when afforded 2 or 3 seconds of gathering information before receiving the ball. This information provides further evidence for the importance of exploratory action in service of the prospective regulation of movement (McGuckian et al., 2018a). The authors believed their study to clearly demonstrate that prospective regulation of movements require visual exploration of a football players environment to discover affordances in the environment (Adolph et al., 2000; Gibson, 1979; Reed, 1996).

One key element in Gibson's ecological approach to perception is the relationship between perception, action and intention (Davids et al., 2015). The goal of perception is to guide us into making good decisions in the future (Jordet, 2004). The movement of a football player creates continuous information about new opportunities for action as a direct consequence of the ever-changing relationship with the environment (Davis et al., 2015). According to Montagne (2005), prospective control is based on a player's perception of his or her relationship to the environment. The prospective control is dependent on exploration in that it needs information gathered from the environment to be able to adjust future actions (Adolph, Eppler, Marin, Weise & Wechsler Clearfield, 2000). Especially visual exploration is seen as one of the key components to prospective control (Jordet, 2004). In football prospective control can be observed in intercepting passes. Interceptions demand high quality perceiving of information to identify where a pass will be played (Jordet, 2003). The visual system is the most important part of the perceptual system, consisting of body, head and eyes (Gibson, 1979). Gibson has split exploratory activity into three levels, with the highest involving body movement, the middle involving head movement and the lowest involving movement of the eyes (Gibson, 1966). The lowest level can only be understood in relation to the two levels above (Jordet, 2004), and will be thoroughly investigated in this thesis. This paragraph has tried to capture the essence of VEB and will conclude with a definition of what it is.

> A body and/or head movement in which the player's face is actively and temporarily directed away from the ball, seemingly with the intention of looking for teammates, opponents or other environmental objects or events, relevant to perform a subsequent action with the ball (Jordet et al., 2013, p. 2).

2.2.1 Field studies

In the last few decades visual exploratory behaviour in football has been researched in real world settings (Eldridge, Pulling & Robins, 2013; Jordet, 2004, 2005b; Jordet et al., 2013). Common for these studies is the application of close-up video films and investigating the head movements of football players. Geir Jordet is seen as a pioneer on the field, claiming that the ecological approach is an appropriate framework for investigating the relationship between perception and action in complex and dynamic team sports, such as football (Jordet, 2004). Findings from his doctor dissertation will be provided, along with other relevant research conducted on visual perception in real world settings.

In Jordet's doctor dissertation, eight elite midfield football players were selected and investigated in four different studies to provide information about their perceptual expertise in a complex and dynamic competitive team context (Jordet, 2004). In the first study VEBs among four players on an international level were investigated. The results could not prove any significant relationship between exploratory behaviour and performance. In the next study, three of the four players were interviewed in order to examine how the players experienced perceiving information to prospectively control their actions. The players reported that VEBs was conducted in order to map out future actions to perform when receiving the ball. They also reported that their visual exploratory behaviour was constrained by playing style, the ball and stress (Jordet, 2004). Further, Jordet followed one player over a period of three years investigating the relationship between exploratory behaviour and performance. This study showed that in periods were performance was high, the VEBs was characterized by higher VEB frequencies, shorter time between the final scan before receiving the ball and more often oriented towards the oppositions' goal. This indicate a positive relationship between VEBs, prospective control and performance in football (Jordet, 2004). The final part of Jordet's doctor dissertation was an individualised 10-14 week long imagery training program. Results showed that two of the three participants improved their visual exploratory behaviour, but only one had marginal improvement of performance (Jordet, 2005b). All of the participants believed the intervention had improved their perception and performance on the ball, which could indicate that the lack of improvement in performance could be due to how performance was judged in this study (Jordet, 2004, 2005b).

In 2013 a study investigating visual exploratory behaviour in three 14-year-old midfield football players in match situations was published (Eldridge et al., 2013). The researchers found that players performed more forward passes, executed more passes into the attacking half, performed more turns when opportunities arose, and experienced less defensive pressure when performing visual exploratory behaviour prior to receiving the ball (Eldridge et al., 2013). The same year a study including 118 English Premier League players investigating the relationship between visual exploratory behaviour and performance was published (Jordet et al., 2013). Separating from Eldridge et al. (2013), this study also investigated visual exploratory behaviour frequency. They counted the number of scans a player made in the final 10 seconds before receiving the ball, comparing this to performance. Performance was measured in completed passes and completed forward passes. Unsurprisingly, the players with the highest VEB frequency completed more passes and especially forward passes, than players with lower VEB frequency (Jordet et al., 2013). These differences were significant in both halves and for both forwards and midfielders, proving a positive relationship between visual exploratory behaviour and performance with the ball (Jordet et al., 2013). A master thesis conducted on eight world class midfield and forward players showed similar results. Players that perform extensive VEB, execute more actions in the attacking direction, are more forward oriented when receiving the ball, and are under less defensive pressure compared to when exploring less (Pedersen, 2016). The study also investigated the timing of when visual exploratory behaviour was initiated, finding that 30 % of head turns are initiated when the ball travels between teammates, 34 % when a teammate has control of the ball without touching it and 30 % when the ball is travelling from a teammate towards the analysed player (Pedersen, 2016).

A PETTLEP imagery intervention study was conducted on five elite academy football players from an U18 elite UK academy (Pocock, Dicks, Thelwell, Chapman & Barker, 2017). The players included were central midfielders (N = 2), wide midfielders (N = 2) and center forward (N = 1). They were put through a six-week PETTLEP imagery intervention program. The researchers investigated visual exploratory activity, which is very closely related to the term visual exploratory behaviour, used in this thesis (therefore, VEB will be used in the continuation). The results indicated that a PETTLEP imagery intervention training program leads to improvements in VEBs, particularly in central midfielders (Pocock et al., 2017).

In 2018 a study including 32 semi-elite male football players from the Australian National Premier League was published (McGuckian, Cole, Jordet, Chakley & Pepping, 2018b). The study was conducted in 11v11 match-play with the players wearing an IMU (SABELSense, Nathan, QLD, Australia) housed within an elastic headband reporting how often a player explores their environment (head turn frequency) and how much of the environment is explored (head turn excursion). The researchers found a strong connection between head turn frequencies and head turn excursion. Also, higher than average head turn frequency and head turn excursion resulted in a higher likelihood of turning with the ball, playing a pass in the attacking direction and playing a pass to an area opposite of where it was received from. These findings suggest that for players to make successful use of their surrounding environment, they must explore their environment sufficiently. This is best done by employing an exploration strategy consisting of high head turn frequencies and excursions (McGuckian et al., 2018b).

Common for most research conducted within the ecological approach to perception is that it tells us nothing about what is actually visible to the players. Knowing where and when to look is of great importance for performance (Mann et al., 2007), suggesting a need for research to be conducted on this field. The use of IMU in McGuckian et al. (2018a, 2018b) is a welcome step forward in applying modern technology to research conducted on perception in football. A natural step further would be to investigate what is visible to the players and where they fixate their eyes in 11v11 match-play. With the technology we have available eye tracking is the best option to do this. Recently, two master theses from The Norwegian School of Sport Sciences have been conducted applying this technology. Schutte (2017) performed an eye tracking study on visual fixations for one goalkeeper in the Norwegian Eliteserien in 11v11 match-play, whereas Pettersen (2018) compared visual exploratory behaviour and fixations between professional and amateur football players in a rondo exercise. Pocock et al. (2017) suggest that future research should examine how player positions and abilities influence VEBs. Further research is needed, and this thesis will try to contribute to the growing field of research on perception in football. The main aim of this study was to investigate the way elite midfield players use their eyes when they perform head turns for information in 11v11 match-play, using a mobile eye tracker.

2.3 Eye tracking

Eye tracking technology is used to track and register movements of the eye. The technology has been applied in a wide array of research fields, such as neuroscience, psychology, marketing and education to name a few (Duchowski, 2002). The first ever study involving eye tracking in sports was by Bard & Fleury in 1976, investigating search strategies in basketball players. The same duo went on to perform an eye tracking study in ice hockey (Bard & Fleury, 1981). During the 80's and 90's eye tracking was used investigating penalty kicks in football (Tyldesley, Bootsma & Boomhof, 1982), baseball hitting (Bahill & LaRitz, 1984), badminton (Ripoll, Papin, Guezennec, Verdy & Philip, 1985) and golf putting (Vickers, 1992). Most of the research using eye tracking technology has been conducted within laboratory settings, because of limitations with equipment and technology. In recent years technology has developed significantly, allowing researchers to bring eye tracking technology to the real world, producing research with higher ecological and external validity (Araujo et al., 2006; Jordet, 2005a; Jordet et al., 2013).

2.3.1 The visual system and eye movements

The eyes are the dominating sensory organs of the brain (Hubel & Weisel, 1968). It is absolutely essential for effective perception of the environment. To explain benefits of applying eye tracking technology, one must first have an understanding of the visual system. Fovea is a part of the eye's retina providing us with the ability to see clear and detailed pictures. The fovea is very small allowing only 2-3 degrees of acute vision (Land, 2006). Consequently, to be able to collect information, we need to move our heads, eyes and body in a way which puts information in the line of the fovea. This process is called gaze control (Panchuk et al., 2015). Gaze control includes several different eye movements that help bring objects of interest onto the fovea and to keep this information steady so that the observer can extract details. Muscles surrounding the eye initiate these eye movements, which will be defined and explained below.

Saccades are quick eye movements that bring our point of maximal visual acuity onto the fovea so that an object can be seen with clarity (Thilo, Santoro, Walsh & Blakemore, 2004). They link fixations and pursuit tracking together providing a cohesive view of a scene. Saccades are the fastest movement the body can produce, and humans supress information processing between saccades in order to prevent a blurry, incomprehensible world.

Fixations are known as a steady gaze to allow for complex processing of visual information from a location (Panchuk et al., 2015). In football, fixations allow attention to be directed towards specific details in the environment, helping guide players with their decision-making and motor control skills. A fixation is the eyes focusing point in the environment, allowing for visual perception (Holmqvist, Nyström, Andersson, Dewhurst, Jarodzka & Van de Weijer, 2011), which in turn helps football players with their prospective control (Adolph et al., 2000; Gibson, 1979; McGuckian et al., 2018a; Reed, 1996).

Pursuit tracking (Panchuk et al., 2015) or smooth pursuit (Holmqvist et al., 2011) is known as "the maintenance of steady gaze on a moving object or target" (Panchuk et al., 2015, p. 177), an important skill in high-speed sporting tasks. In football, this skill is important as a player follows a cross or shot on goal.

2.3.2 The eye tracking technology

Tracking of people's eyes have been a popular approach used by researchers for decades. It started with simple observational techniques (e.g., Hackman & Guilford, 1936). Technological advances now allow researchers to put various eye trackers onto people in order to measure their eyes and eye movements. Previously, the eye trackers were built on complex systems, making them user-unfriendly and highly uncomfortable to wear (Duchowski, 2007). Modern eye tracking devices exist in three main groups; screen based, webcam and wearable. This study will use a wearable device, as the purpose is to investigate football players in a real-world setting. The Tobii Pro Glasses 2 allow for maximum mobility for the participants as well as providing data from ecologically valid environments (Discombe & Cotterill, 2015). The eye tracker will provide data from two sources; sensors directed towards the eyes of the participants and a camera filming what happens around the player on the field.

2.3.3 Possible limitations

Within the research field of eye tracking there are a few limitations one has to be aware of. Historically eye tracking research has been nearly impossible to conduct within the ecological framework, because of limitations in the technology. This is highlighted by Williams et al. (1999) pointing to range and accuracy, calibration and set-up time as well as the time required to analyse data using frame-by-frame video analysis.

One technical limitation proposed by Holmqvist et al. (2011) refers to the sampling frequency of the device. Most wearable eye tracking devices have a frequency varying from 30 to 50 Hz, which is deemed a slow system compared with some of its stationary predecessors (Holmqvist et al., 2011). Some newer systems operate with 120 Hz, which is a big advantage for research conducted in high-speed sports like football. At the same time, research comparing the utility of eye tracking systems using 60 Hz with systems using 120 Hz in a fast aiming task proved no significant differences (Helsen, Starkes, Elliott & Ricker, 1998). The limitations of a slow system are potentially outweighed by the benefits of providing information collected from real-world settings, especially considering the researchers focus on fixations (> 100ms) over saccades (Panchuk et al., 2015). Another technical limitation lies with the equipment's ability to capture the participants entire field of vision. There are blind zones, especially in peripheral fixations, meaning important data may be lost (Tobii, 2016). Further, some methodical limitations must be addressed. Sun light contain high levels of infrared light, possibly affecting the sensors in the eye tracking system (Discombe & Cotterill, 2015). Therefore, controlled and well-lit environments are recommended when carrying out research involving eye tracking technology (Tobii, 2016). Also, the physical features of an individuals' eyes (e.g., eye colour, positioning of the eyes, contact lenses) can limit the possibility of calibrating an eye tracking system. This can lead to selective collection of data, excluding specific sectors of the population, which limits external validity (Panchuk et al., 2015).

The final limitations with eye tracking research relate to interpretation of the collected data. Eye tracking is limited to providing information about what the fovea looks at. No peripheral visual information is provided. Also, just because the eye fixates on a certain object does not mean that attention is focused on the same object (Panchuk et al., 2015). Two football players having similar gaze behaviours will not automatically have seen or attended to the same cues, as their individual interpretation of that they see, and their attention might have differed (Henderson, 2003). Therefore, Panchuk et al. (2015) highlight the importance of identifying performance measures to separate looking from seeing, to determine how football players use visual information.

2.4 Approaches to eye tracking

There are two main approaches to eye tracking in sports; visual search and vision-in-action (Vickers, 2007, 2009). Visual search is conducted in a laboratory setting, with participants giving some sort of a simplified response to stimuli. Early research involved static scenes from the sport in question (Bard & Fleury, 1976). Static stimuli have since been replaced by more dynamic images representing scenarios from the normal task environment. Participants' way of responding has also evolved, varying from verbal response (Buszard, Farrow & Kemp, 2012) to more natural responses like mimicking a cricket stroke (McRobert, Williams, Ward & Eccles, 2009). This approach gives the researcher strong experimental control over presented stimuli and allows for visual information to be manipulated. Criticism has been directed towards the synthetic display used and towards the types of responses required by participants. Critics claim this type of research may lead to visual exploratory behaviours dissimilar to those displayed in real world sport environments when actual responses are required (e.g., movements, Dicks et al., 2010).

The vision-in-action approach investigate the gaze behaviour of individuals as they perform different phases of a sporting task as they do in the real world (Panchuk et al., 2015). The vision-in-action approach represents an important advancement for understanding gaze behaviour. Through the eyes, head and body, this approach allows athletes to selectively control the information they perceive from their real-world environment, when it is perceived and how it is used (Panchuk et al., 2015). An advantage with the vision-in-action approach is that it provides a relatively objective measure of the acquisition of visual information during "free viewing" (Panchuk et al., 2015). It also provides greater flexibility in what skills can be assessed compared with the visual search approach. Although used in this research, the vision-in-action approach also has its limitations. In applying this approach, the researcher sacrifices some experimental control (Panchuk et al., 2015). This can be compensated through careful planning.

This is, to my knowledge, the first ever study conducted on visual exploratory behaviour using a mobile eye tracking device in 11v11 match-play in football. Previous eye tracking studies in football have focused on a player's fixations (e.g. Pettersen, 2018; Schutte, 2017). This study differs, as it investigated what happened only when the players look away from the ball in order to collect information. Therefore, the term "head turns" will be applied when describing the visual exploratory behaviour investigated in this study. The vision-in-action approach to eye tracking was applied, as the research is highly dependent on high ecological and external validity. Separating this study from previous research done on visual exploratory behaviour, is that it focuses on the actual movements of the eye during head turns, using a mobile eye tracker.

The main goal of this study was to provide information about the way elite midfield players from the Norwegian top division (Eliteserien) use their eyes during head turns, using a mobile eye tracker.

Further, the aims of the study were to answer the following problems:

1. What do elite midfield players look at when they perform head turns?
2. What role does fixations play in visual exploratory behaviour?
3. When are visual exploratory behaviour initiated related to what happens on the ball?
4. How is performance affected by visual exploratory behaviour?
5. How does duration affect visual exploratory behaviour?
6. How do contextual factors affect the visual exploratory behaviour of elite midfield players?

3. Method

3.1 Participants

Originally, the participants in this study were six male football players from the Norwegian Eliteserien. Two players were excluded from the study (see situation inclusion criteria for more info). The remaining four participants (M = 20,75 years, SD = 2,87) were all midfield players, split between two different teams in Eliteserien. A written consent form was presented and signed by all participants, as of the requirements from "Norsk Senter for Forskningsdata" (NSD).

3.2 Design

The participants were equipped with the Tobii Pro Glasses 2 eye tracking device in order to track their eye movements and provide information about what is visible to them during VEBs. They were also filmed from above, by a 4K-video camera. Two of the players were filmed in a 11v11 friendly match against a team playing on level 4 for a duration of 20 minutes. The other two players were filmed for 10 minutes each in a 11v11 training drill simulating real world match-play.

3.2.1 Field studies

Field studies involves investigating a phenomenon in the context in which it naturally occurs (Jordet, 2005a). Researchers argue for and call for research with high ecological and external validity (Araujo et al., 2006; Jordet, 2004; Jordet et al., 2013). Cañal-Bruland et al. (2011). In doing so, researchers may sacrifice some control, internal validity and experimental elegance (Jordet, 2005a). For example, Carlson and Morrison (2009) argue that observational studies often include weak control of confounding factors and low precision of measurements. However, an ecological approach excludes the low external validity of laboratory studies, whose results at best can predict behaviour in other laboratories (Martens, 1979). Therefore, the vision-in-action approach was applied to this study. The players perform in a 11v11 match-play scenario, were the only constraints given to the players is in a rule of "no heading" the ball, providing high ecological validity.

3.3 Measurement instruments

The eye tracker used in this study was the Tobii Pro Glasses 2 (Tobii Technology AB, Sweden). It was used to register the player's visual behaviour when performing visual exploratory behaviour (scans) for information. The glasses are a mobile binocular eye tracker operating with 50 Hz. The Tobii Pro Glasses 2 have four built-in infrared sensors catching the movements of each eye. They also contain a High-Definition camera (1920 x 1080p, 25 fps)

to film the visual picture seen by the players. The glasses operate with a visual span of over 160 degrees horizontally and 70 degrees vertically (Tobii AB, 2016). There is also a microphone catching sound stimuli from the environment. The visual behaviour was registered and stored in Tobii Pro Glasses Controller (TPGC) version 1.73.8622 and on a 32 GB memory card. The memory card was localized in a recording unit strapped onto the players. The weight of the glasses are 45 grams. The total weight when including the recording unit with its battery, SD card, wires and nose pad, is 312 grams. The data was analysed using Tobii Pro Lab (TPL) version 1.70.8207 (x64).
The video camera used in this study was a Panasonic AG-UX90 4K/HD Camcorder. The camera was placed on a tripod and filming was conducted from a point higher than ground level on the middle of the pitch.

3.4 Procedure

The eye tracking device consists of many different technological parts, meaning lots of little things can go wrong when using them. To get accurate measurements and decrease probability of challenges arising when gathering data, proper preparations must be done in advance. Pilot testing of the equipment is important to find out if the equipment is fitting to the environment in which the research will be conducted, as well as testing compatibility between software and the technical equipment used. Two pilot studies were conducted on groups of youth football players.

Preparations
Before arriving at the site of data collection the state of the technology and measurement instruments were tested. The batteries, computers and video camera were charged to 100 %, the SD memory card was checked, and the eye tracking device was examined for potential faults. The eye tracking glasses were checked for scratches and other possible damages.

Before the data collection starts
Before the testing start, all participants must have signed a written consent form in which they have been informed that they, at any point in time, can withdraw from the study. Then the selected participants must be checked for mascara, contact lenses and other types of glasses. Further, the technology and measurement instruments must be checked once more. The computer running the TPGC program must be running smoothly and the Tobii Pro Glasses 2's

connected with the recording unit using an HDMI-cable. Next, the recording unit must be switched on with the SD memory card in its correct position. If this is done correctly, a green light will be visible, and the recording unit is ready to establish a WLAN connection to the TPGC on the computer. The next step will be to create an individual profile for the test subject, where the subject is tested and calibrated with the Tobii Pro Glasses 2. This is important, so that the correct equipment (e.g., nose pad, head strap etc.) can be provided. Correct equipment is crucial in order to get the best possible data from the participant's eyes but also to limit the possibility of the equipment falling off during match-play.

Every recording provides a certain percentage of gaze samples. 100 % means that both eyes are found throughout the recording. A low percentage of gaze samples would mean loss of potentially crucial information, highlighting the importance of adjusting the eye trackers properly. The recording unit is strapped to the player, most often in the back of the player's shorts to avoid limiting the natural movements of the player. Using a GPS-vest could be even better, as getting the device closer to your body would limit any added disturbance from having the device strapped to the shorts. It would also make body contact with other players less endangering to both equipment and the study, as the probability of a wire falling out or the recording unit to loosen would lessen.

Inside the TPGC there is an adjustment tool called *The Track (Adjustment) tool* which can be used in order to make sure the eye tracking device catch the pupils of the players. The tracking box tells the researcher if the positioning of the glasses needs to be changed, either higher/lower or to either side (see figure 1). If moving the position of the glasses does not work, the nose pad should be switched out. Making sure the Tobii Pro Glasses 2 are positioned correctly will provide more accurate and valid data to analyse. The last part of the pre-testing procedure is the final calibration. Here, the participant has to stay from 0,75–1,25 meters from the researcher, which holds a calibration card. Further, he or she has to focus directly on the black dot in the middle of the calibration card. This is done in the same conditions where the study will be conducted (See Figure 1). When calibration is successful a green catch will appear on the computer screen. Next, the participant should be granted some time to get to know the equipment. When all this is done, the recording is ready to commence, and the collection of data can begin.

Figure 1: Illustration of the calibration process. Note. From Quick Start Guide Tobii Glasses 2 (p. 4), by Tobii Pro AB (publ), Karlsrovägen 2D, S-182 17, Danderyd, Sweden. Reprinted with permission, see appendix

During data collection

When recording the eye tracking video will be shown on the computer as long as the participant stays within its reach. If the participant moves outside of reach the connection between the computer and the eye tracking device will be broken, but the recording unit will continue recording the data. However, if connection between the eye tracking device and the recording unit is broken, the recording will stop. If that happens, the participant must be re-calibrated before the data collection can restart.

After the data collection ends

When the data collection is finished, the video recording must be terminated according to instructions and recommendations provided from Tobii (Tobii, 2016). This is especially important if the connection between the eye tracking device computer have been broken during the data collection period. When the data recording is terminated properly, all data is saved on the SD memory card placed in the recording unit. Then, the recording unit must be switched off holding the power button for about 5-10 seconds. After this, the SD memory card can be taken out and consequently placed in a computer and on an external hard drive for safe storage and analysing in Tobii Pro Labs.

3.4.1 Procedure – specific for this study

This study was conducted with the help of two teams playing in the Norwegian Premier League, Eliteserien. As with most elite sport environments, gaining access to teams from the Eliteserien can be challenging (Waddington, 2014). This study collected data in partnership with a doctorate dissertation. Geir Jordet, my supervisor, reached out to a range of clubs in the Eliteserien via E-mail. Two clubs showed particular interest, providing us with three players each. One player from each club was later removed from the study for different reasons. These players were informed about the contents of the study, verbally and in writing, signing written consent forms before the study could commence.

Data was collected in two different cities on two different parts of the year. The first part of data collection was performed in May on an artificial turf training pitch. A three-man team of researchers were part of the data collection. The date for the first data collection to be conducted fell on a sun-filled day, providing a possible challenge for the eye tracking equipment (Discombe & Cotterill, 2015). The optimal conditions to conduct an eye tracking study would be on a cloudy day, but rescheduling was not an option. Consequently, the participants had to play for the team least affected by the sun conditions. The first part of calibration and testing of the equipment, a small pilot test, was performed by a research assistant, in the shadows outside the players' dressing room. Individual profiles were created in TPGC. This part of the data collection was performed in a 11v11 match-play split into three 10-minute periods, as part of a full training session. The participants went through warm-ups and a possession drill, before the data collection started. They were re-calibrated by the same assistant in the same manner as before and put into the 11v11 match-play, as data collection was ready to commence. One team played in blue training gear whilst the other wore yellow bibs. Recording of the data was started on the computer, with the research assistant monitoring the video screen throughout the testing period. The recording unit were strapped to their shorts. Unfortunately, a few challenges arose. Two of the players lost the recording unit to the ground, limiting the amounts of situations recorded. One player's recordings were limited to such an extent that he was excluded from the study. Connection between the recording unit and the computer were broken once during the data collection. This did not impact the data.

Part two of data collection was conducted early fall, in similar weather conditions. This time data collection was also conducted by a three-man team of researchers, but the research assistant was replaced by this study's supervisor. The data collection was performed in a

11v11 friendly against a team from level 4 split into three 20-minute periods. Both teams suited up in their traditional full-kits and the match was played on a grass pitch. Calibration and testing of the equipment was performed just outside the dressing rooms and the players were allowed a small pilot test of the equipment. Individual profiles were created in TPGC. The players then went back in to the dressing room preparing for the game. They later re-emerged for a traditional pre-match warm-up. The participants then went through a re-calibration repeating what was done in the first calibration process, just before kick-off. The players wore the recording units in GPS-vests as opposed to strapped to their shorts in the previous study. There were no challenges involving the recording unit falling down, but connection between the recording unit and the computer broke down. This did not impact the data.

3.5 Situation inclusion criteria

This study was originally conducted on six participants but two were excluded for different reasons. One was excluded because of technical difficulties, as there were multiple breaks between the recording unit and the Tobii Pro Glasses 2. This limited the amount of data he produced to less than four minutes. When performing data collection with one of the clubs, a misunderstanding occurred. The club thought the glasses could be put on a central defender, which was not in line with the purpose of this study (or one of the most important positional demands, heading the ball). Therefore, a player who was not part of his clubs first team squad was selected (something which the researchers did not know at the time). This player was later excluded from the study, as he is not classified as an elite football player.

The four participants included in this study provided a total of 2653 seconds of effective game-time to analyse (M = 663.25 seconds, SD =218,59). The quality of the data varied. Each recording provides a certain percentage of gaze behaviour registered. The participants in this study scored 86 %, 83 %, 70 % and 64 %. This is lower than the percentages shown in Pettersen (2018). His research was performed in 5 v 2 rondos, which demands considerably less movement than 11v11 match-play and also involves fewer contextual limitations. Two of the players had long hair, which could have contributed to the percentages being lower.

A total of 871 head turns were registered and analysed. Head turns conducted within two seconds of play being restarted (e.g., throw-ins, free-kicks and goal kicks) was included, as information collected in this period is classified as relevant for subsequent actions. This was challenging in analysing two of the players. There were some customised rules in the 11v11 conducted as part of a training session. The coach was refereeing the matches. When a free kick was received, play was restarted from the team's goalkeeper. Some refereeing decisions were conveyed verbally instead of the traditional blowing of a whistle-technique used by referees in competitive matches. This might have led to a few head turns being excluded from the study unnecessarily. With the other two participants data collection was performed in an 11v11 friendly, with a licensed refereeing team.

3.6 Variables

To find good objective performance measurement tools for this study time was spent searching databases like Web of Science, Sport Discuss, Scholar, Brage etc. Significant time was spent consulting various football analysts, coaches and researches in order to come up with the most relevant variables to investigate in a 11v11 match-play eye tracking study. Previous research conducted using the Tobii Pro Glasses 2 (e.g., Pettersen, 2018; Schutte, 2017) were considered, and a set of variables was compiled in cooperation with my supervisor and a Ph.D. Candidate investigating visual perception in elite football players. A few concepts need to be explained.

> A body and/or head movement in which the player's face is actively and temporarily directed away from the ball, seemingly with the intention of looking for teammates, opponents or other environmental objects or events, relevant to perform a subsequent action with the ball (Jordet et al., 2013, p. 2).

The quote above is a definition of visual exploratory behaviour provided by Jordet et al. (2013), adopted in many studies. The definition is applied to this study as well, but the term head turn is preferred over VEB when referring to the results provided. Previous research using eye-tracking has focused mainly on fixations (eye movements), while this study focuses only on eye movements registered when players perform head turns. "A head turn was defined as a distinct movement of the head about the longitudinal axis" (McGuckian et al., 2018a, p. 8), starting when the ball is no longer visible inside the picture frame provided from Tobii Pro Glasses 2. The head turn ends the moment the ball reappears inside the picture frame.

Below, the key variables in this study will be presented (see Appendix for a complete overview).

3.6.1 What do the players look at during head turns?

In every head turn the number of teammates and opponents visible to the analysed player have been registered. Consequently, if a player is in the picture frame, but not visible to the player, he is not registered as visible. The number of teammates and opponents have been registered during head turns both before, during and after the stop-phase. The stop phase is the exact moment when the head turn stops, before returning back towards the ball. If a fixation is registered in a head turn, the picture frame of the fixation is registered as the stop phase. In the stop phase, defined as the exact moment of the head turns last stop phase, information is registered for what is visible in the entire picture frame and inside the Tobii Pro Fixation Circle. The Tobii Pro Fixation Circle size is set to 100 %.

3.6.2 Fixations and timing of head turn initiation

This study investigated if the head turns include fixations, which is registered by the Tobii Pro Labs Analyzer when the eye fixates in one place for 60 milliseconds (6 hundredths) or more. Several studies (e.g. Cañal-Bruland et al., 2011; Williams et al., 1994) highlight the role of fixations in VEBs. This study will investigate the actual number of fixations registered in head turns in a 11v11 match-play situation, with the aim of providing new data with high ecological and external validity (Araujo et al., 2006; Jordet, 2004; Jordet et al., 2013).
The actions being performed with the ball when the head turn is initiated is also investigated (e.g. player has control over the ball without touching it, when a ball is travelling from one player to another). This variable provides information about the timing of head turns.

3.6.3 Performance

Performance was measured in whether the player performs a successful pass after receiving the ball, and whether the pass is played forward or backwards. The final ten seconds before the player receives the ball is investigated, to provide information about head turn frequency. Head turn frequency was split into three equal groups. Low head turn frequency means 0.3 head turns or less per second in the final seconds before receiving the ball. Medium head turn frequency means 0.31-0.58 head turns per second in the final seconds before receiving the ball and high head turn frequency refers to 0.59 head turns or more.

3.6.4 Duration of head turns

The duration of each head turn is one of the thesis' main variables. The duration of the head turns will be grouped into short duration (≤ 26 hundredths), medium duration (27-42 hundredths) and long duration (≥ 43 hundredths) head turns. The split was decided by finding the cut point for three equal parts of the registered head turns in SPSS. This variable will be presented in relation with different contextual factors.

3.6.5 Contextual factors

Differing parts of the context is investigated. Whether head turns are conducted in in attack or defence was registered. If neither, it will be classified as other. One contextual factor is related to where the player and ball is positioned on the pitch when a head turn is initiated. Therefore, the pitch has been divided into 16 parts, where 1-8 refers to the players own half and 9-16 refers to the opposition's half (see figure 2). Distance between the player and the ball has been registered and will be classified into distant proximity (≥ 22 meters), medium proximity (15-21 meters) and close proximity (≤ 14 meters). The split was decided by finding the cut point for three equal parts of the registered head turns in SPSS. Another contextual factor is whether the ball is positioned closer to the player's own or opponents goal line compared with the player. The direction of the head turn is registered either as right or left.

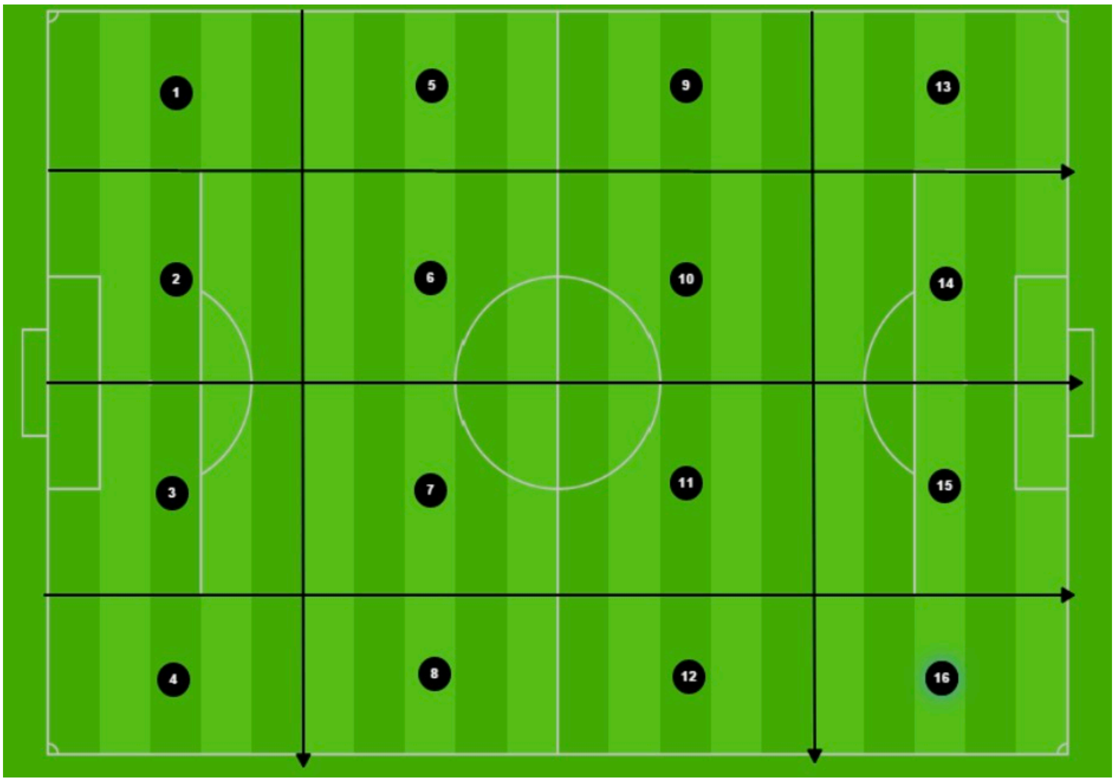

Figure 2: The figure shows a map of the pitch used for operationalisation of the areas on the pitch. The areas from 1-8 refers to the players own half and 9-16 refers to the opposition half, from left to right.

3.7 Video analysis

3.7.1 Tobii Pro Labs

Figure 3: Illustration of Tobii Pro Lab where the VEB analysis were conducted. Note. From the analysis program Tobii Pro Lab (v. 1.70.8207), by Tobii Pro, Tobii AB (publ), Karlsrovägen 2d, S-182 17, Danderyd, Sweden. Reprinted with permission, see appendix

The observational analysis was conducted using Tobii Pro Lab (v. 1.70.8207) (see figure 3) and a split-screen function (see figure 4). During the recordings data was collected with 50 Hz frequency and every single data sample identified with a timecode and X, Y coordinates were sent to be analysed in Tobii Pro Lab. The size of the player's fixation circle was adjusted to 100 % and the gaze filter selected was *Raw*, showing all registered eye movements the player made during the recording. During all visual exploratory behaviour (scans) the *Tobii I-VT Fixation (Velocity-Threshold identification fixation filter)* gaze filter was used to investigate whether or not a fixation was made during the head turn. Tobii IV-T is a velocity filter based on algorithms recognising fixations and smooth pursuit (Holmqvist et al., 2011). However, the filter cannot distinguish between fixations and smooth pursuit, providing an uncertainty regarding whether the participants perform a fixation or a smooth pursuit.

3.7.2 Split-screen function

The aim of this study was to investigate what is visible to football players when they perform visual exploratory behaviour for information in 11v11 match-play. Contextual factors such as distance between the player and the ball, position on the pitch, attacking or defending needs video from a different angle than the eye tracking device can provide. Therefore, an overview video was recorded to be synchronised with the video from the Tobii Pro Glasses 2. This was done using Sony Vegas Pro 13 producing a split-screen video in full HD (1920 x 1080, 50 fps). The eye tracking video was on the left side and the overview video on the right (see figure 4). When performing the data analyses, this allowed for all the data to be analysed at the same time, perfectly synchronised. The eye tracking glasses provided clear images, but in some situations the sun light made it difficult to be 100 % sure about what you saw. Also, the ball was sometimes covered by teammates, oppositions or simply being too far away from the player to see. The overview video provided crucial information in these situations. Sometimes the ball disappeared from the overview video but was visible in the eye tracking video.
The split-screen function was also used in a match-play analysis where the amount of time spent in attack and defence was measured. This was done in order to provide information about the scanning frequency in attack and defence for each player.

Figure 4: Illustration of the split-screen function used to analyse what happens during VEBs. The overview video (right) and the eye tracking video (left) was edited and synchronised.

3.7.3 Reliability

The reliability of measurement in performance analysis is critically important in the area of sport science (Bloomfield, Polman & O´Donoghue, 2007). In this study both interobserver and intraobserver reliability will be tested. The intraobserver test was performed by the author of this thesis six weeks after the original analysis concluded. For observational data to have credibility it is common for one or more observers to confirm the original observer’s data (Kratochwill & Wetzel, 1977). Therefore, an interobserver test was conducted on 10 % (N =

88) of the complete dataset (N = 871). Observational research demands knowledge about the field one is going to research (Kerlinger & Lee, 2000). Therefore, the interobserver test was conducted by a previous football player, now an UEFA B licensed coach, seven weeks after the original analysis concluded. The interobserver analyst has completed a bachelor's degree in Coaching and Psychology at the Norwegian School of Sport Sciences. He went through an intense one-day training period where he familiarised himself with the equipment and the variables included in this study. Both tests were conducted on a randomised selection of head turns from this study, which was selected using Microsoft Excel. In Microsoft Excel the RANDBETWEEN formula was applied, providing 88 randomised head turns from the original 871 registered visual exploratory behaviours.

Cohen's kappa is one of the original and most commonly used ways of checking for interobserver agreement when analysing nominal data (Gisev, Bell & Chen, 2013), as it provides high precision in calculating reliability (Little, 2013). The Cohen's kappa coefficients (k) scale ranges strength of agreement in almost perfect (0.81-1.00), substantial (0.61-0.80), moderate (0.41-0.60), fair (0.21-0.40), slight (0.00-0.20) and poor (<0.00) (Gisev et al., 2013) Cohens kappa has been used in several football analysis studies the last decade (Bloomfield et al., 2007; Tenga, Kanstad, Rongland & Bahr, 2009). Seven of the study's nominal variables were reanalysed and the analysis provided by the interobserver were compared to the original analysis. For the nine scale variables the Intraclass Correlation Coefficient (ICC) was applied. The ICC gives information about the magnitude of disagreement between two observers and is often used for assessing consistency "between judges' ratings of a set object" (Field, 2018, p. 1021) for interval, ordinal and ratio variables (Hallgren, 2012). In fact, the ICC has been suggested as a replacement for the Cohen's kappa, but further research and new indices needs to be developed (Gisev et al., 2013). Small-magnitudes of disagreement result in higher ICCs than larger-magnitudes of disagreement. The ICCs scale ranges strength of agreement in very good (0.90-1.00), moderate (0.80-0.89), acceptable/fair (0.70-0.79) and questionable/poor (<0.70) (O'Donoghue, 2012, p. 364).

3.7.3.1 Intrarater reliability

The reliability for playing phase (k = 1.00) and direction of head turn (k = 1.00) was perfect for intrarater reliabilty (k = 1.00). For ball position (k = 0.954), control or pass (k = 0.979), initiation of a head turn (k = 0.961), ball on the floor or in the air (k = 0.924) and fixation in head turn (k = 0.935), the reliability was almost perfect. The Intraclass Correlation Coefficient agreement was very good for player location (ICC = 0.999), ball location (ICC = 0.996), distance to the ball (ICC = 0.991), teammates (ICC = 0.966) and opponents (ICC = 0.966) in picture frame during head turns, teammates (ICC = 0.989) and opponents (ICC = 0.996) in the picture frame in the stop phase and teammates (ICC = 0.962) and opponents (ICC = 0.962) in the Tobii Fixation Circle in the stop phase in the intrarater reliability.

3.7.3.2 Interrater reliability

The Cohen's kappa interrater reliability for playing phase (k = 1.00) and direction of head turns (k = 1.00) was perfect. For ball position (k= 0.932), control or pass (k = 0.937), initiation of head turns (k = 0.961), ball on the floor or in the air (k = 0.801) and fixation in head turns (k = 0.866), the results were interpreted as almost perfect. The Intraclass Correlation Coefficient for interrater agreement provided very good agreement for player location (ICC = 0.980), ball location (ICC = 0.995), distance to the ball (ICC = 0.986), teammates (ICC = 0.960) and opponents (ICC = 0.993) in the picture frame, teammates (ICC = 0.989) and opponents (ICC = 0.994) in the stop phase and teammates (ICC = 0.783) and opponents (ICC = 0.783) in the Tobii Fixation Circle in the stop phase.

3.8 Statistical analysis

This study was analysed, and all data was processed using IBM SPSS Statistics 24. A Shapiro-Wilk test with the significance level set at $p < 0.05$, was conducted with results showing that all of the variables are significantly different from a normal distribution (Field, 2018). When the dataset is not normally distributed, non-parametric tests should be conducted. Non-parametric tests have been claimed to have less power than their parametric counterparts, but this is only true when data is normally distributed (Field, 2018). The Mann-Whitney U was used to compare two independent samples, and the Kruskal-Wallis H test was used to explore differences between more than two groups and conditions. The significance level was set at $p <0.05$. Both tests are based on ranked data, where data is ranked from lowest to highest (i.e. the lowest score is ranked as 1, the second lowest ranked as 2 and so on) (Field, 2018). Using the Kruskal-Wallis H test the original p value (0.05) is adjusted by dividing it on the number of pairwise comparisons conducted in the test. This is done to decrease the likelihood of a Type 1 error. In SPSS this adjustment of the p value is automatically calculated and interpreted in the Kruskal-Wallis H test. This makes it possible to operate with the significance still level set at $p < 0.05$. Consequently, all results provided from the Kruskal-Wallis H tests are shown with the adjusted p value, where the difference is significant if the p value < 0.05. Binary logistic regression analysis was used to test the probability of a categorical outcome variable to belong in a continuous or categorical predictor variable (Field, 2018). In this type of analysis, Odds Ratio (Exp(B)) is a good way of measuring effect size. Also, Spearman's rho was applied as the non-parametric equivalent to Pearson correlation (Field, 2018).

4. Results

In this chapter data from a total of 871 registered head turns will be presented. The results presented are from a large data set. The data analysed in this study was collected through registration of every head turn performed by four midfield players in the Norwegian Eliteserien during an 11v11 match-play situation. To my knowledge, similar research to what will be presented, has not been published. Therefore, the focus in this chapter, as well as the study as a whole, will be to present descriptive statistics. The descriptive statistics will focus on what the players look at, and fixations and timing of head turns. Some basic tests of the relationship between head turns and performance will be presented, as will the role of contextual factors on head turns. Because performance is only registered in the attacking playing phase, larger emphasis will be devoted to presenting results on attacking head turns and results for the complete data set.

4.1 Descriptive statistics

The players perform more head turns when in attack than in defence. 60.6 % of head turns are conducted when the analysed player's team has possession of the ball. 53 % of the playing time was recorded when the players were in attack and 47 % in defence. By dividing the number of head turns in attack with the amount of time spent attacking, the overall head turn frequency was 0.38/s. In defence, head turn frequency was 0.28/s. Table 1 provides descriptive statistics for the group, and also for both playing phases.

Table 1: Descriptive statistics of overall head turns, as well as for attack and defence.

	Number of head turns	Number of head turns with fixation	Number of seconds recorded	Ball closer to opposition goal line	Head turns performed when the ball is passed	Head turns performed when the ball is under control
Overall	100 % (N = 871)	18.14 % (N = 158)	100 % (N = 2653)	50.7 % (N = 442)	49.7 % (N = 433)	46.4 % (N = 404)
Attack	60.6 % (N = 528)	16.1 % (N = 85)	53 % (N = 1407)	35 % (N = 185)	48.1 % (N = 254)	48.9 % (N = 258)
Defence	39.4 % (N = 343)	21.3 % (N = 73)	47 % (N = 1246)	74.9 % (N = 257)	52.2 % (N = 179)	42.6 % (N = 146)

Note: Ball closer to opposition goal line refers to the number of times the ball was positioned closer to the opposition goal line in relation to the analysed player. Whether a head turn is initiated when the ball is being passed (or travelling between players) or a player has control of the ball, are two categories related to the same variable.

4.2 What do the players look at during head turns?

Separating this study from previous research on visual perception in football, is the information provided about how the players use their eyes. This information is relevant in relation to contextual factors on the pitch. Below the mean number of teammates and opponents visible inside the picture frame and Tobii Pro Fixation Circle in the stop phase is provided (see figure 8 and table 2). For most of the zones, there are more opponents visible in the picture frame than teammates. The players perform the highest number of head turns in the central zones closest to the midfield line, in zones 6, 7, 10 and 11 (81.5 %, N = 710). In zone 6, the mean number of opponents is 0.74 higher than the number of teammates. For zone 7 the mean number is 0.59 more opponents. On the attacking side of the midfield line, there are 0.37 more opponents than teammates visible in zone 10 and 0.75 in zone 11.

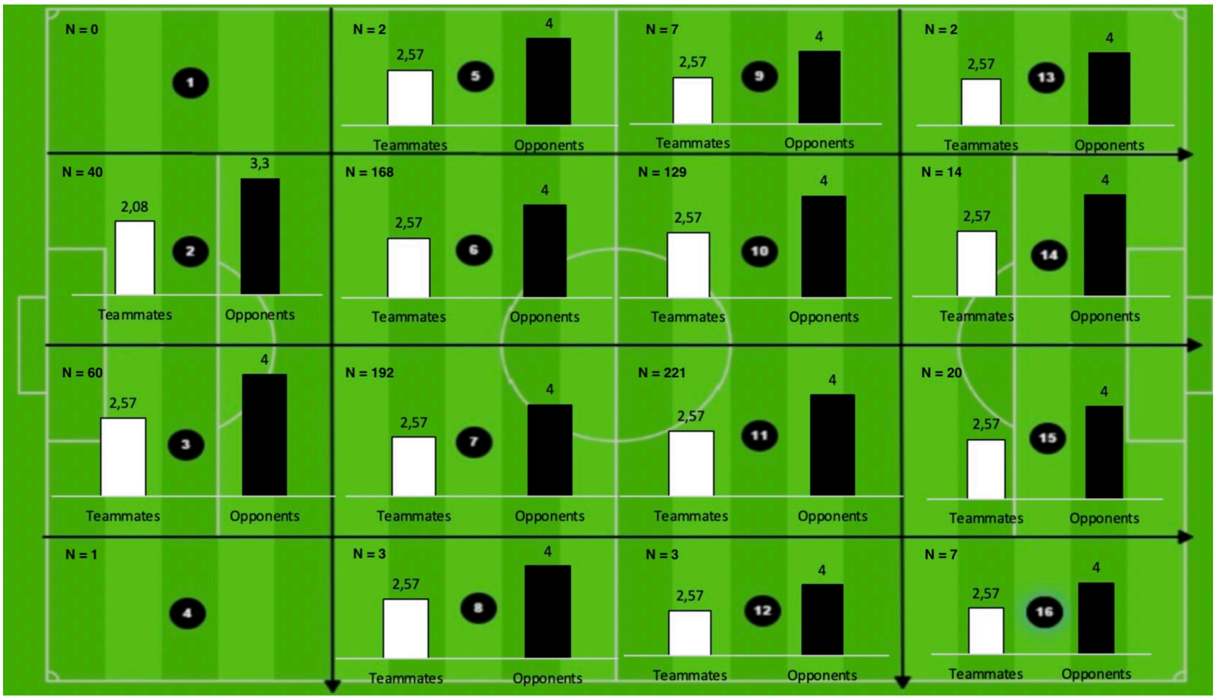

Figure 5: Mean number of players visible in the entire picture frame in the head turns stop phase in the different zones.

The fixation circle provides information about the exact point of fixation for the players. The contents of the fixation circle were registered during the head turns stop phase and is provided in table 2. Inside the fixation circle, the number of teammates and opponents are naturally lower than in the entire picture frame. Still, the same tendencies as reported in the entire picture frame, can be seen in the zones were most head turns are conducted (zones 6, 7, 10 and 11).

Table 2: Mean number of teammates and opponents visible inside the Tobii Fixation Circle in the head turns stop phase. Note: T = Teammates, O = Opponents, (N) = Number of head turns

Zone on the pitch	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
T:	.38	.48	0	1	.34	.32	.33	.75	.30	.37	1	0	.46	.22	.14
O:	.68	.45	0	0	.39	.45	.67	.25	.43	.48	1	0	.15	.22	.29
(N)	37	58	1	2	131	171	3	4	113	199	2	1	13	18	7

Inside the Tobii Fixation Circle, there were no teammates in 60.5 % (N = 527) and no opponents in 53.7 % (N = 469) of the head turns. One teammate (22.8 %, N = 200) and one opponent (28.5 %, N = 248) followed and then two teammates (3,9 %, N = 34) and opponents (4.8 %, N = 42). In 12.7 % of all situations, the Tobii Fixation Circle was missing in the head turns stop phase (N = 111).

4.3 Fixations and timing of head turn initiation

The results of this study show that fixations are not very common in the head turns performed by elite midfielders. Fixations occur in 18.14 % of the head turns registered in this study. In attack, fixations occur in 16.1 % of 528 registered head turns. Figure 11 provides the total number of head turns containing fixations, and the same for when the players are in attack.

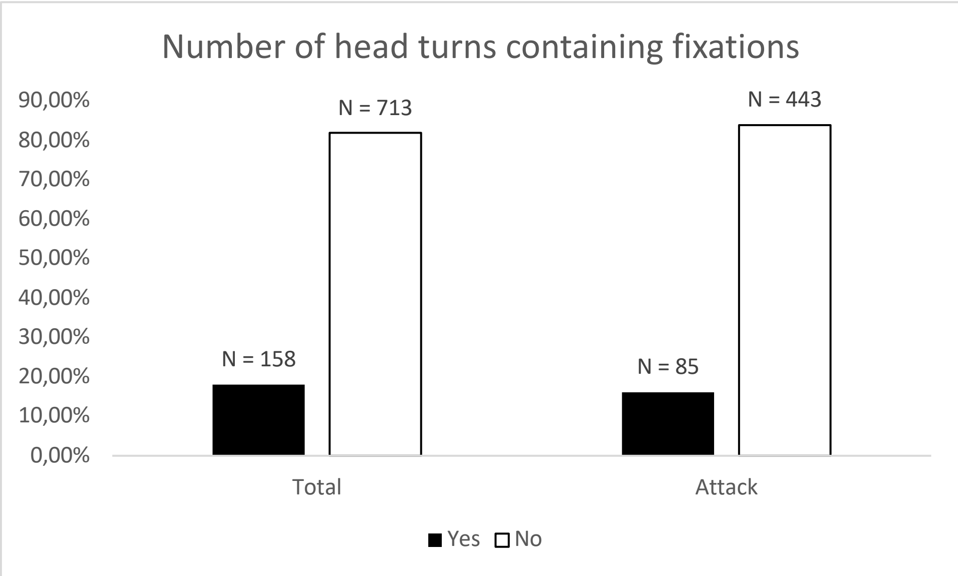

Figure 6: Number of head turns where the players perform fixations

The timing of head turn initiation in relation to game situations is important. In this study, registrations of what happened with the ball at the exact time of a head turn initiation were done. 48.6 % of head turns was initiated when the ball was travelling from one player to another. 41.1 % was initiated when a player had control of the ball without touching it. 2.5 % of head turns was performed when the ball travelled towards the analysed player. Whether a player had control of the ball or a pass was played (either exact moment a pass was played, or the ball travelled from one player to another) was registered. Fixations occur more frequently during passing than when a player has control of the ball (U = 81872, p = 0.017).

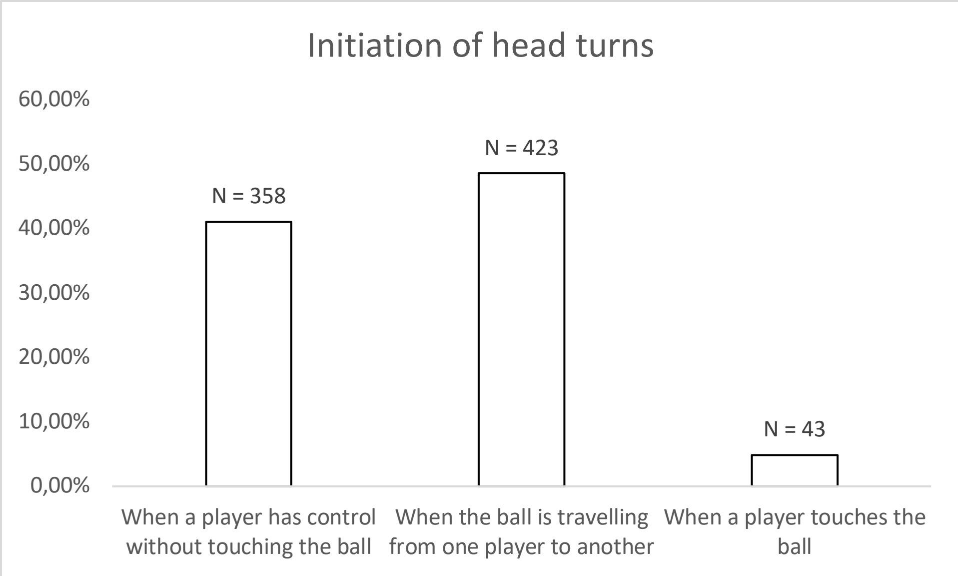

Figure 8: What is happening with the ball at the time a head turn is initiated

4.4 Duration of head turns

The study found that there is a relationship between the duration of head turns and whether or not the head turn contains fixations. Fixations were registered in 34.8 % of long head turns (N = 88), 12.1 % in the medium head turns (N = 36) and 10.5 % in the short head turns. A binary logistic regressions analysis showed that there is 4.5 higher likelihood of a fixation to occur in long duration head turns compared with short duration head turns ($p < 0.001$, OR = 4.5).

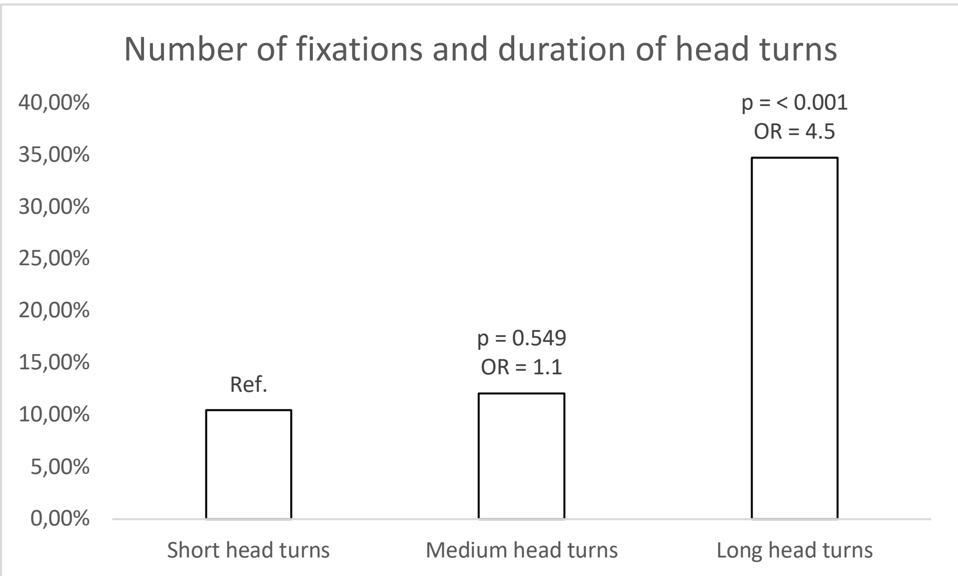

Figure 7: The relationship between head turn duration and fixations.

The Mann Whitney U test indicates that as the duration of a head turn increases, so does the likelihood of it containing a fixation ($U = 33121$, $p < 0.001$). In the defensive playing phase, there are fixations in 42.5 % of long head turns. In attack, fixations are registered in 30.2 % of long head turns.

4.5 Performance

Investigating performance, the results indicate that head turn frequency in the final ten seconds before receiving the ball is positively related to one basic measure of performance, although the sample is too small to conclude. 43 passes were registered in the study, with a total pass completion rate of 88.4 %. The relationship between performance and head turns was investigated by registering all head turns performed by the players in the final ten seconds before receiving the ball. Results from a binary logistic regression analysis provide an Odds Ratio Exp(B) of 7.5 higher chance in performing a successful pass with medium head turn frequency (0.31-0.58/s) when compared with low head turn frequency (≤0.3/s), but not statistically significant ($p = 0.093$). Because there are 100 % successful passes when the head turn frequency is high (≥ 0.59/s), the binary logistic regression analysis provide a very high OR number of 807737421. The analysis indicate a trend; a higher number of head turns performed in the final ten seconds before receiving the ball increases the likelihood of the player performing a successful pass.

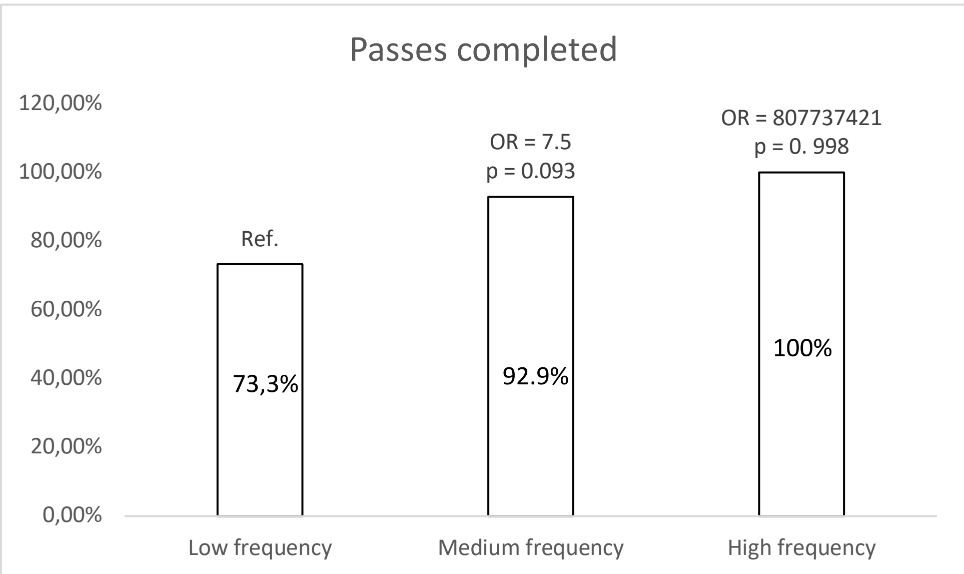

Figure 9: Successful passes in relation to head turn frequency in the final ten seconds before receiving the ball

Figure 10 (below) shows the relationship between forward passes completed and head turn frequency, indicating a positive relationship between performance and the number of head turns conducted in the final ten seconds before receiving the ball. The same binary logistic regression analysis was conducted on forward passes, providing an OR of 7.2 for medium head turn frequency when compared with low frequency. The data indicate that there is a positive relationship between the number of head turns performed in the final ten seconds before receiving the ball and the subsequent success of forward passes, however not statistically significant (p = 0.114).

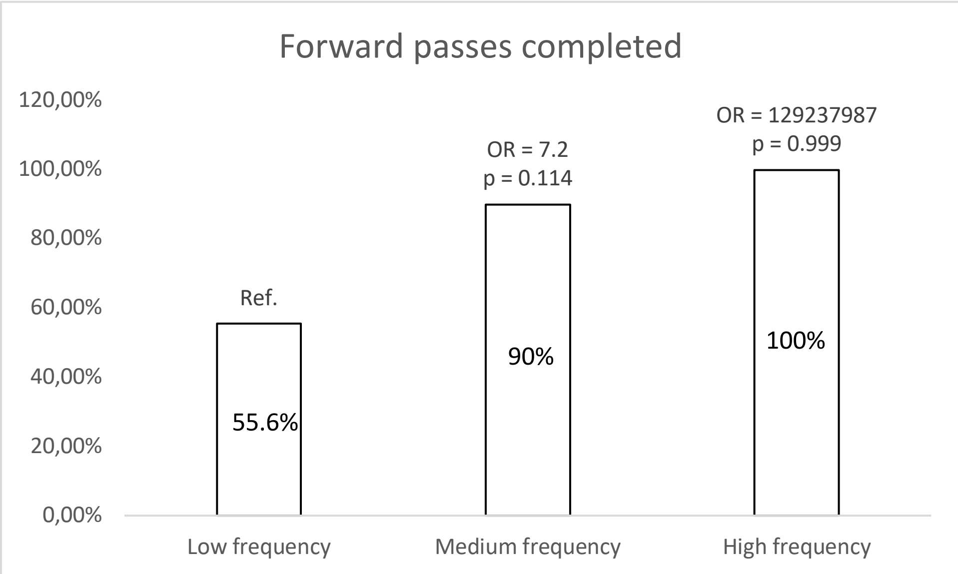

Figure 10: Forward passes completed in relation to head turn frequency in the final ten seconds before receiving the ball

4.6 Contextual factors

Playing phase is the most significant contextual factor registered in relation to head turns in this study. The distance between the player to the ball was divided into three equally large categories; close (≤ 14 meters), medium (15-21 meters) and distant proximity (≥ 22 meters). However, the results show that in the attacking playing phase, 41.9 % of head turns happen when the ball is within close proximity. The same tendency does not show in defence, where the number of head turns are more equally spread. Most head turns in defence happen when the ball was in distant proximity to the player (38.8 %). In attack, the ball is located closer to the players own goal line in 64.6 % of the head turns.

The distance between the analysed player and the ball seems to affect duration of head turns (see figure 11). When the ball is within close proximity of the player, 46.5 % of head turns are classified as short (≤ 26 hundredths). A Spearman correlation test showed that as the distance between the player and the ball increases, so does the duration of head turns (p < 0.001). This relationship also applies for the attacking playing phase, with 50 % of close proximity head turns being classified as short (p < 0.001). No significant relationship could be found between these variables in the defensive phase (p = 0.151).

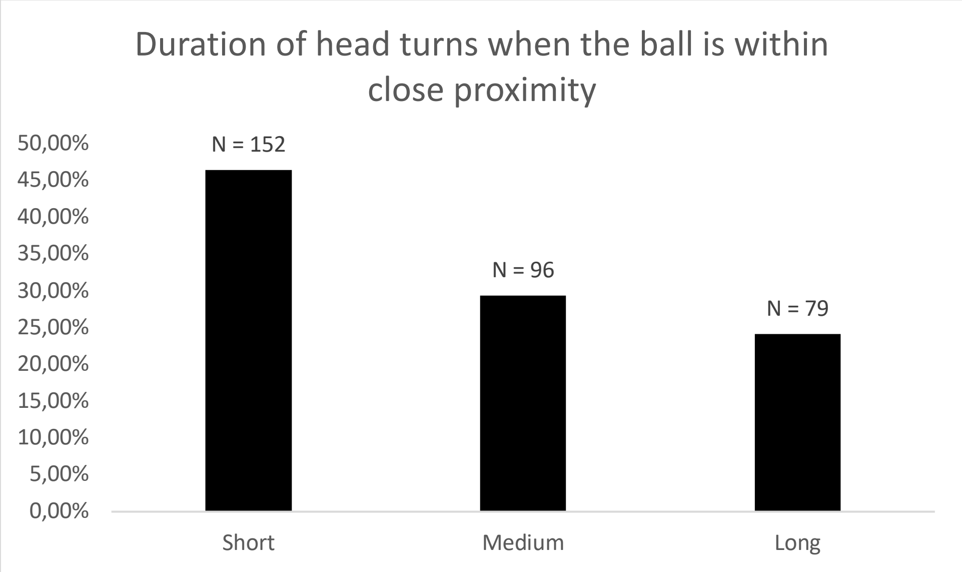

Figure 11: The distribution of head turn duration when the ball is within close proximity to the player (≤ 14 meters)

The football pitch was divided into 16 different zones. The data provided information indicating that the mean head turn duration is dependent on which zone the player is in, as by the results of a Kruskal-Wallis H test (p = 0.019). Below, a full overview of the mean duration of head turns in hundredths, related to each zone on the pitch is provided.

Figure 12: Overview of mean head turn duration in the 16 zones of the pitch, presented in hundredths. Note, N = number of head turns in each zone.

5.0 Discussion

The main aim of this study was to learn more about the way elite midfield football players use their eyes during head turns in 11v11 match-play, including how performance is affected by visual exploratory behaviour, how contextual factors affect the visual exploratory behaviour of elite midfield players, the role of fixations, timing of head turn initiation, and the duration of head turns. This study builds on previous ecological research conducted on visual perception in football (e.g. Jordet, 2004, 2005b; Jordet et al., 2012; Eldridge et al., 2013, McGuckian et al., 2018b), as well as master theses' from the Norwegian School of Sports Science (e.g. Aksum, 2016; Pedersen, 2016; Pettersen, 2018). Building on ecological research, Gibson's (1979) ecological approach to visual perception was applied. This study provides a new way of investigating visual perception in football, as a mobile eye tracker has never been applied in 11v11 match-play situations before. Players were given the full freedom provided in a regular football match, with the exception of a "no heading the ball"-rule, for their own safety. Below, a discussion of this study's most relevant findings will be conducted, in relation to relevant theory and previous research on visual perception in football. This is an exploratory study, which means that the results may not be easily compared to previous research. Still, this study has provided new information in a growing research field and will hopefully generate hypotheses for future research. Further, possible limitations, future research and implications for practice will be provided.

5.1 Fixations and timing of head turn initiation

The major finding regarding fixations was that they were only registered in 18.14 % of all head turns. In attack, the occurrence of fixations was even more rare with fixations being registered in only 16.1 % of the head turns. So, when football players turn their heads to collect information, their eyes rarely fixate on one or more sources of information. Williams & Davids (1998) compared experienced and less experienced football players and found that there was no difference in the search strategies in 3v3 situations, which they attributed to the increased role played by the peripheral vision. The results of this study can also be linked to the research of Vaeyens et al. (2007b), that showed elite youth players focusing their vision centrally, using their peripheral vision to a larger extent. This is proposed as an advantageous visual search strategy, as information is processed more quickly through peripheral vision than through the fovea, which is highly advantageous in time constrained situations. Also, using the peripheral vision means fewer eye movements, reducing the number of saccades, which is considered to be inactive periods of information processing (Wright & Ward, 1994). Limiting the inactive periods of information processing gives more time for the players to perceive the relevant information needed to perform subsequent successful actions. Consequently, the results provided in this study, may support previous findings in their conclusion that elite football players use their peripheral vision when performing head turns to collect information for future actions (Vaeyens et al., 2007b; Williams et al., 1998; Wright & Ward, 1994). Fixations are known as a steady gaze to allow for complex processing of visual information from a location which may be beneficial for football players (Panchuk et al., 2015). The results provided by this study may indicate one of two things; either the players do not need detailed information when they turn their heads looking for information or they do not look long enough for their eyes to fixate on these details. All of the studies mentioned above belong within the cognitive research paradigm, as they used eye tracking technology to investigate eye movements, with participants positioned in front of a TV-screen. Clearly, the methodical differences must be taken into account, but results from this study may have provided support to their conclusions.

The results related to timing of head turn initiation support previous findings by Pedersen (2016). 48.6 % of head turns were initiated when the ball was travelling from one player to another and 41.1 % was initiated when a player had control of the ball without touching it. 2.5 % of head turns were conducted when the ball travelled towards the analysed player. A relatively small amount of research has been published on timing of visual exploratory behaviour. One master thesis analysed eight world class midfield and forward players in attack and the timing of when VEBs were initiated (Pedersen, 2016). Champions League players initiate 30 % of their head turns when the ball travels between teammates and 34 % when a player has control of the ball without touching it. One big difference between the timing of world class players and the analysed players in this study, was related to how many head turns they initiate when the ball is travelling towards them. Champions League players perform 30 % of their total head turns when the ball is travelling towards them, which is significantly more than the 2.5 % registered in this study. There are a few possible explanations to why the results differ, with the most obvious being that world class players have better visual search strategies than players from the Norwegian top division. A positive relationship between VEB frequency in the final seconds before receiving the ball and performance have been found (e.g. Eldridge et al., Jordet et al., 2013), and updating your knowledge about the environment as close to receiving the ball as possible is recommended

(Jordet et al., 2013). Pedersen's (2016) study only investigated attacking situations, while this study investigated head turns in attack and defence. The world class players received more passes and probably spent more time closer to the ball, which comes with higher probability of receiving the ball. This study show that players perform more head turns in attack than in defence. In attack 4 % of head turns are registered when the ball travels towards the player, an increase from the 2.5 % registered overall, which may provide support to that explanation. Another possible explanation is related to the few involvements the players in this study had on the ball. A total of 43 passes were played, which means that the ball did not spend much time travelling towards them. Jordet (2004) asked which factors mostly influenced the players' VEBs and the answers indicate that the ball is the key influential affordance. Tedesqui and Orlick (2015) claim that as the ball is travelling towards you, you already know its trajectory. Therefore, you can turn your head looking for information and control the ball without looking at it. The results of this study support that claim. Timing of head turn initiation in this study suggests that when the direction or possible destination of the ball is likely to change, players experience it as less beneficial to perform head turns for new information. This was proposed by Pedersen (2016), and is supported by this study, as almost 90 % of all head turns are performed when the ball position and/or direction are determined, making it more beneficial for the player to explore other areas of the dynamic and complex environment in order to adapt their goal directed actions (Davids et al., 2015).
One final consideration has to be made in trying to interpret these results. During a football match most of the time is spent either when a player has control of the ball without touching it or when the ball travels between players. Future research should address the amount of time spent in the different situations in relation to the timing of head turn initiation. Also, a larger selection of players and more ball involvement by the analysed players are needed for an adequate comparison between world class players and players from the Norwegian top division to be conducted.

5.2 Duration of head turns

One very interesting finding, which may support one of the proposed explanations to why there are so few fixations in head turns, was that when players performed head turns with long duration (≥ 43 hundredths), fixations occurred in 34.8 %. Consequently, as the duration of head turns increases, so does the likelihood of a fixation to occur ($U = 33121$, $p < 0.001$). The probability of a fixation to occur during a long duration head turn is 4.5 times higher compared with short duration head turns ($p < 0.001$, OR = 4.5). This is not surprising, as fixations only happen when time is afforded for the eyes to gaze steadily. There were fixations registered in 18.14 % of head turns, which may indicate that the peripheral vision plays an important part in football players head turns. Williams et al. (2011) argue that visual search strategies involving fewer fixations of shorter durations are less effective, as they do not provide enough time to process signals that are relevant. This finding may imply that there is not enough time in short (≤ 26 hundredths) and medium (27-42 hundredths) duration head turns for the eyes to perform fixations. On the other hand, expert search strategies with fewer fixations have proven less exhausting and more effective in time constrained situations in football (Helsen & Starkes, 1999), which is also supported by other researchers (e.g. Vaeyens et al., 2007b; Williams et al., 1998; Wright & Ward, 1994).

There are indications that the distance between the analysed player and the ball seem to affect duration of head turns. When the ball is in within short proximity, 46.5 % of head turns are classified as short. A Spearman rho showed that as the distance between the analysed player and the ball increases, so does the duration of head turns ($p < 0.001$). This applies also in the attacking playing phase, where as much as 50 % of close proximity head turns are short ($p < 0.001$). Albeit performed on eye movements, these findings can be related to the previous research of Vaeyens et al. (2007a), which found that skilled decision-makers had more fixations with shorter duration than less skilled decision-makers.

Previous research on visual exploratory behaviour have mainly focused on eye movements and fixations (e.g. Williams et al., 1994; Williams & Davids, 1998; Roca et al., 2011). The rare occurrence of fixations in head turns may suggest that this is not adequate, if the purpose is to provide information about the characteristics of visual exploratory behaviour in football. At the same time, the higher number of fixations registered in long duration head turns provide reason to believe that fixations play a part in elite midfielders' visual exploratory behaviour away from the ball. The results provided may be seen as conflicting. The total number of fixations registered in head turns in this study imply that visual perception skill training in football needs to provide exercises and conditions where information is collected by the peripheral vision. The finding that fixations occur significantly more often in long duration head turns indicates that training players in fixation-related exercises and conditions is also important. Future research needs to investigate this relationship in order to provide valid information about how to develop superior visual exploratory behavioural strategies.

5.3 Performance

In this study, performance was measured in pass completion success and forward pass completion success, as has been done in previous studies (e.g. Eldridge et al., 2013; Jordet et al., 2013). Only 43 passes were attempted by the analysed players in this study, which is for sure an inhibitory factor for the significance levels provided in this study. The success of a pass seemed to be related to the number of head turns performed by the player in the final ten seconds before receiving the ball. When the players performed low head turn frequency (≤0.3/s), they completed 73.3 % of their passes. For medium head turn frequency (0.31-0.58/s), the completion rate increased to 92.9 % ($p = 0.093$), and with high head turn frequency (≥ 0.59/s) the players completed 100 % of their attempted passes. Comparing performance and head turn frequency, there is a tendency, however not significant, that medium head turn frequency increase the chance of a successful pass when compared with low head turn frequency (OR = 7.5, $p = 0.093$). The success rate of forward passes provided similar results, with 55.6 % completed when the head turn frequency was low, 90 % with medium head turn frequency and 100 % with high head turn frequency. The results indicate a similar relationship to what was reported with passes in all directions. Increasing your head turn frequency from low to medium, will increase the likelihood of performing a successful forward pass (OR = 7.5, $p = 0.114$). The results support previous findings, as researchers have found that players perform more forward passes, more turns when opportunities arose and experienced less defensive pressure when engaging in visual exploratory behaviour prior to receiving the ball (Eldridge et al., 2013). The presented results also correlate with results provided by Jordet et al. (2013), as players from the English Premier League with high registered VEB frequency completed more passes than players with lower VEB frequency. The results made them conclude with a positive relationship between visual exploratory behaviour frequency and performance with the ball (Jordet et al., 2013). More recent research conducted using IMU technology, provided results positively linking head turn frequency and performance, where higher than average head turn frequency and head turn excursion resulted in higher likelihood of turning with the ball, more forward passes and passes into areas opposite from where the ball was received from (McGuckian et al., 2018b). To quote the researchers; when performing head turns prior to receiving the ball players "used more complex action opportunities afforded by the surrounding environment". VEB frequency have also been positively linked to more successful performance in two recent master theses' (Aksum, 2016; Pedersen, 2016). The results presented indicate that visual exploratory behaviour provide essential information to football players about their current relationship with the environment (Montagne, 2005). This information provides opportunities to act in the attacking direction, potentially supporting assumptions that exploration is the key to prospective control of further actions (Adolph et al., 2000).

This study did not produce significant results relating head turn frequency to successful performance. However, the results show a tendency supporting previous findings, indicating that there is in fact a relationship between head turn frequency and consequent performance with the ball. A possible explanation for why this study could not provide a significant relationship, might be attributed to the small sample of performances. Also, comparing these results to previous research must be done with caution, as the current study clearly differs from the others in its methodology.

5.4 What do the players look at during head turns?

The results of this study showed that on average there are more opponents than teammates in the entire picture frame during the head turns stop phase. Due to the uneven number of head turns, and the position of the players on the field, the most interesting results are provided for the zones were the players spend most of their time during the game, and consequently perform the most head turns. These zones were the central zones closest to the midfield line, zones 6 and 7 on their own half, and zones 10 and 11 on the opposition's half. In zone 6 there were on average 0.74 more opponents than teammates, and in zone 7 there were 0.59 opponents more than teammates. On the attacking side, there were 0.75 more opponents visible in zone 11, and 0.37 more opponents in zone 10. What is visible inside the entire picture frame in a head turn's stop phase and what is actually seen and perceived by the players, does not have to be related. However, providing some descriptive information about the content visible in this phase, can be useful. Especially since previous research have highlighted the role of peripheral vision as advantageous in time constrained situations (Vaeyens et al., 2007b; Wright & Ward, 1994). The same tendencies are observed inside the fixation circle in the head turns stop phase.

The tendency of more opponents than teammates being visible to the players, may imply that elite midfield players are more focused on collecting information about the positions of opponents than of teammates. Another explanation to the differences can be attributed to how the players position themselves on the field according to the ball. The number of head turns registered according to playing phase showed that 60 % of head turns are conducted in attack.

Data from this study also show that when the players are in attack, the ball is located closer to the players own goal line in 64 % of head turns. Consequently, the players will have spent more time in a position on the pitch where most opponents were positioned closer to the opponents' goal than the player. As the head is turned away from the ball looking for information in these situations, there will be more opponents than teammates in the area where the players look for information, provided that the defensive team is in numerical balance. The results can also be attributed to something as simple as the fact that there are one more opponent on the pitch, seeing as the analysed player can see 11 opponents but only 10 teammates (being the 11th player himself).

Inside the fixation circle in the stop phase, there were no teammates in 60.5 % of head turns and no opponents in 53.7 %. That may indicate that elite midfield football players focus on free space rather than teammates and opponents. This can help players gather a greater amount of information and may also lead to greater use of the peripheral vision in an effective manner (Williams et al., 2011). Pettersen (2018) conducted an eye tracker study comparing professional (from the Norwegian top division) and amateur football players' visual behaviour and fixations. The study focused on eye movements rather than head turns, in a 5v2 rondo exercise. For the professional players the ball was unsurprisingly the focus point for most fixations (75 %), but then followed free space with 11 % of the fixations. Investigating free space was not a focus point in this study, and this is merely speculation that should be viewed with caution. With no previous research to compare the results with, caution is advised when interpreting all data related to what the players look at. Further research is needed, as knowledge about what elite football players look at during visual exploratory behaviour may provide crucial information about how we can help young players develop their visual perception skills in the future.

5.5 Contextual factors

Football players retrieve information in highly complex, dynamic environments to execute consistent and precise actions (for reviews, see Williams, Davids & Williams, 1999; Williams, Ford, Eccles & Ward, 2011). Visual perception skills in football should be investigated within the context it naturally occurs (Jordet, 2005a). With that in mind, this study wanted to provide information about contextual factors which may affect visual exploratory behaviour. A relatively small amount of previous research has been done on contextual factors and how they affect visual exploratory behaviour. Consequently, comparing the results to previous studies has proven difficult.

Playing phase is perhaps the contextual factor affecting football players' visual exploratory behaviour most. For example, the players in this study performed more frequent head turns in attack (0.38/s) than in defence (0.28/s). A three-way equal split was conducted, to group the distance between the player and the ball into categories of the same size. Interestingly, in attack the results show that 41.9 % of head turns are performed when the ball is within close proximity to the player. A possible explanation to the finding is that when the ball is within close proximity to the player, the chance of receiving the ball increases. This explanation is supported by previous research pointing to the superior head turn frequency registered by elite players prior to receiving the ball (e.g. Jordet et al., 2013; Pedersen, 2016).

The ball is located closer to the players own goal line in 64.6 % of all registered head turns when attacking. That may help explain why there are more opponents visible inside the picture frame and fixation circle in the stop phase. It may also indicate that most head turns performed by elite midfield players are conducted with a body position turned at least partly away from the oppositions goal line. However, this was not explicitly investigated in this study. Still, the results may have provided relevant information about positional requirements related to the midfield position. Practitioners can make use of this information in developing young midfielders' visual perception skills. However, more research is needed before this can be asserted with any kind of certainty.

The football pitch was divided into 16 zones and the results indicate that there is a relationship between mean head turn duration and which zones the players are located in ($p = 0.019$). 81.6 % of all head turns are performed in the most central zones on the pitch (zone 6, 7, 10 and 11), were midfield players spend most of their time. The visual exploratory behaviour of midfield players in these zones are therefore most relevant to address in future research. However, all playing positions should be investigated in future research, and the amount of time spent in the different zones needs to be registered. That way head turn frequencies can be provided for different areas on the pitch, which may help in developing characteristics for advantageous visual exploratory behaviour. As with most of the contextual results provided in this study, no similar research is available for comparison and further research on the role of contextual factors related to visual exploratory behaviour is recommended.

5.6 Limitations

This study was conducted with high ecological validity and has provided new information in the field of perception and visual exploratory behaviour in football. However, as with most research, some possible limitations must be addressed. A few studies have already been published using eye-tracking in research on visual exploratory behaviour in football. However, this is the first research published where the data is collected in 11v11 match-play on outfield players. Consequently, there is no methodologically similar research to compare this data to. Still, this research has provided information about the way elite midfield players use their eyes during 11v11 match-play, which is a positive progression in the field of visual perception in football. But as this study has provided new information about what elite midfielders look at, very little can be said about what they actually see and perceive. How much of this information is actively processed and used by the players to perform a subsequent action with the ball, is unknown. Visual exploratory behaviour does not directly tell us anything about perceptual-cognitive processes like anticipation, problem solving, decision making, pattern recall or other executive functions, and is not a sufficient explanation for why some players have better field vision than others (Jordet et al., 2013). A lack of empirical research to compare the data with makes it difficult to conclude on the results provided. This study was an exploratory study, hoping to provide inspiration for further research to be done using a similar approach. Most results were presented as trends, and results could not be discussed in relation to what previous eye tracking studies have provided. Some of the discussion is therefore limited to speculation on whether or not a relationship between variables exist. The inclusion criteria are a possible limitation, in generalizing the results. Although the dataset was large, and many variables investigated, the results come from a small selection of only four players. Also, all players were male midfield players and played in the same league. The study did not register what happened in between head turns, which would have allowed for interpretation of frequencies related to positions on the pitch, playing phase, timing and so on.

There are some possible limitations related to the eye tracking equipment. First, all players complained about the unfamiliarity of playing football wearing this equipment, which could have limited both their visual exploratory behaviour and performance on the pitch. Another limitation related to the equipment is related to the Tobii Fixation Circle, which was often missing, both during head turns and in the stop phase. The aim of providing data with high ecological validity, may have affected the study's internal validity. The players gaze samples were 86 %, 83 %, 70 % and 64 %, which may indicate just that. Also, the Tobii Fixation Circle being missing lead to the exclusion of one variable which intended to register what was visible inside the fixation circle during the entire head turn. Also, in 12.7 % of the head turns, the fixation circle was missing in the stop phase, which means that some potentially crucial data was lost. The reason for this might be related to the tempo of 11v11 match-play, as it might be too quick for the eye tracking device to register data properly. However, the Tobii Pro Glasses 2 are considered one of the best mobile eye trackers on the market for the last decades (Holmqvist et al., 2011). The eye tracking goggles used in this study does not cover the players entire field of vision. There are blind zones, especially in peripheral fixations, meaning important data may have been lost.

Finally, the mobile eye tracking device only provide information about what the fovea looks at. No peripheral visual information is provided. Panchuk et al. (2015) state that just because the eye fixates on a certain object, it does not mean that attention is focused there. Whether information visible inside the entire video frame provided by the Tobii Pro Glasses 2, is seen, registered and interpreted by the players is unknown and should be addressed in future research.

5.7 Future research

Future research should continue investigating visual perception and exploratory behaviour using the ecological framework. Further research with high ecological and external validity is needed. Future research on visual exploratory behaviour using a similar methodological approach to this study on 11v11 match-play situations is recommended. This study investigated central midfield players, but information is needed for all positions in the game of football. Positional requirements should be investigated and used in talent development. Taking a small step backwards in regard to ecological validity, using eye tracking to investigate different positional requirements in specially designed environments makes sense (e.g. strikers in 1v1 against the goalkeeper, defenders in their own penalty area). The key in investigating positional requirements, will be developing relevant, match-like exercises for these types of studies.

Comparing elite players versus sub-elite and/or amateurs is recommended, to provide information about what separates the best from the rest. Visual exploratory behaviour should also be investigated with both male and female football players, in order to increase external

validity. A larger selection of participants than was included in this study, should be investigated in order to secure higher validity. Also, what the players actually perceive out of the information they look at needs to be investigated. This can be done either through questionnaires/verbal feedback shortly after performing, or with new, better and more accurate performance measurements. Future research including total amount of seconds related to every registered head turn is recommended, so that frequencies can be provided for head turns performed in different contexts (e.g. number of head turns in zone 7 related to the time the player spent in this zone during the data collection period).
Future research should also address the tendency found in this study, that fixations occur in less than one out of five head turns for elite midfield players. Also, the finding that long duration head turns include more fixations should be investigated further. Finding out more about this relationship and also relate it to performance, can potentially revolutionize the way we educate young players in visual perception skills.

Virtual reality is another way future research could provide new and useful information about visual perception. The speedy development of technology has made it possible to develop realistic environments in which players can perform and potentially develop their perceptual skills (Correia, Araújo, Watson & Craig, 2014). This may provide a research environment where both external and internal validity is considered high. Virtual reality provides a more complete environment than traditional cognitive research has been able to do in the past, where players can explore and perceive their environments in the 360-degree competitive environment that is the football match (Jordet, 2004; Jordet et al., 2013; McGuckian et al., 2017).

5.8 Implications for practice

The main aim of this study was to provide information about the way elite midfield players use their eyes during head turns in 11v11 match-play using a mobile eye tracker. This study was an explorative study, providing mostly descriptive statistics. Consequently, implications of the results must be considered carefully. This study is the first to investigate 11v11 match-play using a mobile eye tracker, consequently providing information never before presented. So even though this data should not be seen as absolute facts anchored in statistical significance, some practical implications will be provided.

The main implication to practice provided by this thesis support previous findings and recommendations that football players should be encouraged to engage in extensive exploratory behaviour, particularly in the period prior to receiving the ball. There is a trend showing the relationship between head turn frequency and pass completion rate, supporting previous research (e.g. Aksum, 2016, Eldridge et al., 2013; Jordet et al., 2013; Pedersen, 2016). Step one for practitioners, as suggested by Pedersen (2016) is to create awareness about the importance of this skill and the relationship between visual exploratory behaviour and successful performance. The coach plays a central part in educating and motivating their players to train their visual perception skills. Ward and Williams (2003) claim that quality of coaching is the reason why some youth players possess superior skills compared with their peers. Specific training of perceptual skills will build new and better knowledge structures, which will improve perceptual skills and make them more robust (Williams et al., 1999). Therefore, developing exercises to facilitate development of young players' visual perception skill when turning their heads away from the ball is recommended. Also, only 18 % of head turns include a fixation, implying that elite midfield players collect information using their peripheral vision more often than they fixate on one or more objects. Many practitioners provide their players with tasks were fixations are required when performing head turns for information. The results provided by this study, imply that players should rather report on the colour of a vest or some other stimuli in which their vision does not need to fixate. Results from this study show that in long duration head turns fixations are 4.5 more likely to happen, which may indicate that fixations play an important part when the players collect information for a longer duration. Consequently, when training to develop visual perception skills, both exercises that require fixations and use of peripheral vision seems advantageous. More research is needed to provide a stronger connection between head turns and occurrence of fixations. Also, research linking head turns, fixations and performance is recommended, before an optimal method of training visual perception skills can be developed.

5.9 Summary

Visual perception in football was initially investigated within the cognitive research paradigm, where participants were shown pictures or video films on a TV-screen, which consequently produced results on non-sport-specific movement responses such as; verbal responses (Williams et al., 1994; Roca et al., 2013), moving a computer mouse (Williams et al., 1994), writing with pencil on paper (Ward & Williams, 2003), stepping on response pads

(Williams & Davids, 1998), moving a joystick (Savelsbergh et al., 2005) and multiple spheres selection (Romeas et al., 2016). These studies have provided important knowledge and vital contributions to the field of visual perception in football (e.g. Cañal-Bruland et al., 2011, Helsen & Starkes, 1999, Roca et al., 2011; 2013; Vaeyens et al., 2007a; Williams & Davids, 1998; Williams et al., 1994). Research on eye tracking have mostly registered players eye movements, specifically comparing eye movements between experts and amateurs (e.g. Dicks et al., 2010; Gorman et al., 2015; Roca et al., 2011, 2013). Building on this cognitive research, a more ecological approach has been applied in recent years by investigating visual perception in 11v11 match-play settings (e.g. Jordet, 2004; Jordet et al., 2013). Combined, these studies have provided information of a positive relationship between visual exploratory behaviour and performance. Still, no research to date has investigated what the players actually look at when they are performing visual exploratory behaviours. By combining a traditionally cognitive approach to research (eye tracking) with a traditionally ecological approach to research (investigating participants in their actual performance environment), this exploratory study has provided new information to the field of visual perception in football.

The main goal of this study was to provide information about the way elite midfielders use their eyes during head turns in 11v11 match-play using a mobile eye tracker. Fixations occur in less than one out of five head turns, indicating that the peripheral vision may be more important than fixations when players look away from the ball to collect information from the environment. At the same time, when the players perform long duration (≥ 43 hundredths) head turns, fixations occur in one out of three. This may indicate that visual search strategies should be adapted to different playing situations on the pitch. Head turns are mostly initiated when the ball travels between players or when a player controls the ball without touching it. The results provided by this study suggests that when the direction or possible destination of the ball is likely to change, players experience it as less beneficial to perform head turns for new information. During head turns more opponents are visible to elite midfield players than teammates. That applies for the entire picture frame and the fixation circle in the head turns' stop phase. The number of head turns performed in the ten seconds before receiving the ball correlated positively with subsequent performance, however not statistically significant. In attack results show that more than two out of five head turns are performed when the ball is within close proximity (≤ 14 meters) to the player. A relationship was also found between head turn duration and the distance between the analysed player and the ball. When in close proximity to the ball the number of head turns with short duration (≤ 26 hundredths) increases. This finding was even stronger in the attacking playing phase, where one out of two head turns was short when in close proximity to the ball. Having presented the results, caution in interpreting them must once more be advised. This was an exploratory study, aiming to lay groundwork and inspire further research to be conducted applying similar research methodology.

References

Aksum, K. M. (2016). *Visuell eksplorerende søksaktivitet hos unge elitespillere: En studie på søksaktivitet og prestasjon hos utespillere i alle posisjoner i Ajax-akademiet.* Master thesis from The Norwegian School of Sport Sciences, Oslo.

Araujo, D., Davids, K., & Hristovski, R. (2006). The ecological dynamics of decision making in sport. *Psychology of Sport & Exercise*, 7(6), 653-676.

Bahill, A. & LaRitz, T. (1984). Why can't batters keep their eyes on the ball? *American Scientist*, 72(3), 249-253.

Bard, C. & Fleury, M. (1976). 'Analysis of visual search activity during sport problem situations'. *Journal of Human Movement Studies*, 3(2), 214-222.

Bard, C. & Fleury, M. (1981). Considering eye movements as predictor of attainment. In I.M. Cockerill & W.W. MacGillvary (Eds.), *Vision and sport* (pp. 28-41). Cheltenham: Stanley Thrones.

Bergo, A., Johansen, P. A., Larsen, Ø. & Morisbak, A. (2010). *Ferdighetsutvikling i fotball - Handlingsvalg og handling.* Oslo: Akilles.

Bloomfield, J., Polman, R. & O'Donoghue, P. (2007). Reliability of the Bloomfield Movement Classification. *International Journal of Performance Analysis in Sport*, 7(1), 20-27. doi:10.1080/24748668.2007.11868384

Buszard, T., Farrow, D., & Kemp, J. (2012). Examining the influence of acute instructional approaches on the decision-making performance of experienced team field sport players, *Journal of Sports Sciences*, 31(3), 238–247. doi: 10.1080/02640414.2012.731516

Cañal-Bruland, R., Lotz, S., Hagemann, N., Schorer, J., & Strauss, B. (2011). Visual span and change detection in soccer: An expertise study. *Journal of Cognitive Psychology*, 23(3), 302-310. doi:10.1080/20445911.2011.496723

Carlson, M. D. A., & Morrison, R. S. (2009). Study Design, Precision, and Validity in Observational Studies. *Journal of Palliative Medicine*, 12(1), 77-82. doi:10.1089/jpm.2008.9690

Casanova, F., Oliveira, J., Williams, M., & Garganta, J. (2009). Expertise and perceptual-cognitive performance in soccer: A review. *Revista Portuguesa de Ciências do Desporto*, 9, 115-122.

Cavanagh, P., & Alvarez, G. A. (2005). Tracking multiple targets with multifocal attention. *Trends in Cognitive Sciences,* 9(7), 349-354. doi: http://dx.doi.org/10.1016/j.tics.2005.05.009

Correia, V., Araújo, D., Watson, G. & Craig, C. (2014). Using virtual environments to study interactions in sport performance. I: K. Davids, R. Hristovski, D. Araújo, N. Balagué

Serre, C. Button, & P. Passos (Eds.), *Complex systems in sport* (pp. 175- 189). New York: Taylor & Francis.

Davids, K., Araújo, D., Seifert, L., & Orth, D. (2015). Expert Performance in Sport. An ecological dynamics perspective. In J. Baker & D. Farrow (Eds.), *Routledge Handbook of Sport Expertise* (pp. 130-144). London: Routledge International Handbooks.

Dicks, M., Button, C., & Davids, K. (2010). Examination of gaze behaviors under in situ and video simulation task constraints reveals differences in information pickup for perception and action. *Attention, Perception, & Psychophysics, 72*(3), 706-720. doi:10.3758/app.72.3.706

Discombe, R. M. & Cotterill, S. T. (2015). Eye tracking in sport: A guide for new and aspiring researchers. *Sport & Exercise Psychology Review*, 11(2), 49-58.

Duchowski, A. T. (2002). A breadth-first survey of eye-tracking applications. *Behavior, Research Methods, Instruments & Computers*, 34(4), 455-470. doi:10.3758/BF03195475.

Duchowski, A. T. (2007). *Eye tracking methodology: Theory and practice* (2nd ed.). London: Springer.

Eldridge, D., Pulling, C. & Robins, M. (2013). Visual exploratory activity and resultant behavioural analysis of youth midfield soccer players. *Journal of Human Sport & Exercise*, 8(3), 560-577. doi:10.4100/jhse.2013.8.Proc3.02

Erickson, G. (2007). *Sports Vision: vision care for the enhancement of sports performance*. St. Louis: Butterworth-Heinemann Elsevier.

Fajen, B. R., Riley, M. A., & Turvey, M. T. (2008). Information, affordances, and the control of action in sport. *International Journal of Sport Psychology,* 40(1), 79-107.

Faubert, J., & Sidebottom, L. (2012). Perceptual-Cognitive Training of Athletes. *Journal of Clinical Sport Psychology*, 6(1), 85-102.

Field, A. (2018). *Discovering Statistics Using IBM SPSS Statistics* (4th ed.). London: SAGE.

FIFA. (2018, 21.12). More than half the world watched the record-breaking 2018 World Cup. Retrieved from https://www.fifa.com/worldcup/news/more-than-half-the-world-watched-record-breaking-2018-world-cup

FIFA. (2007). FIFA Big Count. Retrieved from http://www.fifa.com/worldfootball/bigcount/index.html

Gibson, J. J. (1966). *The senses considered as perceptual systems*. Oxford, England: Houghton Mifflin.

Gibson, J. J. (1979). *The Ecological Approach to Visual Perception*. Boston: Houghton Mifflin.

Gisev, N., Bell, J. S. & Chen, T. F. (2013). Interrater agreement and interrater reliability: Key concepts, approaches, and applications. *Research in social & administrative pharmacy,* 9 (3), 330-338. doi: 10.1016/j.sapharm.2012.04.004

Gordon, I. E. (1989). *Theories of Visual Perception*. Chichester: John Wiley & Sons.

Gorman, A. D., Abernethy, B., & Farrow, D. (2015). Evidence of different underlying processes in pattern recall and decision-making. *Quarterly Journal of Experimental Psychology, 68*(9), 1813-1831. doi: 10.1080/17470218.2014.992797

Haber, R.N., & Hershenson, M. (1974). *The Psychology of Visual Perception*. London: Holt, Rinehart and Winston.

Hackman, B., & Guilford, J. (1936) 'A study of the "visual fixation" method of measuring attention value', *Journal of Applied Psychology*, 20(1), 44.

Hallgren, K. A. (2012). Computing Inter-Rater Reliability for Observational Data: An Overview and Tutorial. *Tutorials in quantitative methods for psychology*, 8(1), 23-34.

Haugaasen, M., & Jordet, G. (2012). Developing football expertise: a football-specific research review. *International Review of Sport and Exercise Psychology, 5(2),* 177-201. doi:10.1080/1750984X.2012.677951

Helsen, W. F. & Pauwels, J. M. (1993). The relationship between expertise and visual information processing in sport. In J.L Starkes & F. Allard (Eds.), *Cognitive issues in motor expertise* (pp. 109-134). Amsterdam: Elsevier Science.

Helsen, W.F., & Starkes, J.L. (1999). A Multidimensional Approach to Skilled Perception and Performance in Sport. *Applied Cognitive Psychology*, 13, 1-27.

Helsen, W. F, Starkes, J. L., Elliot, D. & Ricker, K. (1998). Sampling frequency and the study of eye-hand coordination in aiming. *Behavior Research Methods, Instruments, & Computers*, 30(4), 617-623. doi:10.3758/BF03209479.

Henderson, J. M. (2003). Human gaze control during real-world scene perception. *Trends in cognitive sciences*, 7(11), 498-504.

Holmqvist, K., Nyström, M., Andersson, R., Dewhurst, R., Jarodzka, H. & Van de Weijer, J. (2011). *Eye tracking: A comprehensive guide to methods and measures.* New York: Oxford University Press.

Hubel, D. H. & Weisel, T. N. (1968). Receptive fields and functional architecture of monkey striate cortex. *The Journal Physiology,* 195, 215-243.

Jansen, R. G., Wiertz, L. F., Meyer, E. S., & Noldus, L. P. J. J. (2003). Reliability analysis of observational data: Problems, solutions, and software implementation. *Behavior Research Methods, Instruments, & Computers,* 35(3), 391-399. doi:10.3758/bf03195516.

Jordet, G. (2003). Læring av perseptuell ekspertise i fotball: En økologisk tilnærming. *Moving Bodies*, 1(2), 133-147.

Jordet, G. (2004). *Perceptual expertise in dynamic and complex competitive team contexts: An investigation of elite football midfield players.* (Doctor Dissertation), Norwegian University of Sport and Physical Education, Oslo.

Jordet, G. (2005a). Applied cognitive sport psychology in team ball sports: An ecological approach. In R. Stelter & K. K. Roessler (Eds.), *New approach to sport and exercise psychology* (pp. 147-174): Meyer & Meyer Sport.

Jordet, G., Bloomfield, J., & Heijmerikx, J. (2013). *The hidden foundation of field vision in English Premier League (EPL) soccer players*. Paper presented at the MIT SLOAN Sport Analytics Conference, Boston Convention and Exhibition Center.

Kerlinger, F. N. & Lee, H. B. (2000). *Foundations of behavioral research (4th ed.*). Fort Worth, Texas: Harcourt College Publishers.

Kratochwill, T. R. & Wetzel, R. J. (1977). Observer agreement, credibility and judgment: Some considerations in presenting observer agreement data. *Journal of Applied Behavior Analysis*, 10(1), 133-139. doi:10.1901/jaba.1977.10-133.

Land, M. F. (2006). Eye movements and the control of actions in everyday life. *Progress in Retinal and Eye Research,* 25(3), 296-324.

Land, M. F. (2009). Vision, eye movements, and natural behavior. *Visual Neuroscience,* 26(1), 51-62.

Little, T. D. (2013). *The Oxford handbook of quantitative methods: vol. 1*: Foundations (Vol. 1). Oxford: Oxford University Press.

Mann, D. T. Y., Williams, A. M., Ward, P. & Janelle, C. M. (2007). Perceptual-Cognitive Expertise in Sport: A Meta-Analysis. *Journal of Sport & Exercise Psychology*, 29, 457-478.

Martens, R. (1979). SPORT PSYCHOLOGY TODAY: About Smocks and Jocks. *Journal of Sport Psychology,* 1(2), 94-99.

McGuckian, T. B., Cole, M. H., Chalkley, D., Jordet, G. & Pepping, G.-J. (2018a). Visual Exploration When Surrounded by Affordances: Frequency of Head Movements Is Predictive of Response Speed. *Ecological Psychology*. doi:10.1080/10407413.2018.1495548

McGuckian, T. B., Cole, M. H., Jordet, G., Chalkley, D. & Pepping, G.-J. (2018b). Don't turn blind! The relationship between exploration before ball possession and on-ball performance in association football. *Frontiers in Psychology, 9.* doi:10.3389/fpsyg.2018.02520

McGuckian, T., Cole, M. & Pepping, G-J. (2017). A systematic review of the technology-based assessment of visual perception and exploration behaviour in association football. *Journal of Sports Sciences*, 36, 1-20. doi:10.1080/02640414.2017.1344780.

McMorris, T. (2004). *Acquisition and Performance of Sports Skills*. University College Chichester, UK: John Wiley & Sons, Ltd.

McRobert, A. P., Williams, A. M., Ward, P., & Eccles, D. W. (2009) Tracing the process of expertise in a simulated anticipation task, *Ergonomics*, 52(4): 474–483.

Neisser, U. (1967). *Cognitive psychology*. New York: Appleton-Century-Crofts.

NeuroTracker (2016). Retrieved from https://neurotracker.net/why-neurotracker-2/

North, J. S., Ward, P., Ericsson, A. & Williams, M. A. (2011). Mechanisms underlying skilled anticipation and recognition in a dynamic and temporally constrained domain. *Memory,* 19(2), 155-168.

North, J. S., Williams, A. M., Hodges, N., Ward, P. & Ericsson, A. (2009). Perceiving patterns in dynamic action sequences: Investigating the processes underpinning stimulus recognition and anticipation skill. *Applied Cognitive Psychology*, 23, 878-894.

O'Donoghue, P. (2012). *Statistics for sport and exercise studies. An introduction*. Abingdon: Routledge.

Panchuk, D., Vine, S. & Vickers, J. N. (2015). Eye tracking methods in sport expertise. In J. Baker & D. Farrow (Eds.), *Routledge Handbook of Sport Expertise* (pp. 176-187). London: Routledge.

Pedersen, D. N. (2016). *World-class football players' visual exploratory behaviour: a close-up video analysis in UEFA Champions League matches.* Master thesis from The Norwegian School of Sport Sciences, Oslo.

Pettersen, S. (2018). *Visuell atferd hos fotballspillere: En eye tracking studie av visuell atferd og fikseringer hos profesjonelle fotballspillere og amatørspillere i en firkantøvelse på trening.* Master thesis from The Norwegian School of Sport Sciences, Oslo.

Pinder, R. A., Headrick, J., & Oudejans, R. R. D. (2015). Issues and Challenges in Developing Representative Tasks in Sport. In J. Baker & D. Farrow (Eds.), *Routledge Handbook of Sport Expertise* (pp. 269-281). London: Routledge International Handbooks

Pocock, C., Dicks, M., Thelwell, R. C., Chapman, M. & Barker, J. B. (2017). Using an imagery intervention to train visual exploratory activity in elite academy football players. *Journal of Applied Sport Psychology,* 31 (2), 218-234. doi:10.1080/10413200.2017.1395929

Reed, E.S. (1996). *Encountering the world: Toward an ecological psychology*. New York: Oxford University Press.

Ripoll, H., Papin, J. P., Guezennec, J. Y., Verdy, J. P. & Philip, M. (1985). Analysis of visual scanning patterns of pistol shooters. *Journal of Sport Sciences*, 3(2), 93-101. doi:10.1080/02640418508729739.

Roca, A., Ford, P., McRobert, A., & Williams, A. M. (2011). Identifying the processes underpinning anticipation and decision-making in a dynamic time-constrained task. *Cognitive Processing, 12*(3), 301-310. doi:10.1007/s10339-011-0392-1

Roca, A., Ford, P. R., McRobert, A. P., & Williams, A. M. (2013). Perceptual-Cognitive Skills and Their Interaction as a Function of Task Constraints in Soccer. *Journal of Sport & Exercise Psychology, 35*(2), 144-155.

Romeas, T., Guldner, A., & Faubert, J. (2016). 3D-Multiple Object Tracking training task improves passing decision-making accuracy in soccer players. *Psychology of Sport and Exercise*, 22, 1-9. doi: http://dx.doi.org/10.1016/j.psychsport.2015.06.002

Savelsbergh, G. J. P., Haans, S. H. A., Kooijman, M. K., & van Kampen, P. M. (2010). A method to identify talent: Visual search and locomotion behavior in young football players. *Human Movement Science, 29*(5), 764-776. doi:http://dx.doi.org/10.1016/j.humov.2010.05.003

Savelsbergh, G. J. P., Van der Kamp, J., Williams, A. M., & Ward, P. (2005). Anticipation and visual search behaviour in expert soccer goalkeepers. *Ergonomics, 48* (11-14), 1686-1697. doi:10.1080/00140130500101346

Schutte, T. (2017). *Keeperens øye for spillet: en eye-tracking studie av visuelle fikseringer I 11v11 situasjoner for en keeper på elitenivå.* Master thesis from The Norwegian School of Sport Sciences, Oslo.

Seifert, L., Button, C., & Davids, K. (2013). Key Properties of Expert Movement Systems in Sport. *Sports Medicine*, 43(3), 167-178. doi:10.1007/s40279-012- 0011-z

Swets J. A. (1964) Is there a sensory threshold? In J. A. Sweets (Ed.), *Signal detection and recognition by human observers (*pp. 122–144), Wiley, New York, USA.

Tedesqui, R. A. B., & Orlick, T. (2015). Brazilian Elite Soccer Players: Exploring Attentional Focus in Performance Tasks and Soccer Positions. *Sport Psychologist*, 29(1), 41-50.

Tenga, A., Kanstad, D., Ronglan, L. T., & Bahr, R. (2009). Developing a New Method for Team Match Performance Analysis in Professional Soccer and Testing its Reliability. *International Journal of Performance Analysis in Sport*, 9(1), 8-25.

Thilo, K. V., Santoro, L., Walsh, V., & Blakemore, C. (2004) The site of saccadic suppression. *Nature Neuroscience*, 7(1), 13–14.

Tobii AB. (2016). *User's manual Tobii Pro Glasses 2.*

Tyldesley, D. A., Bootsma, R. J. & Bomhoff, G. T. (1982). Skill level and eye movement patterns in sport-oriented reaction time task. In H. Reider, H. Mechling & K. Reischle

(Eds.), *Proceedings of an International Symposium on Motor Behaviour: Contribution to Learning in Sport* (pp. 290-296). Cologne: Hofmann

Vaeyens, R., Lenoir, M., Williams, A. M., Mazyn, L. & Philippaerts, R. M. (2007a). The Effects of Task Constraints on Visual Search Behavior and Decision-Making Skill in Youth Soccer Players. *Journal of Sport & Exercise Psychology*, 29(2), 147-169. doi:10.3200/JMBR.39.5.395-408.

Vaeyens, R., Lenoir, M., Williams, A. M., & Philippaerts, M. R. (2007b). Mechanisms Underpinning Successful Decision Making in Skilled Youth Soccer Players: An Analysis of Visual Search Behaviors. *Journal of motor behavior*, 39 (5), 395-408. doi:10.3200/JMBR.39.5.395-408.

Vealey, R. S. (2006). Smocks and Jocks Outside the Box: The Paradigmatic Evolution of Sport and Exercise Psychology. *Quest*, 58(1), 128-159. doi:10.1080/00336297.2006.10491876

Vickers, J. N. (1992). Gaze control in putting. *Perception*, 21(1), 117-132. doi:10.1068/p21011.

Vickers, J. N. (2007). *Perception, cognition and decision training: The quiet eye in action.* Champaign, IL: Human Kinetics.

Vickers, J. N. (2009). Advances in coupling perception and action: the quiet eye as a bidirectional link between gaze, attention, and action. *Prog. Brain Res*, 174, 279- 288.

Waddington, I. (2014). Researching the world of professional football. In A. Smith & I. Waddington (Eds.), *Doing Real World Research in Sport Studies* (pp. 11-25). Oxon: Routledge.

Ward, P., Ericsson, K. A., & Williams, A. M. (2013). Complex Perceptual-Cognitive Expertise in a Simulated Task Environment. *Journal of Cognitive Engineering and Decision Making*, 7(3), 231-254. doi:10.1177/1555343412461254

Ward, P., & Williams, A. M. (2003). Perceptual and Cognitive Skill Development in Soccer: The Multidimensional Nature of Expert Performance. *Journal of Sport & Exercise Psychology*, 25(1), 93-111.

Williams, A. M. (2000). Perceptual skill in soccer: Implications for talent identification and development. *Journal of Sport Sciences*, 18(9), 737-750. doi:10.1080/02640410050120113.

Williams, A.M. & Davids, K. (1995). Declarative knowledge in sport: a by-product of experience or a characteristic of expertise? *Journal of Sport and Exercise Psychology*, 17(3), 259-275.

Williams, A. M. & Davids, K. (1998). Visual search strategy, selective attention, and expertise in soccer. *Research Quarterly of Exercise and Sport*, 69(2), 111-128. doi:10.1080/02701367.1998.10607677.

Williams, A. M., Davids, K., Burwitz, L. & Williams, J. G. (1993a). Visual search and sports performance. *The Australian Journal of Science and Medicine in Sport,* 25(2), 147-204.

Williams, A. M., Davids, K., Burwitz, L. & Williams, J. G. (1994). Visual Search Strategies in Experienced and Inexperienced Soccer Players. *Research Quarterly for Exercise and Sport,* 65(2), 127-135. doi:10.1080/02701367.1994.10607607.

Williams, A. M., Davids, K., & Williams, J. G. (1999). *Visual Perception & Action in Sport*. London: E & FN SPON.

Williams, A. M., & Ford, P. R. (2013). 'Game Intelligence': Anticipation and Decision Making. In A. M. Williams (Ed.), *Science and Soccer: Developing Elite Performance* (pp. 105-121). Abingdon, England: Routledge Taylor & Francis Group.

Williams, A. M., Ford, P. R., Eccles, D. W., & Ward, P. (2011). Perceptual-cognitive expertise in sport and its acquisition: Implications for applied cognitive psychology. *Applied Cognitive Psychology, 25(3),* 432-442. doi:10.1002/acp.1710

Williams, A. M., Hogdes, N. J., North, J. S. & Barton, G. (2006). Perceiving patterns of play in dynamic sport tasks: Investigating the essential information underlying skilled performance. *Perception*, 35, 317-332.

Wright, R.D., & Ward, L.M. (1994). Shifts of visual attention: An historical and methodological overview. *Canadian Journal of Experimental Psychology*, 48, 151-166.

Appendix

Appendix A: NSD approval

Appendix B: Operationalization of variables

Appendix C: Table of the variables used in the data analysis

Appendix D: Informed consent form

Appendix E: Permission to use figures, illustrations and information from original author

Appendix A

NSD

Karl Marius Aksum
Seksjon for coaching og psykologi Norges idrettshøgskole
Postboks 4014 Ullevål Stadion
0806 OSLO

Vår dato: 30.03.2017 Vår ref: 52593 / 3 / LB Deres dato: Deres ref:

TILBAKEMELDING PÅ MELDING OM BEHANDLING AV PERSONOPPLYSNINGER

Vi viser til melding om behandling av personopplysninger, mottatt 01.02.2017. Meldingen gjelder prosjektet:

52593	*Visual exploratory behaviour in 11 vs 11 football match play: A Tobii eye tracker analysis of positional requirements*
Behandlingsansvarlig	*Norges idrettshøgskole, ved institusjonens øverste leder*
Daglig ansvarlig	*Karl Marius Aksum*

Personvernombudet har vurdert prosjektet, og finner at behandlingen av personopplysninger vil være regulert av § 7-27 i personopplysningsforskriften. Personvernombudet tilrår at prosjektet gjennomføres.

Personvernombudets tilråding forutsetter at prosjektet gjennomføres i tråd med opplysningene gitt i meldeskjemaet, korrespondanse med ombudet, ombudets kommentarer samt personopplysningsloven og helseregisterloven med forskrifter. Behandlingen av personopplysninger kan settes i gang.

Det gjøres oppmerksom på at det skal gis ny melding dersom behandlingen endres i forhold til de opplysninger som ligger til grunn for personvernombudets vurdering. Endringsmeldinger gis via et eget skjema, http://www.nsd.uib.no/personvernombud/meld_prosjekt/meld_endringer.html. Det skal også gis melding etter tre år dersom prosjektet fortsatt pågår. Meldinger skal skje skriftlig til ombudet.

Personvernombudet har lagt ut opplysninger om prosjektet i en offentlig database, http://pvo.nsd.no/prosjekt.

Personvernombudet vil ved prosjektets avslutning, 31.12.2018, rette en henvendelse angående status for behandlingen av personopplysninger.

Vennlig hilsen

Kjersti Haugstvedt

Lene Christine M. Brandt

Kontaktperson: Lene Christine M. Brandt tlf: 55 58 89 26
Vedlegg: Prosjektvurdering

Dokumentet er elektronisk produsert og godkjent ved NSDs rutiner for elektronisk godkjenning.

NSD – Norsk senter for forskningsdata AS Harald Hårfagres gate 29 Tel: +47-55 58 21 17 nsd@nsd.no Org.nr. 985 321 884
NSD – Norwegian Centre for Research Data NO-5007 Bergen, NORWAY Faks: +47-55 58 96 50 www.nsd.no

Personvernombudet for forskning

Prosjektvurdering - Kommentar

Prosjektnr: 52593

Utvalget informeres skriftlig og muntlig om prosjektet og samtykker til deltakelse. Informasjonsskrivet er godt utformet, såfremt følgende tilføyes/endres, jf. telefonsamtale med prosjektleder 29.03.2017:

- Det legges til en setning under avsnittet "Hva innebærer deltakelse i studien?" om at det også vil samles inn noe fotballstatistikk om spillerne som deltar i prosjektet. - Dato for prosjektslutt justeres til 31.12.2018.
- Setningene "Alle persondata vil da bli slettet, og videofiler vil bli lagret på en intern datamaskin på Norges Idrettshøgskole. Kun jeg og veileder vil ha tilgang til disse filene i ettertid" omskrives. Vi anbefaler følgende formulering: "Alle innsamlede data anonymiseres, og videoopptak slettes, senest ved prosjektslutt".

Data samles inn ved at en treningskamp mellom to fotballag filmes. Det vil også tas videoopptak via videobriller som spiller har på seg. Samtlige spillere på banen vil således være en del av videoopptakene. Personvernombudet ønsker å understreke at deltakelse i forskning er frivillig, og at det derfor må legges til rette for at det kun registreres personopplysninger om spillere som har samtykket til å delta. Prosjektleder opplyser per telefon at de vil vurdere hvordan det kan legges opp slik at det er et alternativt treningsopplegg for de som evt. ikke ønsker å delta.

Dersom det er tilskuere tilstede under kampen, og disse kan bli en del av videomaterialet, vil prosjektleder informere tilskuerne om prosjektet. Ombudet legger til grunn at tilsvarende informasjon som gis i informasjonsskrivet til spillerne, gis eventuelle tilskuere muntlig eller ved at det henges opp skriv i kamplokalene. Filmingen vil også foregå fullt synlig.

Data samles også inn ved at det registreres noe fotballstatistikk om spillerne som deltar i prosjektet.

Det tas høyde for at det vil kunne fremkomme sensitive opplysninger (om helseforhold, jf. personopplysningsloven § 2 nr. 8 c)) på videoopptakene, dersom spillere blir skadet under kampen.

Personvernombudet legger til grunn at forsker etterfølger Norges idrettshøgskole sine interne rutiner for datasikkerhet. Dersom personopplysninger skal lagres på privat pc, bør opplysningene krypteres tilstrekkelig.

Forventet prosjektslutt er 31.12.2018, jf. telefonsamtale. Ifølge prosjektmeldingen skal innsamlede opplysninger da anonymiseres.
Anonymisering innebærer å bearbeide datamaterialet slik at ingen enkeltpersoner kan gjenkjennes. Det gjøres ved å:
- slette direkte personopplysninger (som navn/koblingsnøkkel)
- slette/omskrive indirekte personopplysninger (identifiserende sammenstilling av bakgrunnsopplysninger som f.eks. bosted/arbeidssted, alder og kjønn)
- slette videoopptak

BEKREFTELSE PÅ ENDRING

Vi viser til statusmelding mottatt: 07.02.2019.

Personvernombudet har nå registrert ny dato for prosjektslutt 30.05.2019.

Det legges til grunn at prosjektopplegget for øvrig er uendret.
Ved ny prosjektslutt vil vi rette en ny statushenvendelse.

Hvis det blir aktuelt med
ytterligere forlengelse, gjør vi oppmerksom på at utvalget vanligvis må informeres ved forlengelse på mer enn ett år utover det de tidligere har blitt informert om.

Ta gjerne kontakt dersom
du har spørsmål.

Vennlig hilsen,
Lise Aasen Haveraaen - Tlf: 55 58 21 19
Lise.Haveraaen@nsd.no
Personvernombudet for forskning,
NSD – Norsk senter for forskningsdata AS
Tlf. direkte: (+47) 55 58 21 17 (tast 1)

Appendix B

Operationalization of the variables used in this study

Variable	**Operationalization**
Head turn duration (hundredths)	The exact time from the initiation of the search until the retraction phase of the search is finished (When the ball enters the picture frame). If there is uncertainty regarding when the search is initiated, the point where we can be absolutely sure that the ball is out of the frame will be used. Measured in hundredths.
Direction of head turn	The direction of the search in relation to the ball. Either left or right.
Objects inside the Tobii Pro Fixation Circle in the stop phase	The teammates and opponents visible inside the Tobii Fixation Circle at the exact moment of the head turn's last stop phase. If there is any uncertainty in what picture frame is the "stop phase", the last frame will always be used. If the circle is not there in the exact "stop phase" frame but is there in the one frame before or after, this frame will be used. If there is a fixation in the search, the fixation point from Tobii Pro Labs will be used as the stop phase.
Objects inside the entire picture frame in the stop phase	The teammates and opponents visible in the entire picture frame in the stop phase.
Objects inside the entire picture frame during the entire head turn	The teammates and opponents visible in the picture during the head turn.
Playing phase	The playing phase variable consists of four different codings. The player is in attack or defence. Attack was operationally defined as the period that the investigated player's team had control of the ball until they lost possession to the other team, the ball goes out of play, or a free-kick is awarded. We operationalized that a team had control of the ball when a player made two or more touches or was able to make a controlled pass/shot using his first touch. Defence was operationally defined as the period that the investigated player´s team did not have control of the ball until the opposition team lost possession of to the investigated player´s team, the ball goes out of play, or a free-kick is awarded. We operationalized that a team had control of the ball when a player made two or more touches or was

	able to make a controlled pass/shot using his first touch. If neither team has control of the ball, the situation is defined as “nulltilstand”. If the situation cannot be defined under any of the three mentioned states, it will be classified as “other”.
Player location	The pitch was divided into 16 different zones (1-16). If we cannot be sure of where the player is located, location will be classified as “missing”.
Ball location	The pitch was divided into 16 different zones (1-16). If we cannot be sure of where the ball is located, location will be classified as “missing”.
Ball position	Is the ball located closer to own goal line or opponent goal line?
Distance from the player to the ball	Will be measured in meters, from initiation of the head turn. If the ball is not in either picture screen, the ball will be classified as “missing”.
Is the ball on the floor or in the air?	Is the ball on the floor or in the air when the search is initiated? Yes or no.
Does any player on the pitch have control over the ball or is it being passed?	Is the ball controlled by a player or is it being intentionally passed from one player to another? Clearances also goes under the definition pass. If neither, it will be classified as “other”.
Initiation of the head turn	When is the head turn initiated? This is seen in reference to what happens in the game at this time. Is the player initiating a head turn when a player touches the ball, when a pass is played or when the pass is traveling from one player to another?
Fixations in head turn	Are there one or more fixations in the head turn? The final fixation in the head turn (as per Tobii Pro Lab) will be used for measuring the number of teammates and opponents in the Tobii Fixation Circle.
Performance (pass completion)	Does the player perform a successful or failed pass? If no pass is performed it will be classified as “no performance”.
Direction of a pass from the player	Is the pass played forward, backwards or sideways?
Head turn performed within ten seconds of the player receiving the ball	Is the head turned performed during the ten seconds before the player receives the ball? Yes or no.

By measuring the time when the player is in attack and defence it is possible to find out the search frequency in different moments of the game.

Appendix C

Table of the variables used in the data analysis.

1	2	3	4	5	6	7	8
Player	**Head turn duration (hundredths)**	**Playing phase**	**Player location**	**Ball location**	**Ball position**	**Distance ball (meters)**	**Ball on the floor or in the air**
Player 1 Player 2 Player 3 Player 4	2 4 6 8 10 12 14 16 *	Attack Defence “Nulltilstand” Other	Zone 1 Zone 2 Zone 3 Zone 4 Zone 5 Zone 6 Zone 7 Zone 8 Zone 9 Zone 10 Zone 11 Zone 12 Zone 13 Zone 14 Zone 15 Zone 16 Missing	Zone 1 Zone 2 Zone 3 Zone 4 Zone 5 Zone 6 Zone 7 Zone 8 Zone 9 Zone 10 Zone 11 Zone 12 Zone 13 Zone 14 Zone 15 Zone 16 Missing	Closer to own goal line than the player Closer to opposition goal line than the player Other	0 1 2 3 4 5 6 7 8 9 10 * Missing	On the floor In the air

9	10	11	12	13	14	15	16
Control or pass	**Initiation of head turn**	**Fixations in head turn**	**Direction of head turn**	**Performance**	**Direction of pass**	**Head turn within ten seconds of receiving the ball**	**Teammates in the picture frame during the entire head turn**
Control Pass Other	When a player touches the ball (pass excluded) When a player has control of the ball without touching it When a pass is played When the ball is travelling from one player to another When a pass is played to the player When the ball is travelling towards the player Other	Yes No	Left Right	No performance Successful Failed	No performance Forward Backwards Sideways	Yes No	1 2 3 4 5 6 7 8 9 10

	When the ball is out of play						

17	**18**	**19**	**20**	**21**
Opponents in the picture frame during the entire head turn	**Teammates in the picture frame in the stop phase**	**Opponents in the picture frame in the stop phase**	**Teammates in the Tobii Fixation Circle in the stop phase**	**Opponents in the Tobii Fixation Circle in the stop phase**
1 **2** **3** **4** **5** **6** **7** **8** **9** **10** **11**	1 2 3 4 5 6 7 8 9 10 Missing	1 2 3 4 5 6 7 8 9 10 11 Missing	1 2 3 4 5 6 7 8 9 10 Missing	1 2 3 4 5 6 7 8 9 10 11 Missing

Appendix D

Forespørsel om deltakelse i forskningsprosjektet

"Visual exploratory behaviour (VEB) in 11 vs 11 football matchplay: A Tobii eye tracker analysis of positional requirements"

Bakgrunn og formål

Formålet med studien er å kombinere bruk av videobriller med videofilm av kampen for å undersøke eksakt hvilke visuelle søksprosesser sentrale midtbanespillere benytter seg av i kamp. Prosjektet er en del av min doktorgradsavhandling om visuell persepsjon i fotball ved Norges Idrettshøgskole.

Et nytt, men lignende formål, er å kun se på spillernes søk ved bruk av det samme datamaterialet. Hensikten med det er å undersøke hvor spillere ser når de utfører søk (visuell eksplorerende atferd). Denne delen av prosjektet er en del av Lars Brotangens masteroppgave ved Norges Idrettshøgskole.

Du/Dere er valgt ut med bakgrunn i at dere er del av et lag som spiller på et nivå som er godt nok, og dere har en alderssammensetning som passer til studien.

Hva innebærer deltakelse i studien?

Som deltaker i denne studien skal du benytte deg av videobrillene Tobii eye tracker under kampsituasjon. Du vil være nødt til å ha på deg brillene i cirka 15 minutter i en kamp. Videoen som genereres fra brillene vil benyttes i forskningen. Det vil også bli tatt video av selve treningskampen. Det vil også samles inn noe fotballstatistikk om spillerne som deltar i prosjektet.

Hva skjer med informasjonen om deg?

Alle personopplysninger vil bli behandlet konfidensielt. Kun meg selv, veileder Geir Jordet, og masterstudent Lars Brotangen vil ha tilgang til dataene i prosjektet. Ingen informasjon eller video av deg vil bli benyttet utover dette prosjektet. Du vil ikke bli gjenkjent i publikasjonen.

Prosjektet skal etter planen avsluttes 31.12.2018. Alle innsamlede data anonymiseres, og videoopptak slettes, senest ved prosjektslutt.

Frivillig deltakelse

Det er frivillig å delta i studien, og du kan når som helst trekke ditt samtykke uten å oppgi noen grunn. Dersom du trekker deg, vil alle opplysninger om deg bli anonymisert.

Dersom du ønsker å delta eller har spørsmål til studien, ta kontakt med Karl Marius Aksum 95974819.

Studien er meldt til Personvernombudet for forskning, NSD - Norsk senter for forskningsdata AS.

Samtykke til deltakelse i studien

Jeg har mottatt informasjon om studien, og er villig til å delta

----
(Signert av prosjektdeltaker, dato)

Appendix E

Permission to use figures, illustrations and information from original author.

Permission from the original author and license to use figures, illustrations and information in various documents from *Tobii Pro, Tobii AB (publ), Karlsrovägen 2D, S-182 17, Danderyd, Sweden.*

DS

Daniel Scheffold <Daniel.Scheffold@tobii.com>
Lars Brotangen
tirsdag 23. april 2019 08:18
Vis detaljer

Hi Lars,

Great to hear you are writing your thesis with the Glasses 2! Feel free to use our illustrations. We have an image gallery with high quality images that you can use:

https://www.tobiipro.com/news-events/image-gallery/?category=32&skip=20

Please cite using our official company name: Tobii Pro AB

Karlsrovägen 2D
S-182 17, Danderyd, Sweden

Good luck with the thesis!

Best Regards,

Daniel

Daniel Scheffold
Director of Customer Success
Tobii Pro

Mobile: +46 73 32 78 765
E-mail: daniel.scheffold@tobii.com
Web: www.tobiipro.com
Linkedin: www.linkedin.com/in/danielscheffold

---

tobii pro