360° VR and Softball Umpire Decision-Making: Lessons and Insights

Keone Kaiser

Supervisors: Associate Professor Kirsten Spencer, Associate Professor Simon Walters, Kevin Sheehy

A thesis submitted to Auckland University of Technology in partial fulfilment of the requirements for the degree of Master of Sport and Exercise

2021 February

School of Sport and Recreation

Abstract

Background: Despite the importance of effective sports officiating for athletes and fans across the world and across sports realms, research into improving the performance of these individuals has been lacking. Few, if any studies, have demonstrated effective methods for improving one of the key tasks of sports officials– accurate decision-making. Officials can improve their decision-making by accumulating experience officiating live games, but this takes time. As a complement to live-game experience and a way to train decision-making outside of a game, decision-making through broadcast video methods has been proposed and utilised. However, the ability of these methods to transfer skills to live games has been questioned. Due to their first-person perspective and accompanying features, 360° VR videos may offer improved decision-making accuracy training alternatives to 2D broadcast videos.

Purpose: The current study examined and compared the use of 2D Broadcast videos and 360° VR videos by a cohort of softball umpires (N =17) to 1) assess sports official decision-making accuracy using 2D Broadcast videos and 360° VR videos; 2) compare Ecological Validity values between the 2D and 360° VR videos; 3) assess the connection between experience level and video condition; 4) obtain qualitative data on the video conditions through interviews of several softball umpires.

Methods: A four-stage mixed-methods approach was used to gain more comprehensive and complementary results. Quantitative data was primarily gathered during the first three stages, while qualitative data was gathered during fourth stage. The results showed no significant differences in decision-making accuracy between the 2D Broadcast videos and the 360° VR videos (decision-making accuracy mean of 8.0 +/- 0.9 s.d. for 360° VR, 8.5 +/- 1.5 s.d. for

2D broadcast, p = 0.242), and no significant differences in accuracy by experience level on either video condition (novice accuracy mean of 8.5 +/- 1.4 s.d. on 2D broadcast and 8.0 +-1.0 s.d. on 360° VR, expert accuracy mean of 8.5 +/- 1.7 s.d. on 2D broadcast and 8.0 +/-0.8 on 360° VR, p=0.961). The 360° VR videos received significantly higher EV values than the 2D Broadcast videos (7.1 +/- 2.0 s.d. on 360° VR, 4.4 +/- 1.9 s.d. on 2D broadcast video, p <0.001).

Conclusion: Despite mixed results, the qualitative feedback from umpires supports the potential of 360° VR as a decision-making accuracy tool.

Contents

List of Figures

List of Tables

Attestation of Authorship

"I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where specifically defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning."

Student: Keone Kaiser

Signature:

28 February 2021

Acknowledgements

Firstly, I wish to express my sincere appreciation to my supervisors: Dr Kirsten Spencer, Dr Simon Walters, and Kevin Sheehy. Each of you has gone above and beyond my expectations to support me in this endeavour. Without your support and reassurances, I cannot imagine setting out upon this journey, let alone finishing it. I have learned skills and approaches to problem solving that I will use throughout my life.

Secondly, I wish to thank Softball New Zealand and the many excellent umpires and professionals that comprise this world-class organisation. You welcomed me into your ranks and gave me insights into how you approach your craft, and ideas on how best to implement my research ideas. I hope that the findings from this research can assist you with your future training endeavours. I am on standby and ready to assist you all.

Thirdly, I would like to thank Tom Stewart for his key assistance with my quantitative data and analysis. Your enthusiasm, friendly feedback and responses to my many, many questions were encouraging and crucial to this research.

I would also like to thank for my parents. Thank you for all the years of support as I have pursued a multitude of personal and academic interests. And thank you for worrying about me.

Lastly, I would like to acknowledge my aunty, Linda Kaiser. This one is for you. Though no longer with us, your support meant everything to me after Grandma passed away. Thank you for honouring your promise to Grandma. Now it is time for me to honour my promise to you.

Ethical Approval

Ethical approval for the study was received by AUTEC on 10th December 2019, 3rd July 2020, and 15th December, 2020.

Key Terminology

2D Broadcast Video – Video recording of a sporting event, usually from a third person perspective in and around a sporting venue

Virtual Reality (VR) – Technologically-produced simulation of the real world; simulation can be interactive or non-interactive

360° VR – Form of virtual reality produced from filming in 360°; usually non-interactive

HMD – Head Mounted Display; computer display unit attached to the head or helmet of a user

VR Sickness – Virtual Reality Sickness; body of symptoms resulting from exposure to virtual reality

180° Video – Form of video produced by filming from a camera, limited to 180° field of view

MLB – Major League Baseball; the leading U.S. professional baseball league

SNZ – Softball New Zealand; the leading N.Z. softball league

FIFA – Fédération Internationale de Football Association; the leading international football association

Run – The scoring unit in softball of baseball; occurs when a player from the striking team advances to the home base plate

Inning – A division of a game within softball or baseball during which each side is given the chance to strike the ball and score points

Pitch – Process of throwing the ball to the opposing striking team in softball or baseball

Bowl – Process of throwing the ball the opposing team in cricket

Thematic Analysis –Qualitative analysis method involving identification of themes via patterns and codes

EV – Ecological Validity; measure of realism

Embodiment – Representation of the body in one's mind in a given simulation experience

Immersion – Technical features of a simulation display system related to its ability to stimulate the senses similarly to the real experience

Presence – In a simulation, the feeling of being someplace despite knowing that one is not in that place

Chapter 1: Introduction

Section 1.1 Sport background

The striking and fielding sport of fastpitch softball traces its origins back to the United States in 1887 and has many similarities to the sport of baseball. The key differences between softball and baseball are primarily the size of the ball (roughly 30 cm circumference in softball versus 23 cm in baseball), pitching style (underhand in softball versus overhand in baseball), number of innings (seven in fastpitch softball versus nine in baseball), and playing area (more ground to cover in baseball). Current estimates indicate that approximately 65 million people in 140 countries participate in softball and baseball, and that collectively baseball and softball have more casual participants than any other sport in the world (World Baseball Softball Confederation, 2017). In New Zealand, softball was imported by American sailors and first played in 1935. Today, softball in New Zealand is primarily played under the jurisdiction of Softball New Zealand (SNZ), which counts nearly 35,000 active participants, invested in 21 associations and 130 clubs (Softball New Zealand, n.d.a). The Black Sox, the national New Zealand mens' team, has continually placed amongst the best in the world in international tournaments, winning the World Championships title as recently as 2017.

The objective of softball is to score more runs than the other team. This is accomplished by a team's offensive player (batter) striking a ball pitched underhand. Softball NZ Measurable Velocity Standards lists the average ball pitch speed at anywhere between 115 to 127 km/h (Mygind, 2011) for experienced males, and 106 km/h for experienced females. The pitcher is based upon a block, approximately 13-14 m from the batter. A batter/runner must progress counter clockwise through a diamond-shaped field consisting of three bases and one home plate. Each base is 18.29 m apart (World Baseball Softball Confederation, 2017). After successfully striking the ball, the batter/runner must reach a base before a defensive player

arrives with the struck ball at the same base whilst the batter/runner maintains contact with base or plate, otherwise the player is considered out. The offensive player is not required to attempt to run through all of the bases in one pass. An out can also occur if the pitcher forces the batter to record three strikes (missed bat swing/contact with pitched ball) during their turn at bat. Three outs constitute the end of the offensive teams' inning.

Section 1.2 Research background

The sports officials responsible for deciding whether a player in softball is out or safe are known as the umpires, and consist of the plate umpire and base umpires. Each softball game endeavours to have a minimum of one plate umpire and one base umpire, though this number can increase to three base umpires as needed. The number of umpires in each game can change the mechanics/rotation and expectations of each umpire accordingly (World Baseball Softball Confederation, 2020a). For example, officiating with 2 or 3 base umpires versus 1 base umpire vastly alters the recommended movement responses to certain plays, with a 1 base umpire rotation requiring the 1 umpire to track players and balls very differently than each of the umpires in a 2 or 3 umpire rotation. Each legally pitched ball that is not hit by the batter is called a ball (when a batter does not swing at a pitched ball that does not enter the strike zone or touches the home plate or touches the ground before reaching the home plate). An umpire calls a strike when any part of a pitched ball enters the strike zone before touching the ground and the batter does not swing (provided the top of the ball is at or below the sternum or the bottom of the ball is at or above the bottom of the kneecap). A foul ball is defined as a legally hit ball that settles on foul territory between home and first baselines or between home and third baselines. The foul territory is an area from the foul line (line between home plate and 1st or 3rd bases) and the deadball line (side fence) approximately 8m wide (World Baseball Softball Confederation, 2017a). The deadball line or fence is approximately 8 m from the baselines (World Baseball Softball Confederation, 2017a).

A base umpire determines if a runner (offensive player after hitting a ball) moving between bases is declared as either safe or out, when the offensive player is tagged with a ball while the defensive player maintains contact with the base or plate. This decision is based on the umpire observing four variables, known as the four elements, which are the leading edge of a base, ball position, fielder (defensive player at the relevant base) position, and runner position (Softball New Zealand, 2020a). Due to the speed of the game, all umpires are required to adjudicate as to a safe or out decision within seconds (Szymanski & Fredrick, 2001). No video replays are allowed to help adjudicate calls in softball, thus the umpire is expected to process and execute accurate decisions quickly. As noted by Softball New Zealand, "as an umpire you must be able to demonstrate great rules knowledge, quick decision-making, an ability to explain and defend decisions and a willingness to keep the game moving at a steady pace" (Softball New Zealand, n.d.b).

With the fast-paced requirement of decision-making in softball, any training method which can improve decision-making and accuracy is welcome by the umpires. Current sports official training methods arguably leave room for improvement across a range of sports, whilst most decision-making training literature has been focused on athletes (Kittel et al., 2019). Improvements in softball umpire decision-making would not only benefit higher-level national/international tournament games, but local and regional games across the world. While much of the research used 2D videos, critiques have arisen as to the usefulness of the 2D video format (Araújo et al., 2006; Petit & Ripoll, 2008; Helsen et al., 2019). This thesis seeks to examine Virtual Reality (VR) technology, and specifically 360° VR technology, as a possible alternative decision-making training device and method for softball umpires.

The aim of this research is to investigate the utilisation of using 360° VR technology for training decision-making in Softball NZ umpires. Specifically, there are three primary research questions this research seeks to address:

(1) Does watching 2D Broadcast or 360 °VR video produce higher decision-making accuracy?

(2) Does watching 2D Broadcast or 360° VR video produce higher ecological validity for game decision-making?

(3) Can 360° VR assess decision-making skill accuracy between novice and advanced sports officials?

A qualitative component will address a fourth research question:

(4) What are the perspectives of participants on the use of 360° VR video to enhance decision-making?

Section 1.3 Research methodology and research design

This is a mixed methods study, using quantitative data gathered from participants viewing softball plays in two different formats, as well as qualitative data gathered from interviews. Venkatesh et al. (2013) have noted that mixed methods research serves seven primary purposes: 1) complementarity; 2) completeness; 3) developmental; 4) expansion; 5) corroboration/confirmation; 6) compensation; (7) diversity. For the purposes of this research, a mixed methods approach was chosen primarily for completeness and corroboration/confirmation purposes. It is important to acknowledge that there has been considerable debate about studies using both quantitative and qualitative methods in relation to being either 'mixed methods' or 'multimethods' (for example see Anguera et al., 2018). Informing this study positioned within the context of mixed methods research, Venkatesh et al. (2013) described completeness as ensuring that a complete picture of a phenomenon was provided, corroboration was described as assessing the credibility of inferences from one information source. The researcher sought to understand the phenomenon of umpire decision-

making training as thoroughly as possible, within the constraints of a Master's level research project.

Section 1.4 Thesis structure

Chapter one has introduced softball and its specific sport official needs. The need for research into improving decision-making in softball umpires was presented, as was the idea of using 360° VR for this purpose. Chapter two will expound the available research into sports official decision-making and outlines how 360° VR for decision-making could improve softball umpire decision-making. Chapter three will discuss the methods and data analysis that the research will implement, as well as how the various ethical responsibilities of the research were satisfied. In chapter four, the results for both quantitative and qualitative components will be presented. A discussion of the results will follow in chapter five. Chapter six will provide a conclusion, as well as recommendations for future research based on the weaknesses and strengths of the research.

Chapter 2: Literature Review

Introduction

When compared to the sport-related research that has focused on athletes, there is a paucity of literature that has focused on the demands of sports officials (Walters et al., 2016). The lack of research focus on sports officials is reflected in the real-world experience of sports officials where resources and attention are predominantly focused on athletes and sports organisations. This was recently highlighted by the COVID-19 global pandemic, where sporting fixtures have been curtailed or cancelled, and organisations have sought ways to minimise the impact and spread of the disease (Castagna et al., 2020). However, using football sports officials (known as referees) as an example, although COVID-19 guidelines have been developed for athletes and coaches, currently no guidelines have been developed for football referees (Castagna et al., 2020). This neglect of support or interest is, unfortunately, similar with regards to the existing research on sports officials and their decision-making processes and training. The dearth of literature on decision-making and sports officials, however, presents an opportunity to contribute findings to promote future research. This chapter reviews the key literature related to this study on sports officials and decision-making, and is divided into four sections. The first section details the current methods of sports official decision-making training. The second examines two key decision-making theories. Section three focuses on representative learning design, and its utility with regards to training decision-making. The fourth section focuses on VR's emerging use in sports, and its suitability for assessing and training decision-making.

Section 2.1 Current decision-making training methods for sports officials

In order to execute their decision-making duties effectively, sports officials must learn how to align declarative knowledge (the rules of the game) with procedural knowledge (how a rule is applied to the game) in a dynamic environment (Plessner & MacMahon, 2013). To date,

sports officials have been required and expected to master the declarative knowledge aspect of decision-making through studying manuals and passing tests or exams to demonstrate competence (Catteeuw et al., 2009; Gulec, 2019; Samuel 2017). In football, for example, Fédération Internationale de Football Association (FIFA) expects aspiring and current referees to understand and apply the Laws of the Game booklet, currently a substantial 229-page document replete with football rules and diagrams (The International Football Association Board, 2020). In the American National Football League, referees must know and apply the Official Playing Rules of the National Football League, currently an 87-page document detailing the rules of the game (National Football League, 2020). Softball NZ requires umpires to understand the rules and diagrams of different level workbooks. For example, a Level 1 umpire aspiring to Level 2 umpire rank must know and apply the rules within the Level 2 workbook (Softball New Zealand, 2020). At the higher end of umpiring levels, those Softball NZ fast pitch umpires aspiring for Level 7 rank must know and understand the rules from the 105-page World Baseball Softball Confederation Umpire Manual: Fast Pitch (World Baseball Softball Confederation, 2020b). While reading and comprehending rulebooks are necessary for sports officials, in order to gain decision-making expertise sports officials must also learn how to apply game rules, otherwise known as procedural knowledge.

Perhaps the most-cited method in the literature for training sports officials to improve procedural knowledge and decision-making has been 2D broadcast video match analysis (Helsen et al., 2019; Kittel et al., 2019a; Mascarenhas et al., 2005). Therein, the vast majority of academic literature on decision-making and sports officials has centred on football (Kittel et al., 2019a). Whilst the dynamics of football and softball are different, due to limited findings related to sports officials, findings from studies on football referees in different parts of the world will be extrapolated to the general nature of sports official decision-making literature and softball. In one study, trainees in Israel's national football sports official training program

(The Israeli Excellence Program), spent approximately 90 hours per season on specific training skills, nine hours of which consisted of video match analysis (Samuel, 2017). These nine hours consisted of a referee coach and their assigned referee reviewing the trainee's previously recorded performances, and the referee coach giving either personalised feedback to improve the referee's skills, or a more formulaic approach. Additionally, referee coaches and their assigned referees used broadcast videos to highlight examples of proficient and poor football. Such training methods were viewed as critical for developing professional football referees (Samuel, 2017). In England, national football referees watched DVDs of various contentious plays on a large screen alongside other referees, after which followed a series of debates, discussions, and commentary (Webb, 2014). It was hoped that the insight gained from these endeavours would equip referees with sufficient insights and responses towards future occurrences of the discussed plays/calls. National football referees in Italy and Spain used a similar video match analysis pedagogy by emphasizing group review and discussion of key plays (Webb, 2014). The Prozone sports official software program was another video match analysis method mentioned in the literature for training football official decision-making and used specially-designed software features to educate sports officials on specific points of interest (Nevill et al., 2013). Noted as a primary benefit of video analysis was the ability for sports officials to train their visual and perceptual experience of games without being present in a game (Larkin et al., 2017). Additional cited benefits of video analysis decision-training included more control and consistency of training scenarios, and improved video match decision-making for sports officials (Larkin et al, 2011; Larkin et al., 2015). Sports officials could focus on key contentious plays or calls that occurred or they believe would occur, and train to improve their decision-making ability on such plays or calls.

Despite the prevalence of video analysis for sports official decision-making training, several criticisms have accompanied its use. Whilst video analysis can help with routine

decisions, earlier studies have found that decisions requiring dynamic, time-sensitive tasks did not seem to benefit from video analysis training methods (Beach & Lipshitz, 1993; Edwards & Newman, 1982; Lipshitz, 1993). More recent critique of video analysis noted that because of its third person-perspective, 2D broadcast video analysis was not representative of actual in-game decision-making demands, thereby diminishing the decision-making training potential (Araújo et al., 2006; Petit & Ripoll, 2008; Helsen et al., 2019). Opportunities for video feedback may also be limited depending on which organization a sports official finds themselves in, as noted by the discrepancy in video analysis access between Belgian national assistant football referees and FIFA assistant football referees, with FIFA referees receiving vastly superior quantities of video analysis in comparison to Belgian national referees (Gilis et al., 2008). Despite the pattern of using video analysis to train decision-making, questions arise as to is validity in actually training decision-making. To date, only one study has demonstrated a transfer of sports official decision-making ability from video match analysis to real-world performance improvement (Nazarudin et al., 2015). One suggested solution to address the limitations of video analysis was for sports officials to run actual live simulation games (Samuel et al., 2019).

In simulations, athletes and sports officials are organized into simulated games to review plays and rules (Samuel et al., 2017; Samuel et al., 2019; Webb, 2014). Whilst such simulations can capture the contextual, technical, and perspectives of actual games for the participating sports officials, the cost in manpower and time is considered prohibitive (Armenteros et al., 2018; Samuel, 2017; Schweizer et al., 2011). Additionally, in some countries such as Italy and Spain, national football sports officials were unable to organise simulation matches for development because of professional restrictions, unlike for English national football sports officials (Webb, 2014). Moreover, research has suggested that simulations are not available for many sports officials, with perhaps the exception of higher-

level sports league sports officials (Gilis et al., 2008; MacMahon et al., 2007). Lastly, there is a lack of data to support the efficacy of this method for improving sports official decision-making (Samuel et al., 2019). Still, if a simulation match has potential to train decision-making, actual matches may offer even more potential.

Experience has been associated with improved ability across a range of sports. For example, there was evidence to suggest that both the number of matches officiated and number of years officiated positively correlated with increased decision-making ability for Belgian national and FIFA football sport officials (Catteeuw et al., 2009). Rugby sport officials with more experience also scored higher on a decision-making accuracy test in a study by Nazarudin et al. (2015). In a study on Australian Football League umpires, Corrigan et al. (2018) found evidence that greater officiating experience was associated with higher decision-making accuracy. Matches, or real games, were thought to offer greater potential for training because of their ability to produce pressure and its accompanying effects on decision-making (MacMahon, 2007). However, not all matches yield equal decision-making training results. For example, surveyed Belgian soccer sport officials determined that competitive league games were richer in decision-making training than exhibition matches (Catteeuw et al., 2009). This might have been affected by the amount of deliberate practice inherent in the type of games officiated. According to the deliberate practice theory espoused by Ericsson et al. (1993), attaining mastery of a task is multifactorial, but is claimed to require large investments of time, estimated at around 10 years following deliberate practice training principles. These deliberate practice principles require activities that are goal-directed, require effort, and monitored by an expert that provides prompt feedback (Ericsson et al., 1993). The work by Ericsson et al. (1993), whilst originally applied to musicians, has garnered the attention of academics such as MacMahon et al. (2007) to study the acquisition of decision-making excellence in sports officials. Reflecting on a 2005 paper by Ericsson et al. in which the authors suggested that

deliberate practice be used to study expert performance in activities which are difficult to simulate or practice, MacMahon et al. (2007) argued that sports officiating was one such activity. Their argument was supported by findings which indicated that football sports officials lacked opportunities to train decision-making skills (Catteeuw et al., 2009; Gillis et al., 2008; MacMahon et al., 2007). Thus, with fewer training opportunities the importance of match officiating certain types of games for decision-making training cannot be overemphasised. The difficulty of gaining expertise in decision-making via officiating real games rests in the time required to gain this experience, and the inconsistency of learning opportunities in each game. Compared to football sports officials, youth football players were found to accumulate enough deliberate practice for sufficient expertise in half the time (Catteeuw et al., 2009; Ford et al., 2009). Video analysis, game simulation, and real matches all offer various decision-making training opportunities. The literature on officiating and decision-making for striking and fielding sports officials in baseball and cricket suggests the usefulness of different types of video analysis for improved decision-making accuracy.

Section 2.2 Officiating and decision-making for sports officials in other striking and fielding games

Striking and fielding sports such as softball, baseball, and cricket share similar game mechanics and rules. Within a set time period (innings), a team must score more runs than the other team. This is accomplished by a batsman/batter attempting to strike/hit a thrown (pitched or bowled) ball to certain areas of the playing field, while the opposing team attempts to defend by catching and returning (fielding) the ball (MoveWell, n.d.). Sports officials in this game must be able to locate and adjudicate on the various interactions between players, balls, and specific sport markers (bases in baseball and softball, and wickets in cricket). To do so requires excellent processing skills (MacMahon & Starkes, 2007). In the literature for officiating and decision-making for baseball sports officials, there was an emphasis on video usage.

Baseball is arguably the closest sport to softball in terms of the rules, equipment, playing field, athlete, and sports official officiating and decision-making. Although the literature on baseball sports officials is limited, the widespread usage of video analysis methods for decision-making training was evident, as were the associated benefits. In 2002, the MLB (Major League Baseball, the American organisation of professional baseball) approved and implemented the usage of a system of networked cameras, called QuesTec in a select number of MLB stadiums (Mills, 2017). The idea was to track, analyze, and report performance metrics to the umpires. In 2007, the PITCHf/x system, used to identify various location and vector factors of a pitched (bowled) ball was installed in all stadiums. By 2009, the Zone Evaluation and Feedback system (ZE) had replaced the QuesTec system in all MLB stadiums. Mills (2017) explained that the reason the ZE system replaced the QuesTec system was because of its more precise data outputs, as well as how quickly feedback was provided to umpires following their officiated games. The QuesTec system seemed to lack either of these features, perhaps explaining the non—significant changes in accuracy coinciding with the years it was used (Mills, 2017). Under the ZE system, however, MLB sports official accuracy with pitch calls increased from 85.3% in 2008, to 89% in 2014 (Mills, 2017). Additionally, research by Mills (2017) demonstrated a link between experience and accuracy, with greater experience being associated with greater call accuracy, but less-experienced sports officials benefitting more from the ZE system. The benefits of proper video analysis usage were corroborated by Davis & Lopez (2015), who reported that MLB sports official accuracy on pitches increased every year after pitch tracking data became available. Results of a study using data from the Taiwanese professional baseball league, the CPBL (Chinese Professional Baseball League) suggested that using regular broadcast video footage and the particular viewing angles from this format were not ideal to improve decision-making in sports officials (Hwang & Tsu, 2020). With such results, video analysis systems paired with prompt feedback has likely secured its

place in the training and improvement of MLB sports officials for years to come. While MLB has used video to help its officials improve their officiating and decision-making and skills, cricket has, at least within the literature, embraced automation and artificial intelligence to mitigate human errors in its sports officials.

Cricket has leaned into using technology to resolve decision-making disputes during matches, especially within the context of test cricket matches, which can last for days (Shivakumar, 2018). Rather than developing new methods to improve the actual decision-making skills of cricket sports officials, the academic literature has focused on the development and testing of machine learning and digital image processing to assist cricket sports officials with determining difficult calls (Iyer et al., 2020; Kowsher et al., 2019; Nelikanti et al., 2021; Vinesh & Sujatha, 2015). In a sport where an additional umpire (3rd umpire) is often responsible for deciding controversial plays, technology has presented itself as a viable tool for assisting with officiating and decision-making. Additional research has tested sound technology to determine if a ball and striking bat actually connected (Ting & Chilukuri, 2009). There is no research to suggest that this heavy reliance on technology will take away the human element of decision-making and fully automate the game in the future, but rather it seems to signal that there may be perceived limits to the accuracy of cricket sports officials, and that the development of such technological assistance is meant to boost the abilities of sports officials to execute their job responsibilities (Shivakumar, 2018).

In summary, a range of methods have been used to train and assist sports officials, however in order to understand how best to deploy them, the nuances of the decision-making process should be elaborated upon. By investigating the various decision-making theories, the variables and factors necessary to study sports officials' decision-making can be identified and used to maximise this study's effectiveness in assessing the impact of various forms of video analysis on game decision-making.

Section 2.3 Decision-making theories

Initial theories and models such as cognitivism, information-processing, and closed systems attempted to explain general decision-making as the end result of a sequential and linear process, using inputs and outputs similar to a computer system (Balagué et al., 2008; Araújo et al., 2006; Starkes et al., 2001). For instance, visual data was inputted through the Central Processing Unit (CPU, human brain), and specific responses (output) were produced from specific cues (input). To illustrate in a sporting context, an offensive player/runner in softball was considered out (output) if the defensive player met the conditions for tagging the player out, or the defensive player touched the base whilst holding the ball before the offensive player/runner made contact (input). However, such a theory suggests a simplistic view of examining decision-making. Decisions proceeded from a finite set of choices, and each individual's resulting actions were independent from context (Schmidt & Lee, 1999). Furthermore, decision-making was described as an entirely mental process dependent on information from the environment to produce choices (Balagué et al., 2008). Poor decision-making was therefore considered to be from the lack of information/stimuli but could be improved by identifying and enriching such input gaps (Araújo et al., 2019).

The focal point of contention against the traditional approach of improving single individual inputs to produce desirable outputs relates to practicality. As noted by Balagué et al. (2008), under the input-output model, the demands placed on an individual would have been excessive. Every decision required a corresponding catalogue of stored information, constantly shifting and changing, especially when the actions of others must be considered. To process all these inputs, and produce one solution to every problem, seemed unlikely and unwieldy (Balagué et al., 2008). While recent research on this type of training has yielded supportive findings, the research results seem to be largely confined to laboratory findings and did not

provide support to any real-world sports performance transfer effect (Renshaw et al., 2019). Essentially, researchers isolated variables of interest without consideration of how the variables interacted with each other. Training decision-making via 2D video illustrated the misalignment of research findings with reality (Broadbent et al., 2015; Williams & Grant, 1999). Subjects were often asked what decision they would make within a given video scenario, without having access to all the information and stimuli they would normally access in a real setting (Mann et al., 2007). In softball, umpires must be able to process multiple information streams simultaneously, such as shifting player positions, viewpoints, inclement weather conditions, and rules, all within seconds. To be able to encapsulate these dynamic information inputs within a 2D broadcast video and mimic the decision-making process of a softball umpire may oversimplify the process. Thus, research findings using the traditional information-processing model were sometimes inconclusive (Araújo et al., 2007; Pinder et al, 2011; Stone et al., 2018). It is with such a concern that researchers turned to ecological dynamics to more adequately explain decision-making (Araújo et al., 2017).

Ecological Dynamics

Ecological dynamics is a theory of decision-making that stems from the work of Gibson (1966, 1979). According to this theory, decisions are rooted within the performer/individual-environment level, and proceed from actions (Balagué et al., 2008). Ecological dynamics differs from the traditional decision-making theory, in that it does not separate context from action, but instead suggests that one moves to perceive, and perceives to act (Gibson, 1979). Ecological dynamics suggests that there is a continually evolving co-regulation of individual-environment factors/constraints (known as affordances), notably individual, task, and environment (Seifert et al., 2019). At any moment, these factors shape each other and the decisions, while the decisions also influence these factors (Davids et al., 2013). Araújo et al. (2006) noted that it "…is from this cyclical process of searching for information to act and

acting to acquire information that decisions emerge" (p.20). Because of all the possible factors, decisions were considered unique and individualised. In softball, these can be expressed through the different ways an umpire might call a safe/out play. For example, the umpire's past experience(s) with a player's performance (individual constraint) may lead that umpire to think that an offensive player sliding into second base was unable to slide fast enough to touch the base before the defensive player touched the player (task), especially if the umpire's view was partially obstructed (environment). The player would then be ruled out; however, an umpire with no history with the same player could make a different call. Ecological dynamics did not modularise and separate the active components in the decision-making process (Araújo et al., 2017), as this detracted from the inherent and necessary interactivity of the components.

With regards to softball umpires, interpreting rules may require using additional information sources to determine a call, such as an obstruction by the defensive player, and/or the afore-mentioned experience with a player, especially when it comes to a critical split-second decision. One relevant method of designing programs to assess or train decision-making with these concepts is known as representative learning design.

Section 2.4 Representative Learning Design

Representative learning design suggests that effective learning in training or research occurs when the conditions of the training or research represented the setting to which the results were directed (Araújo et al., 2007). Originally developed by Brunswik (1952, 1956), this theory of learning design aligned with Gibson's idea on the individual-environment interactivity, and perception-action coupling (Pinder et al., 2011). This required the individual to call upon the various information sources needed to make decisions, which often required movement to gain the information (Davids et al., 2015). Thus, a softball umpire who watched a softball game in the comfort of their home would not have been able to access all the information and perceptual cues needed to make the decision as the umpire who participated

in the game and was able to scan around the playing area while moving into a position to gather the necessary decision-making information. As with ecological dynamics, representative learning espoused the individuality of learning, as the variables needed to optimise learning vary from person to person. Representative learning design shared some of the same criticisms against the traditional approaches as ecological dynamics, namely that researchers designed highly simplistic and controlled experiments, often isolating variables from their natural context (Davids et al., 2013). For a softball umpire seeking to hone their decision-making skills, representative learning becomes relevant due to its attention to matching game decision-making inputs to training design. If one designed a method to train softball umpires that did not account for 2 and 3 umpire system rotation as well as individual umpire movement, for example, the ability for the umpire to produce a game-like decision within the training method would be impacted. Similarly, creating a pure digital softball game environment and using this environment to improve softball umpire decision-making may yield vastly dissimilar decision-making processes and results.

Representative learning design presents itself as a systematic method to improving decision-making in softball umpires but could also benefit from incorporating the concepts of ecological validity. Ecological validity, as defined by Brunswik (1956) referred to the correlation/empirical relation between a cue and its criterion and was represented in numerical form. One may, for example, judge the accuracy of a softball call (criterion) by the speed of a runner (cue) crossing a plate. This cue would be one of many needed in order to make the call, and each would have its own ecological validity value. In designing training or research to assess decision-making, the strength of such cues must be estimated, as well as their relationship with each other understood, in order to allow an individual the chance to act upon the relevant information and make a decision that carries/transfers into the desired performance context (Araújo et al., 2019).

Studies on decision-making training have suggested that lower-skill level sports officials seem to view 360 °VR video decision-making as more game-like than experienced umpires (Kittel et al., 2019b). Perhaps lower-skilled umpires require more information inputs and connections between experiment and real-life conditions to produce sound decisions and can become better decision-makers by training with such inputs and connections. The concept of action fidelity may help in building the connections between training and learning.

Action Fidelity

Action fidelity was a concept developed to explain the link between performance in a simulator and performance in a simulated system, and was measured by task performance (Stoffregen, 2003). It was achieved when behaviours in the experiment setting transferred to behaviours in the intended environment, although it has been noted that the stimuli in both environments did not have to correlate exactly (Araújo et al., 2019). For example, a retail flight simulator system need not produce the same graphical realism or even host the same features as a much pricier commercial flight simulator, as long as the desired results are the same (for example, learning low-altitude flight). To a softball umpire certain information such as field colour, wind conditions, and player uniforms may not be pertinent for decision-making. Instead, factors such as the optimum viewing distance, player kinetics, and ball kinetics are considered crucial for softball umpire decision-making. For those looking into training decision-making in softball umpires, it is crucial that these decision-making factors are implemented in a study design to ensure a bridge between research and practice/performance benefits. While ecological validity ensures a connection between an information cue and criterion, action fidelity arguably ensures a connection between cue/criterion and a desired task outcome. Failure to do so could risk an inaccurate diagnosis of the factors involved in training the desired outcome/decision, thus weakening the end desired performance result (Pinder et al., 2011; Pinder et al., 2015). One technology which might be able to bridge the concepts of

representative learning, action fidelity, and ecological validity into trainable decision-making in softball umpires is Virtual Reality. This is due to its high degree of adjustable individual, environment, and task variables.

Section 2.5 Virtual Reality for Sports and Decision-Making

Virtual reality (a simulated experience of the real world through various technological means) has gained traction over the past decade as a technology to train athletes in a range of domains (Neumann et al., 2018). Within numerous sports, VR movements were found to elicit similar responses to real-world responses (Bideau et al., 2004). VR can also manipulate variables to affect performance, both within the VR realm and the real world (Godse et al., 2019). In handball, VR has been used to train goalkeeper responses, demonstrating a connection between VR's visual uptake abilities and resulting athlete movements (Vignais et al., 2009). Preliminary research suggested that VR promoted longer-term learning retention and real-game skill transfer in baseball and basketball skills compared to alternative methods (Gray, 2017; Page et al., 2019). It has also been utilised to promote desired training behaviour in rowing strategy adaptations (Hoffman et al., 2014). In American Football, VR users demonstrated improvements in decision making in recognising and adapting to opponent formations (Huang et al., 2015), while in Rugby Union VR use was correlated with improved decision-making in recognising opponent gaps (Watson et al., 2011). Another form of VR, 360° VR, has presented itself as a promising candidate for sports official decision-making training. Rather than using computer-generated and/or fully interactive virtual environments, 360° VR uses 360° video footage from cameras, and this footage can then be uploaded into an HMD (Head Mounted Display). Essentially, the user sees whatever the camera filmed. Kittel et al.'s (2019b) research suggested that 360°VR could be used to differentiate skill level between novice and expert level Australian Rules Football referees. VR technology was used to assess the preferred tactical formations of football goalkeepers within a free kick situation

(Brault et al., 2015). With its increasing use in the sports domain for training athletes, recent research also supports using VR to also train decision-making in sports officials.

Studies have suggested that representative learning, ecological dynamics, and the concepts of immersion and presence are all principles that can be incorporated into VR to train decision-making (Duking et al., 2018; Stone et al., 2018). With regards to representative learning, VR displays advantages over traditional 2D video through its perspective presentation. Rather than seeing the game through an allocentric (3rd person) view, softball umpires in VR experience the game through an egocentric (1st person, as their perspective would naturally be in a game) view. As per the principles of representative learning, this first-person perspective would allow an umpire to move their view to acquire information as they would in a game, which may facilitate a more game-like processing of the myriad factors needed for decision-making (Craig, 2013). By effectively deploying the identified relevant variables necessary for softball umpire decision-making (e.g., ball, plate, and player locations) in a seamless and co-interacting method, the action fidelity of a VR training program is greatly augmented, which might result in trainable and desired decision-making outcomes. A VR system can also produce higher ecological validity values because of its programmable cue and criterion factors, which may result in more effective decision-making training outcomes for softball umpires.

Presence, or the sense of being in an environment or place, even when one knows that they are not truly there, is a technology that VR is ideally suited to facilitate (Heeter, 1992; Slater, 2009). Owing to its ability to generate a simulated world through high resolution graphics or actual video footage, and ability to occlude their view to within a specific setting, VR could come closer to helping a VR user believe they are in the middle of a professional team's stadium during game-time. In a study by Gulec et al. (2019) which used a virtual football stadium with virtual fans, participants rated the experience of being in the virtual

stadium as more realistic than watching the stadium on a 2D monitor. A benefit to VR, as opposed to watching broadcast video, would be a higher likelihood of being able to access and utilise many of the relevant cues umpires use for decision-making when they are in-game, because to some extent they would be 'in-game'. This, in turn, would develop training by customising these factors for the umpire, perhaps depending on their skill level.

The immersion property of a VR system refers to technical features of the system and the system's ability to use Sensorimotor Contingencies (Slater, 2009). Sensorimotor Contingencies are essentially how an individual goes about acquiring information. For example, in softball, an umpire may have to run in a certain direction in order to see and then judge a play. A VR system using a Head Mounted Display (HMD) allows the umpire to turn their head and look in the same direction of a play, at perhaps the same angle, as if they were in a real game. As explained by ecological dynamics theory, an argument could be made that both presence and immersion align to help establish and maintain a continual perception-action/decision loop, thus establishing firm groundwork for VR's ability to train decision-making in softball umpires.

Another related VR concept, embodiment, further adds to the decision-making training potential of VR. Tangential to the concept of presence, embodiment refers to the representation of one's body in the brain and incorporates vision, proprioception, touch, interoception, vestibular senses, and motor control (Kittel et al., 2020). Research by Bohil et al. (2011) positively correlated embodiment with a higher potential for change and longer-lasting behavioural changes. Compared to screen-based technology, HMD units (such as VR HMDs) are more likely to produce greater embodiment values. Adding to the value of VR, findings by Riva et al. (2019) suggested that VR enhanced embodiment, which was largely due to the stereoscopic/binocular vision of VR recruiting more visual cues for decision-making (Craig, 2013; Howard, 2012). For softball umpires, training with VR's greater ability to furnish the

environment necessary for presence and embodiment may yield more effective decision-making training benefits compared to traditional 2D broadcast video.

Section 2.6 Virtual Reality Sickness

Despite VR's potential for training decision-making in sports officials, Virtual Reality Sickness, or VR Sickness, has arisen as a hindrance to such potential fulfilment. VR Sickness symptoms include nausea, discomfort, disorientation, dizziness, and blurred vision (Saredakis et al., 2020; Somrak et al., 2019). Research into the prevalence of VR Sickness indicated that between 20% and 80% of users experienced some symptoms as a result of VR use (Gallager & Ferrè, 2018). While its exact cause is currently unknown, VR Sickness was correlated with content, field of view, software, duration of VR exposure, and hardware factors (Davis et al., 2014; Gallager & Ferrè, 2018; Hoffman et al., 2008; Howarth & Hodder, 2008). The Sensory Conflict Theory, developed to explain motion sickness but adapted to explain VR sickness, postulated that the afore-mentioned symptoms arose due to a conflict between vestibular, visual, and proprioceptive signals (Kolasinski, 1998; Oman, 1990, Saredakis et al., 2020; Somrak et al., 2019). Essentially, one's visual information and vestibular information is not aligned, whether it is from not enough visual information, or not enough sensory and vestibular information (Jung & Whangbo, 2017). Although originally developed for assessing flight simulator sickness levels post-simulator, the Simulator Sickness Questionnaire (SSQ) has gained prominence as an assessment tool for VR Sickness (Gersak et al., 2020; Saredakis et al., 2020;), with higher SSQ score numbers indicating greater levels of VR Sickness. Research by McQuarrie and Steed (2017) suggested that 360°VR produces greater levels of VR sickness than 2D television. Thus, any research attempting to utilise 360°VR technology should be informed about the potential impacts of Virtual Reality Sickness, as its severity can impact the experience and feedback of participants. In order for 360° VR to be used on a large scale by softball umpires, VR Sickness's effects must be accounted for, and mitigated, possibly by

adjusting the field of view or minimising extraneous motion in the VR videos (Lim et al., 2020; Kim et al., 2019).

Conclusion

To conclude, current sports official training methods and decision-making theories strongly suggest there is room for improvement. While not intended as a substitute for decision-making training learned from officiating real games, 360° VR may offer a very promising training complement. This is primarily due to its potential to tap into the concepts of ecological dynamics, representative learning, action fidelity, presence, and embodiment to a potentially further extent than traditional 2D broadcast videos. Furthermore, 360° VR technology could diminish the use of broadcast video analysis and/or restrict it to certain conditions. Through analysis of broadcasted softball game videos and 360° VR videos, this research aims to add relevant data and insights into the discussion on sports official decision-making training using various training technology modalities.

Chapter 3: Methods

This research is situated within a post-positivist paradigm acknowledging that knowledge is socially constructed (Ryan, 2006). The characteristics of post-positivism are in a sense pragmatic, bringing together theory and practice, and acknowledging there are many research methods that can be utilised to collect and analyse data (Henderson, 2011). This mixed methods study adopts a pragmatic approach, adopting the methods most suited to answer the research questions.

This pragmatic mixed-methods study consisted of four progressive stages. Stage 1 consisted of softball video clip collection in 2D Broadcast and 360° video formats. Stage 2 consisted of an expert panel formation to view and assess various video clips for study selection and inclusion. Stage 3 required study participants to view and make a decision on softball video clips shown in 2D Broadcast and 360° VR formats. Collectively, data from stages 1–3 served as the quantitative component of the study. A 2x2 cross-over quantitative analysis measured the performance indicator of umpire decision-making accuracy (1–10) under two different conditions (2D Broadcast video and 360° VR) at different umpire levels (1–7).

In line with a pragmatic approach, the quantitative component was supplemented by a qualitative descriptive component to the study (stage 4) and incorporated semi-structured interviews. The aim of a qualitative descriptive approach is to provide a description of the phenomenon under study, staying close to the data and offering a summary or interpretation of the findings using the everyday language of the participants (Sandelowski, 2000). Interview data were analysed using an inductive thematic analysis designed to understand user perspectives on the use of 360° VR's application as a training tool for Softball New Zealand umpires. Stage 4 data served as the qualitative component of the study.

As described above, the study was organised into four stages. Because of the process in which the research questions were approached (with each stage leading to the next stage, and analysis of research questions 1–3 occurring only after stage 3), the ethics approval, study design, participants, and data collection in research questions 1–3 will be discussed separately from research question 4. It should be noted that the stages did not necessarily coincide with the research question (i.e., research question 1 was not directly tied to stage 1 of the study). An overview of the stages is provided below.

Stage one: This involved the collection of video footage from the games at a 2020 SNZ softball tournament (n=10), as well as SNZ softball games obtained from a public Facebook video site (n=6). The 2020 SNZ tournament was recorded for the 360° VR condition, while SNZ softball games were obtained for the 2D broadcast video. The game videos were then clipped to show only second base safe/out decision-making plays (n=30).

Stage two: An expert panel (n=3) evaluated the 30 clips to agree on consensus on the decision-making in each, and to determine if they were appropriate for stage three umpire training.

Stage three: Softball umpire decision-making for both conditions (2D broadcast and 360° VR) were evaluated for both accuracy and perceived ecological validity of each condition. Each umpire (n=17) viewed both conditions with a washout period in between (a technique used to ensure that the effects of one research treatment do not carryover into the next treatment). The cross-over design was chosen to maximise the statistical power of the study given the limited pool of potential participants.

Stage four: Three umpires were interviewed using a semi-structured interview format to gather interviewee perspectives on their 2D Broadcast and 360° VR video viewing. Seven questions were asked that were designed to gain deeper insights into their own experiences. All interviews were conducted remotely over Zoom video. Guided by a qualitative descriptive

approach (Sandelowski, 2000) the interviewee responses were then analysed following the inductive thematic analysis framework proposed by Braun and Clarke (2006).

Background

An explanation of softball officiating basics is provided to give context to the research methods. Softball umpires are required to make the decision whether a runner is safe or out. The decision is based on the interaction of four elements, as specified by the SNZ Level One Workbook (2019a):

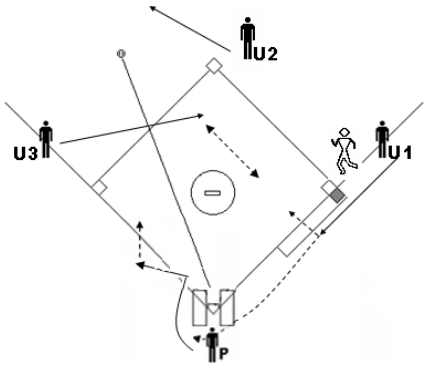
1. The ball
2. The defensive player
3. The offensive player
4. The base or the area of play

For example, the runner (offensive player) is called ‘out’ if two scenarios occur (Figure 1):

1. When the base player (defensive player) receives the ball in their glove and touches the base bag before the runner,
2. The base player receives the ball and touches the runner before the runner touches the base bag.

Figure 1

Softball Play Sample (from WBSC Softball Field Mechanics Manual: 3 & 4 Umpire System)



Runner on 1st base; U1= Umpire 1, U2= Umpire 3, U3= Umpire 3, P= Plate Umpire; White figure is offensive player approaching base 2 from base 1; Line with circular end = ball path; Arrows from umpires equals suggested movement of umpires based on ball path

Cultural Considerations

Cultural considerations were discussed in a conversation with a head Softball NZ umpire official of Māori descent to ensure that the study was culturally sensitive and respectful. The study design was deemed to be appropriate by the official. No objections were offered by the official, who felt that the study was respectful to the Te Tiriti o Waitangi's three guiding principles of partnership, participation, and protection.

Video Equipment for Second Base Decision-Making

The 360° VR video footage was filmed with a Samsung Gear 360 2017 model (Figure 2a). This recorded video in 4K at a resolution of 4096x2048 (24 fps). The battery lifespan was consistent at 100 minutes. The Gear 360 camera was attached via either the VGSION hat and mounting kit, or the VGSION head mounting strap kit (see Figures 2b and 2c), as chosen by the umpire.

Video Editing

Consolidation of the broadcast video and conversion of the 360° VR video was completed using Samsung Action Director 2.0. Samsung Action Director 2.0 was also used to edit the duration of each broadcast and 360° VR video length and isolate the footage relevant to second base decision-making.

Figure 2

Filming Equipment

a)

Samsung Gear 360 Camera

b)

VGSION hat kit

c)

VGSION head mounting kit

https://www.amazon.com/VGSION-Skiing-Bundle-Garmin-Samsung/dp/B07VBRMHKR

Research questions 1–3

Ethics approval

Ethical approval for the research was obtained from Auckland University of Technology Ethics Committee (application reference number 19/449) on December 10th, 2019 for filming participants in 360° for research question 1. With regards to research questions 2 and 3, Auckland University of Technology gave approval on July 3rd, 2020, for the expert panel

selection and tasks, testing participants' decision-making accuracy for both video conditions, and recording EV values (Appendices J–K).

Study design

Research questions 1-3 used a 2x2 cross-over component (see Figure 4) to answer three research questions:

(1) Does watching 2D Broadcast or 360 °VR video produce higher decision-making accuracy?

(2) Does watching 2D Broadcast or 360° VR video produce higher ecological validity for game decision-making?

(3) Does 360° VR decision-making accuracy differ by experience level?

The research hypothesis for each of the afore-mentioned questions was:

(1) Decision-making accuracy will be higher for the 360° VR videos than the 2D Broadcast videos.

(2) EV values will be higher for the 360° VR videos.

(3) 360° VR decision-making accuracy will be higher for the advanced umpires than the novice umpires.

Participants

Participants for the quantitative component of the research were seventeen Softball NZ-affiliated umpires drawn from a range of levels, as well as three expert SNZ umpires. Softball NZ umpires are organised by levels from 1 to 7 (Table 1).

Table 1

Softball NZ Umpire Levels and Jurisdiction

Level	Title	Jurisdiction (highest game level allowed to officiate)
1	Rookie Umpire	County
2	Developing Umpire	County
3	Emerging Umpire	National
4	Badge Umpire	National
5	Senior Badge Umpire	National
6	Senior NZ Umpire	National
7	Certified WBSC Umpire	International

WBSC = World Baseball Softball Confederation

A higher-level umpire designation permits that umpire to officiate a broader scope of games. For example, a Level 1 umpire is qualified to officiate a regional NZ game, whilst a Level 7 umpire is qualified to officiate a regional NZ game or an international game. Of the seventeen umpires who agreed to participate, two were Level 1, two were Level 2, one was Level 3, one was Level 4, three were Level 5, six were Level 6, and two were Level 7 (see Table 2).

Table 2

Participant Demographics

Participant	Age	Gender	SNZ Level	SNZ Experience Years	Condition Order
1	45	F	2	5	BA
2	53	M	6	12	BA
3	18	F	1	1	AB
4	34	M	4	9	BA
5	46	M	2	1	AB
6	30	M	7	12	AB
7	59	M	5	6	BA
8	37	M	6	11	BA
9	66	M	6	15	AB
10	18	M	1	1	AB
11	63	M	6	15	BA
12	37	F	5	11	AB
13	56	F	6	21	BA
14	26	M	6	11	AB
15	49	F	5	8	BA
16	69	F	3	8	AB
17	57	F	7	37	BA
Mean	44.8		4.6	10.8	

SNZ = Softball New Zealand

Potential participants were identified at a meeting with the North Harbour Softball Association President. The researcher met these umpires in person, explained the aims of the research and invited them to participate. The project information sheet was distributed to the umpires. Research purpose, risks to participants, and participant expectations were explained in detail on the information sheets (Appendices A–F). Interested umpires were given a consent sheet to sign and return to the researcher (Appendices G–I). Participants were given the opportunity to opt out of the research at any point during the data collection. After consultation with a SNZ umpire expert, umpires were grouped into novice (Levels 1–4) and advanced (Levels 5–7). Only second-base umpires were selected due to the higher number of safe/out plays occurring at second base, as per the afore-mentioned SNZ umpire expert's advice.

Data Collection

Stage One – Video Collection

Previous to this study, there were no extant databases of softball games filmed in 360°. Therefore, the footage for this study was collected at the annual Vic Guth Softball Tournament in New Zealand, during a 4-day period from January 24 to January 27, 2020. Footage was recorded from 10 games across four tournament days with eight different umpires. The procedure involved filming with the head-mounted Samsung Gear 360 camera (see figures 2a, 2b, and 2c) with a choice of two mounting options: either a provided baseball style cap with a pre-installed camera mounting attachment, or a head strap camera mounting kit that could be adjusted over the umpire's own cap. The preferred mounting choice was at the discretion of each umpire.

Regardless of the mounting option chosen, the video collection protocol was the same. Each umpire wore the camera during pre-agreed games, for the duration of the game. The tournament rules stated that each game duration must be 7 innings or 90 minutes (whichever occurred first). Five minutes prior to each game, the researcher ensured that the video camera was mounted, activated, and operating correctly. After each game finished the camera battery was recharged, to ensure complete recording of the next game. There were no back-to-back games filmed. It took approximately 60 minutes to charge the camera battery between games. On completion of the video footage collection, the researcher converted all the second base safe/out decision-making plays into the 360° VR format. Each play (clip) was 3 to 5 seconds long. Fifteen clips were collected and converted in the 360° VR format.

To enable collection of the 2D Broadcast video footage from previously broadcasted games, the researcher downloaded video footage from the North Harbour Softball NZ Facebook page. Fifteen clips of 3 to 5 seconds duration were collected, using the Video Downloader for Facebook app, focusing on second base plays only. Clips were from softball

games within a five-year period (2015-2020), in traditional 2D video format, and not from any of the games filmed for the 360° VR condition. This 2D video condition is the current video method used by softball umpires for decision-making training.

Stage Two – Expert Panel

The 30 clips (15 360° VR and 15 2D Broadcast) were then evaluated by an expert panel to determine a consensus for each decision and to agree if they were appropriate for stage 3 of the study. After consultation with a North Harbour Softball Umpire Association officer (a SNZ Level 7 umpire), three expert panel member umpires were chosen due to their considerable experience and backgrounds in SNZ umpiring.

This expert panel was composed of one Level 6 and two Level 7 Softball NZ umpires from across New Zealand (see Table 3). The Level 6 umpire officiated in Christchurch, while one of the Level 7 umpires officiated in Auckland, and the other Level 7 umpire officiated in Wellington. These experts were responsible for choosing and classifying the clips before they could be used in the study. The 15 360° VR clips were shown to this panel in umpire room sites in Auckland, Christchurch, and Wellington. Panel members were not together at any point of the research and watched the clips independent from each other. Panel members viewed the clips through an Oculus Quest VR HMD unit. Due to the potential for losing their balance through VR sickness, expert panel members had the option of watching the 15 recorded 360° VR videos while seated. After watching each clip, panel members informed the researcher of their expert umpire decision and rated the clip on an ascending scale of 1–10 in terms of training usefulness (1 being the least useful for training umpires, and 10 being the most useful for training umpires). One week after the 360° VR clip viewing, members were emailed a link to a Google Drive folder with 15 2D Broadcast clips, as well as an accompanying spreadsheet to record their response. Similar to the 360° VR clips, panel members were asked to make a decision for each play and then rate the clip for training usefulness on a scale of 1–10. A score

of 1 indicated little to no perceived decision-making training usefulness, while a score of 10 indicated extremely high perceived decision-making training usefulness. The members then emailed the researcher their responses. From these original 30 clips, the researcher chose ten unanimous decision broadcast video clips (5 safe and 5 out), and ten unanimous decision 360° VR clips (5 safe and 5 out calls). The agreed consensus of the expert panel final decisions were deemed as the correct decision for each clip. If study participant decisions did not agree with these expert panel decisions, then participant decisions were scored as incorrect.

Table 3

Expert Panel Demographics

Expert	Age	Gender	SNZ Level	SNZ Experience Years
1	61	M	7	15
2	62	M	6	26
3	52	M	7	21
Mean	58.3		6.6	20.7

Stage Three – Umpire Participants

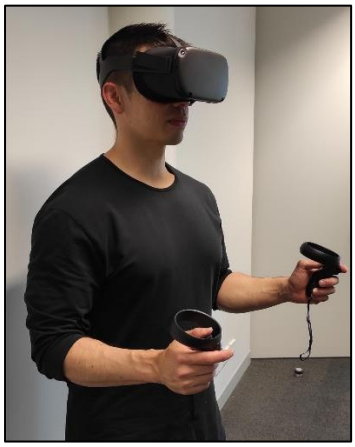
Seventeen umpires, six novice (Level 1–4) and eleven advanced (Level 5–7) umpires, were randomly divided into two groups sized eight and nine (Group 1 and Group 2, respectively). Each umpire then completed a demographic questionnaire (age, gender, years as an umpire, games umpired, current Softball NZ level, possible time as softball player; Appendix M).

The researcher met with the participants at a regional umpire office to explain the procedures and demonstrate the protocol. This meeting enabled participants to familiarise themselves with the VR hardware and software, as well as the broadcast clips. The participants accessed the broadcast clips through the researcher's laptop computer, and the 360° VR clips through the Oculus Quest HMD unit (see Figure 3). To ensure umpire competence with 360°

VR technology, all participants undertook a familiarisation session consisting of instructions on usage by the researcher and were asked to adjudicate five pre-recorded 360° VR softball safe/out clips (these were not clips selected by the expert panel for the research study). Participants were given as much time as they required until they acknowledged they were ready to proceed.

Figure 3

Oculus Quest HMD unit and controllers



Each group was required to view both video conditions, i.e., 2D Broadcast and 360° VR (ten clips for each condition, in a randomised order within each condition) to assess and make a decision as to whether the runner in the clip was safe or out. Group 1 initially watched the 2D Broadcast clips, while Group 2 initially watched the 360° VR clips. Group members then switched video-viewing conditions (Figure 3) after a thirty-minute washout period. While this washout period may seem short, cross-over study designs are largely used in pharmacological research where the washout duration is based on drug half-life (Jones & Kenward, 2014). In this study, no decision-making carry-over effects were expected given the nature of each condition, therefore, the wash-out time was deemed appropriate.

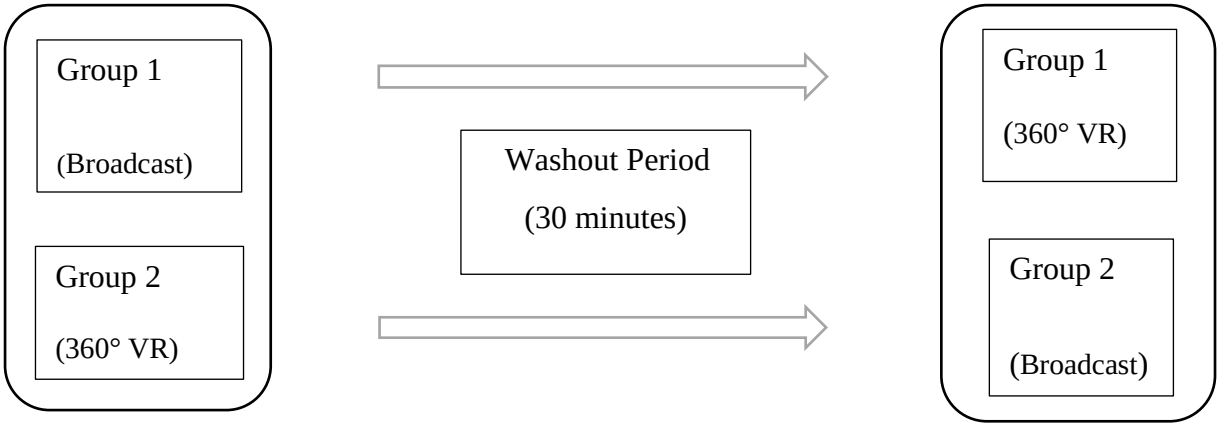
When watching the 360° VR condition clips, chairs were offered to VR participants for comfort and alleviation of any potential VR Sickness symptoms (i.e., loss of balance). The VR

condition participants selected plays from an Oculus HMD display screen menu (randomised order for each participant). After each 360° VR clip the participant paused the video and communicated their play decision to the researcher, who then recorded it. Participants viewing the broadcast videos communicated their play decision to the researcher. Accuracy was assessed post-test vis-à-vis the decisions of the expert panel. A score of 0 indicated zero correct responses, while a score of 10 indicated ten correct answers.

To assess ecological validity, each umpire was provided a printed visual analogue scale questionnaire after the conclusion of their final video viewing (see Appendix A). Participants marked how close their decision-making process in each of the two video conditions felt compared to their regular in-game decision-making process. By marking a 10 cm scale (10 being very game-like, and 0 being not at all game-like), the ecological validity of the video modes could be determined (Catteeuw et al., 2010; Kittel et al., 2019b). If a participant marked the 5.5 cm mark, their rating was considered 5.5.

Figure 4

The cross-over design



Data Analysis

Quantitative analysis

The quantitative data were analysed using JASP version 0.13. For all analyses, an alpha value of 0.05 was used for statistical significance. The analysis plan for research question 1 (decision making accuracy) and research question 2 (ecological validity) followed the recommendations for the analysis and reporting of 2x2 cross-over trials (Wellek and Blettner, 2012). Firstly, a Mann-Whitney U Test was used to check for any differences between the two treatment orders (VR-2D and 2D-VR). A significant difference would suggest a carryover effect (Jones & Kenward, 2014). Upon confirming no carryover effects, participant decision making accuracy (0–10 score) and ecological validity (0–10 score) were compared between the VR and 2D Broadcast conditions using a Mann-Whitney U Test (separately). This test was chosen over a *t*-test as the data were not normally distributed, as indicated by the Shapiro Wilk test. This test determined if the mean rank values were significantly different between the conditions (Jones & Kenward, 2014). The effect size (r) was calculated from the standard score ($r = {}^{z}/_{\sqrt{N}}$) and interpreted using Cohen's criteria of 0.5 for a large effect, 0.3 for a medium effect, and 0.1 for a small effect (Cohen, 1998). Lastly, a two-way ANOVA was used to examine how experience level (amateur or advanced), video condition (VR or 2D), and the experience*condition interaction, were related to decision making accuracy (research question 3). The partial eta-squared statistic (ηp^2) was used as a measure of effect size for each of the main effects, and the interaction. When fitting the model, the Levene's equality of variances assumption was checked, along with visual inspection of the standardized residuals (to confirm residual normality).

Research question 4

Ethics approval

Auckland University of Technology gave approval for the semi-structured interview and research question 4 on December 15th, 2020 (Appendix L).

Study design

The qualitative component of the study involved semi-structured interviews designed to gain insight into participants' perspectives of the experience of using 360° VR video technology. This component was specifically designed to answer research question 4:

(4) What are the perspectives of participants on the use of 360° VR video to enhance decision-making?

When the researcher emailed results to each participant two days after the test, the researcher inquired about the possibility of participating in an interview regarding their experience and thoughts on the two video conditions. Semi-structured interview questions were developed from the study research questions to promote a wide scope of responses. These questions were focused on user preferences, advantages and/or disadvantages of each video condition, technological practicality, limitations, and experience level (see Appendix N).

Participants

The interview participants were drawn from the same original pool of participants. After quantitative results were shared with the participants, they were asked if they wished to complete an interview with the researcher. Expert panel members were also asked if they wished to complete an interview with the researcher. Due to time, research scope restrictions, and the impact of Covid-19, not all willing participants could be interviewed. Instead, three participants were chosen on a first-come first-served basis. Specifically, one lower-level

umpire (Level 3), one advanced-level umpire (Level 7), and one expert panel member umpire (Level 7) were chosen to act as interviewees.

Data collection

Semi-structured interviews were conducted over Zoom (live video link) and recorded for transcription. Interview durations (minutes) were as follows: participant one 15:39, participant two 18:22, participant three 35:20. All interviews were transcribed using the Otter A.I. software program. The Zoom format allowed flexibility and ease of spontaneous conversation, as well as created an opportunity for deeper and more individual responses from participants (Mojtahed, Nunes, Martins, & Peng, 2014; Smith, 2017).

Data analysis

Thematic analysis

As noted by Terry et al. (2017), thematic analysis has become a widely used and respected tool for qualitative analysis. Although its nuances and an exact definition are still developing, the seminal work of Braun and Clarke (2006) attempted to define thematic analysis as a method/tool for "…identifying, analysing and reporting patterns (themes) within data" (p. 79). Thematic analysis is a structured process which, through the generation of codes or patterns of ideas, leads to the identification of larger and more encompassing themes (Braun & Clarke, 2006). Braun and Clarke (2006) proposed six steps to effectively utilise thematic analysis: 1) familiarising yourself with your data; 2) generating initial codes; 3) searching for themes; 4) reviewing themes; 5) defining and renaming themes; 6) producing the report. In this study, the researcher conducted an inductive thematic analysis following Braun and Clarke's six-step approach, as detailed below:

Step one: Initially the researcher familiarised themselves with the data. Each semi-structured interview was recorded using the Zoom meeting software app. Throughout each interview, the

researcher took notes and recorded his thoughts about various answers. The interviews were then transcribed using the Otter A.I. software program. The researcher then listened to each interview several times. While Otter A.I. was effective at transcribing the interview, it was not without errors. Repeated listening of each interview ensured that any errors in transcription were corrected and encouraged active and deep engagement with the information and interviewees (Terry et al., 2017). The corrected transcription was then converted to Microsoft Word. As an additional step aimed at ensuring accuracy, the researcher consulted with the interviewees on the transcription and obtained interviewee consent/member checking on the final transcription (Matthews & Kostelis, 2020).

Step two: Using the guiding research questions, the researcher then inductively analysed the transcripts, generating initial codes and inputting the codes into a Microsoft Excel spreadsheet. Braun and Clarke (2006) suggest there are two primary approaches when generating codes; inductive approach or deductive approach. For the inductive approach the researcher takes a bottom-up view of the data, letting the data speak for itself and not being driven by a "…preconceived coding frame". However, it is accepted that the researcher's own epistemological underpinnings may influence the data coding (Terry et al., 2017). The deductive approach takes a top-down view of data coding, attempting to engage in data coding/theory generating/data generation based on an existing theory or analytical model (Braun et al., 2015).

The inductive approach was used in this study to gain insight into participants' perspectives of the 2D Broadcast and 360° VR experiences.

Step three: The researcher searched for themes by examining the codes, and assembled codes into larger, more meaningful, and dominant patterns (Braun & Clarke, 2006; Terry et al., 2017). These patterns were then identified/named as themes. Relationships amongst codes were

assigned meanings to assist in this process. Where necessary, when several large patterns were identified, these larger patterns were divided into smaller subthemes. Each theme and subtheme incorporated various codes to support its respective ideas (Braun & Clarke, 2006).

Step four: Several candidate themes were identified and needed to be further reviewed and refined (Guest et al., 2012; Terry et al., 2017). Where possible, some of the candidate themes were broken down into smaller themes, or a theme was removed when its component codes were not sufficiently strong. Braun and Clarke (2006) suggested two levels/stages of refinement were needed to ensure both code-level and theme-level consistency. Essentially, the codes needed to support a theme, and the themes needed to be sufficiently distinct from each other to justify their creation and avoid data blurring with other themes (Terry et al., 2017).

Step five: The researcher defined and named themes with an independent researcher acting as a "critical friend" (Croft et al., 2021). Thematic maps were created to identify the essence of each theme and determine which component of the data each theme captured (Braun & Clarke, 2006). By using and elaborating upon the thematic maps, the researcher was able to define various themes both individually, and how they related to each other (Terry et al., 2017).

Step six: Once the themes were identified, the researcher undertook a final refinement and data analysis in order to produce a report. This final step connected the themes and supporting data with the original research questions and ensured the data told a story pertinent to the researcher's analysis (Braun & Clark, 2006). It was also important to stay true to the qualitative descriptive approach and to ensure the outcomes represented the findings while staying close to the participants' words (Sandelowski, 2000). Literature was tied into the various themes to bring meaning and exposition to the original research questions.

Summary

Due to the complexity of decision-making, and the limited existing research on the subject of sports official decision-making, the mixed methods approach was chosen in an attempt to gather as much data as possible. Through combining both qualitative and quantitative approaches, the researcher prioritised adding a human element to the data. By doing so, the researcher sought to use the results to inform their own research as well as future research on the subject of 360° VR and sports-official training.

Chapter 4: Results

Research results are presented in four sections. Each section addresses one of the four research questions and provides supporting insights into umpire experiences using the 360 ° VR and 2D Broadcast videos. The study used a pragmatic mixed methods approach. Research questions 1–3 are addressed through a quantitative analysis, and research question 4 has both quantitative and qualitative (thematic analysis) findings.

In the thematic analysis, the interviews were inductively coded resulting in three themes and eight subthemes. The themes were categorised as: 360° VR decision-making advantages, 360° VR decision-making disadvantages, and current softball umpire training situation. These themes and subthemes are outlined in Table 4.

Table 4

Themes and Subthemes

	Theme		
	360° VR advantages	*360° VR disadvantages*	*Current Training Conditions*
Subtheme	Perspective Engagement Information Technological Suitability	Experience requirements Privacy	Information access variability Teaching & Learning

Quantitative Analysis

Carryover Effects

Prior to the quantitative analysis, a Mann-Whitney U test was performed to determine if the viewing order in the cross-over design produced any carryover effects that may influence decision making accuracy (i.e., number of correct calls) and the ecological validity (EV) scores.

Table 5

Test for carryover effect from treatment order (n = 17)

Outcome variable	**W**	**p**	***r***
EV	143.5	1.000	-0.002
Correct Calls	162.5	0.523	0.113

Note. Effect size is given by r = $^{z}/_{\sqrt{N}}$

Note. W = Mann-Whitney U test statistic.

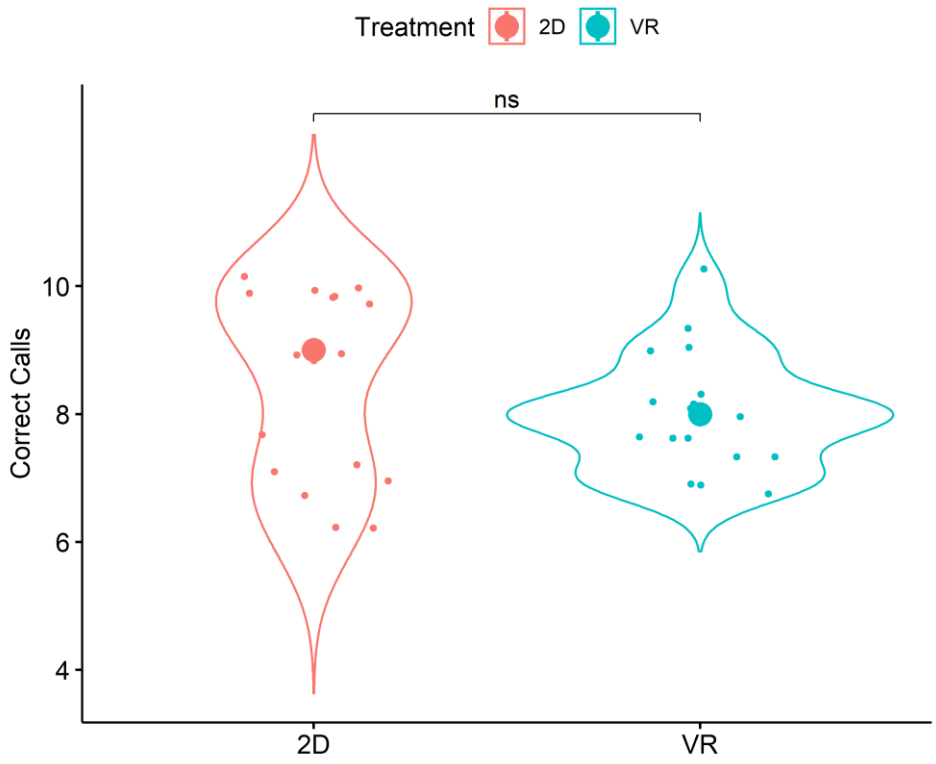
Table 5 shows that there were no significant differences between the treatment orders (VR-2D or 2D-VR) for EV (p = 1.000) or the number of correct calls (p = 0.523). The *r* effect size shows the level of association between each outcome variable and treatment order were small. Thus, no significant carryover effects from treatment order were present.

Research question one – Does watching 2D Broadcast video or 360° VR video produce higher decision-making accuracy?

The mean ± SD for the number of correct calls for 360° VR (out of a maximum of 10) was 8.0 ± 0.9, while the mean for 2D Broadcast was 8.5 ± 1.5. The data for each treatment group, along with the distribution and median, are shown in Figure 5. A Mann-Whitney U Test indicated that there was no significant difference in decision making accuracy between 360° VR and 2D Broadcast video users (W = 178.0, p = 0.242, *r* = 0.204).

Figure 5

Violin plot showing the number of correct calls for each condition



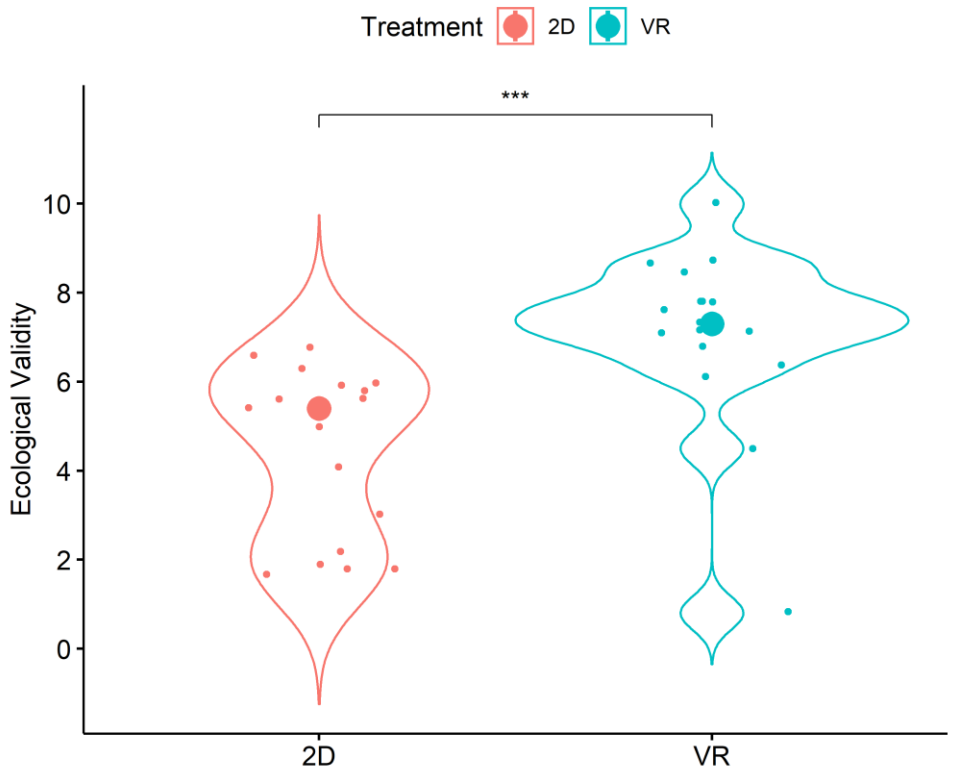
Note: The density curves illustrate the distribution, while the large point represents the median score. The 2D and VR conditions compared with a Mann-Whitney U test

Research question two – Does watching 2D Broadcast video or 360° VR video produce higher ecological validity for game decision-making?

The mean ± SD ecological validity score (1 low – 10 high) was 7.1 ± 2.0 for 360° VR, while the mean for 2D Broadcast was 4.4 ± 1.9. The data for each treatment group, along with the distribution and median, are shown in Figure 6. A Mann-Whitney U Test indicated that there was a significant difference in ecological validity score between 360° VR and 2D Broadcast video users (W = 32.5, p = <0.001, r = -0.626), with a medium-sized effect (Cohen, 1988).

Figure 6

Violin plot showing EV scores for each condition



Note: The density curves illustrate the distribution, while the large point represents the median score. The 2D and VR conditions compared with a Mann-Whitney U test.

Research question three – Does 360° VR decision-making accuracy differ by experience level?

The mean ± SD for the number of correct calls for novice umpires using 2D Broadcast videos was 8.5 ± 1.4, and 8.0 ± 1.0 for the 360° VR condition. For advanced umpires, the means for 2D Broadcast and 360° VR were 8.5 ± 1.7 and 8.0 ± 0.8, respectively. No significant differences were found between experience level and accuracy using either video condition. The results of the two-way ANOVA test comparing the two treatment groups, and the interaction between treatment group and experience level, are presented in Table 6.

Table 6

Two-way ANOVA results for umpire experience level and decision-making ability

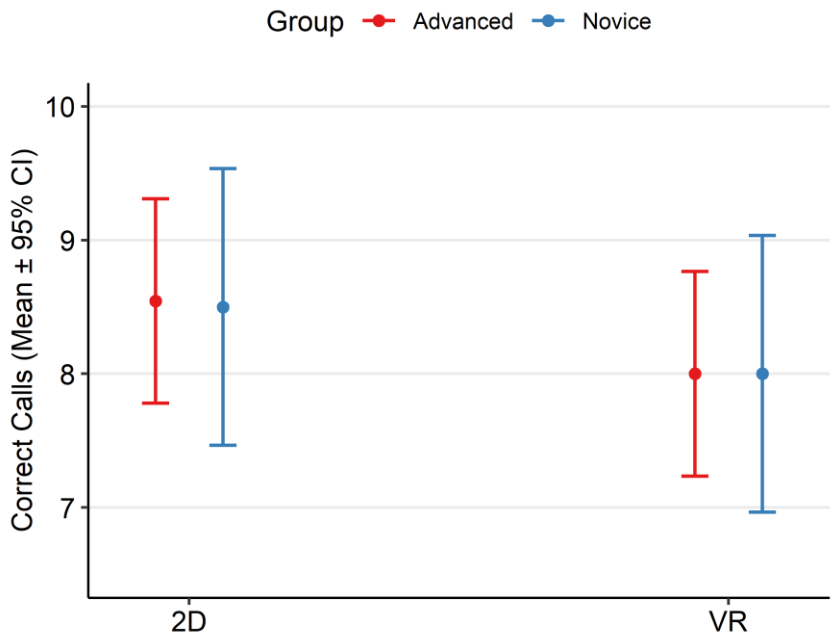
Source	df	MS	*F*	p	ηp^2
Video Condition	1	2.122	1.277	0.269	0.041
Experience Level	1	0.004	0.002	0.961	< 0.001
Video Condition ✻ Experience Level	1	0.004	0.002	0.961	< 0.001
Error	30	1.674			

Note: MS = mean squares; ηp^2 = Partial eta-squared effect size; Model fit using type III Sum of Squares.

The estimated means and 95% confidence intervals for each video condition and experience level are presented in Figure 7. The analysis indicated no statistically significant difference in decision making accuracy between novice and advanced umpires (F = 0.002, p = 0.961, ηp^2 < 0.001) and this did not vary by video condition (p = 0.961).

Figure 7

Decision-making accuracy by experience level and video condition



Note: Values represent estimated means and 95% confidence intervals

Qualitative Analysis

Research question four – What are the perspectives of participants on the use of 360° VR video to enhance decision-making?

Theme 1: 360° VR Advantages

In order for any new training tool to benefit an umpire, it must offer advantages over the current training tools. Interviewees all felt that this was the case with 360° VR, but with a number of varying reasons. Analysis identified five key areas (sub-themes) related to the advantages of VR; these were perspective, engagement, information, enjoyment, and technological suitability and impact.

Perspective

A common theme from all three interviewees was the importance of perspective in softball umpire decision-making. Because the broadcast video perspective was not from an in-game view, interviewee 1 felt a disconnect between himself and the play. However, with the 360° VR, he felt much more connected and able to make a better, more accurate call, because he was able to access the perspective he was familiar with from the position, which was "…a hundred times better than watching a video that's shot from the sideline." For Interviewee 2, the thought process was similar to interviewee 1, as he commented upon the disconnect between umpire decision-making and the broadcast video: "You're in a different angle, so you're not utilising techniques that you would have to from the position of the umpire." However, with the 360° VR videos, he remarked upon looking at the plays through a "familiar position". For Interviewee 3, being able to see a play through the "eyes of an umpire" helped him figure out what an umpire was thinking, as well as their positioning and if they were in the best place to make a call.

Engagement

Engagement, or the power to interact with the video medium to make accurate decisions, was perceived to be greater with the 360° VR amongst all three interviewees. Interviewee one remarked that with 360° VR, "…you can act out what you should be doing and what you would be doing at the same time." This was in contrast to the feeling of disconnect with the broadcast videos and the feeling of being "…one step removed from it all." Furthermore, interviewee one suggested that 360°VR could be used to train multiple people simultaneously with high engagement "… if you had two or three people looking at it at the same time…being able to say, hey, look down to the left…sort of everyone in the same experience." The ability to track a ball as it moved across the field and responding with a decision was far better in 360° VR for Interviewee 2, who commented that 360° VR was "…good for tracking the ball in terms of a judgment call. So it's [the ball] coming into a base and seeing when it gets tagged or when it gets caught." Due to the immersive nature of 360° VR, interviewee three believed an umpire using it could better gauge umpire positioning "…if I had taken two steps to the left, and look right up the line, I would have got a fourth element."

Information, in the form of play information necessary for an umpire to make an accurate decision, was a concern amongst all three interviewees. Being able to identify all the information needed to make an accurate call was of primary importance. This subtheme manifested itself when the interviewees mentioned terms such as angles, distance, and points of focus. For example, an advantage of 360° VR for interviewee 1 was being "…able to focus on the bits and pieces you want to focus on." Interviewee 2 commented that 360° VR was ideal for finding the right angles to call a play, and for being able to better "…see the play and see the elements themselves." Interviewee 3 noted 360° VR's suitability for obtaining optimal angles and distance from a play, noting that through it, umpires could "…understand angle and distance a lot better than through the literature".

Technological suitability and impact

Interviewees remarked upon 360° VR's technological suitability for the younger umpires, as well as its impact factor. Interviewee 2 believed it would work well with younger umpires and saw it as an almost natural fit: "…there's a youth group like myself coming through. And even younger than me. And these people are used to this technology now." While he didn't rule out 360° VR for older umpires, Interviewee 3 expressed excitement about using 360 ° VR for up-and-coming umpires: "You look at our younger umpires, mate, they're technology savvy. So VR to them would be like just playing a game." Interviewee 1 was immediately pulled in by the novelty and excitement of using the 360° VR technology itself, noting it was more "real life" and that he enjoyed using it because it was "cool technology" that made using it more interesting and engaging.

Theme 2: 360° VR Disadvantages

Participants also spoke about some of the disadvantages of 360° VR. These centred around possible user experience requirements and infringement on umpire privacy.

Umpire Experience

The disadvantages of using 360° VR were not as numerous or as expounded upon by interviewees but did appear. One such disadvantage was related to umpire experience, specifically how the technology may benefit certain experience levels more than others. For two of the interviewees, they felt a prerequisite level of real game experience might be needed to fully utilise and benefit from 360° VR technology. According to Interviewee 1, "…if you're a very low, low level umpire, who doesn't have that game experience, you're looking all over the place and you're not sure where you should be focusing." Interviewee 3 shared a similar thought on experience level and discussed how senior-level umpires would be able to look around to quickly identify the four elements: "They just have a bit more experience, and they have a bit more tools around it, I guess. They'll see a lot more than what a novice umpire would

see". Interviewee 2, meanwhile, explained that higher-level or experienced umpires may not even benefit from the 360° VR technology because at higher levels, they might have outgrown the need for reviewing videos to train decision-making: "…unless there's something new, by the time you hit level seven…we've seen these calls from these positions…thousands of times."

Umpire Privacy

The idea of maintaining respect for umpires appearing in the 360° VR videos was a strong concern for interviewee 3. Because of the viewpoint, the 360° VR videos made it easier to critique the actions of the umpire with the mounted camera. For other SNZ umpires following SNZ games, they would be able to identify the filming umpires and perhaps negatively view their actions. This could potentially detract from its widespread adoption: "You would just imagine that it might expose my crew…the gloss would be taken off of what it's [360° VR] trying to achieve by ostracizing someone or really putting someone out there." Rather than the technology being used to train decision-making, it would make it more about the filmed umpire and their performance. As a Māori umpire, Interviewee 3 mentioned that this concept of protecting the individuals in the videos was also about "protecting our mana[1] of our umpires…we always want to keep the mana of an umpire intact." It should be noted that this was more so a concern for the individuals with the broadcast videos because their faces could be seen (unlike the first-person filming perspective of the 360° VR videos).

Theme 3: Current training conditions

Through the interviews, participants shared important opinions on the current state of SNZ umpire decision-making training. Of importance was the ideas of information access

[1] A Māori term defined as prestige, authority, control, power, influence, status, spiritual power, charisma – *mana* is a supernatural force in a person, place, or object (Māori Dictionary, 2021)

variability, and the idea that 360° VR is uniquely capable of improving the current condition through its strengths as a teaching and learning tool.

Information access variability

Interviewees indicated that the current video-training situation and knowledge sharing with SNZ umpires was arbitrary. Interviewee 1 mentioned that it was often up to the umpire to find YouTube broadcast videos, which entailed finding the right video for the right play. This failed to really garner much interest from this umpire, as he noted that he has "…seen a million of those sorts of videos before as well. Which they tend to run into another sort of thing". Interviewee 2 specifically mentioned the ad hoc nature of video selection, noting that regional head umpires would select their own plays to teach umpires, and that this went all the way up to the international level. One high-ranking international softball official "…has his own dropbox videos, and he just uses them as he sees fit of what he wants to teach". Interviewee 3 shared the story of how his beginning foray into umpiring might have gone down an entirely different path if not for the help of a key umpire mentor. Before meeting this umpire, he felt somewhat isolated from learning and improving as an umpire because the senior umpires of his time closed themselves off to him: "…they held on to that information, and they held on to those skills. And they only taught you when you moved up a grade". For this umpire, 360° VR, far more than the 2D Broadcast videos, could be an effective tool to help bridge the information gap, infusing some energy and novelty to help lower-level umpires learn. The sooner the 360°VR video training could be deployed, the better for training information access: "…if I've got the toys man, get 'em out there".

Teaching and learning

On the notion of teaching and learning, interviewees all shared positive opinions on 360° VR as a training and learning tool. For example, Interviewee 1 shared that "…it would be cool to actually get a plate umpire wearing VR [camera] and then being able to experience and

see what they're looking at…and whether that umpire called a ball or a strike and compare that to what you would call." This accuracy-improving training feature was in addition to Interviewee 1's previous positive opinion about the possibility of using 360° VR to teach multiple individuals simultaneously. Interviewee 3 considered 360° VR to be a useful tool for educating umpires on movement techniques, especially with regards to tracking a play "…VR was better for getting experience in practice in techniques to see the play and see the elements themselves." Even more important for interviewee two, was the chance for 360° VR, in the offseason, to prepare umpires for the coming season in a safe, controlled environment, rich with the information necessary to train accurate decision-making. Interviewee 3 was very enthusiastic about 360°VR bridging the gap between decision-making training literature and real play. According to interviewee three, most umpires were kinesthetic learners, and learn by doing. With 360° VR, these umpires could see how a play in the rule book looks like in real life, "…if you show me what that looks like, and I understand that, when I go read the literature, I can link the two."

The current study examined various aspects of 360° VR's use as a decision-making tool through a combination of quantitative and qualitative analysis. Specifically, the current study showed no significant evidence that 360° VR produced higher decision-making accuracy than 2D Broadcast video, nor was higher umpire experience level associated with greater 360° VR decision-making accuracy; however, 360° VR showed significantly higher EV values than the 2D Broadcast videos. Additionally, it became evident that 360° VR offered additional advantages, disadvantages, as well as situated itself well into the current SNZ softball umpire training landscape/situation.

The next chapter will discuss these various features and facets of 360° VR for softball umpire decision-making training. By consolidating the lessons learned from the study, the researcher hopes to establish a foundation and direction for similar research in the future.

Chapter 5: Discussion

Introduction

This chapter is presented in three sections, with each section focusing the discussion specifically related to research questions 1–3, briefly restated here: 1) Does watching 2D Broadcast or 360° VR videos produce higher decision-making accuracy; 2) Does watching 2D Broadcast or 360° VR video training produce higher ecological validity for game decision-making training; 3) Can 360° VR assess decision-making skill accuracy differences between novice and advanced sports officials? Insights from interview data on research question 4 (What are the perspectives of participants on the use of 360° VR video to enhance decision-making?) will be drawn upon throughout the discussion as relevant.

Research Question One:

Does watching 2D Broadcast or 360 °VR video produce higher decision- making accuracy?

Previous research findings highlighted the ability of both 2D Broadcast and 360° VR video to improve sports official decision-making accuracy (Catteuw et al, 2010; Helsen et al., 2019; Kittel et al., 2020; Larkin et al., 2018; Mascarenhas, 2005; Schweizer et al., 2011). The hypothesis that decision-making accuracy would be higher for the 360° VR videos than the 2D Broadcast videos was unsupported. A recent study found a significant difference in decision-making accuracy between Australian Rules Football umpires using broadcast videos or 360° VR videos (Kittel et al., 2020), however in this current study no significant difference in decision-making accuracy between umpires using 2D Broadcast video and 360° VR videos was identified. Although the current study did not demonstrate a significant relationship between video condition and accuracy, information from the interviewees provides useful and actionable insights into factors that may have influenced the results. These factors include missing information and feelings of nausea brought on by use of VR technology.

It is reasonable to expect that the third-person perspective of the broadcast clips introduced barriers to effective decision-making for umpires as participants are effectively making decisions without all the information they normally would possess from a first-person perspective (Mann et al., 2007). Sports official decision-making requires combining both existing knowledge and available sensory information (MacMahon et al., 2014) along with procedural and declarative knowledge (Plessner & MacMahon, 2013). By not being able to move around to receive all the information needed for decision-making (Balagué et al., 2008; Gibson, 1966; Gibson, 1979; Seifert et al., 2019), the resulting decision-making accuracy for the umpires on the broadcast clips was possibly decreased. This presented itself through the camera distance and camera angles.

Due to the camera position in the broadcast clips, participants often had an unclear or incomplete view of the four elements. Many of the 2D Broadcast videos were filmed above and behind the home plate, providing a better overall picture of the entire softball diamond while sometimes sacrificing a closer and clearer view of the second base clips. In some broadcast clips, this problem was further compounded due to the presence of a dark screen mesh net (designed to keep softballs from traveling into the softball stadium audience) in front of the camera. Previous studies have suggested that viewing distance from a play and the angle from which the play is viewed can significantly impact soccer referees' decision-making accuracy (de Oliveira et al., 2011; Hossner et al., 2014; Mallo et al., 2012). Interview data provided some further insight into the effect of the camera angles and distance on broadcast clip decision-making accuracy: "You tend to be blocked out or see a bit of an issue with the angles and the distance" (interviewee 2). He went on to explain his difficulty with the broadcast videos: "…it's hard to focus on exactly what you should be seeing". Some of the 2D Broadcast videos viewed by participants did have zoomed in, tighter views of the play, but there was a lack of consistency with their occurrence. The overall decision-making accuracy effects of the

broadcast video clips could potentially be enhanced with improved clip selection. These effects were expected to be diminished in the 360° VR video clips.

The finding that decision-making accuracy by participants using the 360° VR clips were not significantly different than the 2D Broadcast videos did not support the hypothesis that decision-making accuracy on the 360° VR videos would be higher than the 2D Broadcast videos. Research by Kittle et al. (2019b) suggested that the 360° VR clips would feel more 'game like' to the participants and assist in promoting higher decision-making accuracy, however, as with the 2D Broadcast videos, the participants using the 360° VR clips may have been unable to see all that they needed to see to make accurate decisions. According to interviewee 1, "…the scenarios being white sand, white shoes, white base…things got lost in the definition". How much this influenced decision accuracy is uncertain but was a possible factor. Furthermore, the 360° camera and resulting images were very basic, and the researcher did not have the skills or resources to professionally edit the clips. However, the researcher did notice far fewer comments from participants in both the quantitative data collection period and the qualitative interviewees on image quality. This may suggest that, using a higher specification equipment, 360° VR image quality issues could be minimised to assist with umpire decision making. Besides issues with image quality, issues related to the umpires and movement may have arisen.

Umpires often have to move to make calls, but the 360° VR clips with an umpire moving may not have fully translated how movement changes a user's ability to make a decision. The ability to obtain the needed information during movement or no movement was likely different, as remarked upon by an interviewee: "…if you're seeing it when you're running, it's different from when you're actually staying still". The same interviewee also noted that despite the movement of the umpire, the viewer was not really running with them. Again, this would seem to indicate that the 360° VR clips were unable to totally recapture the

dynamics of user interaction with the environment (Balagué et al., 2008; Gibson, 1966; Gibson, 1979; Seifert et al., 2019). While the participants were able to somewhat adjust their view during either movement or no movement clips, the resulting dynamics of sports official movement and environment interaction was still somewhat restricted from a live game and may have diminished an umpire's decision-making ability.

Decision-making ability may also have been impaired by the duration of the 360° VR clips. The start and end points chosen for the 360° VR clips may have negatively impacted the umpires. All clips were 3–5 seconds in length and did not consistently include the beginning of the pitch. This might have resulted in a decreased ability of the umpire to track and process all the information in the game environment to make an accurate decision, unlike in a live game. To date, research on decision-making has often overlooked numerous factors that account for sports official performance, including individual-environmental interactions and synergies (O'Brien & Rynne, 2020). By not being able to view the play from its beginning, participants using the 360° VR clips may not have been able to effectively utilise all the information sources needed for effective decision-making. One of the interviewees suggested he preferred watching a longer, more complete play, rather than "…you plug in and suddenly you have a play". It is possible that the users needed more information on the play to mimic a sense of the synergies and interactions surrounding a play and its appropriate response (MacMahon et al., 2014). This might have been made more difficult because of user discomfort.

Technical issues with the 360° VR technology may have interfered with decision-making, albeit this might have required the influence of emotions on decision-making. The researcher noted that during the data collection several participants reported minor feelings of discomfort. The wobbling and shaking which occurred with the 360° VR due to umpire movement produced unpleasant feelings, likely a manifestation of VR sickness. This is

purportedly higher in 360° VR videos than 2D Broadcast videos (MacQuarrie & Steed, 2017). VR sickness may have been detrimental to the umpires' ability to make accurate decisions and locate the four elements within the videos. However, while the interviewees acknowledged the instability in some of the 360 ° VR videos, instability or VR sickness symptoms were not cited as a major impediment to decision-making. As interviewee 1 remarked "The stability? Yeah, it wasn't great, but it wasn't so bad that the stability put me off it". Another interviewee mentioned experiencing something akin to vertigo, but gradually adapted to and overcame the sensation. Still, any users experiencing feelings of VR sickness and not enjoying using the 360° VR clips may have produced different decisions than in a live, discomfort-free game. Research suggests that emotions (positive and negative) are linked with information processing, decision-making, and actions (Antoniou et al., 2020; Tenenbaum et al., 2013). Thus, despite the interviewees not ascribing difficulty to the decision-making due to VR sickness symptoms, any negative emotions due to VR sickness may have negatively impacted some of the participants' abilities to optimally make a decision.

In summary, it is unclear from this study why participants did not score significantly higher with their decision-making tasks on the 360° VR clips than the 2D Broadcast clips. However, qualitative interview data indicated that it may be due to user inability to access all the information, in the same manner as they would in a live game. Furthermore, 360° VR video clip lengths may have been insufficient, and user discomfort with the 360° VR also emerged as possible explanations.

Despite a lack of quantitative data connecting 360° VR video to improved umpire decision-making accuracy over 2D Broadcast video, qualitative data showed that 360° VR may offer potential to increase decision-making through the context of training with the technology. The study design did not include a pre- or post-treatment measurement system to assess if the technology was able to produce decision-making accuracy changes over time. Interviewees

remarked upon their belief that the 360° VR technology could be used to train and increase decision-making accuracy. For example, interviewee 3 remarked about training with: "If you had the VR technology, and you can work with it in preseason, they will learn a hell of a lot more…and when they come to the real thing, they'll be able to adjust a lot quicker and a lot easier". Interviewee 2 hinted at actively using and benefitting from 360° VR: "I found it really beneficial in terms of getting the experience of seeing a call come into place, learning how to utilise judgment". By using the words "getting" and "learning", interviewee 2 implied the benefits of the 360° VR may not be immediate, and perhaps would be achievable in a future study design that would include measuring actual game accuracy changes over a series of time after receiving 360° VR training.

Research Question Two:

Does watching 2D Broadcast or 360° VR video training produce higher ecological validity for game decision-making?

The hypothesis that EV values would be higher for the 360° VR videos than the 2D broadcast videos was supported. Research results from this study indicated that 360° VR produced higher EV values than 2D Broadcast videos. This finding supports those of Kittel et al. (2019) who demonstrated that Australian Rules Umpires rated 360° VR videos higher for EV than match broadcast videos. Similarly, research by Kittel et al. (2020) suggested that 360° VR videos showed higher psychological fidelity than match broadcast videos. In this study the experience of using 360° VR allowed the umpires to view each play from a viewpoint almost identical to the real game, therefore enabling them to more easily obtain the four elements (leading edge of base/plate, ball position, fielder location, runner location), thus increasing their decision-making link between cue and criterion (Brunswik, 1956). The benefit of this 'cue and criterion' connection was also acknowledged by all the interviewees. They emphasised the positive aspect of being able to look around in real-time as the play was occurring, in order to

identify the four elements and produce an informed decision. Interviewee 3 touched on this feature of the 360° VR: "You'll be able to identify the key triggers, that kind of say to you, actually, that's happening right now. The angle I've got here…this is not good enough. I need to move". This umpire 'sense of presence' was heightened in the 360° VR videos, which generated a higher level of embodiment compared to the 2D Broadcast video. One interviewee used the word "immersive" to describe their experience using the VR headset and making play calls, which strongly supported the concept of embodiment in action between the interviewee and 360° VR headset. This 'sense of presence' emphasised the usefulness of VR to increase feelings of ecological validity thus promoting decision-making learning retention, and capitalising on heightened embodiment to amplify such learning, thus increasing the chances of long-term behavioural changes (Bohil et al. 2011). As noted earlier, higher levels of embodiment in learning experiences, such as those seen with VR technology, may increase the chances of long-term behavioural changes (Bohil et al. 2011). This finding suggests that there is merit in Softball NZ considering an implementation of 360° VR as an additional tool to train softball umpire decision-making. The interviewees were enthusiastic that with 360° VR they were using a technology that allowed them to engage from a point of view familiar to an umpire, rather than looking at a call through the eyes of a softball television audience member (2D Broadcast video). As interviewee 1 explained, with the 360° VR, you "Get to use cool technology. It just makes it interesting and makes it engaging." That same umpire, when speaking about watching broadcast videos, was decidedly less interested: "You didn't feel like part of it, and it's like you're one step removed from it all. Seen a million of those sorts of videos before as well…one runs into another sort of thing".

To summarise, the findings supported the hypothesis that participants would ascribe higher EV values to the 360° VR clips than the 2D Broadcast clips. Interview feedback suggests that this was due to the 360° VR's abilities to promote embodiment, immersion, and presence.

Research Question Three:

Does 360° VR decision-making accuracy differ by experience level?

Previous research findings suggested a link between experience and accuracy in sports officials (Catteeuw et al., 2009; Corrigan et al., 2019; Kittle et al., 2019b; Nazarudin et al., 2015). Our hypothesis that decision-making accuracy would be higher for the advanced umpires than the novice umpires was not supported. The factors that might have influenced these results include the sensitivity of the videos to assess experience and the familiarity using the 360° VR technology.

It is possible the study design may not have accurately detected decision-making differences according to experience level because of diminished task representativeness. In a study by Kittel et al. (2021), both 2D Broadcast and 360° VR videos were unable to differentiate decision-making accuracy between skilled and highly skilled AFL umpires. Thus, while 2D Broadcast and 360° VR videos can differentiate between novice and advanced sports officials' decision-making accuracy (Kittel et al., 2019b), at higher sports official levels there may be an efficacy cut-off, suggesting that assessing sports officiating proficiency through video methods is not without limitations and requires fine-tuning. The findings of Dicks et al. (2019) suggest that experience on a task is assessed through tasks representative of the simulated environment. For example, an assessment of a cricket player's skills on a basketball court is weakened because of the poor representativeness of the experimental environment to the real environment. As discussed in the discussion on research question one, there were concerns about the study's ability to utilise the benefits of the 360° VR clips to make the decision-making process authentic and game-like. By the very design of the current study, the participants were attempting to call plays without umpiring at a real game. In real sports games, sports officials are required to make decisions amongst a constantly shifting mix of interacting environmental, psychological, and physical variables (Kittel et al., 2019; Morris & O'Connor,

2016). Due to the isolated nature of the testing conditions, these factors were not all present; however, it is likely the testing conditions presented their own unique variables required for decision-making, such as being asked to make a decision in front of a researcher in an umpire room, possibly diminishing transfer of the umpires' experience levels (Renshaw et al., 2019). If the research video-viewing conditions were sufficiently different to the setting to which the play calls were normally directed (a live softball game), task representativeness was compromised (Araújo et al., 2007; Araújo et al. 2019), and the resulting data demonstrating no significant difference between umpire experience and decision-making accuracy is placed into a more understandable context. One notable video-viewing variable which possibly impacted the relationship between accuracy and experience was the utilisation of the 360° VR technology.

Data results and accuracy may have been influenced by user familiarity with the technological medium and various individual characteristics, such as VR sickness lowering accuracy scores, or even the familiarity of using the 360° VR videos. For many of the participants and the majority of the interviewees, it was their first-time using VR technology. One of the interviewees touched upon the familiarity, or lack thereof, with higher technology among different age groups within the umpire ranks: "We've got umpires who are very tech savvy. They would probably school the older generation like myself on the technology that's available" (interviewee 3). Many of the higher-level umpires were older and perhaps less familiar with the 360° VR technology. This might have impacted upon their decision-making accuracy, while the scores of the younger, lower-level umpires were boosted by their familiarity with the technology. Findings by Saleme et al. (2021) suggest that higher age is associated with differing quality of experiences (with higher age groups presenting lower quality of experience scores). Thus, if experience was correlated with age, a lower ability to enjoy the 360° VR may have had an impact on their decision-making (Antoniou et al., 2020;

Tenenbaum et al., 2013). An argument could be made that as the number of younger SNZ umpire increase, and older SNZ umpires retire, issues related to user familiarity with the 360° VR impacting the relationship between experience and decision-making accuracy may decrease. However, the researcher believes that SNZ could ameliorate the impact of technology on its older umpires' comfort and decision-making accuracy through a supportive and customised familiarisation with the 360° VR technology.

Although a connection between experience and decision-making accuracy was not found in the study, comments by the interviewees allude to a perceived ability for the 360° VR to discern this connection. Interviewees one and three implied that a certain level of experience may be needed to use the technology in order to know where to look and what to do during the play (see chapter 4). That this was not reflected in the current study was possibly due to issues related to study design sensitivity or technological familiarity.

Summary

In summary, the findings on research questions 1-3 were a mixture of expected and unexpected results. The 360° VR clips were expected to result in higher EV values. This was supported by the findings. It was also expected that 360° VR's features would have resulted in better decision-making accuracy than the broadcast videos, as well as discerned experience-based differences in accuracy. This was not supported by the findings. Despite these unexpected results, positive feedback from the interviewees supported the use of 360° VR for decision-making training, as the umpires experienced better views of the plays, lauded its ability to effect decision-making accuracy change as a training tool, and indicated greater enjoyment with its use compared to the broadcast videos. As one interviewee explained on its decision-making training potential: "…they will learn a hell of a lot more about angles and distance. And then when they come to the real thing, they'll be able to adjust a lot quicker and a lot easier" (interviewee 3). Through incorporating these insights from the mixed methods

approach of this study, this study can inform and enrich future related studies examining 360° VR and decision-making impacts on sports officials. Of key importance from this study are the abilities of 360° VR to potentially increase enjoyment of learning/training for sports officials, which may, through increased exposure, also increase decision-making accuracy in 360° VR and ultimately live games.

Chapter 6: Conclusion

The following sections will be divided into three sections; section 6.1, the research findings will be summarised; section 6.2, the strengths and limitations of the research will be discussed and section 6.3, recommendations for future research.

Section 6.1 Summary of findings

Due to the pragmatic mixed methods study design approach, it was possible to gain deeper insight into the quantitative research findings through the qualitative interviews. The quantitative data indicated that 360° VR offered softball umpires minimal advantages to decision-making accuracy compared to traditional 2D Broadcast videos, and was limited as an effective assessment tool for decision-making experience; however, the quantitative data did suggest that umpires viewed the 360° VR videos as more game like. The findings of the qualitative data supported the use of 360° VR as a tool to improve softball umpire decision-making accuracy.

Decision-making training tasks should use similar information sources as the desired environment to which they are directed (Araújo et al., 2006; Pinder et al., 2015). Evidence of these similar information sources being present in the 360° VR videos was provided by the interviewees' comments on perspective and engagement. Interviewee feedback praised the better viewpoints (i.e., 'eyes of an umpire'), and ability to shift their viewpoints to acquire more information necessary for decision-making ('good for tracking the ball…'). Quantitively, support for this more game-like training environment was provided by significantly higher EV values. Thus, the researcher believed the higher EV values would also correlate with improved umpire decision-making accuracy and connect experience with improved decision-making accuracy; however, data supported neither of these two hypotheses.

Section 6.2 Study strengths and weaknesses

The qualitative data, and the mixed methods approach in general, was a strength of the study. As far as can be reasonably determined, this study is the only one of its kind to use quantitative and qualitative data to research sports official decision-making with 360° VR. Without the qualitative data, the study's quantitative findings were very constricted and anaemic in terms of providing recommendations for future research directions – 360° VR was more game-like to the participants, but unable to significantly impact decision making. With the qualitative data, however, the study was able to examine how the technology was interacting with participants, and how they were using it, and wanted to use the technology. Such findings emphasised a study by Hong et al. (2020) on the propensity of mixed methods research to: "…better inform decision making…provide a more complete and rich understanding". In this regard, the mixed methods research introduced multiple avenues of insights and offers potential for future research.

A limiting factor of the study is the relatively inconsistent selection of broadcast and clips. As discussed earlier, the ad hoc basis of broadcast video clip selection for NZ training purposes encouraged the researcher to choose clips from an online source. While numerous clips were available, the quality of each clip could vary greatly, with different camera angles and distances. This may have helped participants with their decision-making in some clips, while hindering them in others. Despite the relatively low costs associated with this style of video training, the study results suggested that the training efficacy and results of 2D video broadcast training were mostly unhelpful to the majority of participants. Instead, SNZ umpires would likely benefit more from learning how to implement first-person or 360°VR video training, alongside simulation games, to improve their decision-making. Furthermore, some clips were from under 18 age group games, while others were from adult softball games. A study by Kittel et al. (2021) suggests that failure to match the performance level of the umpires

usually adjudicated by sports officials may impact on the ability of sports officials to accurately call upon their decision-making expertise. The study cannot be certain that these broadcast clips were unanimously valid tests for softball umpire decision-making.

An important constraint of the study was the scope of a Master's study. The researcher was not able to introduce pre and post-test decision-making accuracy tests due to time constraints. The study design examined the participant's decision-making ability based upon clip duration, and this duration may not have been long enough to have captured all the decision-making factors that are used by participants when determining their decisions. As noted by O'Brien and Rynne (2020), a host of interacting factors combine to determine and develop a sports official's performance. The researcher used the qualitative data to assist in gaining the knowledge to understand these factors.

Section 6.3 Recommendations for future research

Further research is needed to ascertain how best to integrate 360° VR to improve training of sports official decision-making. Currently there is limited research on the impact and effectiveness of 2D video-based decision-making training on actual games, and even less on 360° VR's decision-making training transfer. The research does suggest that there is a positive correlation between first-person video watching before sports performance officiating and the resulting officiating in a real game (Nazarudin et al., 2015). Furthermore, there appears to be a positive correlation between sports officiating experience and accuracy using 360° VR, unlike in 2D match broadcast videos (Kittel et al., 2021). This is a gap in the literature worth further exploration. It would be most useful to train and test a large group of sports officials' decision-making abilities with 360° VR during an offseason and compare their accuracy results to a control group over the course of a season. Because of the speed and scope of decision-making in softball, it is likely that the findings of this study could also apply to other sports, though there may need to be adjustments in the filming and study execution due to each sports'

unique officiating needs. In the final analysis, any method that can improve sports official decision-making improves the entire sports official profession, as well as the sports field in general.

Although the present research focused on 360° VR and decision-making for softball umpires and sports officials, the researcher also believes that the cost, risk of VR sickness, and perhaps perceived technical expertise required to implement 360° VR videos represent barriers to many sporting organisations. Thus, the implementation of 1st person videos via a 180° camera such as a GoPro camera would be an option. Although priced similarly, GoPro-type cameras and cameras similar to them are arguably easier to use because of their myriad mounting kits. A softball umpire may simply mount the GoPro camera to their uniform's chest via a chest mount device. This would likely be more comfortable, secure, and less of an impediment to their movements than a 360° camera mounted atop their hat. Umpires may still be able to look at a game through the more beneficial first-person perspective on any display screen. The primary concern with using a GoPro camera and not uploading it into a VR HMD for viewing would be the loss of immersion, presence, and embodiment offered by VR. But for some instructional/training purposes that do not require any of these factors (i.e., an umpire trainer being able to instruct a trainee where their eyes should be looking), a GoPro camera may serve as a cheaper alternative to a 360° camera and VR HMD combination device set. There is also the possibility of uploading 180° GoPro video into a VR HMD. Again, while this may not utilise the full strengths of 360° VR, an argument could be made that some sports may not require 360° viewpoints in VR to effectively learn. In softball, the umpire will rarely need to look behind them. Other sports, such as football, rugby, and American football, may require a more dynamic view of the playing venue for sports official training.

To conclude, despite mixed findings in the present study, 360° VR may positively impact the decision-making of referees and umpires across a realm of sports. Qualitative data

suggests and calls for future research to continue exploring this largely untapped decision-making training tool. 360° VR decision-making training may both sharpen and magnify some of the advantages of the broadcast videos in terms of access to training anytime, anywhere. Lastly, as suggested by one of the interviewees, 360°VR videos can build upon the benefits of training with manuals or rulebooks because it "…brings to life the literature".

References

Anguera, M.T., Blanco-Villaseñor, A., Losada, J.L., Sánchez-Algarra, P., & Onwuegbuzie, A.J. (2018). Revising the difference between mixed methods and multimethods: Is it all in the name? *Quality & Quantity: International Journal of Methodology, 52*(6), 2757–2770. https://doi.org/10.1007/s11135-018-0700-2

Antoniou, P. E., Arfaras, G., Pandria, N., Athanasiou, A., Ntakakis, G., Babatsikos, E., Nigdelis, V., & Bamidis, P. (2020, Sep 2). Biosensor real-time affective analytics in virtual and mixed reality medical education serious games: cohort study. *JMIR Serious Games, 8*(3), e17823. https://doi.org/10.2196/17823

Araújo, D., Davids, K., & Hristovski, R. (2006). The ecological dynamics of decision making in sport. *Psychology of Sport and Exercise, 7*(6), 653–676. https://doi.org/10.1016/j.psychsport.2006.07.002

Araújo, D., Davids, K., & Passos, P. (2007). Ecological validity, representative design, and correspondence between experimental task constraints and behavioral setting: Comment on Rogers, Kadar, and Costall (2005). *Ecological Psychology, 19*(1), 69–78. https://doi.org/10.1080/10407410709336951

Araújo, D., Hristovski, R., Seifert, L., Carvalho, J., & Davids, K. (2019). Ecological cognition: expert decision-making behaviour in sport. *International Review of Sport and Exercise Psychology, 12*(1), 1–25. https://doi.org/10.1080/1750984x.2017.1349826

Armenteros, M., Benítez, A. J., Flores, R., Sillero-Quintana, M., Cid, M. S., & Simón, J. A. (2018). The training of soccer assistant referees beyond on-field experience: the use of the interactive video test. *International Journal of Computer Science in Sport, 17*(2), 163–174. https://doi.org/10.2478/ijcss-2018-0009

Balagué, N., Hristovski, R., & Vazquez, P. (2008). Ecological dynamics approach to decision making in sport. Training issues. *Education. Physical Training. Sport, 71*(4), 11–22.

Beach, L. R., & Lipshitz, R. (1993). Why classical decision theory is an inappropriate standard for evaluating and aiding most human decision making. In *Decision Making in Action: Models and Methods.* (pp. 21-35). Ablex Publishing.

Bechara, A., Damasio, H., & Damasio, A. R. (2003). Role of the amygdala in decision-making. *Annals of the New York Academy of Sciences, 985*, 356–369. https://doi.org/10.1111/j.1749-6632.2003.tb07094.x

Bideau, B., Multon, F., Kulpa, R., Fradet, L., Arnaldi, B., & Delamarche, P. (2004). Using virtual reality to analyze links between handball thrower kinematics and goalkeeper's reactions. *Neuroscience Letters, 372*, 119–122. https://doi.org/10.1016/j.neulet.2004.09.023

Bohil, C. J., Alicea, B., & Biocca, F. A. (2011). Virtual reality in neuroscience research and therapy. *Nature Reviews Neuroscience, 12*(12), 752–762. https://doi.org/10.1038/nrn3122

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77—101. https://doi.org/10.1191/1478088706qp063oa

Brault, S., Kulpa, R., Duliscouët, L., Marin, A., & Bideau, B. (2015). Virtual kicker vs. real goalkeeper in soccer: A way to explore goalkeeper's performance. *Movement & Sport Sciences, 89*, 79–88. https://doi.org/10.1051/sm/2015026

Broadbent, D. P., Causer, J., Williams, A. M., & Ford, P. R. (2015). Perceptual-cognitive skill training and its transfer to expert performance in the field: Future research directions. *European Journal of Sport Science, 15*(4), 322–331. https://doi.org/10.1080/17461391.2014.957727

Brunswik, E. (1952). *Conceptual Framework of Psychology*. Chicago: University of Chicago Press.

Brunswik, E. (1956). *Perception and the Representative Design of Psychological Experiments*. Berkeley and Los Angeles: University of California Press.

Castagna, C., Bizzini, M., Leguizamon, A.P., Pizzi, A., Torquati, R., & Povoas, S. (2020). Considerations & best practices for elite football officials return to play after COVID-19 confinement. *Managing Sport and Leisure*, 1-8. https://doi.org/10.1080/23750472.2020.1783841

Catteeuw, P., Gilis, B., Jaspers, A., Wagemans, J., & Helsen, W. (2010). Training of perceptual-cognitive skills in offside decision making. *Journal of sport & exercise psychology, 32*(6), 845–861. https://doi.org/10.1123/jsep.32.6.845

Catteeuw, P., Helsen, W., Gilis, B., & Wagemans, J. (2009). Decision-making skills, role specificity, and deliberate practice in association football refereeing. *Journal of Sports Sciences, 27*(11), 1125–1136. https://doi.org/10.1080/02640410903079179

Corrigan, S. L., Dwyer, D. B., Gastin, P. B., & Harvey, B. (2019). The influence of match characteristics and experience on decision-making performance in AFL umpires. *Journal of Science and Medicine in Sport, 22*(1), 112–116. https://doi.org/10.1016/j.jsams.2018.06.005

Craig, C. (2013). Understanding perception and action in sport: how can virtual reality technology help? *Sports Technology, 6*(4), 161–169. https://doi.org/10.1080/19346182.2013.855224

Croft, C., Spencer, K. & Robertson, S. (2021). What tactical and technical comments do coaches make during netball matches? A content analysis in netball, *International Journal of Performance Analysis in Sport,21*(1), 74–89. https://doi.org/10.1080/24748668.2020.1846112

Davids, K., Araujo, D., Vilar, L., Renshaw, I., & Pinder, R. (2013). An ecological dynamics approach to skill acquisition: implications for development of talent in sport. *Talent Development & Excellence, 5*, 21-34.

Davids, K., Kingsbury, D., Bennett, S. J., & Handford, C. (2015). Expert performance in sport: an ecological dynamics perspective. In *Routledge Handbook of Sport Expertise* (1st ed., pp. 130-144). Routledge.

Davis, S., Nesbitt, K., & Nalivaiko, E. (2014). *A systematic review of cybersickness.* Proceedings of the 2014 Conference on Interactive Entertainment, ACM, Newcastle NSW, Australia. https://doi.org/10.1145/2677758.2677780

Davis, N, & Lopz, M. (2015). Umpires are less blind than they used to be. Retrieved from https://fivethirtyeight.com/features/umpires-are-less-blind-than-they-used-to-be/

De Oliveira, M. C., Orbetelli, R., & De Barros Neto, T. L. (2011). Call accuracy and distance from the play: a study with Brazilian soccer referees. *International Journal of Exercise Science, 4*(1), 287-296.

Dicks, M., Seifert, L., Papet, V., Strafford, B. W., Coughlan, E. K., Davids, K., O'Halloran, J., & Navarro, M. (2019). Skill transfer, expertise and talent development: An ecological dynamics perspective. *Movement & Sport Sciences* (102), 39–49. https://doi.org/10.1051/sm/2019010

Duking, P., Holmberg, H. C., & Sperlich, B. (2018). The potential usefulness of virtual reality systems for athletes: A short SWOT analysis. *Frontiers in Physiology, 9*(128), 1–4. https://doi.org/10.3389/fphys.2018.00128

Edwards, W., & Newman, J.R. (1982). *Multiattribute Evaluation*. Sage Publications.

Ericsson, K. A., Krampe, R. T., & Tesch-Romer, C. (1993). The role of deliberate practice in the acquisition of expert performance. *Psychological Review, 100*(3), 363–406.

Ericsson, K.A. (2005). Recent Advances in Expertise Research: A Commentary on the Contributions to the Special Issue. *Applied Cognitive Psychology, 19*, 233–241.

Ford, P. R., Ward, P., Hodges, N. J., & Williams, A. M. (2009). The role of deliberate practice and play in career progression in sport: the early engagement hypothesis. *High Ability Studies, 20*(1), 65–75. https://doi.org/10.1080/13598130902860721

Gallagher, M., & Ferrè, E. (2018). Cybersickness: a multisensory integration perspective. *Multisensory Research, 31*(7), 645–674. https://doi.org/10.1163/22134808-20181293

Geršak, G., Lu, H., & Guna, J. (2018). Effect of VR technology matureness on VR sickness. *Multimedia Tools and Applications, 79*(21–22), 14491-14507. https://doi.org/10.1007/s11042-018-6969-2

Gibson, J. J. (1966). *The Senses Considered as Perceptual Systems*. Boston: Houghton-Mifflin.

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

Gilis, B., Helsen, W., Catteeuw, P., & Wagemans, J. (2008). Offside decisions by expert assistant referees in association football: Perception and recall of spatial positions in complex dynamic events. *Journal of Experimental Psychology: Applied, 14*(1), 21–35. https://doi.org/10.1037/1076-898X.14.1.21

Godse, A., Khadka, R., & Banic, A. (2019). Evaluation of visual perception manipulation in virtual reality training environments to improve golf performance. *2019 IEEE Conference on Virtual Reality and 3D User Interfaces (VR).* https://doi.org/10.1109/VR.2019.8798026

Gray, R. (2017). Transfer of training from virtual to real baseball batting. *Frontiers in Psychology, 8*(2183), 1–11. https://doi.org/10.3389/fpsyg.2017.02183

Guest, G., MacQueen, K.M., & Namey, E.E. (2012). *Applied Thematic Analysis*. SAGE Publications. https://doi.org/10.4135/9781483384436

Gulec, U., Yilmaz, M., Isler, V., O'Connor, R. V., & Clarke, P. M. (2019). A 3D virtual environment for training soccer referees. *Computer Standards & Interfaces, 64*, 1–10. https://doi.org/10.1016/j.csi.2018.11.004

Heeter, C. (1992). Being there: The subjective experience of presence. *Presence: Teleoperators and Virtual Environments, 1*(2), 262–271. https://doi.org/10.1162/pres.1992.1.2.262

Helsen, W. F., MacMahon, C., & Spitz, J. (2019). Decision making in match officials and judges. In A. M. Williams, & Jackson, R.C. (Ed.), *Anticipation and decision making in sport* (pp. 250–266). Taylor & Francis Group.

Henderson, K.A. (2011). Post-positivism and the pragmatics of leisure research. *Leisure Sciences, 33*(4), 341–346.

Hoffmann, C. P., Filippeschi, A., Ruffaldi, E., & Bardy, B. G. (2014). Energy management using virtual reality improves 2000-m rowing performance. *Journal of Sports Sciences, 32*(6), 501–509. https://doi.org/10.1080/02640414.2013.835435

Hoffman, D. M., Girshick, A. R., Akeley, K., & Banks, M. S. (2008). Vergence–accommodation conflicts hinder visual performance and cause visual fatigue. *Journal of Vision, 8*(3), 1–30. https://doi.org/10.1167/8.3.33

Hong, Q. N., Rees, R., Sutcliffe, K., & Thomas, J. (2020). Variations of mixed methods reviews approaches: A case study. *Research Synthesis Methods, 11*(6), 795–811. https://doi.org/https://doi.org/10.1002/jrsm.1437

Hossner, E. J., Schnyder, U., Schmid, J., & Kredel, R. (2019). The role of viewing distance and viewing angle on referees' decision-making performance during the FIFA World Cup 2014. *Journal of Sports Science, 37*(13), 1481–1489.

Howard, I. P. (2012). *Perceiving in Depth, Volume 1: Basic Mechanisms*. New York: Oxford University Press.

Howarth, P. A., & Hodder, S. G. (2008). Characteristics of habituation to motion in a virtual environment. *Displays, 29*(2), 117–123. https://doi.org/10.1016/j.displa.2007.09.009

Huang, J., & Hsu, H.-J. (2020). Approximating strike zone size and shape for baseball umpires under different conditions. *International Journal of Performance Analysis in Sport, 20*(2), 133-149. https://doi.org/10.1080/24748668.2020.1726156

Huang, Y., Churches, L., & Reilly, B. (2015). A case study on virtual reality American football training. *Proceedings of the 2015 Virtual Reality International Conference.* Laval, France. https://doi.org/10.1145/2806173.2806178

International Football Association Board (2020). *Laws of the Game*. Retrieved from https://resources.fifa.com/image/upload/ifab-laws-of-the-game-2020-21.pdf?cloudid=d6g1medsi8jrrd3e4imp

Iyer, G.N., Bala, V.S., Sohan, B., Dharmesh, R., & Raman V. (2020, May 13-15). Automated third umpire decision making in cricket using machine learning techniques. *International Conference on Computer, Communication, Chemical, Material & Electric Engineering* (1216-1221), Madurai, India. https://doi.org/10.1109/ICICCS48265.2020.9121078

Jones, B., & Kenward, M. G. (2014). *Design and Analysis of Cross-Over Trials* (Third ed.) CRC Press.

Jung, S. M., & Whangbo, T. K. (2018). Study on inspecting VR motion sickness inducing factors. *Proceedings of the 2017 4th International Conference on Computer Applications and Information Processing Technology*, 1–5.

Kittel, A., Larkin, P., Elsworthy, N., & Spittle, M. (2019a). Video-based testing in sporting officials: A systematic review. *Psychology of Sport and Exercise, 43*, 261–270. https://doi.org/10.1016/j.psychsport.2019.03.013

Kittel, A., Larkin, P., Elsworthy, N., & Spittle, M. (2019b). Using 360 degrees virtual reality as a decision-making assessment tool in sport. *Journal of Science and Medicine in Sport, 22*(9), 1049–1053. https://doi.org/10.1016/j.jsams.2019.03.012

Kittel, A., Larkin, P., Elsworthy, N., Lindsay, R., & Spittle, M. (2020). Effectiveness of 360° virtual reality and match broadcast video to improve decision-making skill. *Science and Medicine in Football*, 1–8. https://doi.org/10.1080/24733938.2020.1754449

Kittel, A., Larkin, P., Elsworthy, N., & Spittle, M. (2021). Transfer of 360° virtual reality and match broadcast video-based tests to on-field decision-making. *Science and Medicine in Football, 5*(1), 79–86. https://doi.org/10.1080/24733938.2020.1802506

Kolasinski, E. M., & Gilson, R. D. (1998). Simulator sickness and related findings in a virtual environment. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 42*(21), 1511–1515. https://doi.org/10.1177/154193129804202110

Kowser, M., Alam, M.A., Uddin, M.J., Ahmed, F., Ulla, M.W., & Islam, M.R. (2019, July 11-12). Detecting third umpire decisions & automated scoring system of cricket.

International Conference on Computer, Communication, Chemical, Material & Electric Engineering, Rajshahi, Bangladesh. *https://doi.org*/10.1109/IC4ME247184.2019.9036705

Larkin, P., Berry, J., Dawson, B., & Lay, B. (2011). Perceptual and decision-making skills of Australian football umpires. *International Journal of Performance Analysis in Sport, 11*(3), 427–437. https://doi.org/10.1080/24748668.2011.11868562

Larkin, P., Mesagno, C., Berry, J., Spittle, M., & Harvey, J. (2017). Video-based training to improve perceptual-cognitive decision-making performance of Australian football umpires. *Journal of Sports Sciences, 36*, 1–8. https://doi.org/10.1080/02640414.2017.1298827

Larkin, P., Mesagno, C., Spittle, M., & Berry, J. (2015). An evaluation of video-based training programs for perceptual-cognitive skill development. A systematic review of current sport-based knowledge. *International Journal of Sport Psychology, 46*, 555–586.

MacMahon, C., Starkes, J., & Deakin, J. (2007). Referee decision making in a video-based infraction detection task: application and training considerations. *International Journal of Sports Science & Coaching, 2*(3), 257–265.

MacMahon, C., & Starkes, J. L. (2008). Contextual influences on baseball ball-strike decisions in umpires, players, and controls. *Journal of Sports Sciences, 26*(7), 751-760. https://doi.org/10.1080/02640410701813050

MacMahon, C., Mascarenhas, D., Plessner, H., Pizzera, A., Oudejans, R., Raab, M., & Oudejans, R. (2014). *Sports Officials and Officiating: Science and Practice*. Taylor & Francis Group. http://ebookcentral.proquest.com/lib/aut/detail.action?docID=1873767

MacQuarrie, A., & Steed, A. (2017). Cinematic virtual reality: Evaluating the effect of display type on the viewing experience for panoramic video. *2017 IEEE Virtual Reality*, 45–54. https://doi.org/10.1109/VR.2017.7892230

Mallo, J., Frutos, P., Juárez, D., & Navarro, E. (2012). Effect of positioning on the accuracy of decision making of association football top-class referees and assistant referees during competitive matches. *Journal of Sports Sciences, 30*(13), 1437–1445

Mann, D., Williams, A., Ward, P., & Janelle, C. (2007). Perceptual-cognitive expertise in sport: A meta-analysis. *Journal of Sport & Exercise Psychology, 29*, 457–478. https://doi.org/10.1123/jsep.29.4.457

Māna definition (2021). Retrieved January 10, 2021 from https://maoridictionary.co.nz/search?idiom=&phrase=&proverb=&loan=&histLoanWords=&keywords=mana

Mascarenhas, D. (2005). Helping the Man in the Middle: *Assessing and Training Referee Performance.* [Unpublished Doctoral Dissertation]. The University of Edinburgh.

Matthews, T. D., & Kostelis, K. T. (2019). *Designing and Conducting Research in Health and Human Performance*. Taylor & Francis Group. http://ebookcentral.proquest.com/lib/aut/detail.action?docID=5984480

Mills, B. M. (2017). Technological innovations in monitoring and evaluation: Evidence of performance impacts among Major League Baseball umpires. *Labour Economics, 46,* 189-199. https://doi.org/10.1016/j.labeco.2016.10.004

Mojtahed, R., Nunes, M. B., Martins, J. T., & Peng, A. (2014). Equipping the constructivist researcher: the combined use of semi-structured interviews and decision-making maps. *Electronic Journal of Business Research Methods, 12*(2), 87–95.

Morris, G., & O'Connor, D. (2017). Key attributes of expert NRL referees. *Journal of Sports Sciences, 35*(9), 852-857. https://doi.org/http://dx.doi.org/10.1080/02640414.2016.1194524

MoveWell (n.d.). *Striking and fielding games*. Retrieved from https://penz.org.nz/wp-content/uploads/2021/05/Movewell-Booklet-4-Striking-and-Fielding-Games.pdf

Mygind, Debbie (2011). *Softball NZ Measurable Velocity Standards.* https://www.softball.org.nz/site/softballnz/images/Development/Pitching/Measurable%20Velocity%20Standards2011.pdf

National Football League (2020). *Official Playing Rules of the National Football League.* Retrieved from https://operations.nfl.com/media/4693/2020-nfl-rulebook.pdf

Nazarudin, M. N., Suppiah, K., Abdullah, M.R., Fauzee, M.S.O., Parnabas, V., & Abdullah, N.M. (2015). Decision making and performance of Malaysian rugby sevens referees. *Movement, Health & Exercise, 4*(1), 61–75. https://doi.org/https://doi.org/10.15282/mohe.v4i0.45

Nelikanti A., Reddy, G.V.R., & Karuna, G. (2021). An optimization based deep LSTM predictive analysis for decision making in cricket [conference presentation]. In J. S. Raj, A. M. Iliyasu, R. Bestak, & Z. A. Baig (Eds.), *Innovative Data Communication Technologies and Application* (pp. 721-737*),* Singapore. https://doi.org/10.1007/978-981-15-9651-3_59

Neuendorf, K. (2017). *The Content Analysis Guidebook* (Second ed.). SAGE Publications, Inc https://www.doi.org/10.4135/9781071802878

Neumann, D. L., Moffitt, R. L., Thomas, P. R., Loveday, K., Watling, D. P., Lombard, C. L., Antonova, S., & Tremeer, M. A. (2017). A systematic review of the application of interactive virtual reality to sport. *Virtual Reality, 22*(3), 183–198. https://doi.org/10.1007/s10055-017-0320-5

Nevill, A., Webb, T., & Watts, A. (2013). Improved training of football referees and the decline in home advantage post-WW2. *Psychology of Sport and Exercise, 14*(2), 220–227. https://doi.org/10.1016/j.psychsport.2012.11.001

Oman, C. M. (1990). Motion sickness: a synthesis and evaluation of the sensory conflict theory. *Canadian Journal of Physiology and Pharmacology, 68*(2), 294–303. https://doi.org/10.1139/y90-044

Page, C., Bernier, P. M., & Trempe, M. (2019). Using video simulations and virtual reality to improve decision-making skills in basketball. *Journal of Sports Sciences, 37*(21), 2403–2410. https://doi.org/10.1080/02640414.2019.1638193

Petit, J. P., & Ripoll, H. (2008). Scene perception and decision making in sport simulation: A masked priming investigation. *International Journal of Sport Psychology, 39*, 1–19.

Pinder, R., Davids, K., Renshaw, I., & Araujo, D. (2011). Representative learning design and functionality of research and practice in sport. *Journal of sport & exercise psychology, 33,* 146–155. https://doi.org/10.1123/jsep.33.1.146

Pinder, R. A., Headrick, J., & Oudejans, R.R.D. . (2015). Issues and challenges in developing representative tasks in sport. In Baker, J. & Farrow, D. (Ed.), *Routledge Handbook of Sports Expertise* (pp. 269–281). Taylor & Francis Group.

Plessner, H., & MacMahon, C. (2013). The sports official in research and practice. In D. Farrow, Baker, J., MacMahon, C. (Ed.), *Developing sport expertise: Researchers and coaches put theory into practice* (pp. 71–95). Routledge.

Renshaw, I., Davids, K., Araujo, D., Lucas, A., Roberts, W. M., Newcombe, D. J., & Franks, B. (2019). Evaluating weaknesses of "perceptual-cognitive training" and "brain training" methods in sport: an ecological dynamics critique. *Frontiers in Psychology, 9* (2468), 1–14. https://doi.org/10.3389/fpsyg.2018.02468

Riva, G., Wiederhold, B. K., & Mantovani, F. (2019). Neuroscience of virtual reality: from virtual exposure to embodied medicine. *Cyberpsychology, Behavior, and Social Networking, 22*(1), 82–96. https://doi.org/10.1089/cyber.2017.29099.gri

Roca, A., & Williams, A. M. (2016). Expertise and the interaction between different perceptual-cognitive skills: Implications for testing and training. *Frontiers in Psychology, 7*(792), 1–4. https://doi.org/10.3389/fpsyg.2016.00792

Ryan, A.B. (2006). Post-positivist approaches to research. In M.M. Antonesa, H. Fallon, A.B. Ryan, A. Ryan, T. Walsh, & L. Borys (Eds.), *Researching and Writing your Thesis: a Guide for Postgraduate Students* (pp. 12-26). Maynooth, Ireland: National University of Ireland.

Samuel, R. D. (2017). Training prospective soccer referees using a deliberate practice perspective: The Israeli excellence program. *Journal of Sport Psychology in Action, 8*(3), 184–196. https://doi.org/10.1080/21520704.2017.1287798

Samuel, R. D., Galily, Y., Guy, O., Sharoni, E., & Tenenbaum, G. (2019). A decision-making simulator for soccer referees. *International Journal of Sports Science & Coaching, 14*(4), 480–489. https://doi.org/10.1177/1747954119858696

Sandelowski, M. (2000). Focus on research methods: Whatever happened to qualitative description? *Research in Nursing and Health, 23*(4), 334–340.

Saredakis, D., Szpak, A., Birckhead, B., Keage, H. A. D., Rizzo, A., & Loetscher, T. (2020). Factors associated with virtual reality sickness in head-mounted displays: a systematic review and meta-analysis. *Frontiers in Human Neuroscience, 14* (96), 1–17. https://doi.org/10.3389/fnhum.2020.00096

Schmidt, R. A., & Lee, T. (1999). *Motor Control and Learning* (3rd ed.). Human Kinetics.

Schweizer, G., Plessner, H., Kahlert, D., & Brand, R. (2011). A video-based training method for improving soccer referees' intuitive decision-making skills. *Journal of Applied Sport Psychology, 23*(4), 429–442. https://doi.org/10.1080/10413200.2011.555346

Seifert, L., Papet, V., Strafford, B. W., Coughlan, E. K., & Davids, K. (2018). Skill transfer, expertise and talent development: An ecological dynamics perspective. *Movement & Sport Sciences*, 39–49.

Shivakumar, R. (2016). What technology says about decision-making. *Journal of Sports Economics, 19*(3), 315-331. https://doi.org/10.1177/1527002516657218

Slater, M. (2009). Place illusion and plausibility can lead to realistic behaviour in immersive virtual environments. *Philosophical Transactions: Biological Sciences, 364*(1535), 3549–3557. https://doi.org/10.1098/rstb.2009.0138

Smith, M. (2017). *Research Methods in Sport*. SAGE Publications. http://ebookcentral.proquest.com/lib/aut/detail.action?docID=6408530

Softball New Zealand (2020a). *Softball New Zealand Umpire: Level One Workbook.* https://www.softball.org.nz/site/softballnz/files/SNZ%20Level%20One%20Workbook.pdf

Softball New Zealand (2020b). *Softball New Zealand Umpire: Level Two Workbook.* https://www.softball.org.nz/site/softballnz/L2%20Workbook%20V1.0%20FINAL%20April%202020.docx.pdf

Softball New Zealand (n.d.a). *About SNZ.* Retrieved January 10, 2021, from https://www.softball.org.nz/Softball+NZ/About+SNZ.html

Softball New Zealand (n.d.b). Welcome to the Home Page of the Softball New Zealand Umpires (SNZU). Retrieved November 15th, 2020, from https://www.softball.org.nz/GET+INVOLVED/SNZ+Umpires/SNZ+Umpires.html

Somrak, A., Humar, I., Hossain, M. S., Alhamid, M. F., Hossain, M. A., & Guna, J. (2019). Estimating VR Sickness and user experience using different HMD technologies: an evaluation study. *Future Generation Computer Systems, 94*, 302–316. https://doi.org/10.1016/j.future.2018.11.041

Spitz, J., Put, K., Wagemans, J., Williams, A. M., & Helsen, W. F. (2016). Visual search behaviors of association football referees during assessment of foul play situations.

Cognitive research: principles and implications, 1(1), 12. https://doi.org/10.1186/s41235-016-0013-8

Starkes, J., Helsen, W., & Jack, R. (2001). Expert performance in sport and dance. In R. Singer, H. Hausenblas, & C. Janelle (Eds.), *Handbook of sport psychology* (pp. 174–201). Wiley.

Stoffregen, T., Bardy, B., Smart, J., & Pagulayan, R. (2003). On the nature and evaluation of fidelity in virtual environments. In L. J. Hettinger & M. W. Haas (Eds.), *Virtual and Adaptive Environments: Applications, Implications, and Human Performance Issues* (pp. 111–128). Lawrence Erlbaum Associates, Inc. https://doi.org/10.1201/9781410608888.ch6

Stone, J. A., Strafford, B. W., North, J. S., Toner, C., & Davids, K. (2018). Effectiveness and efficiency of virtual reality designs to enhance athlete development: An ecological dynamics perspective. *Movement & Sport Sciences 102*, 51–60. https://doi.org/10.1051/sm/2018031

Szymanski, D. J., & Fredrick, G. A. C. (2001). Baseball (Part II): A Periodized Speed Program. *Strength & Conditioning Journal, 23*(2), 44–52. https://doi.org/10.1519/1533-4295(2001)023<0044:BPIAPS>2.0.CO;2

Tenenbaum, G., Basevitch, I., Gershgoren, L., & Filho, E. (2013). Emotions–decision-making in sport: theoretical conceptualization and experimental evidence. *International Journal of Sport and Exercise Psychology, 11*(2), 151–168. https://doi.org/10.1080/1612197X.2013.773687

Terry, G., Hayfield, N., Clarke, V., & Braun, V. (2017). Thematic analysis. In Willig, C. & Rogers, W.S. (Eds.), *The SAGE Handbook of Qualitative Research in Psychology* (pp. 17–37). SAGE Publications. http://ebookcentral.proquest.com/lib/aut/detail.action?docID=4882015

Ting, S., & Chilukuri, M.S. (2009, May 5-7). Novel pattern recognition technique for an intelligent cricket decision making system [Paper presentation]. *IEEE International Instrumentation and Measurement Technology Conference*, Singapore. https://doi.org/10.1109/IMTC.2009.5168594

Venkatesh, V., Brown, S. A., & Bala, H. (2013). Bridging the qualitative-quantitative Divide: guidelines for conducting mixed methods research in information systems. *MIS Quarterly, 37*(1), 21–54. http://www.jstor.org.ezproxy.aut.ac.nz/stable/43825936

Vignais, N., Bideau, B., Craig, C., Brault, S., Multon, F., Delamarche, P., & Kulpa, R. (2009). Does the level of graphical detail of a virtual handball thrower influence a goalkeeper's motor response? *Journal of Sports Science & Medicine, 8*, 501–508.

Vinesh, C.H., & Sujatha, B.M. (2015). Smart third umpire decision assisting system using PLC. *International Journal of Engineering Research in Computer Science and Engineering, 2*(11), 31-36.

Walters, S., Schluter, P., Stamp, D., Thomson, R., Payne, D. (2016). Coaches and referees' perspectives of sideline behaviour in children's team sports: A cross-sectionals study. *International Journal of Sport Management, Recreation & Tourism, 23*, 51–74.

Watson, G., Brault, S., Kulpa, R., Bideau, B., Butterfield, J., & Craig, C. (2011). Judging the 'passability' of dynamic gaps in a virtual rugby environment. *Human Movement Science, 30*(5), 942–956. https://doi.org/10.1016/j.humov.2010.08.004

Webb, T. (2014). *Elite association football referee training and officiating: a comparative analysis of refereeing practices in three European leagues* [Doctoral dissertation, University of Portsmouth]. https://ethosuk.ezproxy.aut.ac.nz/OrderDetails.do?uin=uk.bl.ethos.714132

Wellek, S., & Blettner, M. (2012). On the proper use of the crossover design in clinical trials: Part 18 of a series on evaluation of scientific publications. *Deutsches Ärzteblatt Internationa, 109*(15), 276–281. https://doi.org/10.3238/arztebl.2012.0276

Williams, A. M., & Grant, A. (1999). Training perceptual skill in sport. *International Journal of Sport Psychology, 30*, 194–220.

World Baseball Softball Confederation (2017a). *2018-2021 Official Rules of Softball: Fast Pitch.* Retrieved from https://s3-eu-west-1.amazonaws.com/static-staging.wbsc.org/assets/cms/documents/e77d989a-a798-e635-f180-a94a6cae20ff.pdf

World Baseball Softball Confederation (2017b, May 20). *Report: Baseball/Softball top list as most participated team sport in U.S.* https://www.wbsc.org/news/report-baseballsoftball-top-list-as-most-participated-team-sport-in-u-s

World Baseball Softball Confederation (2020a). *WBSC Softball Field Mechanics: 3 & 4 Umpire System.* Retrieved from https://s3-eu-west-1.amazonaws.com/static.wbsc.org/assets/cms/documents/71548729-ab35-3d0b-f5bd-75db2bec8216.pdf

World Baseball Softball Confederation (2020b). *Umpire Manual: Fast Pitch*. Retrieved from https://s3-eu-west-1.amazonaws.com/static.wbsc.org/assets/cms/documents/8afc03ba-1129-44a4-7e96-f530dcbdbebe.pdf

Appendices

Appendix A: 360° VR Filming Information Sheet

Participant Information Sheet (360° Video Filming)

Umpires and softball players in Softball New Zealand

Date Information Sheet Produced:

13 November 2019

Project Title

Training decision-making in softball umpires using 360° virtual reality

An Invitation

Kia Ora!

You are invited to take part in a novel decision-making research study that is likely to be the first of its kind in New Zealand. My name is Keone Kaiser and I am a candidate for a Master's of Sport and Exercise at AUT. This study involves enhancing softball umpire development (through VR technology) capturing all the action (safes and outs) at the second base, recorded using the 360°camera in two Softball NZ tournaments being held in New Zealand in January and February 2020. You will need to explicitly consent to being identified in the consent form and also need to explicitly consent to having your data shared with AUT.

What is the purpose of this research?

By combining 360°video of crucial softball plays (at 2nd base) and VR technology, this research seeks to determine if VR technology can be utilised to improve decision-making of sports officials. The research compares whether training umpire decision-making is enhanced through the 360° VR training footage compared to using Softball NZ broadcast video.

As such, the novel research will inform sports scientists, coaches and the wider softball community on methods to improve umpire decision-making performance, and methods implementing virtual reality for skill acquisition.

The findings of this research may be used for academic publications and presentations, and will be used towards the researcher's qualifications for a Master's in Sport and Exercise.

How was I identified and why am I being invited to participate in this research?

You have received this information sheet because you expressed interest in participating in this research, and are a Softball NZ umpire of level 1 to level 7.

How do I agree to participate in this research?

A Consent Form is required to be read and signed by you the participant which is obtained at the same time as the information sheet. Your participation in this research is voluntary (it is your choice) and whether or not you choose to participate will neither advantage nor disadvantage you. You are able to withdraw from the study at any time. If you choose to withdraw from the study, then you will be offered the choice between having any data that is identifiable as belonging to you removed or allowing it to continue to be used. However, once the findings have been produced, removal of your data may not be possible.

What will happen in this research?

The research will be divided into two parts: (1) data collection from broadcast video of previous games and 360 video of upcoming games; (2) data analysis.

For the data collection from 360 video:

You will have a Samsung Gear 360° camera mounted on your cap via a special head harness kit, and these cameras will be active during the duration of the game. These cameras weigh approximately 130 g, and measures 10.6 cm x 4.6 cm x 4.5 cm. They will be encased in a silicone case to protect

from any damage. For reference, please see the attached images of the camera, head harness kit, and silicone protective case.

Filming is expected to last from January to March.

What are the discomforts and risks?

It is not anticipated that participants will experience discomfort, which would be greater than that occurring as part of their normal sports officiating duties.

There could be some discomfort when wearing the VR headsets. Some participants may feel uncomfortable being filmed.

There is a possibility that umpires will not find the cap-mounted cameras comfortable.

How will these discomforts and risks be alleviated?

Alternative camera mounts are possible, including shoulder-mounted units, that some participants may find more comfortable.

What compensation is available for injury or negligence?

In the unlikely event of a physical injury as a result of your participation in this study, rehabilitation and compensation for injury by accident may be available from the Accident Compensation Corporation, providing the incident details satisfy the requirements of the law and the Corporation's regulations.

What are the benefits?

This research will provide a novel way of coaching that has previously been used in softball before and will likely improve participants' decision-making skills. It will also provide insights into ways to further enhance umpire training methods.

For softball umpires:

The potential benefits are directly correlated with their umpire duties. These benefits include improved decision-making in softball games. This research may benefit the less-experienced umpires, and serve as a method to improve their skills, potentially accelerating their development and ascension to a level 7 qualification.

For the researcher:

The research serves as a requirement for obtaining his Masters in Sports and Exercise from AUT. Additionally, the research can improve his skills and knowledge in this particular realm. It is hoped that this research can serve as a potential springboard towards future research.

For the wider sports science community:

this research can add to the body of knowledge on Virtual Reality and training decision-making in sports officials. At present, there is a gap in the literature on this subject. It is hoped that this research can inform future researchers on this particular area, as well as sports officials in other sports.

How will my privacy be protected?

Anonymity of umpires will be ensured via ID number assigned to them (the researcher will only see their names on the consent forms).

Only the primary researcher and supervisors will have access to data from the participants. This data will be kept in a secure data storage facility. All data will be deleted. Consent forms will also be kept in the same secure storage facility, and will be destroyed via paper shredder after six years.

What are the costs of participating in this research?

The participant will incur no additional time or financial costs in this research, only their normal game time.

What opportunity do I have to consider this invitation?

Participants will have two weeks to consider the invitation.

Will I receive feedback on the results of this research?

Feedback will be provided on the findings by ways of email if they wish to have them.

Will I receive any compensation for participating in this research?

For their efforts, umpire participants will receive koha in the form of a petrol or supermarket gift card with an approximate $25 value.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor,

Kirsten Spencer, kirsten.spencer@aut.ac.nz, 09 921 9999 x 7239

Concerns regarding the conduct of the research should be notified to the Executive Secretary of AUTEC, Kate O'Connor, *ethics@aut.ac.nz* , 921 9999 ext 6038.

Whom do I contact for further information about this research?

Please keep this Information Sheet and a copy of the Consent Form for your future reference. You are also able to contact the research team as follows:

Researcher Contact Details:

Keone Kaiser, keone.kaiser@gmail.com, 02108354696

Project Supervisor Contact Details:

Kirsten Spencer, kirsten.spencer@aut.ac.nz, 09 921 9999 x 7239

Approved by the Auckland University of Technology Ethics Committee on 10/12/2019, AUTEC Reference number 19/449.

Samsung Gear 360° Camera

Camera with camera mount

Head mount for camera

Appendix B: Broadcast Video Information Sheet

Participant Information Sheet for Softball NZ Broadcast Video

Umpires and softball players in Softball New Zealand

Date Information Sheet Produced:

13 November 2019

Project Title

Training decision-making in softball umpires using 360° virtual reality

An Invitation

Kia Ora!

You are invited to take part in a novel decision-making research study that is likely to be the first of its kind in New Zealand. My name is Keone Kaiser and I am a candidate for a Master's of Sport and Exercise at AUT. This study involves enhancing softball umpire development (through VR technology) capturing all the action (safes and outs) at the second base, recorded using the 360°camera in two Softball NZ tournaments being held in New Zealand in January and February 2020. You will need to explicitly consent to being identified in the consent form and also need to explicitly consent to having your data shared with AUT.

What is the purpose of this research?

By combining 360°video of crucial softball plays (at 2nd base) and VR technology, this research seeks to determine if VR technology can be utilised to improve decision-making of sports officials. The research compares whether training umpire decision-making is enhanced through the 360° VR training footage compared to using Softball NZ broadcast video.

As such, the novel research will inform sports scientists, coaches and the wider softball community on methods to improve umpire decision-making performance, and methods implementing virtual reality for skill acquisition.

The findings of this research may be used for academic publications and presentations, and will be used towards the researcher's qualifications for a Master's in Sport and Exercise.

How was I identified and why am I being invited to participate in this research?

You have received this information sheet because you expressed interest in participating in this research, and are a Softball NZ level 1 to level 7 umpire.

How do I agree to participate in this research?

A Consent Form is required to be read and signed by you the participant which is obtained at the same time as the information sheet. Your participation in this research is voluntary (it is your choice) and whether or not you choose to participate will neither advantage nor disadvantage you. You are able to withdraw from the study at any time. If you choose to withdraw from the study, then you will be offered the choice between having any data that is identifiable as belonging to you removed or allowing it to continue to be used. However, once the findings have been produced, removal of your data may not be possible.

What will happen in this research?

The research will be divided into two parts: (1) data collection from broadcast video of previous games and 360 video of upcoming games; (2) data analysis.

For the data collection from broadcast video:

Publicly accessible broadcast video of previous softball games which may include video of you, will be collected. We will then use Sportscode computer software, to select video clips of all the actions

that occur only at the second base. These clips will contain the action of the players, they will not contain any images of the umpire.

What are the discomforts and risks?

It is not anticipated that participants will experience discomfort as you are participating in softball games as per usual routine activity.

What compensation is available for injury or negligence?

In the unlikely event of a physical injury as a result of your participation in this study, rehabilitation and compensation for injury by accident may be available from the Accident Compensation Corporation, providing the incident details satisfy the requirements of the law and the Corporation's regulations.

What are the benefits?

This research will ultimately provide a novel way of coaching that has not been done and will likely improve participants' decision-making ability. It will also provide insights into ways to further enhance training methods.

For softball umpires:

The potential benefits are directly correlated with their umpire duties. These benefits include improved decision-making in softball games. This research may benefit the less-experienced umpires, and serve as a method to improve their skills, potentially accelerating their **development and ascension to a level 7 qualification.**

For the researcher:

The research serves as a requirement for obtaining his Masters in Sports and Exercise from AUT. Additionally, the research can improve his skills and knowledge in this particular realm. It is hoped that this research can serve as a potential springboard towards future research.

For the wider sports science community:

This research can add to the body of knowledge on Virtual Reality and training decision-making in sports officials. At present, there is a gap in the literature on this subject. It is hoped that this research can inform future researchers on this particular area, as well as sports officials in other sports.

How will my privacy be protected?

Anonymity of umpires will be ensured via ID number assigned to them (the researcher will only see their names on the consent forms). Additionally, any video or images of umpires in broadcast videos will be removed via computer software.

Only the primary researcher and supervisors will have access to data from the participants. This data will be kept in a secure data storage facility. All data will be deleted. Consent forms will also be kept in the same secure storage facility, and will be destroyed via paper shredder after six years.

What are the costs of participating in this research?

As the games were previously broadcasted, particpants in the broadcast video will incur no additional costs.

What opportunity do I have to consider this invitation?

Participants will have two weeks to consider the invitation.

Will I receive feedback on the results of this research?

Feedback will be provided on the findings by ways of email if they wish to have them.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor, Kirsten Spencer, kirsten.spencer@aut.ac.nz, 09 921 9999 x 7239

Concerns regarding the conduct of the research should be notified to the Executive Secretary of AUTEC, Kate O'Connor, *ethics@aut.ac.nz* , 921 9999 ext 6038.

Whom do I contact for further information about this research?

Please keep this Information Sheet and a copy of the Consent Form for your future reference. You are also able to contact the research team as follows:

Researcher Contact Details:

Keone Kaiser, keone.kaiser@gmail.com, 02108354696

Project Supervisor Contact Details:

Kirsten Spencer, kirsten.spencer@aut.ac.nz, 09 921 9999 x 7239

Approved by the Auckland University of Technology Ethics Committee on *10/12/2019*, AUTEC Reference number *19/449.*

Appendix C: Expert Panel Information Sheet (Stage 1)

Participant Information Sheet (Expert Panel)

Umpires and softball players in Softball New Zealand

Date Information Sheet Produced:

13 November 2019

Project Title

Training decision-making in softball umpires using 360° virtual reality

An Invitation

Kia Ora!

You are invited to take part in a novel decision-making research study that is likely to be the first of its kind in New Zealand. My name is Keone Kaiser and I am a candidate for a Master's of Sport and Exercise at AUT. This study involves enhancing softball umpire development (through VR technology) capturing all the action (safes and outs) at the second base, recorded using the 360°camera in two Softball NZ tournaments being held in New Zealand in January and February 2020. You will need to explicitly consent to being identified in the consent form and also need to explicitly consent to having your data shared with AUT.

What is the purpose of this research?

By combining 360°video of crucial softball plays (at 2nd base) and VR technology, this research seeks to determine if VR technology can be utilised to improve the development of decision-making of sports officials. The research compares whether training umpire decision-making is enhanced through the 360° VR training footage compared to using Softball NZ broadcast video.

As such, the novel research will inform sports scientists, coaches and the wider softball community on methods to improve umpire decision-making performance, and methods implementing virtual reality for skill acquisition

The findings of this research may be used for academic publications and presentations, and will be used towards the researcher's qualifications for a Master's in Sport and Exercise.

How was I identified and why am I being invited to participate in this research?

You have received this information sheet because you expressed interest in participating in this research, and are a Softball NZ umpire of level 6 to level 7.

How do I agree to participate in this research?

A Consent Form is required to be read and signed by you the participant which is obtained at the same time as the information sheet. Your participation in this research is voluntary (it is your choice) and whether or not you choose to participate will neither advantage nor disadvantage you. You are able to withdraw from the study at any time. If you choose to withdraw from the study, then you will be offered the choice between having any data that is identifiable as belonging to you removed or allowing it to continue to be used. However, once the findings have been produced, removal of your data may not be possible.

What will happen in this research?

You will be asked to view and determine various videos of previously broadcasted Softball NZ games, and determine if a runner is safe or out. Please attempt to arrive at a consensus with your fellow expert panel peers on the correct call of the plays. These decisions will later be used to determine the accuracy of decision-making for other research participants.

What are the discomforts and risks?

It is not anticipated that participants will experience discomfort, which would be greater than that occurring as part of their normal video viewing experiences.

How will these discomforts and risks be alleviated?

The expert panel participants may opt out of the research at any time.

What compensation is available for injury or negligence?

In the unlikely event of a physical injury as a result of your participation in this study, rehabilitation and compensation for injury by accident may be available from the Accident Compensation Corporation, providing the incident details satisfy the requirements of the law and the Corporation's regulations.

What are the benefits?

This research will provide a novel way of coaching that has not been done and will likely improve participants' decision-making ability. It will also provide insights into ways to further enhance training methods.

For softball umpires:

The potential benefits are directly correlated with their umpire duties. These benefits include improved decision-making in softball games. This research may benefit the less-experienced umpires, and serve as a method to improve their skills, potentially accelerating their development and ascension to a level 7 qualification.

For the researcher:

The research serves as a requirement for obtaining his Masters in Sports and Exercise from AUT. Additionally, the research can improve his skills and knowledge in this particular realm. It is hoped that this research can serve as a potential springboard towards future research.

For the wider sports science community:

This research can add to the body of knowledge on Virtual Reality and training decision-making in sports officials. At present, there is a gap in the literature on this subject. It is hoped that this research can inform future researchers on this particular area, as well as sports officials in other sports.

How will my privacy be protected?

Anonymity of expert-panel umpires will be ensured via ID number assigned to them (the researcher will only see their names on the consent forms, and thus these names will not be associated with the decisions of these participants).

Only the primary researcher and supervisors will have access to data from the participants. This data will be kept in a secure data storage facility. All data will be deleted. Consent forms will also be kept in the same secure storage facility, and will be destroyed via paper shredder after six years.

What are the costs of participating in this research?

The total time umpire participants will be required to give to the project will be approximately 4 hours.

What opportunity do I have to consider this invitation?

Participants will have two weeks to consider the invitation.

Will I receive feedback on the results of this research?

Feedback will be provided on the findings by ways of email if they wish to have them.

Will I receive any compensation for participating in this research?

For their efforts, umpire participants will receive koha in the form of a petrol or supermarket gift card with an approximate $25 value.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor, Kirsten Spencer, kirsten.spencer@aut.ac.nz, 09 921 9999 x 7239

Concerns regarding the conduct of the research should be notified to the Executive Secretary of AUTEC, Kate O'Connor, *ethics@aut.ac.nz* , 921 9999 ext 6038.

Whom do I contact for further information about this research?

Please keep this Information Sheet and a copy of the Consent Form for your future reference. You are also able to contact the research team as follows:

Researcher Contact Details:

Keone Kaiser, keone.kaiser@gmail.com, 02108354696

Project Supervisor Contact Details:

Kirsten Spencer, kirsten.spencer@aut.ac.nz, 09 921 9999 x 7239

Approved by the Auckland University of Technology Ethics Committee on *10/12/2019*, AUTEC Reference number *19/449.*

Appendix D: Video Viewing and Ecological Validity Information Sheet

Participant Information Sheet (Video Viewing and Ecological Validity)

Umpires and softball players in Softball New Zealand

Date Information Sheet Produced:

22 June 2020

Project Title

Training decision-making in softball umpires using 360° virtual reality

An Invitation

Kia Ora!

You are invited to take part in a novel decision-making research study that is likely to be the first of its kind in New Zealand. My name is Keone Kaiser and I am a candidate for a Master's of Sport and Exercise at AUT. This study involves enhancing softball umpire development (through VR technology) capturing all the action (safes and outs) at the second base, recorded using the 360°camera at a Softball NZ national tournament held in New Zealand on January 2020. You will need to explicitly consent to being identified in the consent form and also need to explicitly consent to having your data shared with AUT.

What is the purpose of this research?

By combining 360°video of crucial softball plays (at 2nd base) and VR technology, this research seeks to determine if VR technology can be utilised to improve decision-making of sports officials. The research compares whether training umpire decision-making is enhanced through the 360° VR training footage compared to using Softball NZ broadcast video.

As such, the novel research will inform sports scientists, coaches and the wider softball community on methods to improve umpire decision-making performance, and methods implementing virtual reality for skill acquisition

The findings of this research may be used for academic publications and presentations and will be used towards the researcher's qualifications for a Master's in Sport and Exercise.

How was I identified and why am I being invited to participate in this research?

You have received this information sheet because you are a Softball NZ umpire of level 1 to level 7 who expressed interest in participating in this research and were subsequentially invited to a meeting and/or hui for umpires.

How do I agree to participate in this research?

A Consent Form is required to be read and signed by you the participant which is obtained at the same time as the information sheet. Your participation in this research is voluntary (it is your choice) and whether or not you choose to participate will neither advantage nor disadvantage you. You are able to withdraw from the study at any time. If you choose to withdraw from the study, then you will be offered the choice between having any data that is identifiable as belonging to you removed or allowing it to continue to be used. However, once the findings have been produced, removal of your data may not be possible.

What will happen in this research?

The research will consist of viewing video clips of selected 2nd base softball plays in two formats: (1) 2D broadcast video; (2) 360° VR video

You will be randomly assigned to one of 2 groups (Group A or Group B), and then provided with a demographic questionnaire to complete. This is expected to take approximately one minute to finish.

After completion of the questionnaire, you will be asked to watch 10 3-5 second-long video clips in either the 2D broadcast format or the 360° VR format. These video clips will be watched separately from the other umpires.

The 2D Broadcast videos will be provided via a Google Drive link to your provided e-mail address. Prior to each play, there will be a two-second long white screen to designate the beginning of the play, after which the second-base play presentation will automatically commence. A two-second long black screen will designate the end of the play. After each clip, you will pause the clip and mark whether the call was safe or out on the provided Google document. The order of these clips will be randomised for each participant. The total expected time for this portion of the research is estimated at 1.5 -2 minutes.

To view the 360° VR videos, participants will be asked to meet with the researcher in a secure location of the participant's choosing. The researcher will then assist the participant with setting up the Samsung Gear Head Mounted Display (HMD) VR unit and Samsung Galaxy phone upon which the VR videos were uploaded (see attached pictures). This will take approximately 1 minute. Through operation of the Galaxy phone's buttons, the participant will commence playback of the videos. Each play is preceded by a two-second long white screen, while a two-second long black screen designates the completion of the play. After each play, you will pause the video playback and mark whether the play was safe or out on a Google document (which will be uploaded on the researcher's provided laptop). Video clips will be randomised for each participant. The total expected time for this portion of the research is estimated at between 1.5- 2 minutes.

After you complete viewing of the requested videos, you will wait two weeks and then complete viewing of videos in the other format. For example, if you initially watched videos in the broadcast mode, after the two-week pause period you will then watch the 360° VR videos,

After viewing your last videos for this research, you will be asked to complete a visual analogue scale (see attached picture). This will be provided to you in an envelope prior to video viewing. As

indicated by the instructions on the scale, please mark along the line how close to game-likeness you felt the decision-making was for each video format. This will take approximately 5 seconds to complete. After completion, please return the envelope to the researcher in the provided prepaid envelope.

What are the discomforts and risks?

It is not anticipated that participants will experience discomfort, which would be greater than that occurring as part of their normal sports officiating duties.

There could be some discomfort when wearing the VR headsets.

How will these discomforts and risks be alleviated?

Participants may opt out of the research at any point.

What are the benefits?

This research will provide a novel way of coaching that has previously been used in softball before and will likely improve participants' decision-making skills. It will also provide insights into ways to further enhance umpire training methods.

For softball umpires:

The potential benefits are directly correlated with their umpire duties. These benefits include improved decision-making in softball games. This research may benefit the less-experienced umpires, and serve as a method to improve their skills, potentially accelerating their development and ascension to a level 7 qualification.

For the researcher:

The research serves as a requirement for obtaining his Masters in Sports and Exercise from AUT. Additionally, the research can improve his skills and knowledge in this particular realm. It is hoped that this research can serve as a potential springboard towards future research.

For the wider sports science community:

This research can add to the body of knowledge on Virtual Reality and training decision-making in sports officials. At present, there is a gap in the literature on this subject. It is hoped that this research can inform future researchers on this particular area, as well as sports officials in other sports.

How will my privacy be protected?

Confidentiality of umpires will be ensured via ID number assigned to them (the researcher will only see their names on the consent forms).

Only the primary researcher and supervisors will have access to data from the participants. This data will be kept in a secure data storage facility. All data will be deleted. Consent forms will also be kept in the same secure storage facility, and will be destroyed via paper shredder after six years.

What are the costs of participating in this research?

The total video-viewing and visual analogue scale time commitment for the participant's contribution is estimated at 4 to 5 minutes, and the participant will need two separate days to fully contribute (one for the first video condition, and another day for the second video condition and visual analogue scale completion).

What opportunity do I have to consider this invitation?

Participants will have two weeks to consider the invitation.

Will I receive feedback on the results of this research?

Feedback on the overall summary of results will be provided by way of email. Additionally, if requested the participants' own unique results will be e-mailed to them.

Will I receive any compensation for participating in this research?

For their contribution to the research, umpire participants will receive koha in the form of a petrol or supermarket gift card with an approximate $25 value.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor, Kirsten Spencer, kirsten.spencer@aut.ac.nz, 09 921 9999 x 7239

Concerns regarding the conduct of the research should be notified to the Executive Secretary of AUTEC, Dr Carina Meares, *ethics@aut.ac.nz* , 921 9999 ext 6038.

Whom do I contact for further information about this research?

Please keep this Information Sheet and a copy of the Consent Form for your future reference. You are also able to contact the research team as follows:

Researcher Contact Details:

Keone Kaiser, keone.kaiser@gmail.com, 02108354696

Project Supervisor Contact Details:

Kirsten Spencer, kirsten.spencer@aut.ac.nz, 09 921 9999 x 7239

Approved by the Auckland University of Technology Ethics Committee on 3/7/2020, AUTEC Reference number 19/449.

Oculus Quest Head Mounted Display Unit and Controllers

Make a dash on the line for how each method feels like your match decision-making

360° VR Video

Nothing like match decision-making _____ Exactly like match decision-making

2D Broadcast Video

Nothing like match decision-making _____ Exactly like match decision-making

Visual Analogue Scale

Appendix E: Expert Panel (Stage 2)

Participant Information Sheet (Expert Panel)

Umpires and softball players in Softball New Zealand

Date Information Sheet Produced:

11 June 2020

Project Title

Training decision-making in softball umpires using 360° virtual reality

An Invitation

Kia Ora!

You are invited to take part in a novel decision-making research study that is likely to be the first of its kind in New Zealand. My name is Keone Kaiser and I am a candidate for a Master's of Sport and Exercise at AUT. This study involves enhancing softball umpire development (through VR technology) capturing all the action (safes and outs) at the second base, recorded using the 360°camera at a Softball NZ national tournament held in New Zealand on January 2020. You will need to explicitly consent to being identified in the consent form and also need to explicitly consent to having your data shared with AUT.

What is the purpose of this research?

By combining 360°video of crucial softball plays (at 2nd base) and VR technology, this research seeks to determine if VR technology can be utilised to improve the development of decision-making of sports officials. The research compares whether training umpire decision-making is enhanced through the 360° VR training footage compared to using Softball NZ broadcast video.

As such, the novel research will inform sports scientists, coaches and the wider softball community on methods to improve umpire decision-making performance, and methods implementing virtual reality for skill acquisition.

The findings of this research may be used for academic publications and presentations and will be used towards the researcher's qualifications for a Master's in Sport and Exercise.

How was I identified and why am I being invited to participate in this research?

You have received this information sheet because you are a Softball NZ umpire of level 6 to level 7 who expressed interest in participating in this research and were subsequently invited to a meeting and/or hui for expert-panel umpires.

How do I agree to participate in this research?

A Consent Form is required to be read and signed by you the participant which is obtained at the same time as the information sheet. Your participation in this research is voluntary (it is your choice) and whether or not you choose to participate will neither advantage nor disadvantage you. You are able to withdraw from the study at any time. If you choose to withdraw from the study, then you will be offered the choice between having any data that is identifiable as belonging to you removed or allowing it to continue to be used. However, once the findings have been produced, removal of your data may not be possible.

What will happen in this research?

You will be asked, alongside two other expert umpires, to view various videos of previously broadcasted Softball NZ games, and determine if a runner is safe or out. You will watch 20 3-5 second videos from previously broadcasted Softball NZ games, and 20 3-5 second 360°VR videos from the 2020 Vic Guth NZ Softball Tournament. There will be a five-second-long black screen between each video, for both formats. You may use this period to mark your call on the provided

paper. Thus, the total viewing length for each video format will last approximately 2.5 to 3.5 minutes, totalling approximately 5 to 7 minutes total viewing time.

Previously broadcasted Softball NZ games will be watched alongside your fellow expert-panel peers on a provided computer and projector screen, while the 360°VR videos will be watched solo via a provided Samsung Gear VR headset (see attached picture). When switching from broadcast video format to 360°VR format, there will be a one-minute break for participants. Participants waiting to use the VR headset can expect to wait an estimated 2.5 to 3.5 minutes, plus 10 seconds for antibacterial cleaning of the headset by the researcher. The researcher will instruct you on the proper use of the VR headset prior to commencement of video viewing.

After watching all broadcast videos please attempt to arrive at a consensus with your fellow expert panel peers on the correct call of 10 plays and inform the researcher of your decisions. You will be given 30 minutes to arrive at consensus decisions, and may review the videos as much as needed during this time. After all experts finish watching the 360° VR videos, please discuss amongst your peers and come to a consensus agreement on the correct call of 10 plays. You will be given 30 minutes for this task and may use the VR headset to view the videos as much as needed during this period. The total expected time to discuss calls amongst your peers for both formats is approximately 1 hour. The researcher will disinfect the headset with antimicrobial wipes between each participant's use. These decisions will later be used to determine the accuracy of decision-making for other research participants

What are the discomforts and risks?

It is not anticipated that participants will experience discomfort, which would be greater than that occurring as part of their normal video viewing experiences.

There could be some discomfort when wearing the VR headsets.

How will these discomforts and risks be alleviated?

The expert panel participants may opt out of the research at any time.

What are the benefits?

This research will provide a novel way of coaching that has not been done and will likely improve participants' decision-making ability. It will also provide insights into ways to further enhance training methods.

For softball umpires:

The potential benefits are directly correlated with their umpire duties. These benefits include improved decision-making in softball games. This research may benefit the less-experienced umpires, and serve as a method to improve their skills, potentially accelerating their development and ascension to a level 7 qualification.

For the researcher:

The research serves as a requirement for obtaining his Masters in Sports and Exercise from AUT. Additionally, the research can improve his skills and knowledge in this particular realm. It is hoped that this research can serve as a potential springboard towards future research.

For the wider sports science community:

This research can add to the body of knowledge on Virtual Reality and training decision-making in sports officials. At present, there is a gap in the literature on this subject. It is hoped that this research can inform future researchers on this particular area, as well as sports officials in other sports.

How will my privacy be protected?

Confidentiality of expert-panel umpires will be ensured via ID number assigned to them (the researcher will only see their names on the consent forms, and thus these names will not be associated with the decisions of these participants).

Only the primary researcher and supervisors will have access to data from the participants. This data will be kept in a secure data storage facility. All data will be deleted. Consent forms will also be kept in the same secure storage facility, and will be destroyed via paper shredder after six years.

What are the costs of participating in this research?

The total time umpire participants will be required to give to the project will be approximately 1.5 hours.

What opportunity do I have to consider this invitation?

Participants will have two weeks to consider the invitation.

Will I receive feedback on the results of this research?

After the research's completion, feedback on the overall results will be provided by email.

Will I receive any compensation for participating in this research?

For their efforts, expert panel participants will receive koha in the form of a petrol or supermarket gift card with an approximate $25 value. This is not offered as an inducement to participate, but as a token of appreciation from the researcher for the participant's research contribution.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor, Kirsten Spencer, kirsten.spencer@aut.ac.nz, 09 921 9999 x 7239

Concerns regarding the conduct of the research should be notified to the Executive Secretary of AUTEC, Dr Carina Meares, *ethics@aut.ac.nz* , 921 9999 ext 6038.

Whom do I contact for further information about this research?

Please keep this Information Sheet and a copy of the Consent Form for your future reference. You are also able to contact the research team as follows:

Researcher Contact Details:

Keone Kaiser, keone.kaiser@gmail.com, 02108354696

Project Supervisor Contact Details:

Kirsten Spencer, kirsten.spencer@aut.ac.nz, 09 921 9999 x 7239

Approved by the Auckland University of Technology Ethics Committee on 3/7/2020, AUTEC Reference number *19/449*.

Oculus Quest VR Head Mounted Display Unit

Appendix F: Interview Participant Information Sheet

Participant Information Sheet (Interview)

Umpires in Softball New Zealand

Date Information Sheet Produced:

30 November 2020

Project Title

Training decision-making in softball umpires using 360° virtual reality

An Invitation

Kia Ora!

As a current participant in a research study on decision-making in softball umpires using 360° virtual reality, you are invited to participate in an interview to provide valuable insight on your experience as a participant. Your experiences and opinions will provide crucial information and direction to the research.

What is the purpose of this research?

By combining 360°video of crucial softball plays (at 2nd base) and VR technology, this research seeks to determine if VR technology can be utilised to improve decision-making of sports officials. The research compares whether training umpire decision-making is enhanced through the 360° VR training footage compared to using Softball NZ broadcast video.

As such, the novel research will inform sports scientists, coaches and the wider softball community on methods to improve umpire decision-making performance, and methods implementing virtual reality for skill acquisition.

The findings of this research may be used for academic publications and presentations and will be used towards the researcher's qualifications for a Master's in Sport and Exercise.

How was I identified and why am I being invited to participate in this research?

You have received this information sheet because you are a current participant in my study on training decision-making in softball umpires using 360° virtual reality, and notified me on an earlier consent form that you wanted to receive e-mailed results of your earlier participation. I hope that you are willing to also provide me with feedback on your experiences via an online interview.

How do I agree to participate in this research?

By completing the consent form provided alongside this information sheet, scanning or taking a picture of the signed consent form, and e-mailing it to the researcher. Your participation in this research is voluntary (it is your choice) and whether or not you choose to participate will neither advantage nor disadvantage you. You are able to withdraw from the study at any time. If you choose to withdraw from the study, then you will be offered the choice between having any data that is identifiable as belonging to you removed or allowing it to continue to be used. However, once the findings have been produced, removal of your data may not be possible.

What will happen in this research?

We will schedule a one-hour period of time to conduct an interview via Zoom, Google Meet, Skype, or phone call. Please choose whatever method is most convenient and comfortable with you. During that interview, I will ask you seven questions. Your responses will be recorded via video and audio formats, supplemented by written note-taking by me. Your interview will be recorded with the Otter software program, which will also assist me with transcribing the interview. After transcription is complete you have the option of receiving a copy of the transcript via e-mail. The interview will be analysed using the NVivo software data analysis program. Data from the interview will then be generated and compiled with data from the earlier components of the study to better inform the results and research recommendations.

What are the discomforts and risks?

It is not anticipated that participants will experience discomfort unless they are uncomfortable with using video chat technology and programs, in which case a phone interview will be conducted.

How will these discomforts and risks be alleviated?

Participants may opt out of the research at any point up to publication of the findings.

What are the benefits?

This interview will provide an additional lens to supplement the findings from the earlier phase of this research.

For softball umpires:

the potential benefits are directly correlated with their umpire duties. Your feedback can help shape the future of training SNZ umpire decision-making through resulting adjustments to the technology's deployment.

For the researcher:

the interview data serves will help the researcher produce a more comprehensive thesis submittal, which is a requirement for obtaining his Masters in Sports and Exercise from AUT. Additionally, interview feedback can improve his skills and knowledge in this particular realm. It is hoped that this research can serve as a potential springboard towards future research.

For the wider sports science community:

interview data can add to the body of knowledge on Virtual Reality and training decision-making in sports officials. At present, there is a gap in the literature on this subject. It is hoped that this research can inform future researchers on this particular area, as well as sports officials in other sports.

How will my privacy be protected?

Confidentiality of umpires will be ensured via ID number assigned to them (the researcher will only see their names on the consent forms). If the interview was via online video, for privacy concerns these videos will be deleted immediately after transcription.

Only the primary researcher and supervisors will have access to data and consent forms from the participants. Data and consent forms will be kept separated in a secure data storage facility. Data and consent forms will be deleted after six years.

What are the costs of participating in this research?

The total interview time is expected to take no longer than 45 to 60 minutes of your time. If the participant chooses to review the transcription of their video, the total time commitment will be approximately 90 to 120 minutes.

What opportunity do I have to consider this invitation?

Participants will have two weeks to consider the invitation.

Will I receive feedback on the results of this research?

Feedback on the overall summary of results as well as a copy of the interview transcript will be provided by way of email.

Will I receive any compensation for participating in this research?

For their contribution to the research, umpire participants will receive koha in the form of a petrol or supermarket gift card with an approximate $25 value.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor, Kirsten Spencer, kirsten.spencer@aut.ac.nz, 09 921 9999 x 7239

Concerns regarding the conduct of the research should be notified to the Executive Secretary of AUTEC, Dr Carina Meares, *ethics@aut.ac.nz* , 921 9999 ext 6038.

Whom do I contact for further information about this research?

Please keep this Information Sheet and a copy of the Consent Form for your future reference. You are also able to contact the research team as follows:

Researcher Contact Details:

Keone Kaiser, keone.kaiser@gmail.com, 02108354696

Project Supervisor Contact Details:

Kirsten Spencer, kirsten.spencer@aut.ac.nz, 09 921 9999 x 7239

Approved by the Auckland University of Technology Ethics Committee on 15/12/2020, AUTEC Reference number 19/449.

Appendix G: Consent form for 360° Video Filming

Consent Form

Project title: Training decision-making in softball umpires using 360° virtual reality (VR) technology

Project Supervisor: Dr Kirsten Spencer

Researcher: Keone Kaiser

○ I have read and understood the information provided about this research project in the Information Sheet dated 10 December 2019.

○ I have had an opportunity to ask questions and to have them answered.

○ I understand that taking part in this study is voluntary (my choice) and that I may withdraw from the study at any time without being disadvantaged in any way.

○ I understand that if I withdraw from the study then I will be offered the choice between having any data that is identifiable as belonging to me removed or allowing it to continue to be used. However, once the findings have been produced, removal of my data may not be possible.

○ I am not suffering from heart disease, high blood pressure, any respiratory condition (mild asthma excluded), any illness or injury that impairs my physical performance, or any infection

○ I agree to take part in this research, participating in training using VR.

○ I agree to have my data stored for 6 years in the SPRINZ database: Yes○ No○

○ I give permission for my data recorded from this research to be used for future research projects:

Yes○ No○

○ I wish to receive a summary of the research findings (please tick one): Yes○ No○

○ I give consent for my videos to be used for purposes such as media around this research if they are chosen (please tick one): Yes○ No○

¡ I give consent for any photographs related to this research to be used for purposes such as media around this research if they are chosen (please tick one): Yes○ No○

○ I permit the researcher to use the videos that are part of this project and/or any pictures from them and any other reproductions or adaptations from them, either complete or in part, alone or in conjunction with any wording solely and exclusively for (a) the research; and (b) educational exhibition and examination purposes and related design works.

○ I understand that the videos/photographs will be used for academic purposes only and will not be published in any form outside of this project without my written permission.

○ I understand that any copyright material created by the photographic sessions is deemed to be owned by the researcher and that I do not own copyright of any of the photographs.

Participant's signature: .....

Participant's name: .....

Participant's Contact Details (if appropriate):

……

Date:

Approved by the Auckland University of Technology Ethics Committee on 10/12/2019 AUTEC

Reference number 19/449

Appendix H: Consent Form for Video Viewing and Expert Panel

Consent Form

Project title: ***Training decision-making in softball umpires using 360° virtual reality (VR) technology***

Project Supervisor: ***Dr Kirsten Spencer***

Researcher: ***Keone Kaiser***

○ I have read and understood the information provided about this research project in the Information Sheet dated 22 June 2020.

○ I have had an opportunity to ask questions and to have them answered.

○ I understand that taking part in this study is voluntary (my choice) and that I may withdraw from the study at any time without being disadvantaged in any way.

○ I understand that if I withdraw from the study then I will be offered the choice between having any data that is identifiable as belonging to me removed or allowing it to continue to be used. However, once the findings have been produced, removal of my data may not be possible.

○ I agree to take part in this research, participating in training using VR.

○ I agree to have my data stored in the SPRINZ facility on a memory stick for six years, after which the data will be destroyed: Yes○ No○

○ I understand that my data will not be used for future projects

○ I wish to receive a summary of the research findings (please tick one): Yes○ No○

○ I wish to receive a summary of the research findings (please tick one): Yes○ No○

Participant's signature: .....

Participant's name: .....

Participant's Contact Details (if appropriate):

……

Date:

Approved by the Auckland University of Technology Ethics Committee on 3/7/2020 AUTEC Reference number 19/449

Appendix I: Interviewee Consent Form

Consent Form (Interview)

Project title: ***Training decision-making in softball umpires using 360° virtual reality (VR) technology***

Project Supervisor: ***Dr Kirsten Spencer***

Researcher: ***Keone Kaiser***

- ○ I have read and understood the information provided about this research project in the Information Sheet dated 4 December 2020.
- ○ I have had an opportunity to ask questions and to have them answered.
- ○ I understand that taking part in this study is voluntary (my choice) and that I may withdraw from the study at any time without being disadvantaged in any way.
- ○ I understand that if I withdraw from the study then I will be offered the choice between having any data that is identifiable as belonging to me removed or allowing it to continue to be used. However, once the findings have been produced, removal of my data may not be possible.
- ○ I understand that I will be video recorded and also that the interview will be transcribed.
- ○ I understand that notes will be taken during the interview.
- ○ I agree to have my data stored in the SPRINZ facility on a memory stick for six years, after which the data will be destroyed: Yes¡ No¡
- ○ I understand that I can request a copy of the transcribe recording for review and editing.
- ○ I understand that my data will not be used for future projects.
- ○ I agree to take part in this research.
- ○ I wish to receive a summary of the research findings (please tick one): Yes¡ No¡

Participant's signature: .....

Participant's name: .....

Participant's Contact Details (if appropriate):

……

Date:

Approved by the Auckland University of Technology Ethics Committee on 15/12/2020 AUTEC

Reference number 19/449

Appendix J: AUTEC Approval 360° Video Filming

Auckland University of Technology Ethics Committee (AUTEC)

Auckland University of Technology
D-88, Private Bag 92006, Auckland 1142, NZ
T: +64 9 921 9999 ext. 8316
E: ethics@aut.ac.nz
www.aut.ac.nz/researchethics

10 December 2019

Kirsten Spencer

Faculty of Health and Environmental Sciences

Dear Kirsten

Re Ethics Application: **19/449 Training decision-making in softball umpires using 360 virtual reality**

Thank you for providing evidence as requested, which satisfies the points raised by the Auckland University of Technology Ethics Committee (AUTEC).

Your ethics application has been approved for three years until 10 December 2022.

Non-Standard Conditions of Approval

1. In the Information Sheet for the umpires wearing the camera, insert advice that they are to conform with the 2019 WBSC Softball Field Mechanics 3 & 4 Umpire System guidelines for safety.

Non-standard conditions must be completed before commencing your study. Non-standard conditions do not need to be submitted to or reviewed by AUTEC before commencing your study.

Standard Conditions of Approval

1. The research is to be undertaken in accordance with the Auckland University of Technology Code of Conduct for Research and as approved by AUTEC in this application.
2. A progress report is due annually on the anniversary of the approval date, using the EA2 form.
3. A final report is due at the expiration of the approval period, or, upon completion of project, using the EA3 form.
4. Any amendments to the project must be approved by AUTEC prior to being implemented. Amendments can be requested using the EA2 form.
5. Any serious or unexpected adverse events must be reported to AUTEC Secretariat as a matter of priority.
6. Any unforeseen events that might affect continued ethical acceptability of the project should also be reported to the AUTEC Secretariat as a matter of priority.
7. It is your responsibility to ensure that the spelling and grammar of documents being provided to participants or external organisations is of a high standard.

AUTEC grants ethical approval only. You are responsible for obtaining management approval for access for your research from any institution or organisation at which your research is being conducted. When the research is undertaken outside New Zealand, you need to meet all ethical, legal, and locality obligations or requirements for those jurisdictions.

Please quote the application number and title on all future correspondence related to this project.

For any enquiries please contact ethics@aut.ac.nz. The forms mentioned above are available online through http://www.aut.ac.nz/research/researchethics

Yours sincerely,

Kate O'Connor

Executive Manager

Auckland University of Technology Ethics Committee

Cc: keone.kaiser@gmail.com; simon.walters@aut.ac.nz; kevin.sheehy@aut.ac.nz

Appendix K: Video Viewing and Expert Panel AUTEC Approval

Auckland University of Technology Ethics Committee (AUTEC)

Auckland University of Technology
D-88, Private Bag 92006, Auckland 1142, NZ
T: +64 9 921 9999 ext. 8316
E: ethics@aut.ac.nz
www.aut.ac.nz/researchethics

3 July 2020

Kirsten Spencer

Faculty of Health and Environmental Sciences

Dear Kirsten

Re Ethics Application: **19/449 Training decision-making in softball umpires using 360 virtual reality**

Thank you for providing evidence as requested, which satisfies the points raised by the Auckland University of Technology Ethics Committee (AUTEC).

Your ethics application for stage two (the formation of an expert panel, its video selections of 2D broadcast and 360° VR videos, data collection of 2D and 360°VR video play assessments by umpires, and ecological survey data collection) has been approved for three years until 3 July 2023.

Non-Standard Conditions of Approval

1. Removal from both Information Sheets of statements appropriate to Stage One of the research, for example, the sentence in the 'an invitation' section that states 'you will need to explicitly consent to being identified in the consent form and also need to explicitly consent to having your data shared with AUT'.

Non-standard conditions must be completed before commencing your study. Non-standard conditions do not need to be submitted to or reviewed by AUTEC before commencing your study.

Standard Conditions of Approval

1. The research is to be undertaken in accordance with the Auckland University of Technology Code of Conduct for Research and as approved by AUTEC in this application.
2. A progress report is due annually on the anniversary of the approval date, using the EA2 form.
3. A final report is due at the expiration of the approval period, or, upon completion of project, using the EA3 form.
4. Any amendments to the project must be approved by AUTEC prior to being implemented. Amendments can be requested using the EA2 form.
5. Any serious or unexpected adverse events must be reported to AUTEC Secretariat as a matter of priority.

6. Any unforeseen events that might affect continued ethical acceptability of the project should also be reported to the AUTEC Secretariat as a matter of priority.
7. It is your responsibility to ensure that the spelling and grammar of documents being provided to participants or external organisations is of a high standard and that all the dates on the documents are updated.

AUTEC grants ethical approval only. You are responsible for obtaining management approval for access for your research from any institution or organisation at which your research is being conducted and you need to meet all ethical, legal, public health, and locality obligations or requirements for the jurisdictions in which the research is being undertaken.

Please quote the application number and title on all future correspondence related to this project.

For any enquiries please contact ethics@aut.ac.nz. The forms mentioned above are available online through http://www.aut.ac.nz/research/researchethics

(This is a computer-generated letter for which no signature is required)

The AUTEC Secretariat

Auckland University of Technology Ethics Committee

Cc: keone.kaiser@gmail.com; simon.walters@aut.ac.nz; kevin.sheehy@aut.ac.nz

Appendix L: Interview Approval AUTEC

Auckland University of Technology Ethics Committee (AUTEC)

Auckland University of Technology
D-88, Private Bag 92006, Auckland 1142, NZ
T: +64 9 921 9999 ext. 8316
E: ethics@aut.ac.nz
www.aut.ac.nz/researchethics

15 December 2020

Kirsten Spencer

Faculty of Health and Environmental Sciences

Dear Kirsten

Re: Ethics Application: **19/449 Training decision-making in softball umpires using 360 virtual reality**

Thank you for your request for approval of amendments to your ethics application.

The amendment to the recruitment and data collection protocols (follow up interview) has been approved.

I remind you of the **Standard Conditions of Approval**.

1. The research is to be undertaken in accordance with the Auckland University of Technology Code of Conduct for Research and as approved by AUTEC in this application.
2. A progress report is due annually on the anniversary of the approval date, using the EA2 form.
3. A final report is due at the expiration of the approval period, or, upon completion of project, using the EA3 form.
4. Any amendments to the project must be approved by AUTEC prior to being implemented. Amendments can be requested using the EA2 form.
5. Any serious or unexpected adverse events must be reported to AUTEC Secretariat as a matter of priority.
6. Any unforeseen events that might affect continued ethical acceptability of the project should also be reported to the AUTEC Secretariat as a matter of priority.
7. It is your responsibility to ensure that the spelling and grammar of documents being provided to participants or external organisations is of a high standard.

AUTEC grants ethical approval only. You are responsible for obtaining management approval for access for your research from any institution or organisation at which your research is being conducted. When the research is undertaken outside New Zealand, you need to meet all ethical, legal, and locality obligations or requirements for those jurisdictions.

Please quote the application number and title on all future correspondence related to this project.

For any enquiries please contact ethics@aut.ac.nz. The forms mentioned above are available online through http://www.aut.ac.nz/research/researchethics

(This is a computer-generated letter for which no signature is required)

The AUTEC Secretariat

Auckland University of Technology Ethics Committee

Cc: keone.kaiser@gmail.com; simon.walters@aut.ac.nz; kevin.sheehy@aut.ac.nz

Appendix M: Demographics Questionnaire

Questionnaire

1. What is your age in years?

□ Please specify: _____

□ Prefer not to specify

2. How do you currently describe your gender identity?

□ Please specify: _____

□ I prefer not to answer

4. If so, how many years of experience serving as an umpire do you have?

□ Please specify: _____

□ I prefer not to answer

5. What is your current Softball NZ umpire level?

□ Please specify: _____

□ I prefer not to answer

6. Are you planning to advance to the next Softball NZ umpire level?

□ Yes

□ No

7. Approximately how many games have you umpired?

□ 1-25

□ 26-50

□ 51-75

□ 76-100

□ 101-125

□ 126-150

□ 151+

8. Have you previously participated as a softball player?

□ Yes

□ No

9. If so, for how many seasons?

□ Please specify: _____

□ I prefer not to answer

Appendix N: Interview Questions

Training decision-making in softball umpires using 360° virtual reality

The indicative interview questions will be as follows:

1. Which video method for training decision-making did you enjoy more, and why?
2. What are some potential advantages of each video training method?
3. What are some potential disadvantages of each video training method?
4. Did you enjoy making decisions more with the 360° VR technology, or the broadcast video technology? Please explain.
5. Is 360 ° VR something you think could be used to train SNZ umpires? Why or why not?
6. How did the camera stability of the 360 ° VR affect your experience with the 360 ° VR videos.
7. Do you think reality-likeness in 360 ° VR videos is essential to training decision-making? Why or why not?