Exploring the Applications of Virtual Reality within Sports Coaching

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Abstract

The world we live in is one which is obsessed with sport. It comes as no surprise then, that technology is beginning to find its way into the sporting world. Virtual reality (VR) is a perfect example of a form of technology which is incredibly exciting, and that has already begun to be applied to sports such as American Football, or Soccer (more commonly referred to as football). VR, however, has not yet found its purpose in sports such as football, with the technology often being used as a fun gimmick.

This study, therefore, will discuss the possible applications of virtual reality within sports training. The study will begin by carrying out a literature review, before carrying out detailed user research. Once sufficient research has been completed, a VR football training prototype will be designed and developed in accordance with this research. The prototype for this case study will focus on football, as this is the sport that the dissertation will focus on in detail.

Once development has been completed, the prototype will be tested on a series of football players and experts. Results will then be discussed and applied to other sports. As part of the evaluation process, a VR football training system of the future will be designed using results of tests which feature in this study. This design, along with all other relevant feedback, will form the conclusion of the study, as this project aims to explore how virtual reality can be most effectively applied to the training routines of sports athletes.

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Declaration

I declare that this thesis is a presentation of original work and I am the sole author. This work has not previously been presented for an award at this, or any other, University. All sources are acknowledged as References. These references can be found at the end of this thesis, in the bibliography section.

Introduction

"I think we're off the honeymoon phase of virtual reality" (Lemire, 2016). This is what Brendan Reilly, a member of staff at EON Sports VR, once said about the use of VR (virtual reality) in the world of sports. Formerly a member of coaching staff for the Illinois state basketball team, Brendan and his fellow coaching staff previously questioned how much use someone such as himself would be, when standing in as part of the practice squad to play against the main team in training. "The impetus was, they were making fun of me as a scout-team point guard," Reilly said. "They were like, 'You're 5'9", slow, and you can't shoot. Why are we preparing for our competition against you?'". Reilly did not disagree, and this led him to think more and more about digital solutions to this issue. "I remember thinking, the holy grail would be if the guys played a video game on the court." After two years of enquiries and phone calls, Brendan was offered a job at EON Sports VR, to help work on sports training systems designed for virtual reality headsets. Several years have passed since then, and EON Sports are now one of the more well-known and successful companies in America when it comes to using virtual reality to prepare athletes for professional competition. This brings us back to the opening quote. Various companies and sports teams have already begun to look into the possibilities of using VR to train athletes, and many prototypes have already begun to be tested and used. The "honeymoon" period, as Reilly calls it, is very much over. Virtual reality is no longer the new, unexplored technology that it was once considered to be, and the same goes for that technology within the world of sports. But, as of yet, no one has quite been capable of perfecting this recipe, or demonstrating that virtual reality professional training systems can become the wide scale success that so many believe they are capable of becoming. This groundswell of interest suggests that virtual reality can, and should, achieve great success in this context, we're just not quite sure how.

Therefore, this study will not focus on proving the potential of VR in sports and sports training, as much research has already been carried out on the topic. This very research will be discussed during the literature review chapter of the study. This study will aim to explore how virtual reality can be most effectively used to train professional athletes. There are several forms of VR sports training system which are either currently being used or which are still in development, and in the next chapter of this study these examples will be addressed and critiqued, and it will be explained why these examples are limited, and often share more similarities with a video game than with a training system. In gaming, virtual reality has become a very popular, yet very expensive, trend. There is nothing wrong with this, however virtual reality is capable of so much more, as will be shown throughout this study. This topic will be confronted in more detail later, but it is vital that VR avoids facing the same fate when it is applied to professional training facilities. This study will aim to show what aspects of sports (such as mental or physical) can benefit the most from this form of technology, and subsequently which interaction techniques are most effective in VR in this context. The following is the research question this study will aim to answer:

- What areas of sport can be most effectively trained in virtual reality?

Once this question has been addressed, the project will then aim to determine what interaction techniques in virtual reality most efficiently train these areas of sport. This is a

secondary goal which the project will seek to achieve once the research question has been resolved.

This study will begin by exploring relevant forms of literature, and clarifying exactly why VR has such great potential when it comes to training professional athletes, before going on to develop a solution to this problem.

Later in the study, chapters will be dedicated to the user research phase, the design phase, the development phase, the testing and evaluation phase, and the conclusions reached by the study.

Chapter 1 - Literature Review

1.1 The Potential of VR for Football Coaching

While the recent resurgence of interest in virtual reality has largely been marketed as a platform for games and entertainment, there is much potential for applications of VR in other, professional, contexts. VR is slowly beginning to prove its worth within a professional context. Surgeons and pilots are the most obvious cases of VR being applied to professional training systems, with OSSO VR being one example of a VR simulation of surgery, which is used for training purposes. These examples will be discussed in greater detail later on in this literature review. This research project will attempt to explore the possible applications of VR within sports coaching, and how this exciting form of technology can become a successful sports coaching platform.

The first issue we must address is why this topic is both a matter of great importance and a matter of widespread interest. Despite referring to various kinds of sport, this research project will focus primarily on football. According to the FIFA "Big Count" of 2006, there were 265 million registered football players worldwide, without even counting those who play for fun locally in a non-competitive situation (Fifa.com, 2007). This survey further strengthened football's position as the world's number one sport, showing that football is the ideal sport to use as an example in this study. This is not the only important factor, as the world of professional football has a great deal of financial power and economic value. According to 'The Annual Review of Football Finance 2017', "total European football market revenues reached almost €25 billion in 2015/2016, a 13% increase on 2014/2015" (Annual Review of Football Finance, 2017). High levels of both revenue and participation, both at a grassroots level and professionally, suggest that the successful application of technologies such as virtual reality to football training routines could have a substantial impact economically and socially.

One football club known to be interested in technology such as virtual reality is Ajax. Ajax are very closely associated with the Johann Cruyff Institute, and Ajax famously invest heavily in their academy and the development of young, talented players. It should come as no surprise then, that an article has emerged from the Johann Cruyff Institute about virtual reality, and how it is improving the performance of athletes (Institute, J., 2017). The article pushes the value of virtual reality in sports by stating: "Virtual reality will be big news when its implementation becomes available for all pockets and professional teams. The industry expects to exceed $120bn in revenue in 2020". These forms of technology may seem like science fiction to many, but it is much closer to becoming a reality than people may think, and it is only a matter of time until virtual reality is commonplace is professional sports training.

This project aims to explore not only how useful technology such as virtual reality can become, but also how these features can be implemented to most effectively benefit professional sports training. Virtual reality has the potential to be much more than the commercial gimmick it is so often marketed as, and professional football training is a large market which is in many ways stuck in the past and very much in need of being modernised. Tracking sensors are now often added to vests which players use during training to track their

movements and obtain heat maps (Wright, 2016), but virtual reality has the potential to do so much more. This study, therefore, will attempt to demonstrate how VR can be implemented in sports coaching most effectively, not to replace the current forms of training, but to add to training regimes and ultimately improve the overall quality of the sport.

Virtual reality has already begun to show its potential within sports such as football. Combining sports training with technology to create new, innovative training systems is not a new trend. Patents dated as far back as 1987 have attempted to address this matter, for example, one particular study used different lights to train the reactions of a person (Elstein, Faret and Gazzo, 1987). In this particular case, the user had to hit a series of flashing lights to train technique and reactions. This system was considered useful for American Football players, or goalkeepers in European football. Many studies have also researched the prospect of combining sports and virtual reality, such as that by Richard Kulpa, Franck Multon, and Ferran Argelaguet for the University of Rennes (Bideau et al., 2010). The objective of this study was to explore modern, low-cost immersive systems, and how they could be used to examine human physical activity. The study achieved promising, albeit limited, results, as noticeable improvements were minimal. It also encouraged future studies to continue their research approach with more complex forms of technology, which at the time were not available. Other studies, such as that by Charles P. Hoffmann, Alessandro Filippeschi, Emanuele Ruffaldi and Benoit G. Bardy also cover a similar topic, despite focusing on a different sport. This study was able to conclusively demonstrate that using virtual reality to train energy management is able to improve 2000 metre rowing performance (Hoffmann et al., 2013). During this study, athletes were placed in a virtual boat, and had to decide at what speed the boat travelled throughout a 2000 metre race, as well as controlling how much energy the rower should expend during this race. The purpose of this VR training environment was to improve the energy preservation skills of the user, and results showed improved real world performance from those given access to the virtual reality training system. Products have also begun to be developed for VR sports companies, such as those by EON Sports (EON Sports VR, n.d.) and STRIVR (STRIVR, n.d.). These companies have already partnered with professional sports in an attempt to demonstrate the enormous potential of VR in sports coaching, with American football being the most commonly featured sport. These products focus largely on passing and tactical preparation within American football matches. These products, however, are limited. They are limited because they are designed for VR video playback rather than interactive games or computer programs. The possibility of designing more interactive VR training systems will be discussed later in the study.

To summarise, there is a clear link between sports and virtual reality, and now that this link has been established, we will examine exactly how virtual reality could aid and improve the professional sports industry.

1.2 Possible Applications of VR in Football Coaching

This section seeks to identify which aspects of football coaching can be best targeted by virtual reality. Often, when the topic of virtual reality sports training arises in conversation, many argue that VR is no match for training on a real football pitch, due to the fact that

computers are not able to perfectly recreate the real-world experience. Whilst there is a severe lack of research demonstrating the truth in this statement, one aim of virtual reality is to completely immerse the user in the virtual world they have been taken to. For training systems in particular, the user must feel completely immersed in VR in order for the skills they are being taught to transition into the real world. They will not be able to improve real world performance if the VR training system does not feel at the very least similar to the real-world experience, as the virtual training drills must relate in some way to the real thing. This is where the problem arises. If the user were to practice kicking a ball in virtual reality, it would never feel like the real-world experience as they do not feel like they are kicking a ball. The foot itself does not make any contact with a football, and as a result it becomes very difficult to practice kicking a ball, if the user doesn't truly feel like they are kicking a ball. As a result, this study will not seek to replace any part of the physical coaching that takes place on a training ground, but instead to support it by targeting areas of the game which cannot be practiced in the real world. With this in mind, the first factor to be discussed will be decision making, an important area of not just football, but any high-pressure sport.

1.2.1 Decision Making

Decision making, whilst under intense pressure, is what sets the very best apart from the rest in all forms of professional sports. Being able to perform at the highest level in front of large crowds, with very little time to make important decisions is a very difficult skill to master, and many studies have researched the importance of decision making in team sports such as football (Kaya, 2014). A study by Adam Kaya, from 2014, on exactly that topic, concludes that "in every area of the sports, whether in a professional or amateur, or school setting, coaches and physical education teachers have been dealing with how to teach kids an effective tactic and technique of sports play and help them be better decision makers". Decision making is an important factor that comes into play in professional sports, however, it is very difficult to recreate intense, pressured situations in every day training. In these training sessions, there is no real pressure, as the training drill does not look or feel like the high-pressure situation the player is preparing themselves for. Training decision making in these laid-back scenarios is inefficient, as cognitive skills are hard to perform under pressure due to the fact that adrenal-stress-responses direct blood flow away from muscles groups and areas of the brain which are associated with cognitive skills. Therefore, the most effective way to train decision making, in a manner that will affect the real-world situations the user is preparing themselves for, would be to recreate these situations in such a way that the user associates these them to the real world. This above all is the biggest indication that virtual reality is the most effective method to train decision making in virtual reality, as 2D computer simulations do not immerse the user in these real-world scenarios which elicit adrenal-stress-responses. In summary, VR is able to do what real-life training struggles to do, in that it can create these high-pressure environments more realistically, by putting the user's brain under similar levels of stress as a high-profile match would.

Sports are not the only profession in which decision making is an important factor. Firefighters, surgeons and pilots are all under intense pressure to perform on a daily basis, and many believe that no form of training can prepare them for that level of pressure, or allow them to train their ability to make the correct decision when put under that kind of

stress. In reality, the quality of VR training facilities being developed continues to improve, thus pushing the previous statement further and further from the truth. The rapid evolution in how professions such as these are taught and trained, and how these professionals prepare themselves for high pressure decision making situations, has already shown signs of promise, and these VR training methods will continue to improve and find their place within the world of professional training facilities, both for daily jobs and sports athletes alike. For example, a study was carried out by a selection of university and hospital researchers for the American Journal of Surgery (Ahlberg et al., 2007) which demonstrated that proficiency-based virtual reality training significantly reduced the error rate for patients during their first 10 laparoscopic cholecystectomies. Similar studies for the British Medical Journal (McCloy and Stone, 2001) (Larsen et al., 2009) also achieve similarly promising results within the realm of laparoscopic surgery. This clear evidence further demonstrates that VR is a highly useful tool when training for high-pressure, stressful professions such as a surgeon.

Not only has this form of technology been applied to the field of medicine, but it is also being applied to firefighting. Many experts have researched the possible applications of virtual reality training within firefighting, despite much of the research being carried out before VR technology, such as Oculus Rift or HTC Vive headsets, was made commercially available to the public. Two more recent examples of this are a study carried out for the Fire Safety Journal (Cha et al., 2012) and a second piece of work by Tazama U. St. Julien and Chris D. Shaw entitled the 'Firefighter Command Training Virtual Environment' (2003). Both of these pieces reached a positive conclusion, once again demonstrating the promising potential of VR training systems. This work is further supported by recently developed VR firefighter training simulators developed by FLAIM (n. d.) and Ludus (n. d.). Many other career fields are also carrying out related work, for example, the military now possess VR training simulators for vehicles such as fighter jets (n. d.). In all of these cases, professionals are able to use virtual reality to prepare themselves for real world situations, and train their ability to make important decisions whilst under great amounts of pressure. All of these professions require the ability to react quickly and make good decisions whilst under pressure, and this is also a skill which is incredibly useful in fast-paced team sports such as football. If it can be seen that VR is used to train decision making skills to these professionals, then the next clear step is to use the same forms of technology to train and target similar skills in professionals within the world of sports.

All of the work discussed concentrates on applying virtual reality to professions in which the individual in question is under an immense amount of pressure to succeed. In these high-pressure moments, the individual's ability to make the correct decision when there is very little time to stop and think is vital. That ability to react under pressure is exactly what these virtual reality training systems, along with the research that accompanies them, aim to improve. Furthermore, this form of high-pressure decision making is not too dissimilar to that which is required in fast paced professional sports such as football. If VR can be used to train high-pressure decision making for a surgeon, or a firefighter, then it is not inconceivable to suggest that the same could be done for football.

Good decision making is a difficult skill to acquire. Both in intense professions such as firefighting, and in professional sports, the common conception is that this is a skill which improves over time, with great amounts of experience. Often, when an 18 year old football

player makes his professional debut, he shows raw talent, and good technique, but lacks the ability to make the right decision at the right time. It has become such an important part of the development of young football players that studies such as that by Sixto Gonzalez-Villora of the University of Castilla la Mancha, on tactical awareness and decision making in young soccer players (González Víllora et al., 2013), are becoming much more common. This particular study researches how to best teach these skills to young players, concluding: "We believe that the players are better able to learn and consolidate their decision-making ('doing it') than to acquire conceptual knowledge ('knowing what to do'), as they show when explaining the what, the how, the when and the why of the technical-tactical actions performed on the field of play". The only issue with this, is that it takes great amounts of 'doing it', to actually master the skill. A second study on decision making in team sports, by Jean-Francis Grehaigne, Paul Godbout and Daniel Bouthier (Gréhaigne, Godbout and Bouthier, 2001), reached a rather similar conclusion, stating that "another difficulty is to face the challenge of learning about team sports within a time span of 20 or 30 hours. Researchers on expertise estimate that it takes 10'000 hours of practice to become an expert". Whilst it is impossible to say exactly how long a player may take to master skills such as tactical awareness and decision making, with such long time-periods at stake, being able to practice in virtual reality with no added fatigue or stress can only help the development of these young athletes. If experience is such a huge factor in learning, then VR can allow players to gain this experience much sooner than they would be able to in the real world.

To conclude, decision making is an important part of high-pressure team sports, and it is a very difficult skill to acquire. With so much time in a young players' development being dedicated to these skills, the use of modern technology such as virtual reality to train these abilities appears to be the next important development in its field, especially when it is considered that many other professions already use VR to train skills such as decision making.

1.2.2 Unconscious Decision Making

Virtual reality is not only being used to train for these professions, but also to tackle various psychological issues which are more complex than improving the user's decision making. In these cases, VR attempts to recreate stressful environments to examine and train the knee-jerk reactions of the user. This is important as unconscious thought, and unconscious decision making, are a vital part of decision making within both professional sports and other high-pressure professions, as these sports are played at such a high pace that there is very little time to stop, think, and weigh up the options you are presented with. As a result, copious amounts of research have been undertaken regarding the matter. For example, one study carried out by Ap Dijksterhuis of the University of Amsterdam (Dijksterhuis, 2004) used a journal entry to look into the merits of unconscious thought in preference development and decision making, concluding: "one thing the un-conscious is good at: making complex decisions. When faced with complex decisions such as where to work or where to live, do not think too much consciously. Instead, after a little initial conscious information acquisition, avoid thinking about it consciously. Take your time and let the unconscious deal with it." Other studies targeted at either decision making in sports in general (Bar-Eli, Plessner and Raab, 2011) or at decision making in in specific sports such as baseball (Fadde, 2006) can be found, but to date, there have been very few in-depth studies into how this research can be

applied using virtual reality, or the effects that VR could have on this line of work. Whilst the first of these two was a book written in order to establish the importance of decision making, the latter was a study carried out by Fadde studying decision making in baseball. This study drew on the findings and techniques of sports research in order to develop an interactive video training program intended to enhance the pitch recognition skill of baseball players. This project came to the important conclusion that "it appears that a perceptual decision-making sports skill such as pitch recognition can be targeted for training using interactive video and that such training can affect competitive performance". After ample amounts of work, one study by Armin Kibele of the University of Kassell (Kibele, 2006), which discussed non-consciously controlled decision making for fast motor reactions in sports, came to the conclusion that "there is convincing evidence from various studies in experimental psychology as well as in neurocognitive science showing that visual stimuli may initiate motor responses while participants are unaware of any stimulus presentation". It must then be highlighted that virtual reality has the ability to create computer simulated situations that can be relived multiple times in a very short space of time. Consequently, using VR to create visual stimuli to initiate instinctive reactions repetitively over a period of time will allow the user to work on and improve the instinctive reactions they are normally unaware of. As a result of this, and the conclusions reached by Kibele, it could be argued that virtual reality is the ideal tool for the training of unconscious decision making and motor reactions in sport. Furthermore, due to the very nature of unconscious thought and instinctive reactions, this type of mental training can easily transition into real life situations, whereas it is much more difficult to train physical movements which can be much more easily perfected in the real world, on a training pitch.

Other than skill, technique, and the basic instincts that come with unconscious thinking, another important factor in professional sports is the immense pressure athletes are under to perform. This stress can often lead to competitive anxiety, which in particular can be noticed in high-pressure penalty shoot-outs in football. Many studies have been carried out on both competitive anxiety (Jones and Hardy, 1990) (Martens, S.Vealey and Burton, 1990) and stress and anxiety within the realm of virtual reality (Wiederhold and Wiederhold, 2005) (Powers and Emmelkamp, 2008). However, it remains to be seen as to whether this form of technology, which is now becoming increasingly lifelike due to improvements in computer graphics, can help to reduce stress and anxiety in professional sports. One interesting study from 2014 by the University of Central Florida looked into social anxiety disorder (SAD) and whether or not virtual reality can be used to effectively elicit the forms of distress associated with SAD (Owens and Beidel, 2014). Through thorough testing and comparing different results, the study concluded the following: "the results indicated some ability for a VR environment to heighten physiological and subjective distress over baseline resting conditions but did not suggest that its effect was equal to an actual audience". Despite this result being minimal, it is encouraging that 2014 forms of VR technology were able to elicit these emotions, as VR is a new form of technology which continues to develop over time, and will slowly grow to the point where it is able elicit similar emotions to those which stressful situations encourage in the real world. Due to this, it is entirely plausible to conclude that with new forms of more immersive virtual reality technology, we will be able to create VR experiences which elicit emotions such as stress to such a degree that it can be used to train and improve the performance of an athlete under great pressure and reduce competitive anxiety. Having discussed how virtual reality could improve skill, tactical awareness, instincts,

reactions and unconscious thinking, as well as competitive stress and anxiety, we must now consider how all of this can be applied to football, and what football drills and coaching techniques could benefit most from this technology.

1.3. Previous Work on VR Football Coaching and Decision Making

Before we refer to football coaching manuals, we must first look back on any similar VR sports products to ensure that this project is not only different from its predecessors but that it improves on any previous work in the area and focuses on their mistakes, as well as learning from their successes.

There are many examples of VR being used in sports. One example can be found in the AFL (Australian Football League). Port Adelaide recently adopted VR into its training regime, with their coach Ken Hinkley having gone on to say: "they (players) can use the goggles and all of a sudden be almost playing football while they're on the couch, which is helping them educate themselves" (portadelaidefc.com.au, 2016). The technology is being exclusively used by the club, and was implemented by Jumpgate Virtual Reality. Hinkley also goes on to point out that the advantage of being able to use virtual reality to train whilst avoiding any added physical fatigue, stating that "it's nice to be able to try and learn and educate them a little bit more on the game without actually physically having to hammer them all the time. And that is one of those advantages it does for us." Another high-profile use of virtual reality in sports comes from the US ski team. Members of the US ski team have been training for the Winter Olympics using virtual reality, as was explained in detail in an article written by Terry Collins (Collins, 2018). The article not only shows how useful technology, such as VR, can be, but also how VR was used to prepare Laurenne Ross for the event, despite spending the best part of a year recovering from an ACL injury. The article explains: "it's been almost a year since Ross tore her ACL and the meniscus in her right knee, which should have kept her out of action for about 18 months. Ross was having none of it. Instead, she put herself through a gruelling rehab regimen that included hundreds of VR sessions. She made it back to the slopes in nine months". These VR sessions allowed Laurenne to ski without putting intense pressure on her knee, with the sessions becoming more physically demanding as her rehab progressed, until the knee successfully healed and she was able to return to the ski slopes, having missed very little of her training regime whilst injured. The way in which the US athletes have embraced virtual reality as a means of preparation for an event as important as the Winter Olympics demonstrates just how much VR technology is capable of.

Another particularly interesting project, by Beyond Sports (n. d.), aimed to transform real life match data from Dutch professional football matches into virtual simulations, so that players could re-experience previous match situations and learn from their mistakes. This simulator recreated real world football matches, using computer generated graphics, so that the user is able to experience any moment of the match, from anywhere on the pitch, through virtual reality. This project presented a unique way in which to relive football moments and analyse player performance, as it gives the user the ability to see the match through any of the players eyes, and understand the actions and thought process of each player. The project then went

on to develop VR training facilities that could focus on a players' decision making and tactical awareness. Despite proving to be a success, having been tested by the youth academies of clubs such as Ajax and AZ Alkmaar, the product was limited in various ways. Firstly, Beyond Sports VR only used computer graphics for simulations, and whilst the simulations of real life matches contained animations, the training facilities that could be controlled by the user only featured still 3D models. For example, the user may choose between three players to pass to, but can only choose which player to select, without seeing the consequences of their actions, merely being told if they were right or wrong with little justification. Furthermore, the choice to not use a sequence of 360-degree videos for the product was justified by explaining that 360-degree videos take up a much larger quantity of memory than standard videos, and that both large bandwidth and a strenuous video stitching process made using video content very difficult. Four years later, however, computing power has increased and higher quality virtual reality headsets have been made commercially available, therefore 360-degree video has become a much more viable option. Using video rather than computer graphics would make the product much more lifelike and immersive and thus improve the overall experience. As a result, it appears that the best choice would be to use 360-degree video sequences where possible and to make the product as interactive as possible, in particular, using animations and movement whenever computer graphics are necessary.

1.4. Applications in Football

In order to better understand which training drills would be most effective when recreated in virtual reality, recommendations and guidelines in football coaching manuals will now be considered.

The manual in question is the official FIFA coaching manual (FIFA, 2017). This coaching manual discusses all aspects of football training and coaching, many of which are not relevant to this review, therefore only the most useful and relevant topics will be discussed. In chapter 3, page 4 of the manual, the training of player mentality is discussed. It is mentioned that "a lot of work needs to be done in this area". Despite this, it later states in chapter 4, page 17, that the personality, more specifically mental skill and tactical awareness, are important parts of the development of the young footballer. Mental issues such as those listed below are an area which virtual reality could easily target and improve. This is due to the fact that virtual reality lends itself to psychological training much more than it does to physical training, which can easily be performed in the real world, as was previously explained when discussing unconscious decision making earlier in the review. In chapter 7, page 2, the manual specifies the various mental attributes that can (and should) be worked on. The three most relevant in this study are concentration, attention and resistance to stress. Focusing on these attributes, along with skills such as tactical awareness, play styles and overall playing mentality, seems to be the best way of achieving successful results in professional football training in virtual reality. The FIFA manual further supports the potential for technology such as VR in the sport, by pointing out the importance of developing young talent without pushing the players too hard. This is important, as VR training can complement the existing training sessions, without any added fatigue. This is also ideal for injured players who are unable to participate in physical activities.

1.5 Conclusion

To conclude, we can once again reference the FIFA coaching manual. In chapter 6, page 16, it is specified that “visual pedagogical tools such as blackboards, whiteboards and magnetic boards, as well as video analysis, can be used as complementary training methods”. If FIFA has decided to welcome technology into the game, with introductions like goal line technology (FIFA, n. d.) and the Video Assistant Referee (VAR)(FIFA, n. d.), then clearly there is room to broaden the horizons further than a whiteboard, a blackboard or a television. Virtual reality is the future of professional sports training. This project will attempt to demonstrate how VR can achieve the best results possible within this sector.

Chapter 2 - User Research Phase

Throughout the literature review, it was established that there is considerable research in the fields of professional sport and virtual reality, along with a selection of examples of how these two may combine. Whilst various aspects of sport which could be improved by VR have been singled out in the literature review, there is very little research demonstrating exactly how virtual reality can be most effectively used to train athletes, or which aspects of sports VR should be applied to in order to achieve the most success. Therefore, the user research phase of this study will aim to establish how virtual reality should be applied to the sports training industry, and exactly what an effective VR sports training system should consist of. Due to the fact that this study focuses primarily on football, various football experts were asked to participate in this study. Football clubs across the country were contacted via email, asking for coaches' views and opinions on virtual reality, going on to ask if they would be open to an interview during which they would be asked multiple questions regarding football, and the potential use of VR within the sport. A total of thirty English professional football clubs were contacted, with two agreeing that one coach from their club would be open to an interview. The majority of clubs contacted were not open to discussing training routines or techniques with any member of the public, as they wished to keep any such information private to the club. Subsequently, clubs situated in the north of Italy were also contacted in order to find more participants for the study. Three out of a total of fifteen clubs contacted offered their assistance, and agreed to allow a coach to participate in the study.

A total of five professional coaches were interviewed during the user research phase of this study. All five of these interviews were carried out over the medium of Skype, as these coaches are based far away from one another. Two of these participants are based in the north of England. The three remaining coaches are based in the north of Italy. Throughout this study, all individuals who participated in this research project shall remain anonymous, and the collective opinions of these individuals will be summarised in this chapter. Each coach was interviewed for a total of fifteen minutes, with the intention being to use all of the gathered information to design the virtual reality coaching system which would then be developed, tested and analysed. These interviews consisted of the following series of open questions:

1) Virtual reality in football. What do you think about it? Do you see it having a future in the game?

2) What age groups of footballers do you think this study would be of most use to?

3) What areas of the game do you think could be best targeted by virtual reality?

4) Are there any specific features you can think of that you would like to include in the software to use virtual reality to coach?

The responses of all participants will be discussed in the following subsections in detail. Comments made by coaches during these interviews were recorded on paper, and these transcripts were subsequently analysed, in order to search for patterns and important

comments. The transcripts from these interviews will not be shared due to privacy and data protection agreements.

2.1. Question 1: Virtual Reality in Football

For the most part, the participants were all open to the idea of virtual reality. Using technology in football is becoming increasingly common, but there are remaining concerns regarding cost, especially from the Italian coaches as forms of technology like VR headsets are less common and as a result, more expensive, in countries such as Italy. Some football clubs, however, are beginning to invest in the technology at a professional level. Another issue is that many people are yet to try out virtual reality for themselves, and remain unconvinced and largely uneducated about the benefits of this technology. However, the coaches agreed that football must make sure it does not become 'stuck in the past', and that virtual reality is an ideal way to keep up with the times, with one Italian coach stating that: "in Italian football, the money is all at the top level, and this makes it difficult to believe that many small clubs could afford virtual reality, however, the development of young players here [in Italy] is not as successful as it once was, and maybe technology like VR is the next step". On the whole, this question received a very positive response, which is also supported by the research covered earlier in the study.

2.2. Question 2: Age Groups

The second question received a much more varied response. Interestingly, the Italian coaches strongly believed that this type of technology belonged exclusively within professional football, and not in youth academies. This is due to the fact that there is less money involved in Italian football, and as a result there is much less investment in youth development. This issue of cost often arises in the discussion of virtual reality, and the Italian coaches were open to the use of cheaper VR alternatives for use at youth level. The English coaches were much more open to the use of VR for all age groups. They insisted that all age groups could benefit, as young players can be taught the basics of the game, and develop their tactical awareness, and senior players could use it to prepare for specific match situations or prepare themselves to face a specific opponent.

To summarise, the second question received very useful feedback, although the research does suggest countries such as Italy may take more time to adapt to the use of modern technology in the game. The English coaches concluded that players of all ages should be exposed to VR coaching, however, they did also agree that younger players have the most to gain from the technology as they are the ones who have the most to learn.

2.3. Question 3: Which Areas of Football Should Be Targeted

The third question appeared to be the one which garnered the most interest from the coaches. There are a lot of possible applications for VR in sports like football, with anything from tactical analysis, to reaction training and shooting practice being a possibility. The

English coaches were very intrigued by the suggestion of using VR for decision making, as they agreed it is not only a big part of the game, but also a very tricky skill to acquire and teach. One coach went on to explain: “decision making is a very difficult skill to teach, as it comes with experience. If players were able to gain this experience in VR, being put into virtual situations where they had to react quickly to make the correct decision on a football pitch, they would be able to acquire and improve these skills much more efficiently than they are current able to do”. The Italian coaches believed VR would be very useful when preparing for set pieces, such as corner kicks or free kicks, as well as being used for decision making. More specifically, decision making where the user has a limited amount of time to pick between a selection of viable passes. They believed that preparing players for specific situations like these, over and over again for long periods of time, would be a good way of drilling certain concepts into players heads and encouraging those skills to transition from training to matches more efficiently.

The options of training decision making under pressure in-game, or preparing for set pieces, are both options which will be explored in more detail, in order to understand which is the better option to take for this study. It does, however, seem as though decision making is one of the key areas of football which this study should focus on training in virtual reality. Once again, this question received positive feedback that will contribute towards the design phase.

2.4. Question 4: Any Specific Features You Would Like to See

In the final part of the interview, the coaches were asked if there were any specific features they would like to see incorporated into the project. From this feedback, there were four main uses and features which were very popular among the coaches, and these four points will be taken forward and studied in more detail below. These four points were recreating match situations, styles of play, fatigue and tactical awareness.

2.4.1 Recreating Match Situations

One significant criticism of virtual reality based training is that it does not teach skills that transition into the real world, and often does little to make the experience feel realistic. As a result, the end-product often shares more similarities with a game than with a training system. This is something which must be avoided, and the coaches involved in the study all agreed on this.

One step towards avoiding this situation is the idea that when faced with a decision in VR, the player would also be given a match situation. This means that, when standing still with the football at their feet and facing a choice between three possible passes, the user would be told they were losing to a better team than themselves, and have to make their decision whilst taking the information given to them into account. Not only this, but also the feedback given to them after they make their decision will be affected by this match situation they have been placed in. The player could be given the specific score in the match, as well as their opponents identity, and they could either be winning, drawing or losing. This feature was suggested by

two coaches, and the other three, when asked about the idea, all believed that it is a concept which has very good potential.

This feature will be explored in more detail in the design phase of the project, but is one of the key contributions the interviews carried out will have on the prototype that is later to be developed and analysed.

2.4.2 Playing Styles, No Right or Wrong Answer

Football can be played in many different ways. There is no such thing as the 'perfect' or 'ideal' way to play football. There are many different playing styles, and the style of the team depends heavily on the manager of the side. Current Manchester City football manager Pep Guardiola is a manager famously known for his attacking, passing style of play. Manchester United manager, Jose Mourinho, however, is his polar-opposite, renowned for his slow, defensive approach to matches. As a result, when a player is faced with a decision on a football pitch, there is no "right" or "wrong" answer, simply a variation of options which can be considered more or less appropriate given the situation that they find themselves in.

This concept, explained by one of the coaches during these interviews, will not only heavily influence how feedback is given to the user in the product to be developed, but also brought the topic of playing styles into discussion. Consequently, when the player is given a match situation to take into account (as previously discussed), they will also be told which style of play their manager wants them to play. This could either be a slow passing style of play or a fast, long-ball style of play. The feedback given to the user after the decision making process could, as a result, take into account the score of the match, the opponent they are facing or the style of play encouraged by their manager.

2.4.3 No Fatigue, From Anywhere in The World

Another advantage to using virtual reality, which the interview participants heavily supported during the research process, is the lack of fatigue that training in VR would cause. Consequently, not only could it be used in between training sessions whilst resting, but it would allow certain players who would otherwise be unable to train, to take part in team activities; more specifically, injured players or loanee players.

Normally, if a footballer is injured, they are isolated from the group and instructed to train by themselves in order to give their injuries time to heal. In this case, the injured player would be able to take part in the virtual training sessions, as they are far less physically demanding. This means that not only can the player be kept up to speed with the team's training routines and activities, but that once they are fully recovered they would already be tactically prepared enough to be immediately reintegrated into the team without having to be told where or how to play the role that is asked of them.

Furthermore, it is common for football players belonging to a specific club to be loaned out to another club for short periods of between six months and a year. This often involves young

players being loaned out to a smaller club to give them more game time to encourage their development. It was suggested, during the user research process, that virtual reality could be used to coach players who are currently loaned out to another club. This would allow the parent club to maintain control of the player and track their progress, whilst simultaneously allowing the loanee player to be kept out to date with the training regimes of their parent club (parent club being the club that owns the player).

2.4.4 Teaching the Tactics

One more possible use of this project was pointed out by the football coaches. As discussed during the literature review phase of the study, the teaching of tactical awareness and mentality is an important part of the development of young players. It is also one which is not easy to teach. Even professionals such as Ruben Loftus-Cheek suffer from this issue. Despite being a player who featured heavily for England at the 2018 FIFA World Cup in Russia, he was told by his manager, Chelsea FC coach Maurizio Sarri, that he still has a lot to learn tactically, less than a month after returning from the World Cup (teamtalk.com, 2018).

Therefore, there is very much demand for new methods of teaching skills such as tactical awareness and vision, and VR is more than capable of filling this void. VR is not only fatigue-free, but would also allow players to be put through training drills teaching these skills over and over again, without the need to physically set any training drills on a football pitch, or the need to train constantly with all of your team mates. Young players would be able to dedicate a lot more time to these forms of training without it affecting the training regime of the rest of the team.

All of the features discussed in the user research phase of the project will be further discussed in the design phase of the study, as most of the information gathered from the interviews carried out will influence and inspire any VR software created during the study.

Chapter 3 - Design Phase

Based on the literature and user research conducted, the decision has been made to make a system to support decision making training in VR. In this chapter, we will describe the decisions and process that led to the design of this prototype.

3.1 Starting Out

The design and development of software used during this study was a lengthy process, beginning before any research was undertaken, and ending once all relevant literature was analysed and user research was carried out. Initial concepts and ideas, formed at the very beginning of the study, were changed and improved in accordance with any research that was undertaken. Each stage of the design and development process will be discussed in detail, but first, the concepts and ideas upon which the project was created must be discussed. The project began with two main ideas of how to use VR to coach and interact with football players.

3.2 Choosing Between Immersive Video and 3D Graphics

The first idea was to use artificial intelligence (AI) in a computer simulated virtual environment. Taking inspiration from video games such as FIFA 18 (EA, 2017) which now also feature football training drills, the idea was to immerse the player within a FIFA video game inspired training environment, featuring opposing players controlled by AI. If this concept were to become a reality, the project could be used to recreate any football match or training drill in virtual reality and allow any one player to use the technology without the need for team mates to participate in the same drills. This idea, however, would be very difficult to create as developing computer AI is a very difficult, time consuming task.

The second idea was to use a series of 360-degree videos to coach football players. Each video would be shot from a first-person perspective, and after watching each of these videos in virtual reality, the user would be given the chance to make a football related decision, and the next video to be played would be a direct consequence of the choice made by the user. This second concept is arguably more immersive as it consists of video content and not computer simulated graphics, thus seeming much more realistic, though it is much less flexible than the first idea. It is less flexible as the user would have to choose between a limited amount of options and would not be free to act as they wish.

3.3 Research Inspired Designs

The first designs involved the player being able to control the ball in virtual reality. For example, in these designs the user would be able to kick a ball in VR. As well as kicking the ball, they would also be able to perform goalkeeper training. In this virtual goalkeeper training programme, the AI would take shots at the goal, and the user would have to save those shots. The following image, figure 1, is an example of what this would look like.

Figure 1

This concept, however, is limited, as has also been discussed at the beginning of section 1.2, during the literature review carried out for this study. It is important that VR is used to add to sports coaching, and not replace it, as many drills are proven to be more effective in the real world rather than virtual reality. In this case, there is nothing the user could do in VR that they would not be able to do in any average goalkeeper coaching session. Other options, therefore, must be considered.

In the literature review phase of the study, decision making was heavily discussed as a skill that could be targeted effectively in virtual reality. Then, user research carried out supported this notion. Football coaches, who were involved in the research which was carried out, suggested that being able to coach decision making whilst preparing for specific match situations may be the ideal form of virtual reality sports training. The first design involves training the user how to cross the ball, and they are able to control both the power and direction of the cross, as well as the timing.

Figure 2

The second design, which can be seen in figures 2 (above) and 3 (below), focuses on shooting. In this concept, the player is able to control the power and direction of the shot, whilst once

again having to master the timing that is required. This design also features AI-controlled defenders and a goalkeeper.

Figure 3

These two designs are much closer to the look and feel of the end-product of this development phase, but changes must be made before these designs fully support the research which has been carried out. For example, shooting practice, much like the goalkeeper training discussed previously, does not add to any pre-existing form of real world football training, and the aim of this study remains to research and understand how virtual reality could be used to best improve current forms of football training, not simply attempt to replace them.

3.4 The Final Design

As a result of research carried out in chapters one and two, football related skills such as decision making and tactical awareness will be the primary focus in the final design for this project. Passing is an important part of football which is heavily dependent on the players decision making abilities. Consequently, the prototype created for this study will focus on passing, and to maintain the simplicity of tests carried out, each drill will allow the user to choose between three passing options after being given a set of instructions. The user will have to follow these instructions whilst under pressure in VR, as if they were following their managers instructions in a real-world football match. The VR drills the user is put through will be located in all areas of the football pitch, in order to add variation to each training drill. This design will allow the player to practice their decision making, whilst having to follow different play styles and improve their tactical awareness, as these were points raised by coaches during the user research phase of the study.

As previously discussed, a program will be developed which contains a series of 360-degree videos. After each of these videos, the user will be able to choose between a selection of three videos. More specifically, the user will be shown a video in which they receive a pass from a team mate, and then have to choose which opponent, between the three options they

are presented with, they should pass to next. Three white arrows will appear in front of the user at waist height. Whichever of the arrows they choose to touch with the VR controller, will trigger the next 360-degree video. For example, if the user touches the arrow pointing to the left, the ball will be passed to your teammate to the left. This passing drill will be repeated over and over, from a possible nine locations on a football pitch. These nine locations can be seen in figure 4 below, with the user attacking from left to right. There are three drills for the attack (close to the opponent's goal), three for the midfield (in the centre of the pitch), and three for the defence (far away from the opponent's goal).

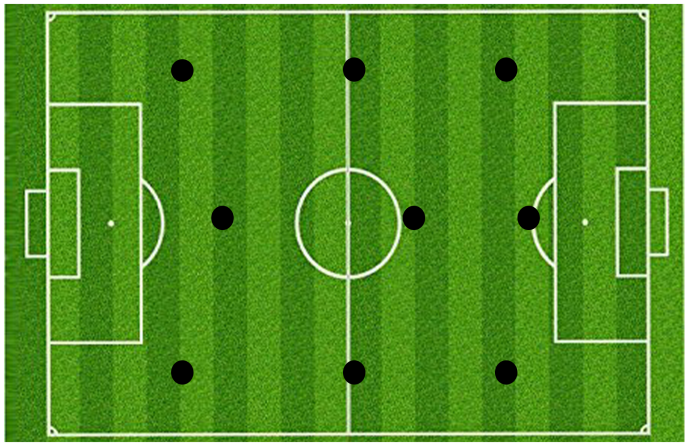

Figure 4

Furthermore, they will be told if they are winning or losing the football match they have been placed in, as well as the preferred style of play of their manager. This information will be fed to the user via a scoreboard placed in the centre of the screen, above the football pitch the user finds themselves on. The information given to the user will influence the decision made by the user, and that very information will also affect what feedback is given to the user regarding the decision made. The aim of this feedback is to teach the user how to make important decisions in football matches in short spaces of time, whilst also being aware of their surroundings and the score of the match they are playing. Feedback, which will be shown on the scoreboard previously displaying the score of the football match, will tell the user if they chose the most appropriate pass, as well as explaining why they did so. By the same account, if the user makes an incorrect decision, feedback will be given to the user explaining why they could have made a better decision. The aim of this study, therefore, will be to demonstrate that these decision making abilities are the sporting skills most effectively trained in virtual reality, and the user will have to take into account the current score of the virtual football match, as well as the style of play demanded by their coach, before they make their decision. Two images (figures 5 and 6) displaying the final design can be found below. In figure 5, the user is instructed to choose between three passing options. In figure 6, the user has made their choice, and is shown the consequence of their actions.

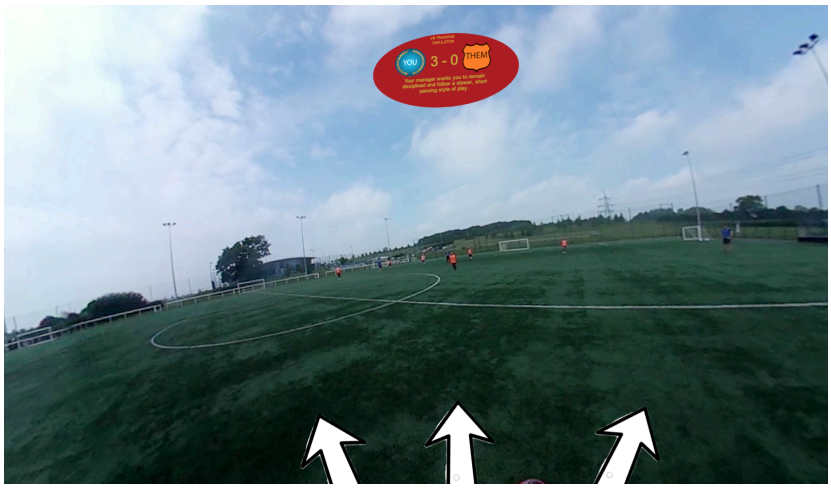

Figure 5 Screen pre-choice

Figure 6 Screen post-choice

This program has been developed for the HTC Vive virtual reality headset, and the user is able to control the virtual training environment using a motion sensitive HTC Vive controller. Following the development of the program, it will be tested by both coaches and football players to determine how efficiently virtual reality is able to train football skills, and these tests will also inspire future designs and determine how VR can be best used for virtual reality sport training.

Now that the VR training program has been described and shown in screenshots which can be found above, the next step will be to detail how the virtual reality software was developed.

Chapter 4 - Development Phase

The development phase of this project consists of two main parts. The first is to plan and record all 360-degree videos that are required as part of the final design. The second is to then use these 360-degree videos as part of a program created in Unity for virtual reality headsets. All videos were recorded, edited, then imported into Unity, where they were played on the inside of the face of a sphere, with the user being placed in the centre of the sphere. The structure and implementation will be described in more detail in section 4.2.

4.1. Recordings

The first step in the development of this training system prototype, a series of 360-degree videos were recorded. These videos were recorded using a Samsung 360 Gear camera. This camera was placed onto a frame to further stabilize the device whilst recording footage, as the camera needed to remain as stable as possible whilst the same individual holding the camera also played football. Without stable 360-degree video footage, the training system is at risk of inducing motion sickness from its users. Once the camera and frame were prepared to record stable video footage, the next step was to form a detailed plan of the video shoot.

A minimum of 10 participants were required for this shoot, and participants were all students at the University of York, who were offered a £5 Amazon voucher in exchange for participating in the video shoot. In order to purchase said vouchers, an application was made to the university for funding. This application was eventually approved, and all necessary £5 Amazon vouchers were purchased by the department of Theatre, Film & Television at the University of York. A total of 11 students were found for the shoot, and each of those 11 individuals received a voucher in exchange for their services. Furthermore, the York Sports Village allowed for their 3G football pitch to be booked free of charge for one hour to accommodate the video shoot.

Once this plan was formed, participants were invited to the York Sports Village football pitch for the shoot. Videos were recorded from nine different locations on a football pitch. From each location a video was recorded of the player holding the Samsung camera receiving the football from a teammate. Then, a video was recorded for each of the three passes the user is able to make from this location. This process is repeated for all nine of the locations previously discussed, with a total of 36 videos being recorded.

Once these 360-degree videos were recorded, each video file was imported onto a computer from the camera using Samsung software specifically designed for the camera used in this study. The program then allows the user to stitch each of these videos into a 360-degree clip, as the camera used records raw footage using two 180-degree lenses, producing two raw video files which require stitching. Once all videos were copied from the camera and successfully stitched into a 360-degree video, they could then be imported into Unity for use in the VR training system. All participants of the video recordings were informed of this process.

4.2. Unity

The first step of development in Unity was to import all necessary video files into a new project. Secondly, all files were renamed according to the location at which they were filmed on the football pitch. Each video name began with a number from one to nine indicating their location on the pitch, then a second number (1, 2 or 3) indicating whether the video features a pass to the left, to the centre or to the right of the user. For example, a pass to the right of the user, at the second filming location on the pitch was renamed '2.3'. This allowed for the videos to be organised efficiently, and made the selection of the next 360-degree video to be played in VR much easier, as the necessary video could be easily located.

Next, the SteamVR library was imported into Unity. This library contains a series of scripts controlling the VR first-person camera which tracks the movement of any VR headset compatible with SteamVR. In this case, SteamVR software connects the HTC Vive VR headset to Unity. These SteamVR scripts are added to a camera object in Unity which, as previously explained, will track the head movements of the user and pair up Unity with the VR headset being used.

Once all videos files were imported into Unity and organised, and the SteamVR library has been imported, a high-quality 3D model of a sphere was created in Unity. A shader was then added to the sphere model which allowed Unity textures to be shown on the inside of the model rather than on the outside of it. Next, a video player class was added to the sphere model, as well as the main C# script which controlled the majority of the Unity project. Before code could be added to this script, the scoreboard was added to the project. This scoreboard was made up of a 2D model of an ellipse, which was covered by an image created in Adobe Photoshop of the crests of each team playing in the virtual match. Text was then added to this model containing the score of the match, as well as the style of play the coach has instructed the team to play. This text can be manipulated by the C# script assigned to the sphere model. Furthermore, all predetermined text files which are used for feedback, for the current score and for the style of play required are contained within this script.

Next, three white arrows were added to the project, placed roughly at waist height in front of the user. The first of these arrows points left, the second arrow points forwards and the third arrow points to the right of the user. This arrow models also contain a C# script which changes the directory of the video being played on the model sphere, every time the VR comes into contact with that arrow. Whenever the controller touches the left arrow, for example, the file name of the video currently being played will be changed to the name of the video in which the player passes the ball to the left. The script contained in each arrow model also accesses the main controller script (assigned to the sphere model) in order to change the content of the scoreboard to display feedback, rather than the current score of the match. Examples of these scripts, as well as feedback given to the user, can be seen below in figure 7.

```
playStyle = 1;//1 for short passing style, change to 2 to long ball feedback

style1 = "Your manager wants you to remain disciplined and follow a slower, short passing style of play.";
style2 = "Your manager wants you to play a more aggressive, long ball style of play.";

option1 = "Yes! You are losing and are in need of a goal but you must remain patient and look for a safe pass.";
option2 = "Yes! You are losing and are in need of a goal, you need to get the ball high up the pitch quickly.";
option3 = "No! You are losing and are in need a goal, but must remain patient and look for a safe pass.";
option4 = "No! You are losing and are in need of a goal, you need to get the ball high up the pitch quickly.";
option5 = "Yes! You are winning and need to protect your lead, but must remain calm, not panic and look for the safe pass.";
option6 = "Yes! You are winning and need to protect your lead by getting the ball high up the pitch and away from your goal.";
option7 = "No! You are winning and need to protect your lead, but must remain calm, not panic and look for the safe pass.";
option8 = "No! You are winning and need to protect your lead by getting the ball high up the pitch and away from your goal.";
option9 = "Yes! You are drawing and are in need of a goal but you must remain patient and look for a safe pass.";
option10 = "Yes! You are drawing and are in need of a goal, you need to get the ball high up the pitch quickly.";
option11 = "No! You are drawing and are in need a goal, but must remain patient and look for a safe pass.";
option12 = "No! You are drawing and are in need of a goal, you need to get the ball high up the pitch quickly.";
```

Figure 7

As can be seen in figure 7, the computer code shows that the various feedback and play-styles inserted into the software are contained in the sphere-assigned controller script. These variables will then be accessed by scripts which are contained in each of the arrows located in front of the user.

```
void OnTriggerStay(Collider other) {


    print ("up arrow collider");

    float position = GameObject.Find ("Sphere").GetComponent<controller> ().position;
    float random1 = GameObject.Find("Sphere").GetComponent<controller>().random1;
    float random2 = GameObject.Find("Sphere").GetComponent<controller>().random2;
    int playStyle = GameObject.Find ("Sphere").GetComponent<controller> ().playStyle;

    string option1 = GameObject.Find("Sphere").GetComponent<controller>().option1;
    string option2 = GameObject.Find("Sphere").GetComponent<controller>().option2;
    string option3 = GameObject.Find("Sphere").GetComponent<controller>().option3;
    string option4 = GameObject.Find("Sphere").GetComponent<controller>().option4;
    string option5 = GameObject.Find("Sphere").GetComponent<controller>().option5;
    string option6 = GameObject.Find("Sphere").GetComponent<controller>().option6;
    string option7 = GameObject.Find("Sphere").GetComponent<controller>().option7;
    string option8 = GameObject.Find("Sphere").GetComponent<controller>().option8;
    string option9 = GameObject.Find("Sphere").GetComponent<controller>().option9;
    string option10 = GameObject.Find("Sphere").GetComponent<controller>().option10;
    string option11 = GameObject.Find("Sphere").GetComponent<controller>().option11;
    string option12 = GameObject.Find("Sphere").GetComponent<controller>().option12;

    var player = GameObject.Find("Sphere").GetComponent<UnityEngine.Video.VideoPlayer>();
    var video = position.ToString() + ".1.mp4";
    player.url = "Assets/" + video;
    player.frame = 0;


    if (random1 > random2)//winning
    {
        if (playStyle == 1)
        {
            GameObject.Find("Text").GetComponent<Text>().text = option5;
        }
        else if (playStyle == 2)
        {
            GameObject.Find("Text").GetComponent<Text>().text = option8;
        }
```

Figure 8

In figure 8, C# code can be seen from the script contained within one of the arrow models. Whenever the arrow collides with another object (the only mobile object in the project being the VR controller), the OnTriggerStay function is triggered. The script first accesses all variables contained within the main controller script, and then changes the 360-degree video currently playing, as well as the text shown to the user in the form of feedback.

Now that the VR software has been developed within Unity for the HTC Vive headset, there is one final factor to consider before concluding the development process. This factor is mobile development.

4.3. Mobile Development

As previously explained, this VR football training computer program was developed for use on the HTC Vive virtual reality headsets. The biggest criticism of VR headsets such as these remains to be the price tag that accompanies them. Whilst professional football clubs would

comfortably be able to afford the high costs that virtual reality demands, prices of around £700 would be very difficult to justify for some. This is specifically this case both at lower level football clubs and at football youth academies, where there is considerably less funding from club owners, sponsors and third-party investors.

Therefore, there is the clear need for a more cost-efficient option for accessing virtual reality. The one obvious solution is a device which is at the epicentre of human behaviour in the modern world we live in which is dominated by technology, and that solution is the smartphone. Coincidentally, smartphones are also becoming increasingly powerful devices, with the capability to run virtual reality software. This form of mobile VR began life as little more than 360-degree video in a plastic casing, that the user could strap to their face and place in front of their eyes. Now, however, mobile phone companies running Android operating systems, such as Samsung or Google, have begun to develop their very own VR headsets which can be paired with Android smartphones. These new headsets are much more effective than previous attempts, with one example of this being the Google Daydream View virtual reality headset. The Daydream is compatible with many new Android phones, and for the purpose of providing a less costly solution to the problem this study aims to address, the VR football training program already developed for the HTC Vive was adapted for use on Android devices through the Google VR SDK (Software Development Kit). More specifically, the VR software will run on the Google Pixel XL 2 smartphone, which is compatible with the Daydream View.

In order to get the Unity project created for the Vive running on Android, a few changes must be made. The first main difference between the two programs is the third-party libraries which are used. A library is a file containing several examples of pre-written code which all serve a similar purpose. For example, the SteamVR library contains files which allow communication between Steam compatible VR technology, and the Unity program itself. But in order for the program to function correctly on the Google Daydream, a Google VR library must replace the SteamVR alternative, in order to allow Unity to communicate and function with the Google smartphone and VR headset. The second change to the original program is in regard to the controllers used. The code which previously accessed the HTC Vive controllers must be replaced with code which accesses the Bluetooth controller paired with the Daydream headset.

This mobile development of VR football training software will be used in the testing phase of this study, as well as the Unity project designed for the HTC Vive.

Chapter 5 - Testing Phase

Following the design and development of the virtual reality football training system, it must now be tested. The purpose of these tests is primarily to establish if the football skills the training system targets and the interaction methods which have been applied are indeed the most effective method of coaching sports within VR, as research has suggested thus far.

It is important that from these tests both qualitative and quantitative analysis can be gathered. Therefore, there will be two types of tests carried out. Firstly, there will be one carried out on football coaches, which will establish how useful the players find the technology, and whether through using this system, they are able to show an improvement of any sort within the skillset targeted. The second test will involve football coaches and experts, who will be shown the project in the form of a presentation with a short demonstration. They will also be allowed to try it out for themselves. Afterwards, the coaches will be interviewed, to establish what their thoughts are on the study, what changes they would make to the project, and how similar forms of technology could find their way into the sports industry.

Once these two tests have been carried out, and all relevant results have been gathered, the next phase will be the evaluation phase, where results are discussed and analysed, and final designs and solutions are proposed. It must also be stressed that the study will not be judged upon the quality or complexity of the VR software itself, as the purpose of the software is to be a prototype which offers the user an idea of how virtual reality could be used in professional sports training. The key to this study will be the analysis and evaluation of all results and research gathered, in order to establish how best VR can be used to coach professional sports.

Before the tests in question can be discussed, however, the planning and organization of said tests must be briefly detailed. Various clubs were contacted throughout this study to ask for their participation, with the greatest participation coming from Venice, Italy. Marcon is a small town in the north of Italy, located on the mainland near the island of Venice. This very town, during the summer of 2018, was host to a Valencia Football Club summer camp, aimed at football players between the ages of 13 to 16. This summer camp was run by Valencia Football Club officials, and organised by a selection of top Italian youth scouts and coaches. Representatives from the summer camp believed that testing a simple prototype such as the one developed during this study on younger players like those at the camp, would give a good idea of how a more detailed and developed VR training system would affect more senior professional. Therefore, the coaches at the Valencia summer camp were more than happy to take part in the study, and the very same summer camp will be the location of tests carried out for the study.

5.1. Player Testing

As previously stated, testing a prototype on its intended audience is an important part of the evaluation process of this study. For this reason, the prototype developed for this study will be tested on football players. The aim of this particular test is to establish if VR can help to

teach football players mental and psychological skills such as decision making. Since the prototype will focus on teaching these skills at a lower, much more simplistic level, due to limited software development time, the test will therefore require the participation of players who can still learn from this basic information they are being shown, despite the topics covered being the training program being reasonably straight forward. Therefore, as was also agreed in the user research phase, it is best to test this prototype on young footballers. This is due to the fact that teaching basic information to a lower level of player, could then easily be scaled up to become a much more complex product suitable to more senior players, thus making the results of tests carried out for this study much more relevant. It must also be clarified once more that these tests aim to establish what football-related skills are most appropriate to be coached in virtual reality, not the training drills that feature in the virtual football training environment.

In the first testing phase of the study, 15 youth players will be given access to the VR prototype, and each of those 15 will be asked to try out the virtual training drills for a five minute period, on a HTC Vive headset. After the training drill is complete, coaches of the participating players will be asked their opinion on the tests carried out. The results from tests carried out on the young players, along with feedback on said tests from football coaches, will form the results for the first phase of prototype evaluation. Before tests are carried out, all participants are to be briefed on the study, and the purpose of the tests being carried out. Furthermore, as participating players are under the age of 18, approval and written consent to participate in the study will have previously been given by the parents of all players. After players have used the prototype, the coaches present will also be allowed to test the software. Coaches will also be faced with a series of questions, for example asking for suggestions on possible changes that could be made to the project, and asking if they would use similar forms of virtual reality football training when running their own football training sessions.

5.2. Player Testing Results

Results of these tests are an important part of the evaluation process, and will build towards the conclusions of this study. The first set of conclusions to discuss are those belonging to tests carried out on youth players. As has already been explained, players tested the VR football training prototype for five minutes each. After this process, they were each asked a series of simple questions regarding their experience.

The first point to be covered is how players performed on the training system. At first, players struggled, as they had little to no previous experience using virtual reality. However, as each player progressed, they achieved better results, making the most appropriate decision in the football decision making simulation far more often as time progressed. After the five minutes of use given to each player, each participant had begun to understand the prototype, making each decision in accordance with the information given to them by the program (current match score and style of play). In the first minute using the virtual coaching system, only 10% of decisions made resulted in the correct pass being selected. During the last minute of testing, on average 80% of decisions resulted in the best pass being selected, with participants showing clear improvement in their ‘virtual performances’.

Subsequently, players were then asked the following questions regarding their experience testing the VR football training system developed for the study:

1) Did you enjoy the experience?
2) Did you learn from the experience?
3) Have you faced any similar situations in real-world football matches to those you faced in virtual reality?
4) Do you think what you have learnt from this would help you in those situations?

Below is a table containing the results from this test (Table 1).

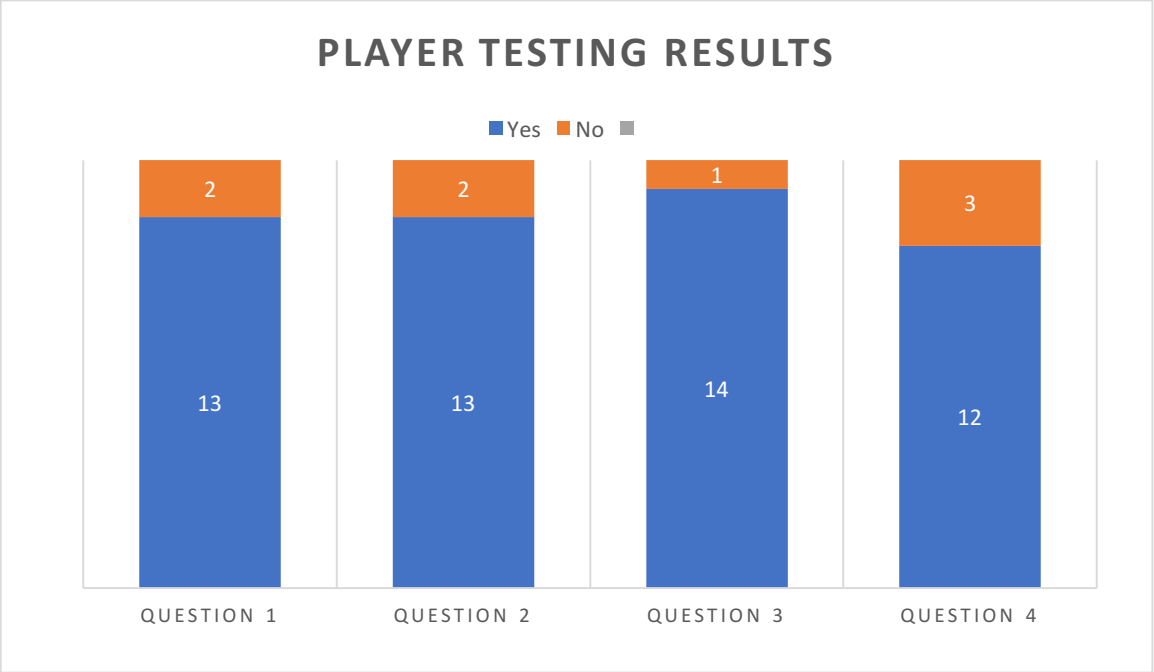

Table 1

The first question asked received a very positive response. The large majority of the participants all found the virtual reality training system to be an enjoyable and engaging experience. This is important particularly for younger players, as it is important that the user remains focused and interested, and making the experience a fun and engaging one is a great way to ensure this.

In response to the second question, the majority of participants responded with a resounding yes, and went on to often add one of two comments. The first comment that participants added was that they during this test they learnt the ability to understand how a changing match situation changes the way you make decisions during a football game. The second common response was how they had learnt how important a skill such as decision making, whilst under great pressure, with limited time to react, can become in football. The ability to remain calm and make a difficult decision, whilst under intense pressure, is a difficult skill to master, and virtual reality can only boost a player's chances of mastering that very skill.

Next, players were asked if they had faced many situations in football matches that were similar to situations they found themselves in when using virtual reality, with most participants once again responding with a 'yes'. Most of the participants agreed that situations like those in the VR training system are commonplace in football, but despite being very common, remain very challenging. As a result, it appears that simulating simple, common, real-world match situations in VR is an ideal way of using this technology for football training in order to prepare players for situations they face frequently on the pitch. It must also be pointed out that the very same decision making skills targeted in this study for football players are also very common in other fast-paced team sports such as rugby, and that virtual reality could also be used to coach similar skills in other sports.

To conclude this series of questions, participants were asked if they believed that what they had been taught in VR could carry over to those real-world football match situations previously discussed, and as a result improve their performance. The participants came to a consensus that being able to rehearse simple football match situations would definitely be able affect the decisions they made during competitive matches, however, players would need to use the technology much more frequently over a long period of time, in order to influence their footballing ability on a more permanent basis.

Demonstrating in numbers that players' performances on the pitch are improved by the virtual reality experience is a lengthy process, that would require repeated use of the software over a long period of time in order for a player to show significant statistical improvement. There are, on the other hand, very promising signs beginning to show in tests carried out for this study. Not only do players show improvement in their virtual performances, but their responses also indicate that they understand how this information would carry over into a real-world situation, and how using virtual reality to train skills such as decision making would influence and improve their performances, and the decisions they make, on the pitch.

5.3. Asking the Experts

The second half of the testing and evaluation phase consists of a presentation and interview with four football experts. Two of the experts are professional football coaches, who have both coached to a high level in Italy, and throughout this study will be referred to as 'Coach A' and 'Coach B' in order to maintain their anonymity. The second two experts are professional football scouts, who in the past have worked with big Italian football clubs such as Lazio and Roma. Once again, in order to maintain anonymity of participants involved, these scouts will be recognised in the study as 'Scout A' and 'Scout B'.

During the presentation, the study was explained in detail to the participants. Subsequently, the VR software developed for the study was shown to the experts, both in the form of software developed for the HTC Vive VR headset and the mobile application designed for the Google Daydream 2018 headset. Following the presentation, the football coaches and scouts were asked a series of question regarding the presentation and the study. The responses and opinions of these participants, along with results from the previous phase of testing, are what will form the final set of results from which the conclusions of the study will be drawn.

These responses and beliefs can be found below, and will be separated into a different section for each coach or scout.

5.4. Expert Analysis Results

Coach A

The first coach participating in the study was very excited by the project, having had experience working with virtual reality in football in the past. This coach referred to a previous experience of his at the Ajax football club youth academy, where they are currently using virtual reality to improve player technique, using foot sensors and a virtual reality target practice simulation in which the player must kick a virtual ball at targets. This is done by measuring the angle at which the player strikes the ball, as well as the body position of the player at the moment of impact with the ball. Whilst this is an interesting use of virtual reality, it requires huge amounts of investment, and is only really applicable at the very highest level of football.

The coach shared this experience in order to demonstrate to other participants in the study that VR is very much the future of professional sports such as football, and is an exciting form of technology which has great potential and is very much worth investing in. Furthermore, the coach also stated that using virtual reality to address the psychological aspect of sports is something which has been done very little, but is something that also has great potential in the world of sports.

'Coach A' then concluded by stating that they had been shown sufficient evidence to believe that using VR to coach decision making in sports is indeed one of the most interesting and effective uses of the immersive technology in the context of sports training. 'Coach A' was, however, unsure at what level of sports the technology would be most useful.

Coach B

'Coach B' had considerably less experience with virtual reality, and as a result time was spent explaining the technology, as well as showing other examples of software designed for VR. They agreed, as is now the common consensus, that VR is an exciting opportunity which also has great potential. Their main concern, as was previously addressed in this study, was that virtual reality must not become a gimmick, or a game, because it can, and should, be much more than that.

The coach went on to say that the software developed for the study, whilst being reasonably simple, effectively demonstrates how virtual reality could coach decision making. They then agreed that the software in question would be very useful for young footballers, but that the program could easily be scaled up and adapted in order to become an important part of a senior player's daily training regime. Once this study reaches its goal of demonstrating how virtual reality can best be used to train sports athletes, more complex designs will be

suggested, explaining how software developed for this study could be scaled up to a professional level, using the feedback of participants involved in this evaluation phase.

'Coach B', along with the other participants present, then went on to offer suggestions for features which could be added to a more complex design, which would be suitable at a professional level of football. These features will be discussed in detail in the next chapter of the study, where future designs for the project will be put forward.

Scout A

Both scouts involved in this phase of the study, similarly to 'Coach A', had previous experience working with VR. 'Scout A' was also impressed with how the VR software targeted a player's decision making skills.

The scout in question then went on to discuss the use of video in sports training, explaining that professional coaches and players frequently watch back videos of previous matches, as well as video footage of teams they are yet to play, in order to improve and target specific weaknesses. 'Scout A' suggested that virtual reality could replace this, if players could watch back previous games in virtual reality to analyse their own performances. Another suggestion was that players could use virtual reality to prepare for specific upcoming matches. For example, they could face up against their opponents (controlled by AI, or using opponent's match footage) in VR, analysing the opponent's preferred formation and line-up. Furthermore, it was proposed that VR could also prepare a football team for different approaches to one specific game. For example, a team could be instructed how to play and react if they were winning or losing the game, with these differing approaches heavily influencing player decision making.

Finally, 'Scout A' suggested that software similar to that developed for this study could be used to prepare players for specific set piece situations, such as corner routines or free-kick routines.

Scout B

The final participant in the study, 'Scout B', showed great interest in the different applications of technology in sports training. This scout discussed a cage known as "The Footbonaut", currently being used by German football team Borussia Dortmund and Hoffenheim. The Footbonaut is a multi-million euro investment, which consists of a cage containing a small football pitch. The walls surrounding this pitch are comprised of 1x1 metre square panels which each have the ability to light up. One player will enter the cage, and footballs will be passed to the player from multiple angles. The player will then have a limited amount of time to hit the wall panel which is currently lit up. This process is repeated several times, training the accuracy and reaction times of the player in question. 'Scout' A used this example to demonstrate how investing in technology to be used in sports training has the ability to achieve very impressive results, convincing other participants present that virtual reality is a form of technology worth investing in.

‘Scout B’ strongly believed that using VR in sports like football would be much more appropriate at a professional level rather than at a youth level, due to the high costs potentially involved. The scout did, however, conceive that whilst this may be true in countries such as Italy, where there is considerably less financial investment in youth football, it is also a viable option for young sports teams in the UK due to the presence of much higher levels of funding.

5.5 Evaluating the Results

Now that all testing has been carried out, the results will be examined in more detail.

The first point to be made, when looking back over feedback given during the testing phase, is that the choice to use 360-degree video to target decision making was a success, as it showed promising results both during tests on young football players as well as when presented to a panel of football experts. The basic features of this prototype appealed to those involved in the testing phase, but it is important that these basic features are scaled up to create a more immersive design which is more appropriate for use at a professional level of football. This was also mentioned during the research and testing phases, as it was suggested that by testing a basic prototype on younger players, results could indicate how successful a more complex product would be when tested on professional football players.

Despite professional football requiring more expensive equipment, such as the HTC Vive VR headsets used during this study, it must also be pointed out that mobile forms of VR training appealed highly to players and coaches. This would also be an effective method of making virtual reality sports training more available, as most modern smartphones are capable of running software similar to that which was created during this study.

5.6 Changes to be Made

The following section will address comments made by coaches during the expert analysis phase of testing, and these comments will be used to highlight important features which will play a large role in future renditions of VR football training systems.

5.6.1 Same Principles

As was explained at the beginning of section 6.1, the prototype created demonstrated promising results, and it would therefore make very little sense to radically change the design for any future implementation of the concepts this project has researched. Therefore, any future design should focus on the same principles that this study has focused on. For example, the use of 360-degree video was a success, as it added a level of immersive realism that computer generated graphics does not. Furthermore, the choice to focus on decision making within football also received plaudits from football players and experts, as not only is it a skill which is vital in all kinds of fast-paced team sports, but it is also a skill which is difficult to

target in real world training regimes. On the whole, it seems as though using 360-degree video in virtual reality to target decision making in past paced team sports is the most effective way to use VR to support current methods of sports training.

The design suggested in this chapter will, then, continue to be built around the same design concepts used during this study, and that is to use video to train decision making. However, there are many changes which can still be made to improve the product.

5.6.2 More Video Content

The first change to be made is simple. More video content should be added to the software. The product created for this study was a good representation of a virtual reality sports training system which was able to demonstrate how VR could be used to train decision making in sports such as football. However, hours of video content would need to be added to the product in order to make it appropriate for use at a professional level of sport. Adding this extra content would allow for many more training drills to feature in the product, thus adding variety and making the training system far less repetitive. The software created for this project lacks this video content as it was created solely for research purposes. Despite being a simple addition to the current design, it is an addition which would transform the software from a prototype into something resembling a finished article. Furthermore, adding more video would allow for the product to cover more areas of the game, for example, confronting decision making in more complex situations, or preparing for specific match situations (this is also something which was suggested during the testing phase of the study). This topic will be discussed in more detail in the next section.

5.6.3 Opponent Specific Match Preparation

The main addition to be made to future designs which aim to use virtual reality to train decision making in sports such as football, should be to add content involving more specific match related situations. As was agreed by football experts during the testing phase, professional football teams often use technology to analyse their next opponent and prepare for specific upcoming matches. They do this in the hope of singling out their opponent's weaknesses, and analysing what they can do in order to exploit these weaknesses. This form of match preparation is something which would be well suited to virtual reality systems similar to that which was designed for this study.

There are many ways in which this could be done. For example, if the team using virtual reality were due to play Manchester City in an upcoming football match, video content could be recorded where participants mimic the defensive positioning and movements on the pitch that Manchester City players have been known to do in previous matches. This would allow players to face up against a recreation of their opponent (Manchester City in this case) in virtual reality in the lead up to the match, and players would be able to study their next opponents to find weaknesses which could then be exploited. This way, football teams would be able to find key areas on the pitch in which the opponent displays any form of weakness. Any sort of gap in the opponent's midfield or defence could be shown to the players in VR

well in advance of the match, so that players could go into an important match knowing exactly what areas of the pitch they should focus on in order to achieve the most success. An example of this could be a VR decision making program in which players are taught which types of passes are more likely to expose their future opponents defensive line, as this type of opponent analysis is already common in football but could be aided greatly by virtual reality.

Furthermore, this design should also be used to rehearse other forms of match situations such as set-pieces. Set-pieces in football include corners, throw-ins and free-kicks. Using VR to target player decision making in these specific situations is something which was repeatedly suggested during this study, as football relies heavily on set-pieces as they are not only very frequent but also very productive. Former US national footballer Alexi Lalas was recently quoted saying: “in a game that is often so random, [a set piece] is the one time where obviously it stops, and the players and the team and the coach can do something that alleviates some of the randomness. It’s probably the closest thing we have to American football in a soccer game, and you ignore [set pieces] at your own peril. A set piece is to soccer what water is to life. You need it to survive.” (Wahl, 2018). As Alexi explains, set pieces are the one time during a game where everything grinds to a halt. As a result, it is the one situation which coaches can go to great lengths to prepare in great detail. The very same article which features these quotes from Alexi Lalas also states that “set pieces fuelled deep World Cup runs for England and Uruguay, to say nothing of Russia 2018 itself. Through the quarters, 30% of the tournament’s goals had come on free kicks and corners, outpacing the previous high of 23% (in ’02 and ’06) among the five most recent men’s World Cups”. It only makes sense therefore, to prepare players for this vital part of football in immersive VR systems. This will allow players to prepare for set pieces by themselves, despite this being a part of the game where all team members have a role to play.

5.6.4 Higher Quality Production

One other overall improvement should be made to the design. This is to improve the overall production values of the product. Software designed for this project was limited both by time and by funding. Larger amounts of funding would allow for the use of more professional 360-degree cameras, which would greatly improve the quality of any video included in the new design. More funding would also allow for more participants to be paid to take part in filming video shoots, which would lead to more variety in the videos shot, and also allow for football drills recorded to include two full football teams, as well as spectators. Furthermore, dedicating more time and staff to this project would allow for the creation of an end-product, rather than the creation of a prototype which was more suited to this study.

To summarise, using the same values and principals of this design in future implementations is key, however higher production values, more video content and more specific match situations and tactical features are the main ways in which the designs featured in this study could be improved upon in the future.

Conclusion

The final chapter will be the conclusion to the study, in which all progress made will be taken into account and we will examine how the research question, which was set out at the beginning of the research process, was answered.

Work for this study began with a literature review. This review gave us various ideas and concepts which were then examined in more detail during the user research phase. The user research carried out also allowed us to form a better understanding of how football players could benefit most from using virtual reality headsets as part of their daily training routine. Interviews carried out during the user research phase backed up the conclusions made during the literature review, and it began to seem as though decision making would be the best footballing ability to target in virtual reality. Next, during the design phase, the decision was made that VR was the perfect fit for decision making in sports. Football was used as a case study, and a virtual reality computer program was developed in which the user must pick the most appropriate pass in a football match, whilst taking into account the playing style demanded from them, as well as the current score of the football match. This training system not only encourages tactical awareness on the pitch, but allows the player to directly train their decision making abilities, something which is very difficult to do on the football pitch, a conclusion which was reached during the research process.

Once the development of this software was complete, it was then tested on young football players and a panel of football experts, who gave their detailed opinions on the study and the prototype created. Next, this feedback was used to suggest design features which should be incorporated into any future developments similar to the prototype created during this study. These future developments should be based around the same basic concepts that this project focuses on. These concepts are: a virtual reality training system which targets decision making in sports, using 360-degree video, whilst giving sporting context to the video, such as preferred playing styles or the current score of the virtual match that the user has been placed in. These concepts should be maintained as results showed that they were very promising, and offered an alternative solution to the gap in the market that is VR sports training systems. These concepts are an alternative solution as this system is designed to support work done on the training ground, rather than to replace it or transform it into a novelty videogame, and focuses on details which other VR training programs do not tackle. These design features, intended for use in future developments in VR sports training, have been added as they support the results of this study, as well as offering a more detailed solution to the study question upon which this project is based.

The following research question was set out at the beginning of the study:

- What areas of sport can be most effectively trained in virtual reality?

It was concluded during both the research phase, and during the testing and evaluation phase, that decision making is the area of fast-paced, team sports which can be most effectively trained in virtual reality. The study also aimed to discover which interaction techniques are the most effective when coaching sports in VR. In response to this the study went on to demonstrate that the use of 360-degree video is an effective method of execution

as it is more realistic and immersive than computer generated graphics, therefore can be carried over to real-world sporting situations more smoothly. Allowing the user to hit arrows with a controller to make their decision then was the logical option as it is a quick and easy gesture which does not involve any added thought process once the user makes their decision.

In summary, this study has responded to the research questions it aimed to solve by concluding that using virtual reality for sports training is a successful combination, which is most effective when targeting decision making in team sports. The study also concluded that the use of 360-video is an ideal method of doing so, as it allows the training system to feel like real world training, and as a result carry over to real world situations seamlessly.

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