Developing decision-making skills and tactical awareness in rugby union players through user-centred serious games

A Thesis Submitted for the Degree of Doctor of Philosophy

By

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Abstract

Serious Games have been used as a training and learning tool in a variety of different educational fields with positive results in enhancing skills. However, within the domain of team sports, there is limited research to ascertain if Serious Games can have such an impact on athletes. Existing training methods within team sports remain conventional pitch training, with video analysis and classroom sessions using flip charts. Whilst these methods have proven success, there exists limitations such as availability, costs, content rigidity as well relevance to all experience levels of athletes. Serious games have the potential to overcome these issues with a highly available, low cost, interactive serious game with dynamic content, which could allow players to continue their training off the pitch, as well as being tailored to their own experience level and playing position.

The aim of this thesis is to investigate the suitability and effectiveness of Serious Games as a training aid to develop decision-making skills and perceptual-cognitive abilities of Rugby Union players. The research followed 4 objectives: first a systematic literature review on the perceptual-cognitive abilities and decision-making skills in team sports, and specifically Rugby union, to establish the key factors and state-of-the-art approaches for decision-making training in team sports and serious games approaches, to develop a conceptual framework; next a user-centred approach was designed to refine the framework and design a serious game for training rugby union players in decision making, using a key participant group of rugby union experts to inform the design as well as refine the conceptual framework; third, a serious game was implemented based on this design as a proof-of-concept prototype for improving decision-making skills of Rugby Union players; finally, the hypothesis was validated and evaluated with a participant group, using the prototype game, the usability and effectiveness of decision-making training impact were both evaluated. The findings from this found that the serious game was usable and engaging by rugby players and coaches, as well as had a direct impact on the decision-making skills of the participant group, as assessed by proxy by their coaches. Contributions in this thesis include: the Headlights: Conceptual Framework, a Research Artefact & Shieldwall: Rugby (the proof-of-concept prototype), as well as a User-Centred Design Methodology. Findings showed that the user studies' highlight the potential for serious games to be used as an impactful training aid for rugby union, and other team sports to compliment existing coaching methods which will overcome current issues with existing training methods, whilst providing accessible and adaptive training environments for athletes at all performance levels.

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Publications

Alexander N., Fukaya K., Daylamani-Zad, D. Angelides, M.C., (*Under Review*) Serious Games for Decision-Making and Team Tactics Training in Sports: A Conceptual Framework and Review of State-of-the-art, *Entertainment Computing*.

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Chapter 1: Introduction

Serious Games are games that are designed with the primary objective being learning, rather than enjoyment [1]. These games are created for the main purpose of educating players in a variety of ways [2]. Serious games have had a wide range of uses in training environments, such as a Virtual Reality simulator for multicausality triage – a skill trained to first responders to assess the scene of major incidents and be able to establish priority of patients' dependent on injuries. This simulator has gone on to be used in training for Military Pre-Deployment, Military Sustainment as well as Civilian Disaster Response [3]. The entertainment nature of games coupled with the high level of customisation possible, turns games into a highly suitable platform for training which can increase engagement and allow for high levels of personalisation. Cognitive Abilities can be enhanced when using a serious game were scenario variation and enjoyment are key principles within the design of such a game [4].

Serious Games have already been used in team sports applications previously as a means of a training. Basketball is one example of a sport previously being used as a subject matter for a serious game. In this example the Nintendo Wii platform was used to incorporate a 'virtual' training and testing method for young basketball players to improve the motor skill of basketball throwing, i.e., throwing and scoring 'baskets' [5]. In addition, the topic of Serious Sports explores the use of a category of different sports games for the means of coach training, exploring the use of Sport Simulation Games, Sport Arcade Games, Sport Management Games and Exergames [6].

Rugby Union is a contact sport in which two teams play competitively against each other, and the winner is the team that scores the most points during a match [7]. To become an expert of any sport, an athlete must master a number of areas including the cognitive abilities related to their sport; the tactical awareness and decision-making skills that allow an athlete to succeed [8]. Within any team-based sport, coaches attempt knowledge transfer from a sports training environment into a competitive environment – i.e., a match. Athletes may compete as part of team, but decision-making within their matches can prove pivotal to success on the pitch [9]. Performance analysis techniques such as video analysis are currently used in sport as a means of learning and feedback for athletes. However, these techniques face difficulties in application as these methods may not be suitable for newcomers to a sport. They also require an analyst to be available, which can often be a time-consuming and mentally demanding role [10], [11].

Video analysis (learning from playback of video clips) is widely used in modern sports and considered a method of facilitating feedback to improve sporting performances [10]. To carry out team video

analysis, match play video footage will need to be available for a team to use – this will be analysed by a team analyst (if a club has one). This can prove time-demanding due to the analyst having to annotate the video recordings as well as mentally demanding due to them being required to memorise clips for use by the team [11]. Whilst using video analysis as a form of learning can benefit experienced athletes, novices or players with less experience lack the knowledge of the sport in order to process the information fed back [10]. Using a Serious Game could provide a solution to these issues as scenarios could be custom created without the need for analysing video clips by an analyst and these scenarios could also be designed to train experienced or novice athletes. Furthermore, research suggests that game-based training can improve cognitive abilities using a specifically designed video game to meet the goals of improving these skills. In one particular example the skill of shifting (an ability to switch focus from one task to another) was improved [4]. It is plausible therefore that a Serious Game designed with a specific sport-based relevance could enhance the abilities of Rugby Union players.

The problems faced by current sport performance analysis techniques could be solved by using Serious Games as they do not have such a need for analysis of match footage from the sport of Rugby Union. A game could be created which matches the competence and expertise level of the athletes. In addition, a Serious Game can increase user motivation by creating a fun experience whilst they can also create a custom-made hypothetical environment [12], which would solve the issue of having no relevant match footage available. This project investigates if such a game can be used to as a method of training Rugby Union players. The project also ascertains that when used, do the Cognitive Abilities and Decision-Making skills of these athletes improve as a result.

Studies have found that using above real-time video-based training can significantly improve the accuracy and response time of athletes in Australian Rules Football [13]. This is another facility that can be incorporated into Serious Games and add further customisation to the scenarios within the game. Allowing to speedup or slow down a scenario which is being played would add further functionality and impact on cognitive and decision-making training.

In team sports, athletes with higher skill levels have been shown to have stronger than average Perceptual-Cognitive abilities [14]. Therefore, for athletes with lower skill levels of Rugby Union, the Serious Game designed for this project will identify and look to strengthen the Perceptual-Cognitive abilities vital for the playing abilities of Rugby Union players. This project aims to develop a Serious Game that can be used to train and improve these cognitive abilities as well as improve their overall

Decision-Making within the sport. An athlete that performs well within a match of rugby union must be able to understand key core elements of the sport, such as recognising tactical patterns of play and being quick to respond. Skills such as these must be applied often when under pressure from players in the opposing team [15]. Often an athlete is required to perform these skills during stressful situations within a match [16]. In addition, an individual's understanding of the sport requires effective use of motor skills such as visual scanning, anticipation, adaptability and decision-making in attacking and defensive plays in key areas of the pitch [17].

This research investigates the effectiveness of Serious Games for improving the Cognitive Abilities and Decision-Making skills of rugby union players. Video analysis is currently used as a key facilitator for athlete learning within sports [10]. However, this has limitations due the availability of a Sports Analyst to individuals and teams [11]. Feedback from videos could also prove to only be beneficial to experienced athletes and not as useful for novices to a sport [10]. A Serious Game is a potential solution to both issues – it removes the need for an analyst to consistently be analysing match footage. In addition, training scenarios within the game could be custom-made to benefit a novice or an experienced athlete.

For this research, a Serious Game was designed and developed that will target the Decision-Making skills crucially required for rugby union players based upon their role (position) within a team. For less experienced rugby players, the game also seeks to train the key perceptual-cognitive abilities associated to high-level performing rugby players such as pattern recall and visuospatial capacity. Participants were recruited that have a high and low-level of experience in playing the sport of and are actively members of a rugby club. The participants were given the final proof-of-concept game prototype developed to use as a training aid. The participants assessed the usability of the game as a training tool. They were also monitored for change in their cognitive abilities and decision-making by their team coaches, assessing the impact of the prototype by proxy. The next section of this report will set out the project aim and objectives.

1.1. Research Aim & Objectives

This study investigates the use of a Serious Game to improve cognitive abilities and decision-making in Rugby Union players. These cognitive abilities include visuospatial capacity, pattern recognition. A serious game was designed using a user-centred design approach to enhance the decision-making skills of these athletes in an individual, positional-specific context as well as developing team tactical awareness. Once implemented, a participant group of rugby union players will be given access to the

game prototype to use as a training aid. This group of players will assess the usability of the proof-of-concept prototype by means of a questionnaire. The group will then take part in their regular team training session, where the players will be assessed by proxy by their coaches – who will be interviewed on conclusion of the session to assess this impact. The aim of this research is:

To investigate the suitability and effectiveness of Serious Games as a training aid to develop decision-making skills and perceptual-cognitive abilities of Rugby Union players.

This overall aim will be achieved by carrying out work on the following objectives:

1. A systematic literature review on cognitive abilities and decision-making skills in team sports, and specifically Rugby union, to establish the key factors and state-of-the-art approaches for decision making training in team sports and serious games approaches in this area, in order to develop a conceptual framework.
2. A user-centred approach to refine the framework and design a serious game for training rugby union players in decision making based on the findings of objective 1.
3. Implement a serious game based on the design as a proof-of-concept prototype for improving decision-making skills of Rugby Union players, based on the findings of objective 2.
4. Validate and evaluate the hypothesis, with participants, using the proof-of-concept game implemented in objective 3. Evaluate this based upon the usability and effectiveness of decision-making training impact.

Table **1.1** represents an overview of the research aim & objectives, **Figure 1.1**. representing a conceptual representation of the research aim.

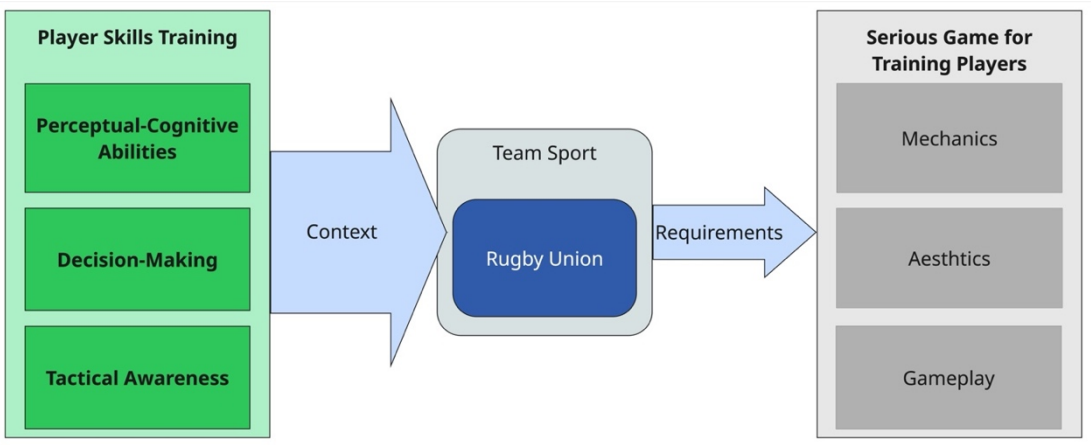

Figure 1.1: Conceptual Representation of Research Aim

Table 1.1: Summary of objectives, methods, and deliverables

Objective	Description	Method	Deliverable
O1	Identifying the cognitive abilities and decision-making strategies which contribute towards the success of rugby union players, in context of a serious game	PRISMA	Key cognitive abilities and decision-making strategies contributing to success of rugby union players. A Conceptual Framework for using a Serious Game for training decision-making in Rugby Union.
O2	Design a conceptual framework, and a serious game in context of rugby union based on the findings of objective 1.	Thematic Analysis User-Centred Design with expert focus group	A refined conceptual framework for training in decision-making in rugby union by a Serious Game. Design of a game for cognitive and decision-making training in rugby union.
O3	Develop and implement a proof-of-concept prototype based on the design of objective 2.	RAD	Proof-of-concept serious game to validate the hypothesis.
O4	Evaluate the design and framework from objective 2 using the developed prototype in objective 3.	Thematic Analysis	Evaluated Conceptual Framework, design and proof-of-concept prototype.

1.2. Research Approach

Objective 1

During the initial stages of the project, a systematic PRISMA-based literature review was carried out to investigate which Perceptual-Cognitive abilities as well as Decision-Making skills contribute to a successful match performance of a Rugby Union player. This review also investigated the use of Serious Games, with particular focus on learning with these in sports, to ascertain if using such technologies has been attempted in the past. It was found that Perceptual-Cognitive abilities, such as

Visuospatial Capacity and Pattern Recall amongst rugby union players are at particularly high levels, [15], [18]. The literature review also found that decision-making in Rugby Union can be improved by developing a training program based upon a nonlinear pedagogical methodology, a method where specific training tasks have their constraints manipulated to encourage developing decision-making, to create a constraints-led decision-making framework for rugby union [19]. With the key skills identified, a proof-of-concept prototype was designed and developed using rugby-based scenarios to train and improve these abilities. This follows similar research which found that using games designed to improve specific cognitive abilities was much more effective than using games designed to improve a generic set of mental skills [4].

The results of the literature review formed the basis of developing a conceptual framework, providing a background of key areas for this research. A Serious Game was designed in a modular manner, which considers player experience as well as their position on the team. By doing this, specific training programmes within such a game can be tailored to the player to give them the best benefit from playing the training aid game. When designing rugby-specific scenarios, there was factors to consider that are relevant to the sport – such as positioning of the scenario on the field of play, as well as any specific team tactics. As is common in team sports, offensive and defensive decisions will need to both have scenarios designed as rugby union players will find themselves with decisions in both situations. As the cognitive abilities for experienced rugby union athletes are already high for Perceptual-Cognitive abilities, the game difficulty for the prototype can be altered which increases the in-game speed, requiring quicker cognitive reactions for more experienced players.

Objective 2

Using the findings established by the systematic literature review in objective 1, a prototype game was designed that enhances the perceptual-cognitive abilities and decision-making of rugby union players. This game focuses on improving the decision-making skills of Rugby Union players in offensive and defensive scenarios, a key component to an athletes' understanding any team sport. These skills look to be enhanced for both experienced and inexperienced Rugby Union athletes. For less experienced players, the Serious Game also trains Perceptual-Cognitive abilities of Pattern Recall and Visuospatial Capacity, two skills which more skilled rugby players have higher skills of. To achieve both, the game is divided into a modular approach with scenarios designed based upon specific player positions in a rugby team and considering a players' experience. Creating scenarios with a players' position in-mind was a key element to developing a user-centred design approach, as identified in objective 1. Using a modular design methodology allows a player of any position to have training that

is relevant and follows a Knowledge-Based Coaching System (KBCS) methodology. This involves four main areas: domain knowledge, trainee model, performance evaluation and training controller. This is a system used in other sports such as Table Tennis to create automatic and intelligent sports training [20]. Using a KBCS system also fits into creating a Content Management System for Serious Games, a verified design methodology for games of this type [21]. Previous research has found that by using above real time video within analysis training, athletes can enhance the rate at which they improve their skills [13]. This project will follow a similar methodology and create scenarios within a game environment that the participants will observe at a speed that is faster than they would observe in an actual rugby union match.

The game itself was designed so that players can select their playing position as well as their experience level, and the game presents a series of targeted scenarios that are most relevant to them. Feedback on decisions made within each scenario is given to all players at the conclusion of each scenario. All players can be given detailed feedback; areas of strength as well as weakness in terms of all skills trained whilst playing the training aid game. This means that the player has a mechanism for understanding their own weaknesses and which areas to improve on. This follows a manipulated constraints led approach to creating a training model for the rugby athletes, as identified earlier from previous research [19].

To ensure the usability of such a Serious Game, rugby union athletes were recruited at this stage. Following previous research methodologies, participants in this study were recruited with a range of experienced and less experienced Rugby Union athletes. These athletes also had a range of playing positions which are defined in the common rugby positional groupings of ‘Backs’ and ‘Forwards’, as well as came from both Men’s and Women’s playing teams. These groups of players positions have unique roles within the sport, so knowing which players play what position is crucial to developing a successful training aid game prototype [22] [15]. A minimum number of participants were recruited to follow a repeated measures design [18]. These athletes were given access to a proof-of-concept prototype and asked to complete a usability survey to ensure that such a training tool is suitable to rugby union players. This ensured the viability of the research at this stage. Making sure all designed scenarios are rugby-relevant is also important, as such, experienced rugby union coaches were recruited to verify all designed decision-making scenarios for the Serious Game. These coaches to be also gave tactical information that is relevant to the decisions made by their players.

Objective 3

Based on the design methodologies from objective 2, the prototype game was then created. The working prototype for the project required a game to be developed with different mechanics to be able to accurately validate the project theory. An Agile methodology details an iterative approach to development where a large project is divided into smaller sprints to gradually move towards the desired functionality [23]. This ethos was replicated by this project to allow the game to gradually be developed stage by stage. A Scrum framework is a sprint-based development framework where goals are worked towards in specific time frames, with the overall aim of a project in mind [23]. To ensure the project remains consistent whilst implementing game features, Scrum was also used.

During this design process, key participants such as experienced Rugby Union coaches and players were identified and recruited. These persons were surveyed on the possible training game to identify key training scenarios for use in decision-making exercises, as well as identifying any rugby relevant perceptual-cognitive training. These participants were consulted throughout the design and implementation process, with initial interviews to gather information on key scenarios to identify for the game prototype prior to the final design. Once the design framework was completed, they were then consulted again for feedback on this, with required changes being made as a result from comments. Recruiting experts to feedback on research design in this manner is common in previous sports research, where expert coaches have been recruited from a rugby union background to help understand decision-making skills within rugby union players [24] and similar rugby experts were also used to identify sufficient examples for use in pattern recall tasks [15].

As identified by objective 1, the game prototype was to be created in a modular fashion to follow a KBCS sports training methodology. This, in turn, will allow for a custom set of specific Rugby Union-based scenarios to be created within the Serious Game that are relevant to a variety of positions on a rugby field. It allowed these scenarios to be tailored to players of a range of different skill levels and experience. At this point, experienced Rugby Union coaches were consulted within a key participant group to ensure that all scenarios created are relevant to the sport, as well as identify which scenarios are best suited to which playing positions as well as the relevant playing experience level for their difficulty. Using coaches as a means of developing a coaching strategy has been used in previous rugby-related research, to ascertain the best methodologies for coaching decision-making to players [24]. Using a modular method to develop a Serious Game is a verified game design methodology, as it would be similar to that of a Content Management System (CMS) used by previous research to develop a digital storytelling Serious Game [21]. A modular CMS game design methodology was used to help

to maintain game "flow". This is a concept where a game is designed to present players with challenges that are just above their current skill level to prevent player boredom and increase enjoyability. The challenge should not be too far advanced of player skill so that it causes frustration [25]. By using a modular CMS, a players' rugby union experience can be considered, and specific scenarios presented to relevant players that are challenging enough to a player given their rugby union experience and skill level. In addition, the Serious Game prototype was created using 3D virtual environments to best simulate a rugby-union based environment. Replicating the actual environment for the targeted training is common within Serious Games research and can be found replicated in settings such as Virtual Operating Theatres [26] and within sporting contexts such as a Basketball court [27].

Objective 4

After the game is implemented from objective 3, an experiment was carried out to validate the hypothesis that a serious game can be used to improve the cognitive abilities and decision-making skills of rugby union players. To prove this theory a test group of participants received this specifically designed and created game prototype to use as a training aid. This prototype was scenario-based to train the abilities of rugby union players. The participating players received the Serious Game prototype to use as a training aid. After the initial playthrough of the prototype, each of these participants completed a validated usability questionnaire to ensure that such a game is a suitable training aid for rugby union players. This follows similar research carried out by [28], which measured the usability of two serious games using a validated questionnaire. Feedback with usability was gathered at this stage, to allow the future development of the game prototype to address these issues before further experimentation takes place. This follows an Agile development methodology to game development, as identified within Objective 3 [23].

Following this usability test, interviews were carried out with expert coaches of the group of participants, to ascertain the improvement of player decision-making and cognitive abilities (Coach). The coaches were interviewed on an individual basis, after the participant players had used the prototype and taken part in a subsequent regular team training session. Coaches were interviewed following these sessions and this was done in this fashion as a proxy assessment of the impact of the prototype, as used in other Serious Game research with games designed with a User-Centred approach, as with this research [29]. During the interview's questions, like with the previous research stage, were open-ended. Coaches were made aware of which players had used the prototype prior to the team sessions, to compare with improvements during the session to those that did not have access. This was done to further validate the prototype's impact. This means that any improvements can be compared between a group of participants who will use the training aid and a group who do

not, validating any improvements gained from direct exposure to the game. Similar has been done in previous research were a group of young basketballers to attempt to train the skill of basketball throwing using a serious game [5]. Therefore, using rugby union players will follow a similar ethos of using participants with experience in the sport. Results from this test were used as proof-of-concept for this project.

1.3. Planning

To achieve the objectives set out in the previous sections, a timeline with milestones was planned and set out as shown in Figure 1.2. Objectives were set out and completed in order as laid out, with relevant findings informing future objectives within this research. First, a systematic literature review was carried out to provide a pool of relevant literature about Serious Games to train decision-making in team sports, with a focus on the sport of Rugby Union. The literature was dated from 2015 until present and this objective was concluded in August 2022. The Headlights: Conceptual Framework was formed from the initial findings in this literature review and was designed in August 2022. At this point, interviews with a key participant group involved in the sport of Rugby Union was carried out, the findings of which formed a refined conceptual framework for training in decision-making in rugby union by a Serious Game. During this initial experiment stage, a High-Fidelity Prototype was developed based on an initial design of a game for cognitive and decision-making training in rugby union. This prototype was presented for feedback to the participant group, with the findings further refining the Conceptual Framework as well as the game design for the next objective. This stage of research was completed in March 2024. A Proof-of Concept Prototype game was then created for the next objective to be used to validate the hypothesis that a Serious Game can be used to improve the decision-making of rugby union players, using a user-centred design approach. This was completed in November 2024. Finally, an evaluation of Headlights Framework, as well as the subsequently design proof-of-concept prototype was carried out by usability and impact assessment, assessed by rugby union athletes and coaches. This final experiment and evaluation were completed in June 2025. During this research, as new literature became available – relevant papers were added to the literature review and updated the Conceptual Framework accordingly.

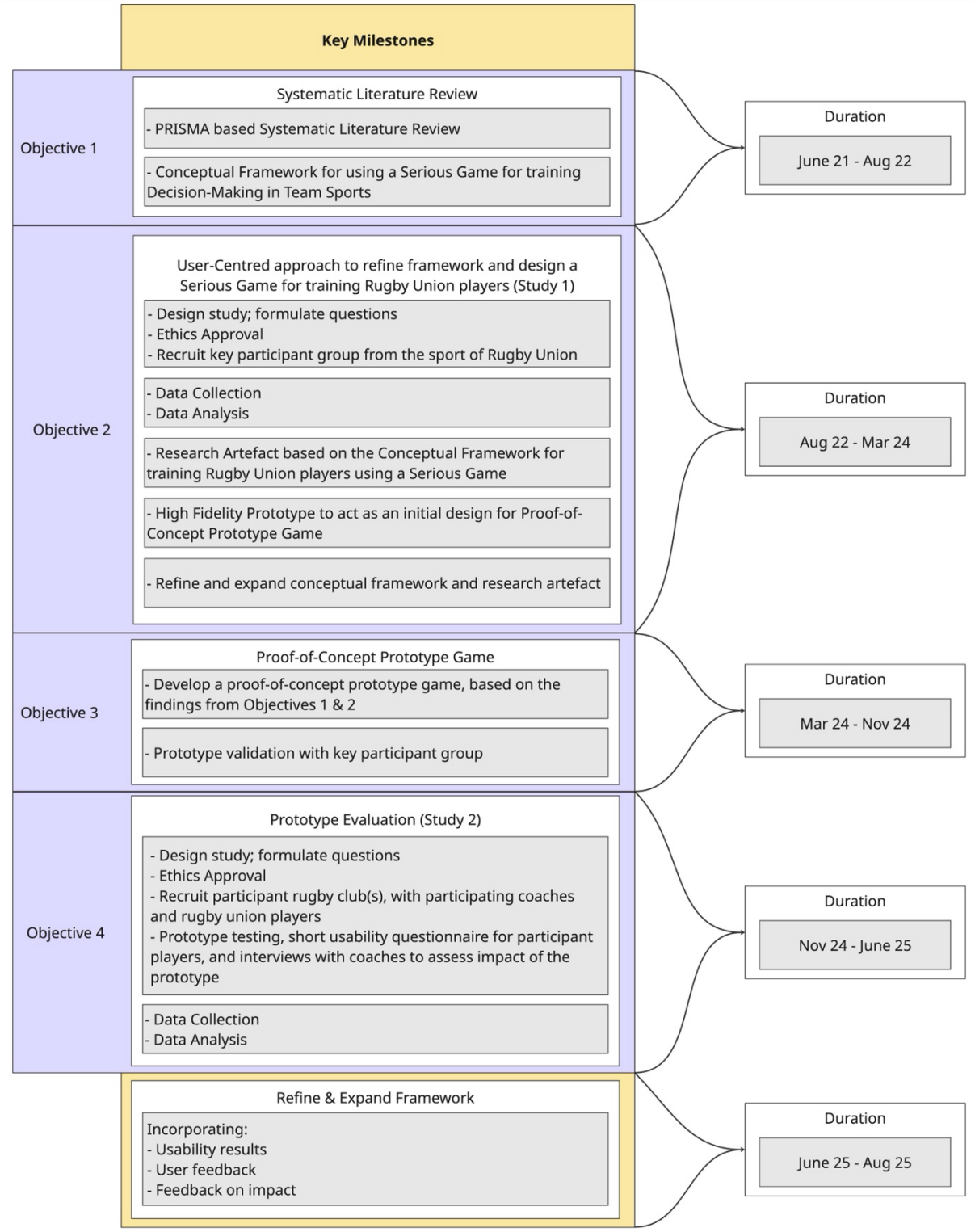

Figure 1.2: Key milestones & timeline durations for each objective

1.4. Outline

In the next chapter (Chapter 2), a systematic literature review is carried out with findings presented. This is evaluated using the PRISMA framework. The findings from this developed an initial Conceptual Framework for using a Serious Game as a training aid within team sports to train Decision-Making and

Perceptual-Cognitive abilities. This will establish the current state-of-art of use of Serious Games in sports in this way, as well as existing training methods and performance analysis techniques for the sport of Rugby Union.

To expand on this initial framework developed, specific user needs for athletes within the sport of Rugby Union is required. Therefore, Chapter 3 designs an initial study following a User-Centred Design methodology, with a key participant group to better ascertain these needs. Any Serious Game being developed for a team sport in this way should follow a User-Centred game design approach, and by carrying out this initial study, this approach will be ensured as key requirements will be identified and prototyped. This chapter identifies 3 different phases: initially to identify the requirements for the Serious Game, a second time to feedback on the development of an initial High-Fidelity Prototype (developed after phase 1), and a final interview is carried out with the group to feedback on the final developed prototype (which is developed from the results of the feedback of phase 2). The findings of each phase will be collected and further develop the Conceptual Framework initially presented in Chapter 1, and in addition a refined Research Artefact will be created from this that specifically identifies the requirements for the team sport of Rugby Union. This artefact will form the basis of the Game Design of the proof-of-concept prototype which will be used as a training aid for Rugby Union.

Chapter 4 begins this user study by interviewing the key participant group to ascertain the key skills and initial requirements for any serious game training aid. This phase 1 interview ascertains these needs to follow the established user-centred design methodology. This chapter uses the findings from this chapter to further develop the conceptual framework established in chapter 2. The findings also helped to ascertain the contextualisation of this framework for the creation of a research artefact in chapter 5.

Chapter 5 begins by creating this research artefact, which is used as an initial design framework to create a ‘storyboard style’ interactive High-Fidelity Prototype (HFP), to give the key participant group an outline as to how the final research serious game prototype will play for a user. The HFP is shown the participant group, who could interact with it prior to the phase 2 interviews. From this, the interviews were used to gather feedback from the findings, to further alter the current research components (conceptual framework, research artefact, HFP). This feedback altered the design framework used in the next chapter to create the research prototype.

Building on the findings from the previous Chapters, in Chapter 6 a proof-of-concept prototype Serious Game for training Decision-Making and Tactical Awareness within the sport of Rugby Union is developed using the Unity game engine. This chapter initially sets out the Game Architecture, the overarching design framework, which is based upon the Research Artefact established in Chapter 3.

The chapter then explores the Game Modes and Gameplay Mechanics that are used to create a decision-making training aid for Rugby Union. Following this, the key participant group is again interviewed for their feedback after being presented with the prototype. The findings of which develops the prototype further and again adds to the conceptual framework and research artefact.

In Chapter 7, a user study is carried out to analyse the usability and impact of the proof-of-concept prototype developed in Chapter 6. This is done by working with a Rugby Union club to recruit senior men's and women's coaches, as well as a group of participants of rugby player athletes. These players were given the prototype to use prior to a regular team training session and then were assessed by proxy for improvements to their tactical awareness and decision-making during that subsequent session by their coaches. These coaches were then interviewed after the training session to assess the impact of the prototype. The usability is assessed by the means of a questionnaire given to the players after using the prototype to assess the proof-of-concept prototype. The findings from this ascertain the impact and usability.

The thesis is then concluded in Chapter 8, which consolidates the findings and contributions throughout the entire thesis. This begins with a summary of the thesis, followed by a full discussion on the contributions made throughout. The research limitations are then also discussed as well as in-depth discussion on the future research and developments.

Chapter 2: The State of the Art in Serious games for Decision-Making Training & Perceptual-Cognitive Abilities in Team Sports: Headlights Framework

The following chapter provides a thorough detailed analysis of the literature survey conducted. This survey explored the state-of-the-art in Cognitive Abilities and Decision-Making skills associated with team sports, with a specific focus on Rugby Union, as well as their current training methods. it also investigated Serious Games for learning and training, as well as looking at core Game Design concepts for them. The chapter starts by presenting the literature review methodology and a detailed explanation of the process. It then follows by presenting the findings which have formed the basis of the proposed conceptual framework, the Headlights framework.

2.1. Introduction

Serious Games have been used for a range of different learning environments, and across multiple different platforms such as PC, Mobile, Virtual Reality (VR), Motion Capture and Mixed Reality (such as Augmented Reality). The purpose of these games is to educate players using the gameplay elements, rather than being primarily for enjoyment. Extensive research into the impact of such games has been carried out in various fields, such as detecting learning difficulties within school children [30], as well as disaster response education [3].

Interest has been shown in the potential use of Serious Games within the field of sports for athletes, such as within team sports like Basketball [31]. Whilst technologies such as VR have been used for Rugby Union [32], there is a gap in research for the use of specifically designed Serious Game for the purpose of improving the skill sets of Rugby Union players. To understand the relevant important skill sets for the success of an athlete within the sport, this chapter will investigate the latest developments in Decision-Making Training in Team Sports, including developments within Team Sports such as Rugby Union – as well as the key Perceptual-Cognitive Abilities and Decision-Making Training & Learning techniques used to enhance rugby player skills. Within any Team Sport like Rugby Union, coaches use different techniques to enhance their player's skill sets, such as Pitch Training and Video Analysis. Whilst skills can be improved in this way, Video analysis techniques can prove time-demanding and may not be suitable for less experienced players [10], [11]. Therefore, this chapter will also look at these existing training methods within the sport, to understand what shortcomings a Serious Game could overcome within a specifically designed game for the sport.

Training techniques such as using Serious Games have been found to impact the skills such as decision-making and perceptual-cognitive abilities of their users. Understanding the techniques used by games of this type is required to know of their potential impact for a use-case within the sport of Rugby Union. Therefore, this chapter's literature review will also investigate the latest state-of-the-art for the relevant topics for a Serious Game for Decision-Making in Rugby. This will be done by looking into Serious Games, and their underlying applications and approaches. The Hardware & Platform Interfaces currently used by Serious Games, as well as Serious Game Design and Mechanics, with relevance to the context of the sport of Rugby Union, and training relevant skills found in other literature review sections.

In this chapter, the state-of-the art methods used by Serious Games as well as training methods used and employed within the sport of Rugby Union have been aggregated with the goal of answering the following research questions:

RQ1: Can Serious Games be used for training Decision-Making in Team Sports?

RQ2: Would players and coaches engage with games as a training tool?

RQ3: What should a Serious Game for this type of activity be like?

RQ4: Which Perceptual-Cognitive Abilities do these games need to focus on to achieve their aim?

Within this chapter, the goal is to discover the existing methods used within the current body of literature and apply these

2.2. Literature Search Methodology and Process

The literature search strategy was a two-stage process, following a PRISMA [33] methodology. Figure 2.1 represents a visual representation of the literature search strategy. In the initial stage of the literature review, phase zero, papers where sourced to gain a background knowledge of the subject area. Specifically, to understand the areas of serious games, sports training aids as well as training decision-making and cognitive abilities within sport. Where possible, any background of these areas was investigated with a Rugby Union context. However, as this is an area which has not had extensive research previously, papers identified had as much relevance as possible but in areas some research into other sports was utilised. This early pre-process provided grounding for the key search terms to start the literature review process. There are four different areas of interest in this research; Serious games, Team Sports, Learning and, Tactics and Strategy. Accordingly, the key terms are divided into

four groups. The terms were created by combining the terms in Table 2.1 using AND and OR combinators. The Equation 2.1 presents the process used for creating the full list of combined key terms for this phase.

Table 2.1: Initial literature key terms

Serious Games (G1)	Team Sports (G2)	Learning (G3)	Tactics and strategy (G4)
Games	Sport	Training	Decision Making
Gamification	Rugby Union	Learning	Cognitive Abilities
Game Design	Rugby		Cognitive Skills
Design Framework	Team Tactics		

Equation 2.1. The equational representation of the process used to create the full list of combined search terms based on the groups of key terms.

Let G_1, G_2, G_3, G_4 be the four groups of terms. and KT_i to represent key term *i* permutations.

* Two-Group Permutations

$$KT_2 = \big((G_1 \text{ AND } G_2) \cup (G_1 \text{ OR } G_2) \cup (G_1 \text{ AND } G_3) \cup (G_1 \text{ OR } G_3) \cup (G_1 \text{ AND } G_4) \cup (G_1 \text{ OR } G_4) \cup (G_2 \text{ AND } G_3) \cup (G_2 \text{ OR } G_3) \cup (G_2 \text{ AND } G_4) \cup (G_2 \text{ OR } G_4) \cup (G_3 \text{ AND } G_4) \cup (G_3 \text{ OR } G_4)\big)$$

* Three-Group Permutations

$$KT_3 = \bigcup_{\{i,j,k\}\subseteq\{1,2,3,4\},|\{i,j,k\}|=3} \big[\big(G_i \text{ AND } G_j \text{ AND } G_k\big) \cup \big(G_i \text{ OR } G_j \text{ OR } G_k\big) \cup \big(G_i \text{ AND } G_j \text{ OR } G_k\big) \cup \big(G_i \text{ AND } G_k \text{ OR } G_j\big) \cup \big(G_j \text{ AND } G_k \text{ OR } G_i\big) \cup \big(G_i \text{ OR } G_j \text{ AND } G_k\big) \cup \big(G_i \text{ OR } G_k \text{ AND } G_j\big) \cup \big(G_j \text{ OR } G_k \text{ AND } G_i\big)\big]$$

* Four-Group Permutations

$$KT_4 = \bigcup_{\text{all permutations of AND, OR}} (G_1 \text{ op}_1 G_2 \text{ op}_2 G_3 \text{ op}_3 G_4)$$

* Full combination of key terms used

$$KT_{full} = KT_2 \cup KT_3 \cup KT_4$$

In the first phase literature search was carried out on identified databases (IEEE, ACM, ScienceDirect, SportDiscuss/Ebsco, Scopus) using the key terms to find papers that would fit the area of research. These papers would have an initial scan of the title and abstract for each paper to ascertain if they should be considered further, by establishing its relevance to the subject area. The second stage of

the process was to read each paper to ascertain how relevant to this study the paper was, this was carried out to identify key papers and to remove those that were of little relevance, despite appearing in the initial search. If a paper was deemed relevant after this stage, key papers that were cited in each paper were then also added to the considerations list for this literature review to make sure no key area of research was missed. In a rugby context, there has not been a great amount of research into the use of games technology, i.e. Serious Games as a possible training aid for decision-making and cognitive abilities, so by using a two-stage process to identify relevant research this meant that this review left out no key area of research.

Search terms, as identified in Table 2.1 were based on the themes identified during initial searches. These were expanded during the systematic literature review to obtain higher quality results from previous successful searches. These new key terms were three groups of personal abilities, design approaches and learning methods. These were also grouped into three groups accordingly as in Table 2.2 and were used to create search terms with the same approach as in Equation 2.1. Doing the review in this manner prevented bias in any possible paper identification during the review. Duplicate papers, incomplete studies, as well as those written in a language other than English were excluded from the considered papers. All searches carried out where between 2015 and 2025 to ensure that this review represented the most recent, state-of-the-art developments within the field were included.

Table 2.2: Expanded key terms.

Skills (G1)	Design Approaches (G2)	Learning Methods (G3)
Visuospatial Capacity	User-Centred Design	Kolb's Learning Cycle
Pattern Recall	Skill-Based Learning	Nonlinear Pedagogical Methodology
Visual Attention	Cognitive Interaction	

This inclusion and exclusion criteria as identified by Table 2.3 was used to identify the appropriate studies during the literature review. The area of study for this thesis has limited previous research in the field, so papers were judged on their relevance to sport training aid for decision-making AND/OR cognitive abilities (Rugby Union preferred) as well as relevance to Serious Games technology. If a paper was judged to have not met any of the inclusion criteria, it was excluded from the search results.

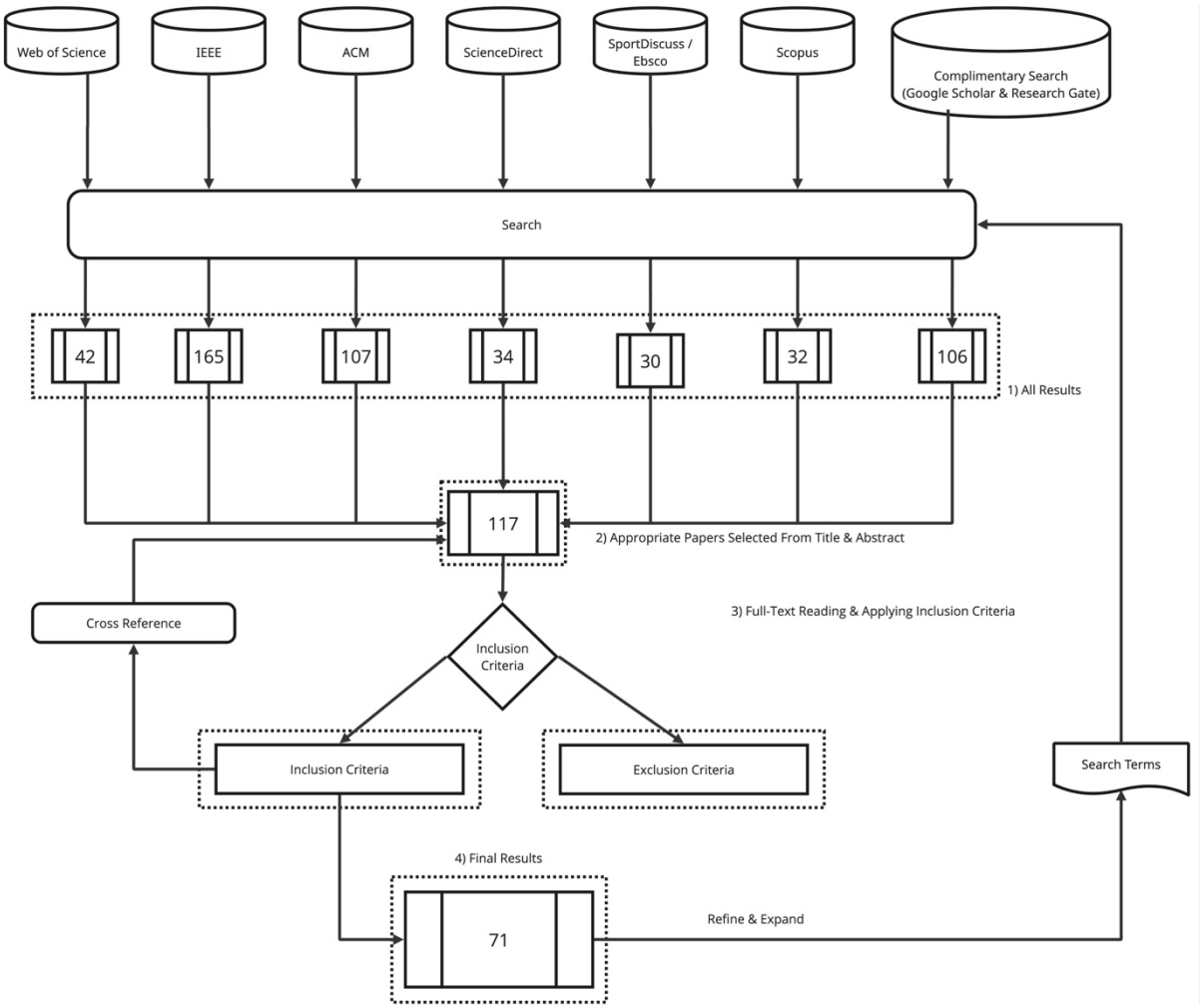

Figure 2.1: Systematic literature review process

The search terms were entered into the databases identified within the specific time-period range, with the initial results being found in this Search. Results from these initial queries formed the papers within All Results. From this the inclusion and exclusion criteria shown in Table 2.3. were applied, with an initial examination of the papers' titles and abstracts conducted. Anything deemed not relevant was excluded at this stage, and remaining papers were then further examined within their conclusions and methodologies. The full text of papers that passed this relevance check were then fully examined, again using the same inclusion and exclusion criteria. The Final Results of these papers formed the accepted pool of literature. During this process, papers which passed the inclusion criteria were also cross referenced for any relevant source papers, which then went through the same relevance checking process. Results from each query were processed with the criteria considered until search results were exhausted, or in the case of the queries which returned high numbers of results, papers were considered until a consistency emerged were papers were not deemed relevant, and in cases where an end of a page was reached. This was done as some queries had so many results that would not be possible to assess all papers. The number of pages of results were also recorded. Within the

accepted literature pool, relevant papers were also cross-referenced and evaluated against the inclusion and exclusion criteria. In addition, supplementary searches were also carried out on each used database. During the search process, two clear themes emerged to form the basis for the Conceptual Framework, the Headlights Framework, as described in the next chapter. These themes formed two separate sections to this framework: Decision-Making Training in Team Sports, and Serious Game for Decision-Making in Team Sports. These themes are linked together by Team Sport Key Performance Indicators (KPIs).

Table 2.3: Inclusion & Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Relevance to Serious Games technology	Literature reviews (systematic reviews, narrative reviews)
Rugby Union OR other relevant sport training aid for decision-making AND/OR cognitive abilities	PhD/Masters thesis
Published between 2015 and 2022 (initial search)	Non-peer-reviewed articles
Written in English	Studies that are not in English
Peer-reviewed journal & conference articles	Outside of date range

2.3. Headlights: Conceptual Framework

Based upon the findings of the systematic review of literature in previous section, a latest state-of-the-art conceptual framework was developed. The Headlights: Conceptual Framework can be found in Figure 2.2. The purpose of this was to establish the key themes for training Decision-Making in the sport of Rugby Union, as well as the key components needed to create a Serious Game that can be used to train these skills within this and other team sports. This approach allowed for these themes to emerge from the literature that was identified from the accepted pool of literature. Each paper was analysed for its content with all papers kept recorded by spreadsheet entries. These entries were tagged with relevant codes as they emerged from reading and were thematically grouped together – forming a category structure. Papers were then also classified by established categories. During this review specific theme distinctions became evident regarding the use of Serious Games for training skills in team sports, as well as for training decision-making skills of Rugby Union players, with associated cognitive abilities. The results of this analysis formed the basis for the Headlights Conceptual Framework; this is represented by Figure 4. These key themes are important in the development of a Serious Game for use as a training aid to develop decision-making skills and perceptual-cognitive abilities of Rugby Union players. The Headlights Framework was developed into 2 sections: Decision-Making Training in Team Sports, and Serious Game for Decision-Making in Team

Sports. These are linked together by Team Sport KPIs (Key Performance Indicators), which provide the sporting context – for example, Rugby Union.

Regarding Decision-Making Training in Team Sports, three key themes emerged: Team Sports, Perceptual-Cognitive Abilities, and Decision-Making Training & Learning. Rugby Union is a Team Sport, which requires players on a team to make many individual decisions throughout a match. A Rugby Union player's decisions are often influenced by their Perception, their understanding of a given match scenario within the context of their sport. This player's perception will be dependent on what is within their field of vision, as well as their memory of what has previously occurred and forms their Perceptual-Cognitive Abilities. Decisions within a Team Sport may also be made by multiple players within a match, this is referred to as Collaborative Decision-Making. Perceptual-Cognitive Abilities are the visual mental skills that allow a person, or in this case athletes, to think and process information. Previous experiences and trained knowledge will aid effective and efficient decision-making within their sport. The Decision-Making Training & Learning section of the Conceptual Framework looks at the methods used to train decision-making skills by Rugby Union athletes. This includes Decision-Making Training Approaches, Building Process of Decision-Making Training and Specific Decision-Making Learning Methods. Decision-Making Training Approaches identifies the current approaches used within the sport of Rugby Union to train Decision-Making within the sport. The Building Process of Decision-Making Training looks at a specific action model to build a training technique for improving decision-making. Finally, Decision-Making Learning Methods looks at how Decision-Making training is applied.

Within any team sport, such as Rugby Union, there are different metrics and indicators that identify the success of any athlete within the sport. These Team Sport Key Performance Indicators (KPIs) are important context for athletes and how any training aid impacts their playing level at their sport. For example, for Rugby Union this can include 'Gainline Success' achieved by 'Line Breaks' in attacking situations, as well as defensive situation success rate. These Rugby Union KPIs can also include success at set-piece, structured play types.

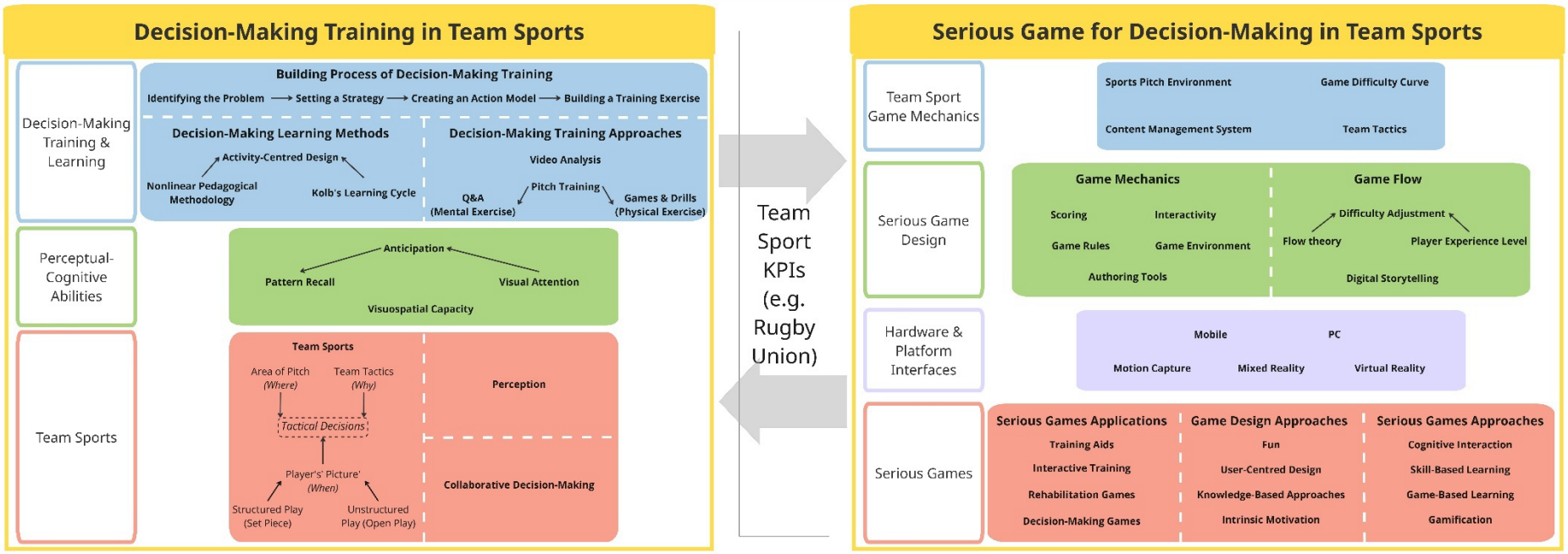

Figure 2.2: Headlights: Conceptual Framework

The primary purpose of a Serious Game is to be used as an educational or training tool for learning. In a Serious Game for Decision-Making in Team Sports, 3 key themes emerged within the topic of Serious Games: Serious Games Approaches, Serious Games Applications and Game Design Approaches. Serious Games Approaches are varied in the type of learning they try to provide for their players. Serious Games Applications have been found varied uses in team sports. Training Aids are tools used by teams to enhance learning and understanding of their sport. In Serious Games, there are multiple Game Design Approaches used to achieve the goals of learning through games created for this purpose. Serious Games have also been used on multiple different Hardware and Platform Interfaces. A desktop computer, or PC is one commonly used platform, as well as other platforms identified within the literature. The Serious Game Design comprises of two key sections of themes: The Game Flow and the specific Game Mechanics. The Game Flow is created to enhance player enjoyment when playing a game. Game Mechanics, or the specific rulesets, actions and interactivity definitions of any game are required for any Serious Game design. To achieve a successful Serious Game Design – specific Team Sport Game Mechanics which are appropriate to the sport, the game's context will be needed.

The following sections will examine each concept of the established Conceptual Framework in detail, whilst also reviewing the latest state-of-the-art in the subject area. Section 2.4. will discuss Decision-Making Training in Team Sports, whilst section 2.5. will examine Team Sport Key Performance Indicators (KPIs), Serious Game for Decision-Making in Team Sports will be discussed in section 2.6.

2.4. Decision-Making Training in Team Sports

Every day, humans use their decision-making skills in various ways and settings, such as sport. Athletes are often presented with various scenarios which require them to make often split-second decisions, therefore *Decision-Making Training in Team Sports* is often considered in training by coaches. During the literature review this formed one area of the developed conceptual framework, as shown in Figure 2.3.

Within a Rugby Union match, players are often frequently required to make decisions based upon specific match situations. This can occur in any area of the pitch, and selecting a correct decision given a situation can lead to a team scoring points or winning a penalty. In addition, Virtual Reality (VR) has been used in array of sports, and research has shown that this technology can be used in Rugby Union to improve tactical understanding for athletes at all levels of the sport [32]. To understand how a Serious Game training aid can be developed for the sport of Rugby Union to train decision-making,

this literature review will assess the topics of *Team Sports, Perceptual-Cognitive Abilities* as well as *Decision-Making Training & Learning*.

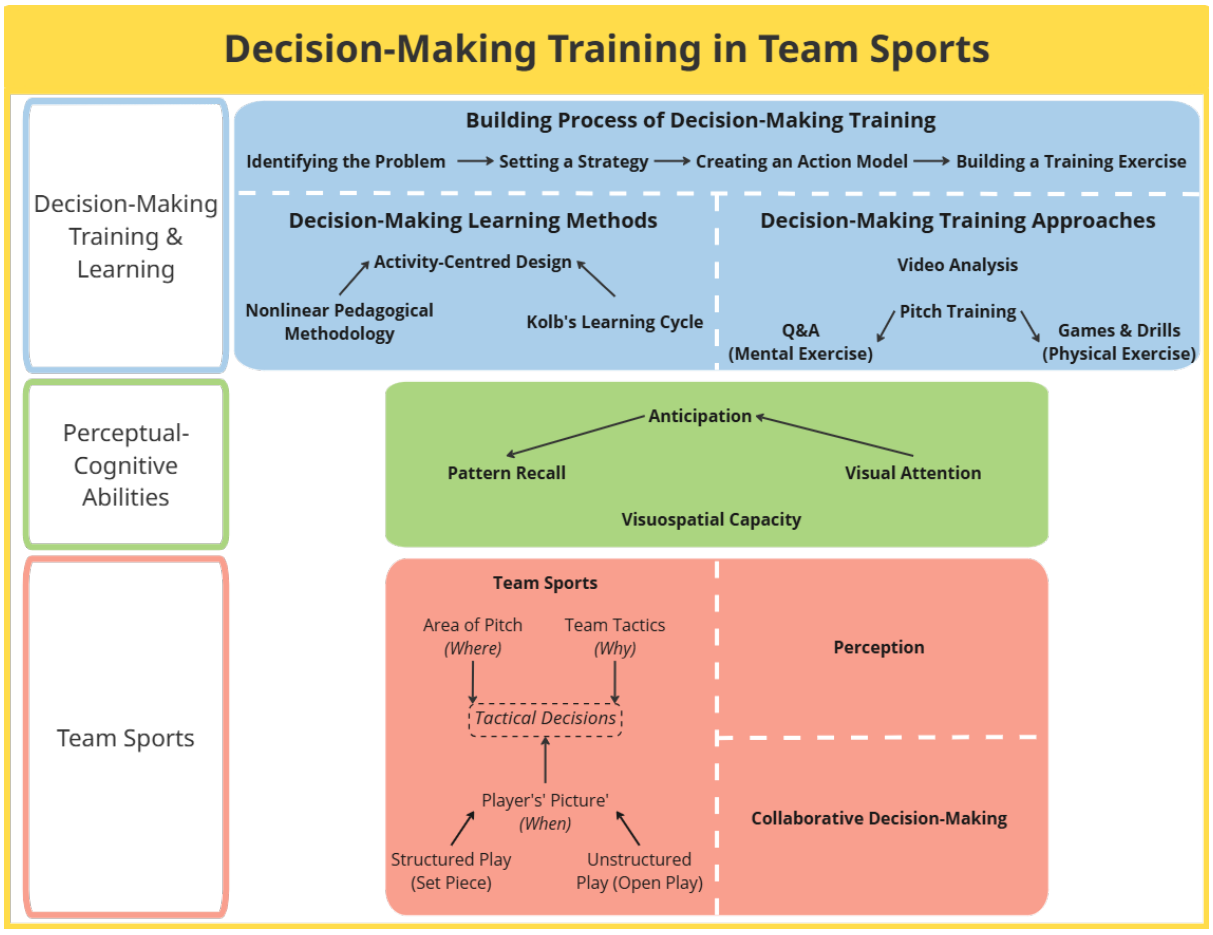

Figure 2.3: Decision-Making Training in Team Sports, Headlights: Conceptual Framework Area

2.4.1. Team Sports

Team Sports are activities were groups of athletes form a 'Team' work together against an opposing team to earn victories [7]. Rugby Union is an example of such a sport that relies on variable team play, with athletes reacting to an ever-changing environment, or *Player's 'Picture',* and making decisions based upon this. Team Sports concepts are discussed under three topics: *Tactical Decisions*, *Collaborative Decision-Making* and *Perception.* The patterns of play a team uses to achieve victory as part of an agreed plan results in *Tactical Decisions* during a match which can impact its outcome. These decisions can also often be made were multiple teammates work together to make decisions, or *Collaborative Decision-Making*. These themes within Team Sports in the conceptual framework is shown in Figure 2.4. All decisions will be made as part of the picture unfolding in a match, and what individual players can see, or perceive in front of them. The *Perception* of the match is vital to a player making specific decisions.

One fundamental aspect of an athlete's understanding and performance level within the sport of Rugby Union includes *Tactical Decisions*, with correct decision-making in attacking and defensive scenarios needed to lead to successful match performance. Analysis has been previously carried out by interviewing Rugby Union coaches from a range of different levels, with every coach interviewed agreeing that decision making was an important skill for a Rugby Union player with tactical considerations being an important factor. However, the coaches also agreed that this skill was an incredibly hard skill to coach and develop with athletes. The coaches also agreed of key importance to player decision making, was their ability to react to their individual Player's 'Picture', i.e. what is unfolding on the pitch that the players can see and analyse [24]. This picture often is relative to the Area of Pitch the player and events of the match are, as well as include contextual understanding of an athlete's Team Tactics – the agreed plan a team attempts to execute during a match. Difficulties identified by coaches in training the skills associated to these could be addressed through the development of a Serious Game to be used as a training aid. Mental Imagery, the skill of an athlete to picture a scenario in their head to evaluate the best decision to make contributes to these reactions by players during matches, and it has been shown in previous studies that this skill can be improved within a Serious Game designed to improve decision-making skills of athletes, as well as improve the confidence an athlete has in their decision-making [32][34]. A Serious Game learning tool could be specifically designed to address tactical decision making within a rugby union match and could be designed to present players with decisions to make in specific areas of the pitch. Furthermore, a tool like this could be designed with coaches, to present tactical information specific to their team – presenting players with the opportunity to make decisions based upon their team's individual tactical aims. Where cognitive abilities impact a Rugby Union players' perception of structured plays (set pieces like lineouts or scrums), decision making has been found to be key in a players' success in unstructured situations in a game (i.e., open play). Coaching these types of situations to players has been found to improve their decision-making skills, with better understanding of the on-going 'picture' of the pitch [35]. A Serious Game as a learning tool for Rugby Union could present players with specific scenarios in structured and unstructured situations, to enable better understanding of what to do given a specific situation.

Collaborative Decision-Making is a concept where a team of individuals will make decisions together with specific goals. In Team Sports, multiple athletes will make decisions together with Tactical-Decisions considered. Serious Games have also explored this concept of Collaborative Decision-Making previously; These are games designed to be played by multiple players where the goal is to make group-based decisions, following discussions. Such a game has been used for collaborative

decision-making within an Operating Room environment, with players faced with multiple options they can take based on a given scenario. This system allowed players to discuss their options, before voting on a final decision. This research found such a system can be used in this way [26]. Similarly, a Rugby Union based collaborative Serious Game could be designed for a rugby team, allowing for greater group understanding of specific team tactics.

Perception is how a person processes information and acts given a specific environment, and has previously been studied in behaviour psychology, where adaptive behaviour is considered to derive from such contextual information [36]. An athlete within any sport processes the information they see in a Team Sports match can be considered their Perception of the on-going Player's 'Picture' unfolding. This Perception of events can often impact athlete decision-making, and previous research has analysed how this perception, can lead to actions such as decision-making [37]. *Perception*, in a Team Sports setting has often been well-documented as having an impact on athlete decision-making, as well as impacting *Cognitive Abilities*, such as *Perceptual-Cognitive Abilities* like *Visual Attention, Anticipation, Pattern Recall* and *Visuospatial Capacity* [38]. This Perception was also found to be crucial to understanding Expert action, i.e. the actions a more experience athlete in their sport would make compared to a novice. To perceive events in a sport, Cognitive Abilities are used to process information, in a team sport such as Rugby Union this is particularly important for Perceptual-Cognitive Abilities, the visual skills an athlete has. Some Perception skills have been found in previous research to be particularly high amongst Rugby Union athletes, such as pattern recall [15]. Therefore, the next section will discuss visual *Perceptual-Cognitive Abilities* associated with *Team Sports*.

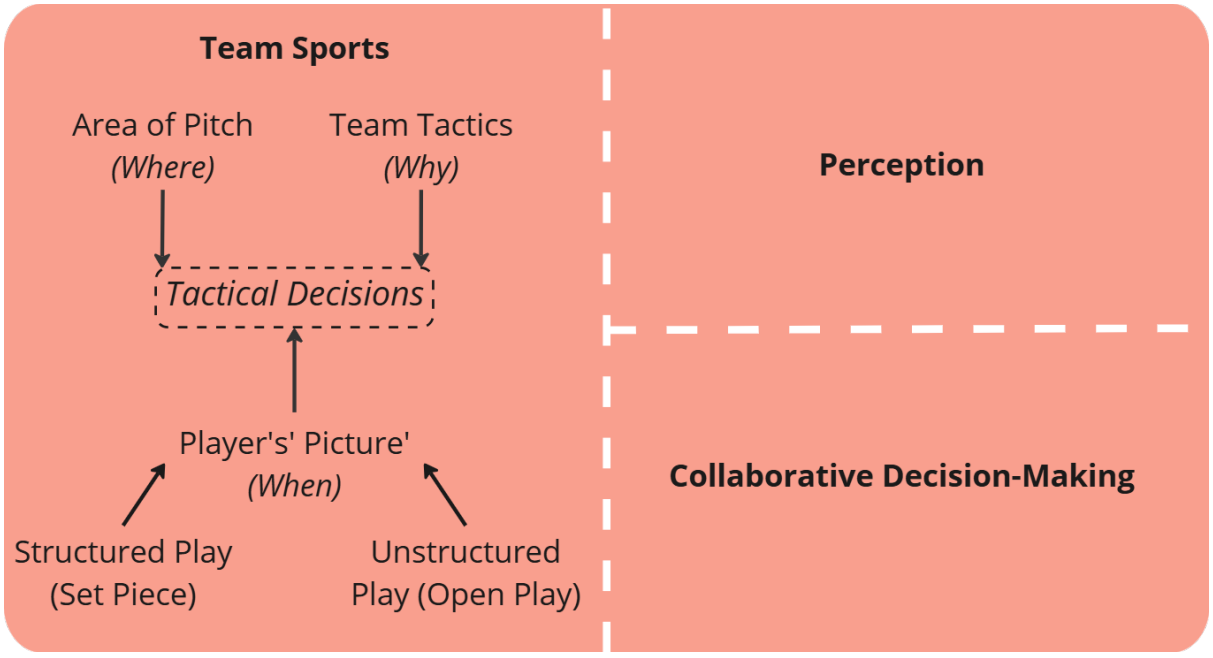

Figure 2.4: Team Sports in Headlights: Conceptual Framework

2.4.2. Perceptual-Cognitive Abilities

Whilst participating in their sport, athletes will use various *Perceptual-Cognitive Abilities* to process situations they have found themselves in – i.e., match scenarios. Their ability to process information based on previous experiences and trained knowledge will aid effective and efficient Decision-Making, which could lead to success or failure within a match. The 4 key *Perceptual-Cognitive Abilities* found in Rugby Union players from research are *Visuospatial Capacity, Visual Attention, Anticipation* and *Pattern Recall.* Therefore, it is important to consider the testing and training of such skills that are relevant to sports, particularly in Rugby Union. Understanding the key *Perceptual-Cognitive Abilities* required of a rugby athlete as well as how to train them will aid in the research of implementing a serious game that could train and improve such skills. This developed sub-section of the conceptual framework is shown in Figure 2.5.

Athletes with higher skills in team sports such as football (soccer) have been shown to have greater *Perceptual-Cognitive Abilities*. In particular, the ability of an athlete to process a specific situation within their sport and make a correct decision is particularly important – so much so that the use of virtual environments to ascertain the skill levels of athletes has been researched previously [14]. Using a virtual environment may prove useful when developing a Serious Game to improve the cognitive abilities of rugby union players. Such an environment could be designed that replicates a rugby-based environment (i.e., the match pitch). Shooting has also been looked at in recent research, neurofeedback training being given to elite-level shooters to improve the athletes' *Cognitive Abilities*. Each participant was given a Vienna Test, a series of psychological tests that are used to measure cognitive ability – this was done to measure the cognitive ability of sustained attention for each shooter. The research found that using neurofeedback training can improve the performance of elite-level shooting athletes [39]. Further research has also been carried out in the sport of Rugby Union, finding that perceptual-cognitive abilities are greater in higher skilled, more experienced athletes than those with less ability.

One *Perceptual-Cognitive Ability* that may have specific relevant to Rugby Union is *Visual Attention*. Research has indicated that within an object tracking sport like Rugby Union or Football, athletes have higher tracking skills than other non-tracking sports such as rowing or swimming. The study used analysed the Multiple Object Tracking (MOT) method where participants are required to track multiple moving objects. Participants were given a black screen with 8 identical white discs with 3 highlighted in red which the participants where to track. Eye gaze was tracked during the experiment to ascertain the skill level of each participant [40]. Within a Serious Game designed for Rugby Union, a game could

present a rugby-relevant virtual environment where participants are asked to track rugby-specific virtual objects, such as a representation of opposition players.

Anticipation is one such skill that was analysed finding that elite level rugby union athletes were stronger at this skill when predicting a rugby ball bouncing. This study also overcame issues identified in other research regarding low numbers of participants in elite-level 'expert' cases, by recruiting a large range of professional-level rugby-union players for the purposes of the study. This proves thoroughly then, that rugby union players of higher level of expertise and playing ability will have greater perceptual-cognitive abilities [22]. *Anticipation* is the ability to predict future actions based upon an environment and is considered a skill that is critical in success within sport. Research has been carried out that proves that anticipation within higher-skilled athletes, in this case football, is higher than those with a lower skill set. This research specifically looked at how other perceptual- *Cognitive Abilities*, such as *Pattern Recall*, is linked to an athlete's ability to anticipate actions. The study found that participants could anticipate actions based upon their ability to recall structured patterns, meaning that there is a direct connection between pattern recall ability and anticipation within an athlete [41].

Pattern Recall is another perceptual-cognitive ability that has been investigated in a rugby context. This skill is the ability of an athlete within a sport to be able to recognize and remember patterns that are formed on the playing area of key components, such as opponents and teammates. Studies have identified this as a key skill for rugby union athletes. This research also found that expert-level Rugby Union players have higher pattern recall abilities than novice rugby union athletes, particularly when attempting to recall fully structured or semi-structured patterns within their sport. Such studies used patterns of still images of a rugby union pitch, where participants were required to recall where on the pitch specific patterns, such as a scrum or lineout, took place on the images they were shown [15]. *Pattern Recall* is therefore also a cognitive ability that should be considered when developing a training aid for Rugby Union players. Like this previous research, rugby players could be shown specific scenarios encountered within a game of rugby, they would then be asked to recall specific patterns (being structured or semi-structured, such as a set piece arrangement from a scrum in-game), this skill could be trained in this way to improve participants recall ability of these patterns. Improving such a cognitive ability which has specific importance to the sport of Rugby Union would improve the viability of such a training aid as a Serious Game for Rugby Union athletes.

Visuospatial Capacity, the cognitive ability associated to a person's ability to identify the relationship between objects and space, is an ability that has recently been shown to be an important skill to an athlete in a team sport such as football, where research has previously used the Corsi Block testing, from the Delis-Kaplan Executive Function System (D-KEFS) procedure to test such visuospatial *Cognitive Abilities* [42]. In addition, this skill has also been found to be particularly important to rugby players, with athletes being found to have stronger abilities in this skill compared to average [43]. Therefore, to develop a useful training aid for Rugby Union player, *Visuospatial Capacity* would be a *Perceptual-Cognitive Ability* that if improved could lead to improvements in playing performance of Rugby Union players. Developing a Serious Game that can target this cognitive ability would make such a game usable as a possible training aid. Scenarios within a Serious Game could be presented to participants where a space would require to be identified. Previous research has also found that Visuospatial executive functions are also sensitive to training within rugby players. This research used verified tests in order ascertain baseline cognitive functions as well as monitor impacts of brain training. This included using Processing Speed Indices subtests from WAIS-IV as well as using the Cambridge Neuropsychological Test Automated Battery (CANTAB). Of note is the Design Fluency test from the latter, which assesses Visuospatial Fluency, planning and cognitive flexibility. Participants connect arrays of dots into 4 straight lines to create as many designs as possible within a 60 second time limit. Such a test could be used during research to ascertain the Visuospatial skills of Rugby Players that use a Serious Game training aid to improve their skills. This research also verifies that these skills are important to contact sports such as Rugby Union [18]. Understanding that Visuospatial skills are also receptive to training means that these skills can be targeted for use by a training aid, so using these in a Serious Game could be beneficial to participant rugby players.

To better understand a person's level of *Perceptual-Cognitive Abilities*, research has also analysed Cognitive Ability Testing. It has been found that high-level athletes of various sports, including Team Sports such as Basketball and Football (Soccer) have higher cognitive abilities. This study used recognized tests from the KOG3 battery of tests – including the IT-1 test for assessing input processer efficiency (perceptive reasoning), the AL-4 test for assessing serial processor efficiency (symbolic reasoning), and the S-1 test for parallel processor efficiency (relation recognition and correlations). This research found that athletes from a variety of sports had a good general factor of their cognitive abilities. This was particularly strong with their perceptive abilities from the IT-1 test, which showed high levels of perceptive reasoning; the ability that relates to quick observation as well as recognition of space and memory [44]. By using verified tests such as the KOG3 tests, specific *Cognitive Abilities* of rugby union players could be tested, giving an important insight into any research participants' baseline cognitive ability level prior to allowing them access to any training aid. Such tests could be

used whilst they any participant uses a Serious Game to train these skills as a means of providing them with a score during use. Testing *Cognitive Abilities* would also be relevant after using such a training method, as the rugby union players could then be tested again with their scores compared to their initial baseline score to ascertain if they have improved their *Cognitive Abilities* because they used a Serious Game as a training aid.

To develop a viable training aid for Rugby Union players, an athlete's mental skills or Cognitive Abilities are an important consideration – particularly their visual skills, or Perceptual-Cognitive Abilities. To ascertain baseline ability as well as how much these skills improve whilst using such a training aid, verified tests such as the KOG3 set of tests as well as the Vienna Test can be used. Important Perceptual-Cognitive Abilities for high-performing Rugby Union players include Visuospatial Capacity as well as Pattern Recall – therefore, developing a training aid which enhances these skills will be of particular use to athletes. Testing, as well as training these skills will be important, so scenarios for them could be custom created within a Serious Game with this intention.

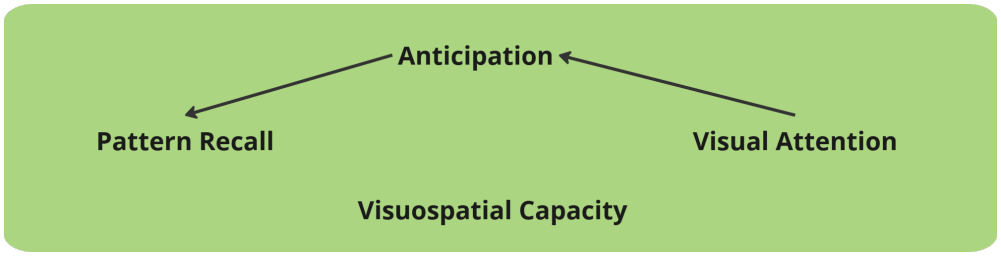

Figure 2.5: Perceptual-Cognitive Abilities in Headlights: Conceptual Framework

2.4.3. Decision-Making Training & Learning

To understand the methods by which *Decision-Making Training & Learning* is carried out within *Team Sports*, analysis of this topic area was carried out. Each decision within a sporting context requires specific approaches to understanding a scenario given to an athlete, which includes their individual role, their team tactics as well as the situation they find themselves within [9]. As presented in Figure 2.6, there are 3 topics discussing *Decision-Making Training & Learning* are *Decision-Making Training Approaches, Decision-Making Learning Methods*, and the *Building Process of Decision-Making Training*. Previous studies have found that there are existing methods of *Decision-Making Training Approaches* within *Team Sports* such as Rugby Union, that includes *Video Analysis* and *Pitch Training* techniques [9][45]. To better understand the methodologies used in *Decision-Making Learning Methods*, existing training methods was investigated. Therefore, to create the Headlights Conceptual Framework which fully captures *Decision-Making Training & Learning*, these concepts were explored.

Rugby Union is a team sport which requires athletes to make numerous consequential decisions during a match. Therefore, different *Decision-Making Training Approaches* are used by coaches using tools such as *Video Analysis* and *Pitch Training* to improve these skills. Research has been conducted into the methods training Decision-Making within the sport of Rugby Union, finding that ever-evolving in-match Player's 'Picture' can make it particularly challenging for coaches with existing methods to develop effective Decision-Making Training [46]. Therefore, by introducing a new technique of using *a Serious Game for Decision-Making in Team Sports*, a game could identify the issues with existing training methods such as *Video Analysis* and *Pitch Training* and be used for more in-depth *Decision-Making Training & Learning*.

The use of video footage from within a sport to improve learning, *Video Analysis*, is a training method used within team sports such as Rugby Union. Previous research identifies this as a commonly used training method for training decision-making within the sport, often combined with other training methods such as on-pitch training [45]. This study interviewed coaches within the sport, who identified this as such a training method, with footage from a team's specific games being used for learning, whilst also looking at video footage of other teams for tactical understanding. A further study identified this tool as a key part of a process of using a *Nonlinear Pedagogical Methodology* of *Building Process of Decision-Making Training* exercise, and that it can be an impactful aid for recognising patterns in play and identifying actions to take within a match, adding to a team's tactical understanding [47].

Outdoor *Pitch Training* within *Team Sports* is where a team will meet on a practice pitch and take part in various skills and drills, with research highlighting this as an existing common method for training decision-making within the sport. This *Pitch Training* can comprise of different constraint-manipulated tasks to give an athlete specific decisions and scenarios within their training, in the form of Games & Drills. Additionally, this research also found that mental exercises such as Q&A also are used by coaches within the sport [48]. This would involve coaches asking about specific decisions a player could make given a scenario, requiring reflective thought on their actions.

There are different ways in which a person can learn decision-making within a specific context, these *Decision-Making Learning Methods* can be utilised by a training aid for *Team Sports*, which is the purpose of this research. *Activity-Centred Design* is involves designing a learning environment that gives the user activities to participate with to learn by interacting with the application. It has been used previously in examples such as to teach organisational learning [67]. Part of this learning

methodology is *Kolb's Learning Cycle*, a multi-stage process for learning. In addition, *Nonlinear Pedagogical Methodology* is used as a learning method that focuses on exploration and learning experiences of the user, with consideration for the teaching environment and has been previously used within a Rugby Union setting. [19]. To create a training aid with the purpose of being used for *Decision-Making Training & Learning*, these topics were therefore explored.

Serious Games are used as a training and learning tool as part of an *Activity-Centred Design*. *Kolb's Learning Cycle* is used as part of this design to train skills such as to enhance decision-making skills, with different established and emerging hardware. For example, a recent study analysed the use of the emerging technology of Smart Watches with a Serious Game to enhance organisational learning. This game required the players to make story-based decisions. This example of using a Serious Game followed an *Activity-Centred Design* approach, where during the design of the application, the activity is focused on producing a certain outcome – in this example to enhance organisational learning [67]. Serious Games have also been developed that enhance decision-making skills of engineers for their logistics training. Whilst the impact on learning of these games is still to be researched, this paper did utilise the *Kolb's Learning Cycle* to develop games that improve these decision-making skills. This cycle is a four-stage learning cycle; concrete experience, reflective observation, abstract conceptualisation, active experimentation [68]. Such a learning cycle could be used when designing a decision-making Serious Game for Rugby Union athletes.

Rugby Union is a team sport that requires players to make often quick decisions based upon specific circumstantial scenarios. Previous research has shown that a *Nonlinear Pedagogical Methodology* is one such methodology used currently by the sport's coaches to train decision-making skills, which involves creating a *Building Process of Decision-Making Training*. Exploring methods to train these decision-making skills then, would prove to be useful when developing a Rugby Union athlete. Research has found that such a training provision should be given on a balance between variability and stability – variability in different actions for a situation creating uncertainty in opponents, and stability giving players a reliable option to execute in a specific situation. This study found that decision-making training should be structured upon four key principles: identifying the problem, setting a strategy, creating an action model, and building a training exercise. This is defined as the *Building Process of Decision-Making Training*, which follows a four-stage *Nonlinear Pedagogical Methodology* (NPM). Identifying a problem could relate to looking for a specific behaviour from a player such as timing an action on the field of play or identifying a lack of space in a situation. Setting a strategy looks to allow coaches to address such tactical-based issues within their teams by

identifying learning tools to use for the team to learn, such as video analysis. Creating an action model involves identifying player-position specific roles in the given scenarios, which can include actions the players should take to execute a tactical strategy. Finally, building a training exercise can have on-field and off-field tasks for players to carry out to learn correct decisions in the identified areas. This study created this model to allow Rugby Union coaches to identify problem areas for tactical understanding among their playing squad and develop a training framework to improve decision-making. This was done by following a *Nonlinear Pedagogical Methodology*, a method where specific training tasks have their constraints manipulated to encourage developing decision making, to create a constraints-led decision-making framework for rugby union. [19]. With all these areas in mind, a Serious Game could be used within setting a strategy as a training tool for Rugby Union players, with such a tool being used when building a decision-making training exercise as an off-field learning tool. Variability and stability could be considered in the creation of a tool, by allowing for multiple 'correct' decisions to be made in each scenario.

Decision-making can be improved by an athlete playing in matches, or by deliberate practice [17]. The use of games as a training tool has also been explored in the past for the sport of Rugby Union. Previous research has found that by using these technologies, expert and novice rugby players can be identified by giving these athletes defensive decisions to make within a VR virtual environment which replicates rugby-relevant scenarios [49]. The research found that the more experienced athletes had quicker and more accurate reactions than the novices. Whilst this proved that virtual environments, such as those used in Serious Games, could be utilized within the context of Rugby Union - it did not prove whether using such tools as a training aid would lead to better performances by athletes during their matches on the pitch. Therefore, this research will investigate this.

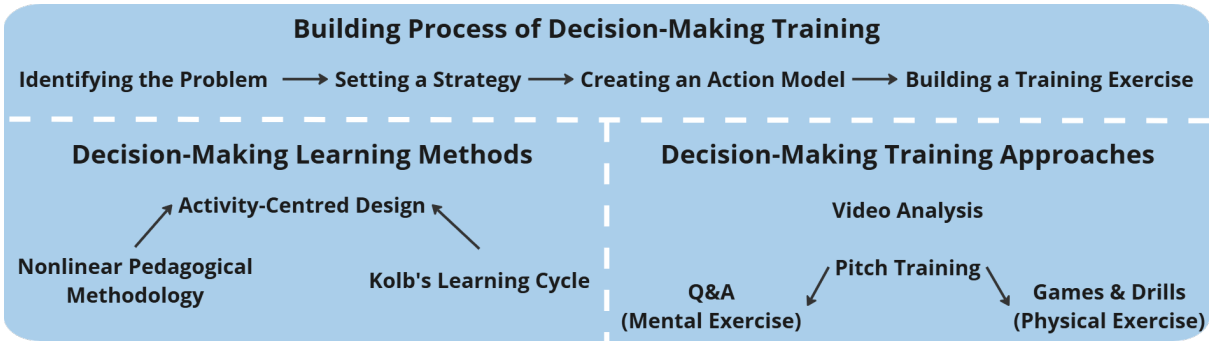

Figure 2.6: Decision-Making Training & Learning in Headlights: Conceptual Framework

2.5. Team Sport Key Performance Indicators (KPIs)

To understand the context of a sport using a Serious Game training aid, and how successful an athlete may be using such a training tool, *Team Sport Key Performance Indicators (KPIs)* will require understanding. As an example, the Team Sport of Rugby Union could be used. A part of tactical awareness within Rugby Union is understanding which running lines are used by attacking players within set plays. A player must understand a role in their attack, and decoy lines have been found to result in higher 'Gainline Success' and 'Line Breaks', two important key performance indicators to the success of a play within the sport. A team that executes decoy lines successfully with individual players also performing these lines with key behaviours (such as running with their hands up or changing their line of attack), research has found that there are improved numbers in these key performance indicators [50]. It is also commonly known within the sport that defensively an athlete and their team should be able to make positive defensive decisions, which leads to 'offensive tackles', i.e. making a tackle on a ball carrying opponent behind the gain line from the previous play [51]. To supplement tactical understanding, using a Serious Game training tool could present players with scenarios where they are asked to identify specific roles in set-play attacking lines, such as decoy runs or the position the ball will be passed to. In addition, there has been further research into the physical attributes of Rugby Union players, which used a specific list of rugby based key performance indicators (KPIs) to further understand how specific physical profiles relate to how successful a player is [52]. Such a KPI list could be used within the analysis of using a learning tool such as a Serious Game to better understand the impact the tool has on a players' decision-making skills.

2.6. Serious Game for Decision-Making in Team Sports

To create a *Serious Game for Decision-Making in Team Sports*, it is important to understand the concepts and approaches used by games of this type. These are a game-based learning tool used in a wide variety of sectors such as education, healthcare, disaster response, military training and in sport (as is the purpose of this research). These types of games are designed with the primary focus on learning. This research will look to develop such a game for the use of training decision-making skills of Rugby Union players, so it is important therefore to understand recent research using a *Serious Game*, to understand frameworks and design methodologies behind the implementation of these games. The *Game Design Approaches* are also important to consider – and how they focus the needs of the user, concepts such as *Human-Centred Design* and *User-Centred Design* focus on such needs when designing software such as Serious Games. The *Hardware & Platform Interfaces* that a Serious Game for this purpose uses will be required to know which device and platform to design a game for with the needs of the users in mind. To understand the game elements required for the Serious Game,

the *Serious Game Design & Rugby Game Mechanics* will need to be understood as well. This Serious Game for Decision-Making in Team Sports area of the Headlights: Conceptual Framework as well as these sections are shown in Figure 2.7.

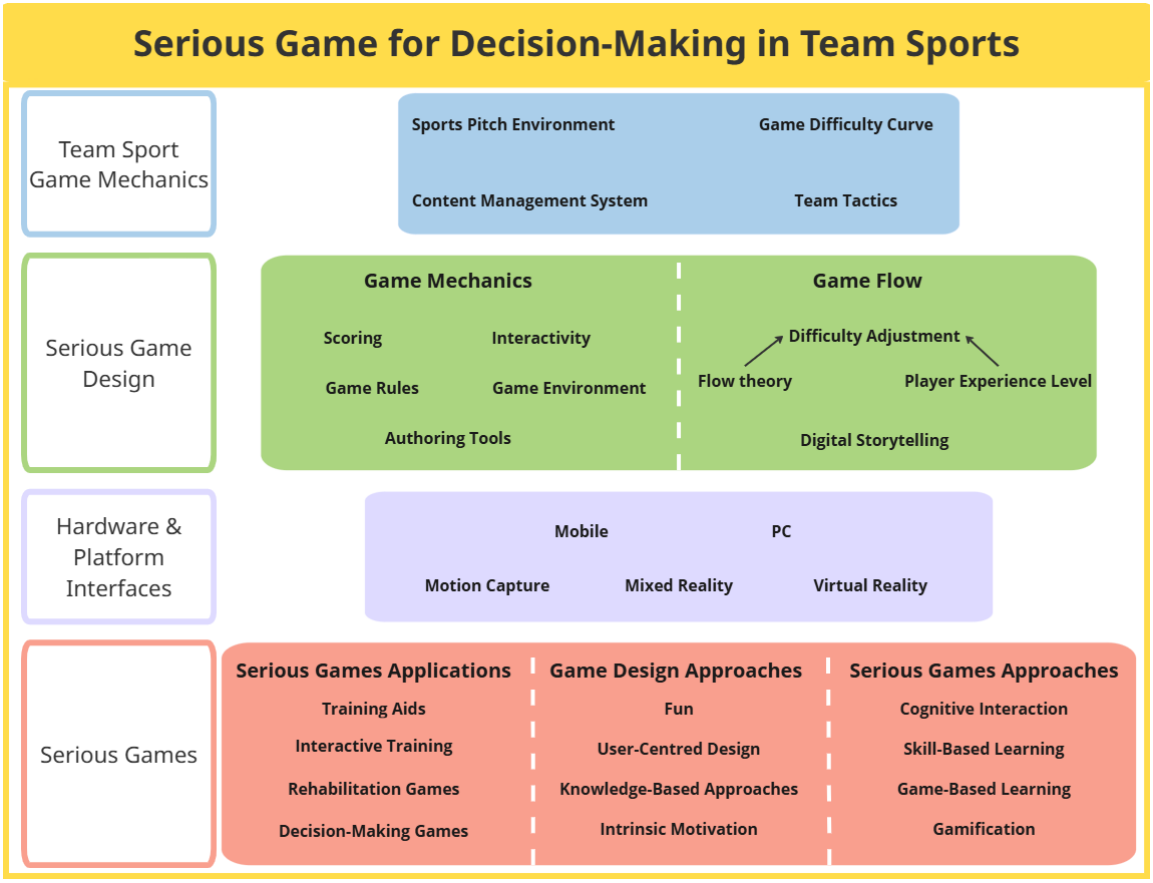

Figure 2.7: Serious Game for Decision-Making in Team Sports in Headlights: Conceptual Framework

2.6.1. Serious Games

*Serious Game*s are often used as a decision-making training aid; these are found to be used in various educational settings for the purpose of learning new skills. To understand a *Serious Games*, its design and uses, three topics are discussed: *Game Design Approaches, Serious Game Approaches,* and *Serious Game Applications.* These themes and the overall Serious Games sub section of the developed conceptual framework can is shown in Figure 2.8. Outside of education, game-based learning has been used for fire evacuation decision making training. This game considered the stress of such situations to as an aspect of decision-making, which would be replicant within a sports context with time-pressured decisions being always required by athletes in a match. This study found that a *Serious Game* could be used to replicate stressful environments such as fire evacuations [53]. The game in this example was designed using a Lu-Lu framework, a game design framework created for use in collaborative decision-making games. The Lu-Lu framework stipulates that the design of a *Serious Game* should balance two dimensions – the Ludic dimension handling the entertainment value of a

game and the Lusory dimension which is the serious purpose (learning outcomes) of the game being designed [54]. Rugby Union players are often required to make time-sensitive, pressured decisions during a rugby match, so having this considered within a Serious Game training aid would be vital to the success of such a game which can be achieved through replicating pressured scenarios within the game, like with this fire evacuation study which replicated the emergency scenario and presented decision repercussions. Likewise, using a balanced system-design framework like Lu-Lu will be critical to the success of any training aid *Serious Game* as user satisfaction by enjoyability of using such a game will need to be balanced with the learning-based purpose.

There are different *Game Design Approaches* to be considered for developing a *Serious Game* training tool for Decision-Making Training in Team Sports. Approaches often focus on the athletes in question, such as a *Human-Centred Design* methodology which focuses on human experiences when interacting with an application. To achieve certain outcomes, *User-Centred Design* is often used in recent research for Serious Game design to ensure a developed game meets the specific needs of its user-base, in this case a game would be designed with Rugby Union athletes carefully considered. To achieve successful design in either of these manners, it's also important to consider the expert knowledge of an area to influence the design, known as *Knowledge-Based Approaches*. Finally, what motivates a player to play any Serious Game will also be required to be considered, this *Intrinsic* Motivation will ensure enjoyable and repeated use of a Serious Game.

Human-Centred Design concepts are used in software development to understand the user needs for an application being designed. As the Serious Game for this research is being designed for a specific user-group, rugby union players, the needs of these users will also need to be analysed so to successfully implement a usable training aid for these athletes. HCD techniques looks at the user needs and requirements from the software during the design process. Recent research analysed a current software system in use by the medical industry to ascertain if the needs of the users were being met. It used the HCD system to understand the problems with the current software and used this with game design principles to propose new changes to improve the system's usability and user experience [55]. For the purposes of this research, the needs of rugby union players will need to be looked at, particularly what decision-making skills and cognitive abilities are crucial to the sporting performance of these athletes. Understanding this element is key to this research, but the wider needs of the rugby players will also need to be understood in a similar way that the healthcare research sought to understand the needs of the users for their software. This study will use a usability test on the first prototype developed to see if these needs are being fulfilled. Where issues are identified, these will

be resolved in further development of a game prototype before the final study is conducted to ensure HCD principles are followed.

Another design methodology that is linked to *Human-Centred Design* is *User-Centred Design*. The purpose of *User-Centred Design* is to create systems that puts the needs of the users first to design any given system. These needs are considered at each stage of the design process cycle, with the aim of this methodology to create systems that increase user productivity with the designed application, their satisfaction as well as decreasing user training time [56]. Whilst Human-Centred Design considers the users' needs during a system design, *User-Centred Design* will consider the requirements for tasks required of the users at each stage of the design process. As previously identified, there are frameworks in place to that put users' needs at the heart of a design process such as that of the TURF framework (Tasks, Users, Representation & Function). With TURF, the usability of a system for the intended users' needs are measured by three dimensions; useful, usable, and satisfying. These dimensions are measured in different ways. A system is classified as 'useful' if the system successfully supports the goals of the users' key tasks. Usefulness is usually measured by identifying these key tasks and ascertaining how many of these tasks a system successfully implements. A system is 'usable' if it straightforward to learn whilst being efficiently used by the intended users. This can be analysed by ascertaining the amount of learning required to complete tasks within the system whilst also measuring the effectiveness of the users to complete those tasks, with appropriate error tolerance accommodated for. 'Satisfaction' under TURF is user-subjective about how they found using the system. This typically is measured using survey questions on user perception. Therefore, the TURF framework creates a subjective and objective framework for creating a user-centred system. The TURF framework creates a User Model by interviewing key individuals (in a recent study, healthcare professionals were used) as well as using surveys. In addition, for the healthcare example, an Activity Model was developed by conducting a field study where these professionals were shadowed in their daily work to establish key functions [57] . For this research, a *User-Centred Design* approach can be used by identifying the key decision-making skills and cognitive abilities of Rugby Union players. This can include user analysis by identifying key individuals involved in Rugby Union to form these needed tasks for users, in this case the rugby players. These can then have specific Game Mechanics created for these skills whilst the learning curve of the game can be measured. By following up with user-based surveys within the experimentation period, it can be ensured that the designed game is useful, usable, and satisfying. If required, a field study of a rugby team could be carried out to establish an Activity Model which could incorporate a specific teams' own match tactics which could enhance the

relevance and usability of a game prototype to a research group. Using these measures would ensure that a *User-Centred Design* approach using the TURF framework is followed.

Knowledge-Based Approaches to design, such as the use of a Knowledge-Based Coaching System (KBCS) involves four main areas: domain knowledge, trainee model, performance evaluation and training controller. This is a system used in other sports such as Table Tennis to create automatic and intelligent sports training [20]. To create a game to be used to train Rugby Union athletes, any Serious Game would require autonomous training by the athletes using the system. A KBCS system could be used within the design of Serious Game for rugby union athletes by introducing modules on different areas of the sport, as well as position-specific training modules which could look at details related to a players' role within a rugby union team. Athletes could select the modules most relevant to them, or alternatively a coach/trainer could pre-designate specific training modules for their players to engage with as part of their training program. To support such a KBCS system, a means of managing content for rugby union players and coaches will be required for any Serious Game of this type.

Research into the motivating factors behind why someone is motivated to play any video game, such as a *Serious Game* has been studied before. This *Intrinsic Motivation* can be used to motivate players to engage with a game, which can also improve performance whilst using a game [58]. As mentioned in previous sections, by designing any Serious Game using a User-Centred approach that tailors the game to their needs, this *Intrinsic Motivation* can be tapped into. Therefore, using such motivation factors during the development of a research prototype for this study will be considered.

In the design and implementation stages, *Serious Game Approaches* can have different varying objectives to the learning and type of game created. *Skill-Based Learning* is what is often the purpose of any Serious Game, and this can vary from decision-making skills to motor skills. Mental, cognitive abilities can also be targeted for improvement for the player in the form of *Cognitive Interaction*. Serious Games are a form of *Game-Based Learning* which can cover all these types of learning and interaction, with the learning going through *Gamification* techniques to make them enjoyable to play for the player. These themes were therefore explored to better understand the *Serious Game Approaches* taken in existing research.

As Serious Games are a learning tool and training aid, these games represent a *Skill-Based Learning* technique where different skills can be taught to their player's. Therefore, *Skill-Based Learning* is an important consideration for a *Serious Game for Decision-Making in Team Sports*, and it will be important to assess which skills will be required to enhance the Decision-Making of these athletes.

This will also include the *Cognitive Abilities* of Rugby Union players, particularly the *Perceptual-Cognitive Abilities* that underpin decision-making. These key skills were discussed in the previous section, where rugby players decision-making skill level was connected to their understanding of a given scenario – or the Player's 'Picture' in front of them [24]. To be able to process this information, key *Perceptual-Cognitive Abilities* were also identified such as *Visual Attention, Anticipation, Pattern Recall* and *Visuospatial Capacity* [15][41][43] – all skills that impact the athlete's ability to visually process information presented to them. Therefore, these key abilities will be the focus of the *Skill-Based Learning* required for this research.

Serious Games have been used as training tools for Cognitive Abilities before, these games engage with *Cognitive Interaction* to teach certain mental skills. An example of this is the game design framework for use of gamification in e-learning for children with ADHD [59]. Additionally, Serious Games have been used to measure cognitive decline by assessment to detect mental conditions early [60]. To create a Serious Game for Decision-Making in Rugby, any game would need to be able to engage in *Cognitive Interaction*, to improve the Perceptual-Cognitive Abilities that underpin Decision-Making, as discussed in a previous section. This could take the form of visual prompts and in-depth scenarios that recreate common patterns seen within the sport.

As Serious Games are games which are designed for the specific purpose of learning, this means that they fit into the game design concept of *Game-Based Learning*. Training earthquake first responders by use of a Serious Game is the result of a recent study. This used Immersive Virtual Reality (VR) with *Game-Based Learning* as a design concept. For that game, the *Game-Based Learning* was adaptive, so players had to react to given scenarios and make the correct decisions [31]. Recent studies also found that a Serious Game designed for basketball players using VR can reduce decision-making time for athletes, a key requirement to enhancing the performance of team sports athletes. This study also did identify thought that whilst using Serious Games with VR in this way has this benefit, it does not improve tactical understanding for such team sports [61]. Similar could be achieved for the purposes of this research by giving rugby players a range of scenarios that adapt and require the players to make reactive decisions. The purpose of this study is using such a Serious Game to training the *Perceptual-Cognitive Abilities* and Decision-Making skills of Rugby Union players. Therefore, this research will need elements of *Game-Based Learning,* as the intention for those using the game is to learn and develop the key skills to improve as a rugby player. By understanding the game mechanics that will form the basis of the outlining framework for the game design for this study, the concept of *Game-*

Based Learning will be fully explored. These mechanics will be the fundamental elements to the *Gamification* side of the training aid developed as a prototype.

Gamification is a key component of any Serious Game, where the purpose of such a game is to provide a fun or enjoyable experience whilst playing. Research has identified that *Gamification* techniques have been found to improve performance of in learning in educational settings [62]. In addition, with specific context applied to a Serious Game, *Gamification* techniques can take often complex issues and present them in user-friendly ways for non-experts to a field [67]. These are important considerations for a Serious Game for Decision-Making for the sport of Rugby Union, as a gamified training aid could be designed to tailor for different rugby experience levels, as well as be a motivational tool for engaging athletes with Decision-Making Training & Learning. Research has analysed the use of video games, and their *Gamification* techniques and their impact on Rugby Union athletes [63]. Additionally, *Gamification* techniques have also followed *Game Design Approaches* in the past, targeting specific learning, these have been shown in research to follow *User-Centred Design* methodologies [64]

Throughout the field, there are different ranging *Serious Game Applications* where games have found different uses in learning. Serious Games are a form of *Interactive Training* where learning and enjoyment are both considered. This literature review looked at these uses in the form of *Training Aids, Rehabilitation Games* – where injuries are recovered from using these games. The purpose of this research is to create a *Serious Game for Decision-Making in Rugby*; therefore, *Decision-Making Games* were also investigated in literature.

Interactive Training is one means of education where those learning are involved and can interact with their learning process. This includes Serious Games, which by design are interactive forms of digital media where their use can see increased learning motivation [65]. Research has also shown that using *Interactive Training* as a learning method can increase immersion for the player within the game, as well as *Game Flow* [66]. *Interactive Training* can also use existing *Game Design Approaches*, where *Knowledge-Based Approaches* have been used to design a game framework and has been used in within a sports context [67]. This Serious Game Application has also been found to be used in *Cognitive Interaction* games, such as identifying cognitive deficiencies in preschool children [30]. *Serious Games Applications* therefore make use of *Interactive Training* and is important to consider the *Serious Game Design & Rugby Game Mechanics*, discussed later that are used for the purposes of this research.

Using games as *Training Aids* in sport has also been a focus of recent research. It has been shown that one possible use for such an aid would be by a game to improve the attacking and defensive decision making of basketballers, with a study finding the time taken by the athletes who trained with this game was quicker than a control group without it [27]. Serious Games have also found use with VR in sports training, such as being used to improve the performance of clay pigeon shooters [68]. Therefore, Serious Games have got a proven track record for being viable training options within the context of sport making this an appropriate technology to develop a training aid for Rugby Union players.

Serious Games as applications for injury recovery have also been used and studied previously. These *Rehabilitation Games* are designed to assist a person with their recovery, often by gamifying the exercises required to enable this. A previous study found that the use of such a game for such exercises can be used to overcome other at-home therapies shortcomings, such as lack of feedback [69]. Additionally, previous research has also found that *Rehabilitation Games* can be used for assisting with long-term health conditions such as Osteoarthritis, with this game-type being easy to use and designed in a user-centred manner, by considering the needs of the patient [70]. Whilst not in the scope of this research, rugby injuries could be consideration for a Serious Game training aid for the future.

Recent studies have made use of games technology in the form of *Decision-Making Games* to enhance the decision-making skills of athletes, in one case these skills where targeted for basketballers with a group using a Virtual Reality training system and a group using a computer-simulation training system, to enhance their decisions for their sport – this system presented the athletes with different scenarios often found in a basketball match, these were designed by professional basketball coaches. This study used 11 different basketball offensive actions such as passing or shooting. Basketball players were recruited and shown specific scenarios and asked to determine an immediate offensive action to take. If a player is judged by the system to have made an incorrect decision in the scenario, they would be prompted with correct actions to take and asked to repeat the scenario until a correct decision was made. This 'repeat until success' methodology was shown to result in participants being able to take less time to make correct decisions, with the computer-simulations being considered more effective at designing decision making exercises that are individual-specific for the team sport of basketball [27]. For research into using a serious game to improve rugby union athlete decision-making, a similar method could be used. A game loop could be developed to present players with a decision to make, if the player makes an incorrect judgement a prompt could appear with a correct decision to make in

that given scenario. The scenario could then be repeated until the player is successful in making a correct decision. Like with the basketball research, rugby union coaches could also be contacted to develop appropriate rugby-related scenarios and actions for such a training tool.

Serious Games Applications	Game Design Approaches	Serious Games Approaches
Training Aids	Fun	Cognitive Interaction
Interactive Training	User-Centred Design	Skill-Based Learning
Rehabilitation Games	Knowledge-Based Approaches	Game-Based Learning
Decision-Making Games	Intrinsic Motivation	Gamification

Figure 2.8: Serious Game for Decision-Making in Headlights: Conceptual Framework

2.6.2. Hardware & Platform Interfaces

Serious Games have found varying uses on different *Hardware & Platform Interfaces* in recent years – from early detection of learning difficulties in preschool children [71], to aiding senior citizens in their knee maintenance [72]. Such games have made an impact in education with *Mobile* games, showing positive immersive experiences in games that are developed on this platform, which can also be accessible in multiple settings – from a classroom to museums using *Mobile* platforms for this reason [74][73]. It has been shown that one possible use for such a tool would be by using *Motion Capture* technology to improve the attacking and defensive decision making of basketballers *Serious Game* development has also encapsulated modern technologies; the Nintendo Wii has been used to enhance the cognitive functions of patients suffering from dementia [74]. The advent of *Virtual Reality* (VR) has also found various uses. Similarly, to the Nintendo Wii, VR has been used in cognitive training [75]. Other areas of research have utilized this technology using Serious Games such as training best practices in the event of an earthquake [31]. In a mental health setting, VR and Serious Games have also been shown to be impactful when dealing with phobias such as speech anxiety, with previous research using this technology as an exposure therapy to aid with this [76]. When developing a prototype training aid for the use of Rugby Union players, using a platform that is most easily accessible and usable by these athletes is an important factor in Serious Game development. All currently available technologies for the prototype will be considered for this reason and can be found listed within Figure 2.9.

Figure 2.9: Hardware & Platform Interfaces in Headlights: Conceptual Framework

2.6.3. Serious Game Design & Rugby Game Mechanics

Whilst Serious Games can have a variety of uses, it is important to develop a design-framework for such games to have their intended results. In any given research, the *Serious Game Design* will be a key consideration with the game's context and mechanics, in this case the *Rugby Game Mechanics*, carefully considered. By understanding such core design concepts as *flow, game difficulty curves, human-centred design,* and *game-based learning*, we can establish the outline of a framework for a Serious Game for training rugby union players. This framework outline can then be filled with the *Game Mechanics* that will support the learning, enjoyment, and usability for those that play the game prototype. This section will discuss two topics of *Serious Game Design*: *Game Mechanics* and *Game Flow*. This section will also discuss *the Rugby Game Mechanics* that support the concepts in these topics. These two sub sections of the conceptual framework are presented together in Figure 2.10.

The design of Serious Games has been considered previously in research, with one study analysing the design approach for a Serious Game in Higher Education with a literature review pairing educational outcomes to game design frameworks, such as coupling these learning objectives with game rules, goals, and choices. This study paired learning 'attributes' such as information transmission to game attributes such as scoring and task descriptions [77]. Following a similar methodology, key game attributes for a rugby union training aid can also be established and paired with learning objectives. This would ensure viability as such a training aid by these athletes. Designing a Serious Game framework in such a manner would follow a user-centred design approach. This is a model where the needs of the user are central to the design of a system and has been used for Serious Games before, in the implementation of a Serious Game to teach clinical reasoning to medical students. This study ensured a user-centred design by conducting a usability evaluation as part of the game development process whilst also recruiting study participants from the nursing student community to ensure relevance [78]. The needs of the rugby players are very specific for this study, so keeping them central to the design of such a game is necessary for the final game prototype to achieve it's intended goals. Therefore, a user-centred approach like this will be necessary whilst also recruiting any study groups from the rugby union community. The clinical reasoning study also used a usability framework called

TURF (Tasks, Users, Representation & Function). This framework is described as considering the usability of and satisfaction of a given system for the users attempting to accomplish their goals within a work domain by task performance [57]. Using a similar methodology, Rugby Union players could be carefully considered in the design of a Serious Game framework which will meet their needs through Serious Game tasks. This will involve creating scenarios within the game that are relevant to them and will help their understanding of tactical situations and improve specific desired decision-making. Similar has been done in the field of Serious Games previously, where a Serious Game for tourism used a player's inputted data to determine the most relevant game scenarios to give the player [79]. A Serious Game for rugby could use the player's relevant playing experience and position to determine scenarios to give the player in a similar fashion.

How a *Serious Game* is played is defined by the *Game Mechanics* that are used by the player to interact with it. This *Interactivity* is defined by its *Game Rules & Scoring*, which dictates the way in which the player can play the game. Any game will also require a *Game Environment* which is relevant, in the case of this study, a *Rugby Pitch Environment*. A *Serious Game* for learning will also require an element of *Content Management*, where a game will select or alter scenarios facing the player. These can also exist as *Authoring Tools* to alter scenarios. *Game Mechanics* will be an essential characteristic of a *Serious Game Design* for Decision-Making in Rugby, where previous studies have found that gameplay elements like mechanics can be grouped with end-users' in mind [80].

The *Interactivity* of a Serious Game, how the player engages with the game, is an important consideration of its design. This is often characterised by its Game Rules & Scoring, the Game Environment where the game takes place as well as the Game Flow, which establishes how the game plays and the level of challenge presented to the player. Research has shown that *Interactivity* with a game can be used in multiple ways to achieve learning through Serious Games, such as by identifying cognitive deficiencies in preschool children [30], as well as increasing immersion within the game and improving its *Game Flow* [66]. To design a *Serious Game for Decision-Making in Team Sports*, the *Interactivity* must be central to its overarching design and incorporate appropriate immersive mechanics that establish clear *Game Rules & Scoring.*

The *Game Rules* of any game are important to establish the acceptable parameters to players whilst playing the game. These can take the form of actions the player can and can't take as well as rules that are effect triggering (consequences of player choices and actions). *Game Rules* when established should also consider the specific player of the game being designed [81]. As with games, the sport of

Rugby Union has various rules and *Scoring* systems, which can lead to a variety of different scenarios that players may find themselves in during any given game, an area where coaches have differing training strategies to coach their teams [24]. These must be considered in the design and implementation of any rugby-based training aid, so is important to this study. The Game Mechanics must follow the specific rules set out for that game, therefore considering the rules for this research is important when implementing the prototype game. A Serious Game has been developed for the purpose of teaching solder adults about medical knee maintenance. This game was designed with clearly established effects rules such as massaging methods used by the patients. The Senior Knee Maintenance game also explored game *Scoring* systems [72]. The use of *Scoring* systems is important to the design of a Serious Game. In one such example, scores of older and younger dementia patients were used when playing such a game to distinguish the cognitive status of the patients [82]. Similarly for this study, scores from game sessions could be used to track the development of the skills with a given research group. This means a picture of the progress of those taking part in the research would be able to be gathered.

Important design considerations for *Game-Based Learning* have been previously established, one of such considerations is constructing a relevant context with the use of *Game Environment*. Studies also show that by using a relevant environment, realism within a Serious Game is improved, which also enhances motivation to play the game [83]. Previous studies have identified this as one of the most critical for *Game-Based Learning* [84]. As the context for the *Serious Game* in this study is Rugby, it makes sense therefore to use a *Rugby Pitch Environment* to replicate the sport. Previously, Serious Games have also been the subject of User-Centred design, which can lead to high levels of user engagement for games designed in this manner [85]. Therefore, in the creation of any Serious Game, the environment presented to the player must be appropriate for the subject. In the context of team sport-related training aids, as is the purpose of this research, the *Game Environment* often either closely replicates the playing pitch or arena commonly used for the sport or uses real footage from matches of that team sport (with the aid of technologies such as Virtual Reality) as found for examples in football, basketball and rugby [49] [27] [14]. Additionally, studies have shown a Serious Game can improve skills with the correct *Game Environment* included and shown that this is best done using a game made in 3-dimensions (3D) instead of 2 [86]. As with these examples, this research will look to use a *Game Environment* that replicates a *Rugby Pitch Environment*, to best replicate the environment for the athletes taking part in the research.

A *Content Management* System (CMS) is a digital system where content is created and modified for the user. *Authoring Tools* can support this by allowing custom-targeted content to be created and used within a *Serious Game*. Recent research has found that using such a system is possible for young patients suffering type I diabetes as a means of knowledge acquisition – where the user could create stories related to their condition and how to manage it. This study found that 85% of participants were able to do what they wanted using the CMS system, with 90% finding the system easy to use. The QUIS (Questionnaire for User Interaction Satisfaction) was used by this research to ascertain the CMS system's usability [21]. As such, a CMS system could be designed for use by rugby union players, to customize their own learning experiences – this could focus on specific areas for development that an athlete would wish to focus on. Using a CMS system in this way could tailor the game scenarios and training that a player using the game experiences, based upon factors such as their rugby playing position, playing experience level and even team tactical scenarios.

Game Flow is a concept where a person is invested in the interaction, they are having so much so that attention is invested into achieving goals, enjoyment from this can be achieved by steps such as the person having tasks with a reasonable chance of completion, clear goals, feedback, deep involvement, a sense of control over actions [87]. Previous research has found that achieving this *Game Flow* state within a game-based learning can result in higher reflective processing, allowing players to reflect on problem-solving activities. It also showed that contextual learning within a game with realistic scenes can facilitate learning with flow [88]. It has also been found that *Game-Based Learning,* such as a *Serious Game*, can result in higher chance of the learner entering this state of flow than traditional learning methods [89]. Within game-based learning, such as a *Serious Game for Decision-Making in Rugby*, *Game Flow* can be achieved by following similar design steps such as constructing learning environment that teach activities, setting clear goals and direction, creating meaningful experiences through the learning desired, placing educational challenges with different difficulty levels, as well as implementing gameplay mechanics that enhance motivation and learning.

Considering *Game Flow* whilst carefully analysing the *Game Difficulty Curve* therefore is an important concept for this research, as both skill retention as well as player engagement are desirable for the purposes of training rugby players using a specifically designed Serious Game. The *Game Difficulty Curve* can be tailored based-upon any given player's skill and experience level by means of *Difficulty Adjustment*. In addition, previous research has shown that considering learning from a Serious Game, with interactive scenarios with the scaffolding technique (which tailors the knowledge of the user, reducing reliance to gradually increase learning) will improve the motivation to learn of the Serious

Game player [65]. Whilst designing the prototype, flow can be carefully considered as well as player skill level, however, this will need to be tested to ensure that the difficulty curve reaches the desirable levels. A previous study into using a Virtual Reality Serious Game to improve assembly line training showed that using such a game but tailoring the difficulty in this fashion can improve the training results, whilst also being supported by given players appropriate feedback whilst using the game [90]. One way to ensure difficulty curves of the Serious Game are appropriate for players could be by ensuring it through player usability testing in the initial research period of testing, with feedback altering the designed difficulty curve.

The concept of *Flow Theory* was established to enhance player enjoyment when playing a game. A game designed with successful *Flow Theory* will present challenges to the player that are just above their current skill level to prevent player boredom – it also stipulates that the challenge not be too far advanced of player skill so that it causes frustration. Balancing challenge with skill level is therefore an important consideration when designing any game [25]. *Flow Theory* is an important consideration when even considering cognitive processes, a topic of this research, as recent research has used flow as a concept when analysing the *Game Difficulty Curve* to not overwhelm players. This research used a *Serious Game* to ascertain that a data-informed design process could be used to ensure that the flow and difficulty curve of a game is of a suitable level [91]. The findings from this study found that by pacing the flow and difficulty of the game in this way, player engagement can be increased whilst also improving the skill retention sought after by the *Serious Game*.

A multimedia educational approach, such as found in Serious Games, *Digital Storytelling* combines these techniques to create engaging narratives for players to enjoy within a game-based learning environment. The concept of using *Digital Storytelling* techniques has been used in previous Serious Games research, which showed games such as this can be designed to allow players to choose which scenarios to play using a *Content Management* System (CMS) [92]. This method of selecting tailored content and creating specific engaging scenarios using *Digital Storytelling* methods could be used for a *Serious Game* for the sport of Rugby Union. It would use the sport as a context and allow players to tailor the scenarios they would use within a training aid which can be based upon their own experience and playing position within the sport. Decisions can be made by players with tactical background that is provided by their coaches, which provides influence during a match. Games have been shown to improve the decision-making of Rugby Union players before, with Video Games, not specifically designed for educational purposes being used to improve the understanding of the sport for novices

to the sport [63] – a tailored *Serious Game* could have the same impact, using the *Rugby Team Tactics* as the context behind the *Digital Storytelling* techniques used within such a game.

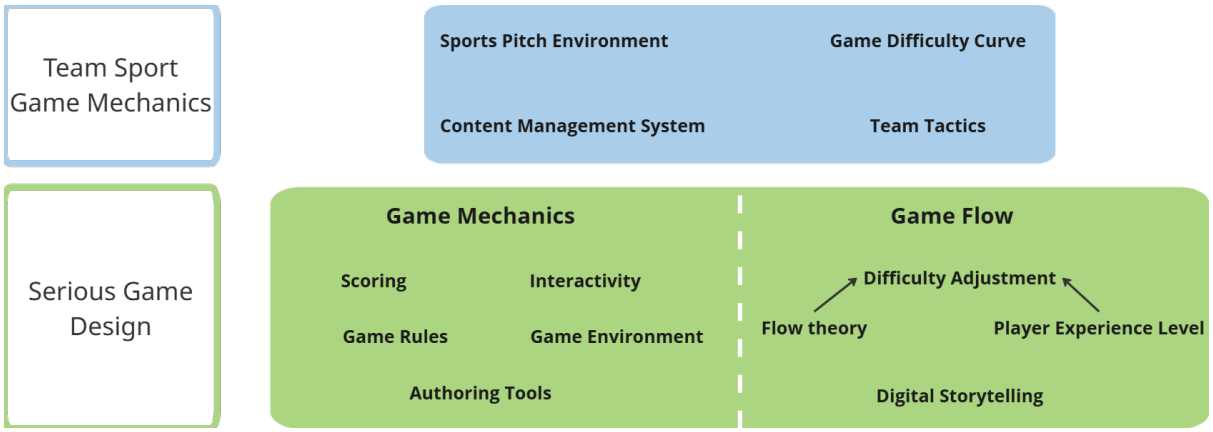

Figure 2.10: Team Sport Game Mechanics & Serious Game Design in Headlights: Conceptual Framework

2.7. Discussion

The purpose of this systematic literature review, carried out following the PRISMA technique, was to establish the latest state-of-the-art developments in Serious Games, particularly when being used for Team Sports such as Rugby Union. From which, two clear themes emerged from this review: Decision-Making Training in Team Sports, and Serious Game for Decision-Making in Team Sports. These formed the two sections of the Headlights Framework. These themes were linked together with indicators of success for an athlete in the sport, called the Rugby Union Key Performance Indicators (KPIs). The resulting themes, and key concepts underlying this formed the basis of the Headlights Framework.

Most recent research into Decision-Making Training in Team Sports was explored, which established the latest trends in Team Sports. Within Team Sports, Tactical Decisions were identified as a key concept where an athlete's understanding of pre-agreed patterns within their team's structures were noted as important to the success of the athlete and their team. Within Rugby Union, Tactical Decisions can be made either in structured play (set pieces) as well as unstructured play (open play) within the sport. Decision-making within the sport has different factors that influence decisions – this includes a team's tactical structure (both offensive and defensive tactics), and associating correct decisions with a Player's 'Picture' – what is put in front of them, what area of the pitch they are in. Collaborative Decision-Making in Team Sports is where athletes would jointly make decisions for a team given a specific scenario and following their team tactics for Tactical Decisions – this has been used in a Serious Game context previously. An important link to Cognitive Abilities and Decision-Making is an athlete's Perception – what they can see and how they understand the scenario in a

match unfolding in front of them. This Player's 'Picture' is a key concept in understanding Tactical-Decisions, which will be required for a Serious Game training aid for this research. Exploring how to best represent this in a game format will be explored within the next chapter, with a key participant study within the sport.

As part of the literature review it was vital to learn which Cognitive Abilities were crucial to the performance success of Rugby Union players, so as best to design these to be implemented within any training aid. It was quickly ascertained that visual skills, Perceptual-Cognitive Abilities such as Visual Attention, an athlete's ability to track and pay attention to objects as well as their Anticipation, the skill to predict what will happen ahead of time were key skills for a Rugby Union athlete. Pattern Recall was also found to be a key skill for Rugby Union players, as they could use this skill to recognise structured and unstructured plays within the sport. Visuospatial Capacity was also identified as a key skill for rugby players, as it relates to objects and the spaces between them (for example this could relate in the sport of rugby to an approaching opposition player and the space around them which can be exploited by a player). As part of the reading on Cognitive Abilities, testing techniques for these skills were identified such as the D-KEFS set of tests, as well as standardised tests such as the S-Test. Whilst exploring further into Cognitive Abilities and the underlying tests is not the principle purpose of this research, it is important to best understand the visual skills underlying decision-making by Rugby Union players, therefore these concepts were key and added to the Headlights Framework.

The current methods for Decision-Making Training & Learning, particularly within the sport of Rugby Union were then explored. The most common approaches to Decision-Making training were found to be the study of game footage, called Video Analysis, as well as traditional, team training sessions, referred to as Pitch Training. For Decision-Making Learning Methods, different learning techniques used by coaches in the sport were explored. Different studies identified appropriate staged learning methodologies for teaching decision-making, such as constraints-led approaches incorporated into Activity-Centred Design of training. One such methodology used the Kolb's Learning Cycle, a four-stage learning cycle; concrete experience, reflective observation, abstract conceptualisation, active experimentation. Decision-Making Learning Methods also included approaches where constraints are manipulated, to improve decision-making such as found in a Nonlinear Pedagogical Methodology. This methodology also identifies the key stages of a Building Process of Decision-Making Training. To develop a framework which is reflective of all key concepts of Decision-Making Training in Team Sports, existing methods for training were needed to be understood – therefore these as well as the methodologies used by coaches to train decision-making were added to the Headlights Framework.

In addition, understanding the strengths and weaknesses of using these existing methods will be important to develop a Serious Game training aid for the sport of Rugby Union, this will be further explored in the next chapter where interviews with a key participant group in the sport was undertaken.

Overall, literature for the theme of Decision-Making Training in Team Sports identified the different ways in which decisions are made in Team Sports, the visual Cognitive Abilities that underpin the experience and success of any Rugby Union athlete, as well as the Decision-Making Training & Learning methods currently used by coaches in the sport. The concepts underlying this theme were added to this section of the Headlights Framework, which better lays out the design considerations for making a training aid for Decision-Making Training in Team Sports, the purpose of this research.

The latest research on the theme of Serious Game for Decision-Making in Rugby was also explored in this literature review. A Serious Game is a game where the primary purpose of playing the game is for learning. As this research is focused on learning via a training aid for Rugby Union, the literature for Serious Games was investigated. Game Design frameworks such as the Lu-Lu framework were identified. This stipulates that the design of a Serious Game should balance two dimensions – the Ludic dimension handling the entertainment value of a game and the Lusory dimension which is the serious purpose. As part of this investigation, the latest state-of-the-art for existing Game Design Approaches, Serious Game Approaches, as well as Serious Game applications were explored. Finally, a review of the latest Hardware & Platform Interfaces found in literature was conducted.

The latest Game Design Approaches were identified within the literature for the purpose of the Headlights Framework. These included approaches which widely considered the end users such as Human-Centred Design. This approach is used in software development to understand the user needs for an application being designed and has been used in recent research to improve user satisfaction. However, this is not an approach that specifically looks at the individual user needs, such as User-Centred Design. Whilst Human-Centred Design considers the users' needs during a system design, User-Centred Design will consider the requirements for tasks required of the users at each stage of the design process. A TURF framework (Tasks, Users, Representation & Function), as used in User-Centred Design, puts users' needs at the heart of a design process – improving system satisfaction and decreasing required training time to learn new skills. Knowledge-Based Approaches to design, such as the use of a Knowledge-Based Coaching System (KBCS) involves four main areas: domain knowledge, trainee model, performance evaluation and training controller. This methodology required coach

input to learn knowledge from the system, therefore in the next chapter of this research, an expert group of key participants from the sport of Rugby Union will be identified to fulfil these requirements, as well as to follow the TURF framework at the heart of User-Centred Design. Intrinsic Motivation was also identified as important to understanding why players would wish to use a Serious Game training aid, so this will need to be considered as well.

Serious Game Approaches were also investigated, with four key areas found in literature. This included Skill-Based learning, Cognitive Interaction as well as the Game-Based Learning methods used and the Gamification elements of their design. These were important background considerations for the Headlights Framework, as they identify the ways in which Serious Games have been used in the past, with research even finding examples within sporting contexts. These Serious Game Applications included Interactive Training, Training Aids, as well as Rehabilitation Games and Decision-Making Games. Past literature found that whilst Rugby Union had not been used in this specific context previously, decision-making as well as Team Sports have been used and the topic of Serious Games. Turning to the Hardware & Platform Interfaces used by these games, whilst developments have been made on platforms such as Virtual Reality, the purpose of this research is not to enhance new technologies but create an accessible training aid – therefore Mobile or PC platforms will be considered for the development of a prototype, with the next chapter of this study identifying which would be more accessible by interviewing a key participant group.

The final layers of the developed Headlights Framework, found from this literature review, covered Serious Game Design & Rugby Game Mechanics. One layer looking at the Serious Game Design, with the other covering the Rugby Game Mechanics to be used for this. Existing Game Mechanics used in Serious Game covered Interactivity, Game Rules & Scoring as well as Authoring Tools & Content Management. These are the fundamental blocks to be used to create a Serious Game design framework. Context and difficulty level for any Serious Game was also found to be important to the immersion and enjoyment of the players for any Serious Game. Therefore, for this research the Game Flow will also be considered, with considerations of the Difficulty Adjustment & Game Difficulty Curve, as well as the Flow Theory and Digital Storytelling, where the specific game context will come into place. These concepts were added to the Headlights Framework and will form the basis of the Design Framework which will be further considered in the following chapters, where a User-Centred Design approach will be used, the next chapter of this study will begin this process by interviewing key participants from the sport of Rugby Union.

2.8. Chapter Summary

In this chapter a systematic literature review following the PRISMA technique was conducted. This examined the latest developments in research for using a Serious Game as a training aid for a Team Sports such as Rugby Union. From this literature review two key themes were developed into sections of the Headlights Framework, a conceptual framework of the latest state-of-the-art in the topic area. These two themes are Decision-Making Training in Team Sports, and Serious Game for Decision-Making in Team Sports. These two themes are connected by the context of Team Sport Key Performance Indicators (KPIs). Recent developments have shown that team sports can be used in a Serious Game as a means of training, however there is no significant research showing if using such a game can improve the decision-making skills of athletes in a team sport, such as Rugby Union. Investigating this will be the purpose of this research, and in Chapter 3, a study will be undertaken that aims to create a working prototype game to be used for this purpose by interviewing a key participant group of experienced people from the sport. This approach will ensure a User-Centred design approach is taken for the Serious Game development.

Chapter 3: Study 1: User-Centred Design & Development

To ascertain if a Serious Game can be used as a training aid to develop decision-making skills and perceptual-cognitive abilities of Rugby Union players, a research plan was created and followed. This research was separated into two studies. The first stage aimed to create a design framework and working prototype with the involvement of a key participant group as a means of feedback to ensure the prototype achieved its intended purposes. To establish a design framework for this prototype, the participant group was shown an initial High-Fidelity Prototype to act as a storyboard to present the key areas for the training aid prototype game. The resulting prototype was used in the second stage as a proof-of-concept, this stage analysed the working prototype's usability as well as measuring the impact of such a training aid. Both parts of analysis used a participant research group, with a control group also used during the second stage of the research as a means of measuring the impact of the research.

This study involved the design and creation of a prototype Serious Game that aimed to be used as a training aid to enhance the decision-making skills and perceptual cognitive abilities of Rugby Union players. To achieve this, a key participant group was identified that included key people from a range of backgrounds within the sport of Rugby Union. This group was recruited based on four recruitment categories given their background: Experienced Rugby Players, Rugby Coaches, Sport Psychologist, and Performance Analyst. Participants included Rugby Union players with a certain level of playing experience, as well as experienced coaches who are currently working with rugby union clubs. Participants also included backgrounds within other areas of the sport such as performance analysis, which was desired to understand existing training aids used in the sport by coaches and players. Experience of backs and forwards positional groups were also recruited as part of the criteria. By using a participant group in this way, the research carried out followed a user-centred game design methodology. This was key to developing a rugby-union focused training aid, so a TURF methodology was followed in the development of a working prototype, as identified by the literature review section of this research [57]. This group will act as the Subject Matter Experts for developing the Serious Game prototype, and they were presented with an initial High-Fidelity Prototype to act as a 'storyboard' for the Serious Game, a method which is followed in ensuring User-Centred design approaches [93]. The study was approved by Brunel University of London, College of Engineering, Design and Physical Sciences Research Ethics Committee, Reference Number: 41100-LR-Nov/2022- 42390-1.

3.1. Study 1 Phases

This study aims to design and create a game to be able to improve the decision-making and cognitive abilities of rugby union players. This part of the research study will identify a key stakeholder group within the sport of Rugby Union, with suitable experience to be able to contribute towards the design and implementation of a Serious Game training aid for rugby players. There will be a group of key stakeholders recruited for this stage of the research which covers all possible key stakeholders (players, coaches, performance analysts). This group will be of various age ranges as they are recruited based upon their previous rugby experience and roles held, rather than their age. A TURF framework was used for the prototype development (Tasks, Users, Representation & Function). With TURF, the usability of a system for the intended users' needs are measured by three dimensions; useful, usable, and satisfying. Participants were interviewed at each phase of development to ensure these three factors were considered throughout the research process [57].

This stage of the research will form the design and implementation research stage of the project. It will have 3 development phases:

1) **Pre-Implementation - Design Framework**

   This phase was used to identify the requirements of a game prototype for the purpose of this research. The key participants were interviewed in two sections - to establish stakeholder backgrounds, and for the purposes of TURF, establish the key tasks required. This will form the design framework with game mechanics & scenarios mapped to these tasks. Tasks required will be asked of both sets of playing positions within rugby, i.e., backs and forwards.

2) **Design Framework Feedback**

   Key stakeholders will be presented with a 'storyboard'-style design framework, a High-Fidelity Prototype, to gather feedback from interview. This was presented as a 'player journey' whilst using the training aid game from the perspective of a rugby player who is a back or forward (as appropriate to the key stakeholder's background).

3) **Post Implementation Feedback**

   Key stakeholders will be given the game prototype to test to gather feedback from interviews.

3.2. Key Participant Group

For the purposes of the research, a key participant group was required to be recruited from a range of backgrounds within the sport of Rugby Union. This was to ensure that this research followed a user-

centred design methodology, as the aim of this research was to put the needs of rugby union players at the centre of the design training aid system. To follow a user-centred design methodology, user needs must be considered at each stage of the development cycle, so this was a consideration of each research phase within this stage as the prototype training aid went from an initial concept to fully developed. The benefits of using such a methodology in the design process is that user productivity with the final designed prototype will be improved, as well as improve user satisfaction and training speed [56].

Once a Key Participant Group was recruited, there were three different phases of individual interviews with each participant. Each phase was conducted at different stages of the development of the design framework for a Serious Game and then the subsequent development of a working prototype. Interviews were conducted on an individual basis, which meant that availability of the participants was adjusted for. This included the scheduling of interviews as well as the splitting up of interviews into multiple sessions when required. All interviews were conducted following a set-structure of questions, with appropriate follow-up questions asked where needed. Each interview was conducted, and transcripts were open coded as part of a thematic analysis research methodology. The coding from these interviews was used to develop a refined conceptual model a continuation of the literature review in a previous chapter of this research. The codes were used across these phased interviews to refine and add to the existing Conceptual Framework, developed during the initial Literature Review for this research. These interviews, when analysed with the Conceptual Framework identified key recurring themes from this, which developed a Research Artefact of the key concepts that would be required for the research game prototype. This would aid the development of a suitable prototype to be created as a video game training aid with the aim of being able to develop the cognitive abilities and decision-making skills of rugby union players, as it would focus on the key areas that would be needed by users, in this case rugby union players. This would mean that this methodology to develop the game prototype would follow a user-centre design methodology.

The same participant group was used for all phases of this study. The key participant group was recruited based upon their backgrounds within four categories:

- **Experienced Rugby Players:**

  The usability for the target group of any Serious Game designed with the intention of being used as a training aid is critical. Therefore, experienced athletes from the sport of Rugby Union were recruited for the key participant group. This meant that the feedback of the group that the game was designed for was considered during the development process. To ensure that

views of the widest range of experiences within the sport were considered, a player that plays a Forward position and a player that plays a Back position were recruited.

- **Rugby Coaches:**

  To provide insight into current training methodologies within the sport of Rugby Union, coaches were recruited from the sport. To ensure that the views of the widest range of experiences within the sport were considered, a coach specialising in coaching players that play Forward positions and a coach that specialising in coaching Back positions were recruited.

- **Sport Psychologist:**

  Sport Psychologists are tasked with analysing the mental aspects of sporting performance of various sports, including Rugby Union. Their role is to enhance these mental skills. As this study is focused on the decision-making skills and cognitive abilities of rugby union players, this participant was not considered relevant enough to recruit for the key participant group. The findings of research phase 1 confirmed this, as none of the participants identified the work of a Sport Psychologist as relevant to the design and implementation of a training aid game.

- **Performance Analyst:**

  A currently used training aid for the sport of Rugby Union and other sports is video analysis. A performance Analyst often uses video analysis as a means of feedback for rugby players. This can be used for player decision-making as well as tactical understanding of team strategies. Therefore, a Performance Analyst was recruited for the key participant group to provide insights into such technologies that are currently used within the sport.

3.3. Chapter Summary

In this chapter, a User-Centred Design methodology was considered for the purposes of carrying out a user study in the following chapters. As part of this, a research study was proposed and approved to be carried. The design of this study included the identification of a key participant group from the sport of rugby union to be interviewed in 3 different phases, each contributing to the final design and development of a working prototype Serious Game for training Rugby Union players. Once the criteria were identified, the group was recruited based upon their backgrounds from the contact network of the principal researcher. The findings of each phase will be considered in this design and implementation, with the key participant group interviewed at each phase. The next chapter will begin this user study by undertaking the first phase of interviews, which will further add to the Headlights: Conceptual Framework developed in the previous chapter.

Chapter 4: Study 1, Phase 1: Identification of Requirements

Phase 1 of the user study included an initial interview which was carried out with each key participant recruited as a means of ascertaining their background as well as getting insight into what they believed would be the key requirements of any rugby training aid developed for the purposes of improving decision-making and the cognitive abilities of rugby union players. This interview was split into two sections accordingly, with a section focusing on the background of the participant and another section focusing on training aid requirements. This phase of interviews provided insight into the key components required for a rugby union training aid of this kind, so transcripts were coded, and the results formed the basis of a research artefact derived from the conceptual model. Using this research artefact, a game storyboard would then be created for the next phase of interviews for feedback from the same participant group. A full list of the questions asked can be found in Appendix A. The findings from each interview were coded and analysed to find key themes throughout the interviews. These key themes were then compared with the themes found within the Conceptual Framework, which was developed initially during the Literature Review, prior to Stage 1 of this research being carried out. Key themes that recurred during the Literature Review and Phase 1 interviews, as well as any new concepts were considered to create a refined Research Artefact. This would contain the key themes and concepts that would be required for a game prototype to be used as a training aid for rugby union players.

4.1. Phase 1 Procedure

During the first phase of interviews with the key participant group, each participant was individually interviewed. Questions were asked about each participant's rugby union experience, followed by asking each participant key areas any possible training aid for cognitive abilities as well as decision-making should seek to address. Background questions were also asked on existing training aids for rugby union players, as well as existing methods for rugby union players to train these skills for their sport. By identifying possible areas that the existing methods do not address, a video game training aid could be tailored to address the key areas needed for any training aid whilst overcoming difficulties with existing methods.

The interviews were all carried out on a 1-2-1 basis with the researcher either interviewing each participant digitally via video call, or in person. All interviews were recorded, with transcripts produced and edited for each call. In total, five participants were recruited with relevant and various rugby union backgrounds to be a part of the key participant group. Those in this group included experienced coaches, both with experience of coaching backs and forwards positional groups, with one of the

coaches also having a background within performance analysis in the sport of rugby union. The group also included rugby union players of a mix of playing positions, also including both backs and forward positions. A sport psychologist was originally sought for, but after proving to be difficult to recruit one of a relevant background, it was deemed this was not a priority for this research, as the psychological impact of a training aid is out with the scope of this research.

Following the interviews these transcripts were then open coded following a qualitative data analysis methodology. Whilst analysing the transcripts, a list of thematic codes from the key themes of the interviews were produced. The findings from this phase were used as the initial basis, with the Conceptual Framework, to form the first High-Fidelity Prototype – an interactive prototype to demonstrate the possible usability of a Serious Game prototype for the sport of Rugby Union.

4.2. Phase 1 Findings

During this stage of interviews, the following key themes were identified. The table below shows the number of participants who mentioned each area, the number of references made to each key theme and the area within the conceptual model of this research these themes would fit within. An importance "weight" was given to each of the themes identified. This scale was between 1-5, with 1 being completely irrelevant, 3 being of a fair amount of importance, and with 5 being vitally important to take forward within the research. The summary of the findings from the Phase 1 interview transcripts can be found in Table 4.1.

Table 4.1: Summary of Phase 1 Code Findings

Category	Area in Conceptual Model	Weight	Instances Mentioned
Pitch Training	Decision Making Training	3	19
Video Analysis	Decision Making Training	3	15
Attacking Decisions	Decision Making	4	34
Pass, Kick, Carry	Tactical Decisions	5	18
Defensive Decisions	Decision Making	4	22
Spatial Recognition	Perceptual-Cognitive Abilities	2	17
Accessibility	Hardware & Platform Interfaces	2	10
Playing Position	Decision Making	5	32

Pitch Training

On-field *Pitch Training* is a means for coaches to deliver training sessions in team sports such as Rugby Union. These are sessions taken by coaches on training pitches. Coaches can use these sessions for training skills such as decision-making [94]. One of the key themes identified by the participant group was this method of *Pitch Training* for rugby union players to train and enhance their cognitive abilities and decision-making skills. Within the interviews, *Pitch Training* was established as the method of rugby union team's running training sessions on often outdoor, grass pitches to practice skillsets and work on team tactics.

Participants identified that using *Pitch Training* to train cognitive abilities and decision-making in this way was done in two methods: *Q&A (Mental Exercise),* and *Games & Drills (Physical Exercise).*

- *Q&A (Mental Exercise),* including question-and-answer style elements within their training session which serves as a 'mental exercise', was one method of training decision-making identified by the key participant group.
- *Games & Drills (Physical Exercise)* and tailoring these within the training sessions is another method identified by the participant group to train these skill sets.

In relation to both methods above, Participant 1 commented *"As coaches we try to incorporate as much decision-making as we can, by, you know, open-ended questions or adding different oppositions."*

Pitch Training was identified by the participant group as a key current method for skill training of decision-making and cognitive abilities, with all five members of the group identifying this method, with 19 references during the interviews. This research aims to create a Serious Game that will operate as an effective training aid for Rugby Union players, so understanding existing methods such as *Pitch Training* is important to this research, this background perspective will require consideration for the development of the research prototype. Due to this method being referenced consistently throughout the interviews, this was given a weight of 3 out of 5.

Video Analysis

Video Analysis is the method of learning using video clips from previous matches as a means of facilitating feedback and improving performances. This is widely used in modern sports such as Rugby Union [10].

Participants highlighted some of the limitations of using *Video Analysis* as a training method during the interviews. Accessibility, as well as the reactive nature of *Video Analysis* were highlighted as challenges. These could be addressed within a training aid during development.

- When asked about accessibility of such techniques, Participant 3 commented: *"Huntly don't have a clubhouse for example. So therefore, we can't get a team in. Sit them down and go right, here's a video analysis tool."*

- On the reactive nature of *Video Analysis*, Participant 5 commented: *"It's reactive, that's the issue. So, it's reactive in terms of the game before it can be proactive in terms of going into the next match. But it would be lovely to have something that you could preload information into."*

Positives of using such tools were also discussed during the interviews – some elements of this could be used for a Serious Game training aid for the sport such as using overhead or a 'bird's eye view' of team structures within the game. This exists within using *Video Analysis* tools with Participant 2 highlighting this benefit for player's: *"Looking at the big picture, it's really easy to see. When you're looking at an overview of the pitch where all the players are."*

During the interviews, participants often mentioned these techniques as a key existing learning method for Rugby Union players to develop their cognitive abilities and decision-making skills. *Video Analysis* was mentioned by all participants (5) and there was a total of 15 references during the interviews. This research aims to create a Serious Game that will operate as an effective training aid for Rugby Union players, so understanding existing methods such as *Video Analysis* is important to this research. Therefore, this was given a weight of 3 out of 5.

Attacking Decisions

To develop as a player in a team sport such as Rugby Union, a player will need to develop their *Attacking Decisions* (when their team has the ball), and defence (when their team does not have the ball) in key areas of the pitch, i.e., the field of play [17].

Key to the correct *Attacking Decisions* was the ability of players to identify and utilise space – which relates to their *Perceptual-Cognitive Abilities* of *Visuospatial Capacity,* as well as Visual Attention. identified by the systematic literature review as of high importance to Rugby Union players. Participants highlighted these when discussing *Attacking Decisions:*

- Participant 2 referenced the spatial orientation skills associated with *Visuospatial Capacity* when commenting on *Attacking Decisions*: *"It's identifying where space is or identifying where weaknesses are in other teams. It's something that we like to do."*

- *Visual Attention*, in the form of a player 'scanning' what they see was also identified during the interviews. With Participant 3 commenting: *"Scanning. I think scanning is a massive one. The ability to look at something and problem solve."* When asked about this abilities' influence on decision-making in Attacking Decisions, the participant went on to say: *"Yeah it definitely has to feed in 100%, needs to feed in decision-making."* The participant then highlighted that this could be a key consideration for the development of a training aid for the sport: *"If we had an aid that then influenced their decision-making to then scan a little bit more.".*

Participants also highlighted different scenarios that could be used to train *Attacking Decisions*. These could be considered for scenarios within a Serious Game prototype training aid. For this area, this could be 'overlaps' where an attacking team has more available players than there are defenders.

Participant 4 highlighted such scenarios when training decision-making currently: *"Usually just run different scenario basis, like you do general 3 on 2, just general open play attack".*

Participants were asked during each interview about what key areas of decision-making a training aid should seek to address, and all participants (5) identified a form of attacking decision-making, with a total of 35 references throughout the interviews. 4 of the 5 participants gave different examples of types of *Attacking Decisions*, and all the participants also identified the core 3 decisions any attacking player has when they are carrying a rugby ball – whether they *Pass, Kick, or Carry*. It was already established from the systematic literature review that *Attacking Decisions* were an important aspect that any research prototype for a rugby union training aid should explore, however, this phase of interviews confirmed its importance. Therefore, this theme was given a weighting of 4 out of 5.

Pass, Kick, Carry

Pass, Kick, Carry was identified during the interviews as the 3 key decisions a player can make for *Attacking Decisions.* Whilst from the literature review it was clear that attacking and defensive decision-making skills would be required as part of the conceptual framework for this research, further information on which decisions a player can make when making *Attacking Decisions* was required.

During the interviews, key participants in the participant group were all asked about which kind of tasks are key to developing decision-making in rugby union players. All the participants (5) identified 3 key elements of the ball carrier's decision-making, whether to *Pass, Kick, or Carry* the ball into contact (being tackled by an opposition player).

Participant 1 commented on the different decisions players make in attack: *"In terms of attack do players carry the ball into contact? Do they pass the ball? Do they kick the ball? And I think that's the three things that you can do as an attacking player."*

Participant 3 identified the 3 decision types as a 'triple threat': *"When the balls passed to you, which decision do you make? As a rugby player, you're known as a triple threat, so the three things you can do as a rugby player is pass, run or kick".*

In total, there were 18 references to these 3 attacking options. Participants identified that this is often a tactical-based decision, depending on an individual team's tactics.

Pass, Kick, Carry provides the contextualisation of *Attacking Decisions* specific to Rugby Union players. This was a key piece of information regarding attacking decision-making that had not been identified within the literature review, and its importance was clear through the various examples given by participants. For the development of a High-Fidelity Prototype for Phase 2 of this user study, this concept was used to develop attacking-based decision scenarios as a key game design component. This theme was therefore given a weight of 5 out of 5 due to this and was added to the Research Artefact, representing *Attacking Decisions.*

Defensive Decisions

Team Sport athletes are required to make competent decisions in *Defensive Decisions* within their sporting context. This occurs in rugby when a team does not have possession of the ball. These skills will need to be developed to make impactful decisions in all areas of the pitch to further develop within a given team sport [17], such as Rugby Union. This theme was identified during the interviews with key participants, with all 5 participants mentioning *Defensive Decisions*. Participants were asked what the key aspects were a training aid should cover for rugby union, and in total 22 references were made to a form of this type of decision-making.

There are 3 key areas of the game where a rugby union player will make *Defensive Decisions*, including *Tackling, Rucking,* and *Defensive Line*:

- *Tackling* refers to the type of tackle should make given a specific opponent or situation (also referred to as the 'Tackle ID'), which was mentioned by 4 participants, with 6 references. This can refer to a player's decision on the nature of the tackle (height and general aggressive nature of this) as well as which player to tackle. Participant 2 referenced these choices: *"Who to tackle? How to tackle? Are the two key ones I use".* Participant 5 also referred to the identification of the tackle players must decide to use: *"So Tackle ID, we're now calling it. That's the new term tackle ID. But I would just call it decision-making in the tackle."*

- *Rucking*, the contest for the possession of the ball that occurs when a tackle has been made involves players deciding from a defensive perspective whether to compete to try to regain possession. In attacking situations, decision-making is more limited where it is simply about retaining possession. This was mentioned by which was mentioned by 3 participants from the key participant group, with 9 references. Participant 4 mentioned how the decisions associated with a player competing defensively in a ruck can influence other defensive areas for a team: *"If a team is quite quick off the ruck you might want to go in and slow it down or if you know a team has like a quite a quick attack. You might want to just leave the ruck and fill the field."*

- *Defensive Line*, the type of defensive strategy a team and players will attempt to execute given specific defensive scenarios was also mentioned by 3 of the participants interviewed. Participant 1 referenced different types of *Defensive Line* when discussing *Defensive Decisions*: *"In defence, whether you would blitz defence or whether you would have a sot defence would probably be my ones."*. Participant 1 also mentioned that these defensive strategies are a part of a team's *Tactical Decisions*, illustrating that this would be set within these strategies: *"Some teams will look to play a softer defence, to take teams to the edge. Other defences look to really put pressure on when blitzing."*. *Defensive Line* was mentioned by 3 of the participants, with 7 references in total.

These 3 key areas of *Defensive Decisions* contained multiple references which gave more in-depth background on the types of decisions rugby players need to be able to make. Therefore, this theme of *Defensive Decisions* was given a weight of 4 out of 5 and added to the conceptual framework. In addition, the 3 types of decisions in defence a player can make *(Tackling, Rucking, Defensive Line*) was added to the research artefact to represent the *Defensive Decisions* made in the team sport of rugby union – providing relevant sporting context.

Spatial Recognition

Spatial Recognition in *Team Sports* is the understanding of the athlete of the relationship between objects and spaces. During the Systematic Literature Review stage of this research, key *Perceptual-Cognitive Abilities* that impact the performance of a Rugby Union player were identified. This included *Visuospatial Capacity*, a person's ability to identify the relationship between objects and the space between objects, which was recognised as of vital importance to the success of a Rugby Union player [43]. When asked questions around which cognitive abilities would be key for a training aid for Rugby Union players, the key participant group almost all identified a form of *Spatial Recognition* (4 of the 5 participants), and means to manipulate this space, such as *Attacking Decisions* such as whether to *Pass, Kick or Carry,* were also often mentioned (3 participants mentioned this with 6 references in total).

Commenting on this *Spatial Recognition,* Participant 1 stated its importance for Rugby Union players: *"Space is probably the big one and how to identify it."*. Participant 3 made a link to the decision-making of players given their *Spatial Recognition: "When it comes to spatial awareness, you can't sometimes you can't see everything that's in front of you and make it. That goes back into the decision-making aspect of it. So, you make a decision, it might not be the right decision.".* The same participant also commented that Defensive Decisions can depend on this *Spatial Recognition,* such as the space a player decided to leave between themselves and their teammates: *"More so, the spacing between you and your teammates because if you leave a gap massive and you've got a smart player, they're going to run at that gap".*

Spatial Recognition is a component of *Visuospatial Capacity*. This means that this ability is important to add to the conceptual framework, as it acts as a component of the key cognitive ability for rugby union players. *Spatial Recognition* was therefore to the conceptual framework and given a Weight score of 2 out of 5 in terms of importance.

Accessibility

An area of consideration that was identified during the systematic literature review stage of this research was the *Accessibility* of any possible training aid prototype developed in terms of the *Hardware & Platform Interfaces* the training aid would be available within. As this study is to be user-centred it is important to understand which platforms are most regularly used by the user group, in this case rugby union players. The literature review in chapter 2 identified different hardware platforms that can be used in a Serious Game. The purpose of this phase of interviews with the key

participant group was to ascertain key components required for any rugby union-based training aid. During the interviews, 10 references to accessibility were made by 3 of the 5 participants. The greatest number of references were made towards *Mobile* platforms such as phones with 5 references from the 3 participants. *Virtual Reality* was only mentioned by 1 participant whilst 2 participants mentioned Computers (*PC*).

Specific comments were made about using *Mobile* devices, as opposed to *PC*'s by Participant 1 when asked about which devices would be suitable for a training aid: *"Mobiles probably. I guess mobiles is the easiest one, isn't it? Everyone's got smartphones now, don't they? Maybe computer, not so much. But definitely phones would probably be the most accessible."*

Therefore, it can be reasoned then that *Mobile* platforms would be a suitable platform to build a training aid prototype for rugby union players. Whilst Accessibility is worth considering in prototype development, there was clearly a low number of mentions of this during the interviews, meaning the weight score for this theme was given as 2 out of 5. For purposes of developing the Conceptual Framework, the mobile platforms will be considered for the development of a refined Research Artefact.

Playing Position

Team Sports require players to play the roles of a different *Playing Position* per player. In the sport of Rugby Union, there are Forwards and Backs playing positional groups, both with different roles on the pitch and specific characteristics per position:

- *Forwards* positional group contains the positions of: Prop, Hooker, Second Row, Flanker, No 8.
- *Backs* positional group contains the positions of: Scrum Half, Fly Half, Centre, Winger, Full Back.

The key participant group identified that a *Playing Position* often contributes to tactical understanding – i.e. what a team is trying to do during a match. Often, specific decisions are often made by specific team roles such as *"lineout callers"* as well as key decision makers such as fly halves. It was identified by Participant 1 that these key roles and the decisions they make can be vital for a team's understanding of the *Tactical Decisions*: *"what set plays, you run and where on the field you would run them. Would probably be the best one for outside halves for fly halves".*

This means that a training aid should address *Playing Position* for the specific user, making to ensure that the training aid is relevant to Rugby Union players. All key participants mentioned positional decision-making during their interviews, with a total of 32 mentions. As such the weight was given of 5, with it clearly being an important theme for this research. In addition, this was added to the Conceptual Framework.

4.3. Phase 1 Conclusion

After the first round of interviews with the key participant group, the Headlights: Conceptual Framework that was developed during the systematic literature review was altered to include new key concepts that emerged from the first phase of interviews with the key stakeholder group of participants. This included a new section to the model which added the methods coaches use to train decision-making, including video analysis, question & answer sessions, pitch training as well as specific training games & drills. Also added was a new key concept of defensive decision-making within the team sport environment, as well as spatial recognition within the key perceptual-cognitive abilities required of a rugby union player. On the game design elements, rugby-related scenarios were added as well as multiple choice options as considerations for development of a training aid game prototype. The updated Headlights: Conceptual Framework can be found in Figure 4.1.

As a result of the Systematic Literature Review conducted for this research, a user-centred design methodology was chosen to be followed for the development of a working prototype. This was considered prior to interviews being carried out, and any prototype should be as rugby union specific as possible. Therefore, it was decided a *Sports Pitch Environment* should be used within any Serious Game prototype for this purpose, and this was added to the Conceptual Framework.

A new theme of *Decision-Making Training* was added to incorporate the background findings of existing training methods for rugby union players to improve their cognitive abilities and decision-making. Two items were added to this theme because of these interviews, were *Video Analysis* and *Pitch Training* were identified. Within *Pitch Training, Games & Drills (Physical Exercise)* and *Q&A (Mental Exercise)* were identified as the key training methodologies. The key participant group were asked about what should be considered for any rugby union training aid, when seeking to improve player decision-making. During the first phase of interviews, participants identified that attacking players, when in possession of the ball have 3 decisions they can make: *Pass, Kick, Carry* the ball. These options are important to following a user-centred design approach for this Serious Game so this was added to the conceptual framework within the Decision theme, within *Tactical Decisions* as this can

often be influenced by a specific team's tactics. *Defensive Decisions* were added to the conceptual framework within the decision-making theme. These types of decisions were identified by the participant group as key to developing overall decision-making within rugby union players. Participants identified tackling, rucking and defensive line decisions as the types of decisions made defensively by Rugby Union players.

The relationship of a person's understanding between objects and the space between them is defined as *Visuospatial Capacity* – this is a key *Perceptual-Cognitive Ability* that was identified during the Systematic Literature Review. The interviews with key participants developed a theme of rugby union player's being able to identify space in the first instance (i.e., their spatial recognition). This is directly related to *Visuospatial Capacity*, so therefore *Spatial Recognition* was added to the Conceptual Framework within the *Perceptual-Cognitive Abilities.*

During the first phase of interviews, participants identified that an attacking player has 3 key options when in possession of the ball during a match; whether to *Pass, Kick, Carry*. These options present a *Multiple-Choice Options* for any rugby union player. So, this is crucial to consider when the training aid Serious Game is being designed for this research. Therefore, this was added to the Game Design theme of the conceptual framework. Throughout the participant interviews, participants were asked what a rugby union training aid should seek to address. Each participant identified specific *Rugby-Related Scenarios* that should be addressed. Therefore, it makes sense that this should be key to the conceptual framework and was added to the Game Design theme.

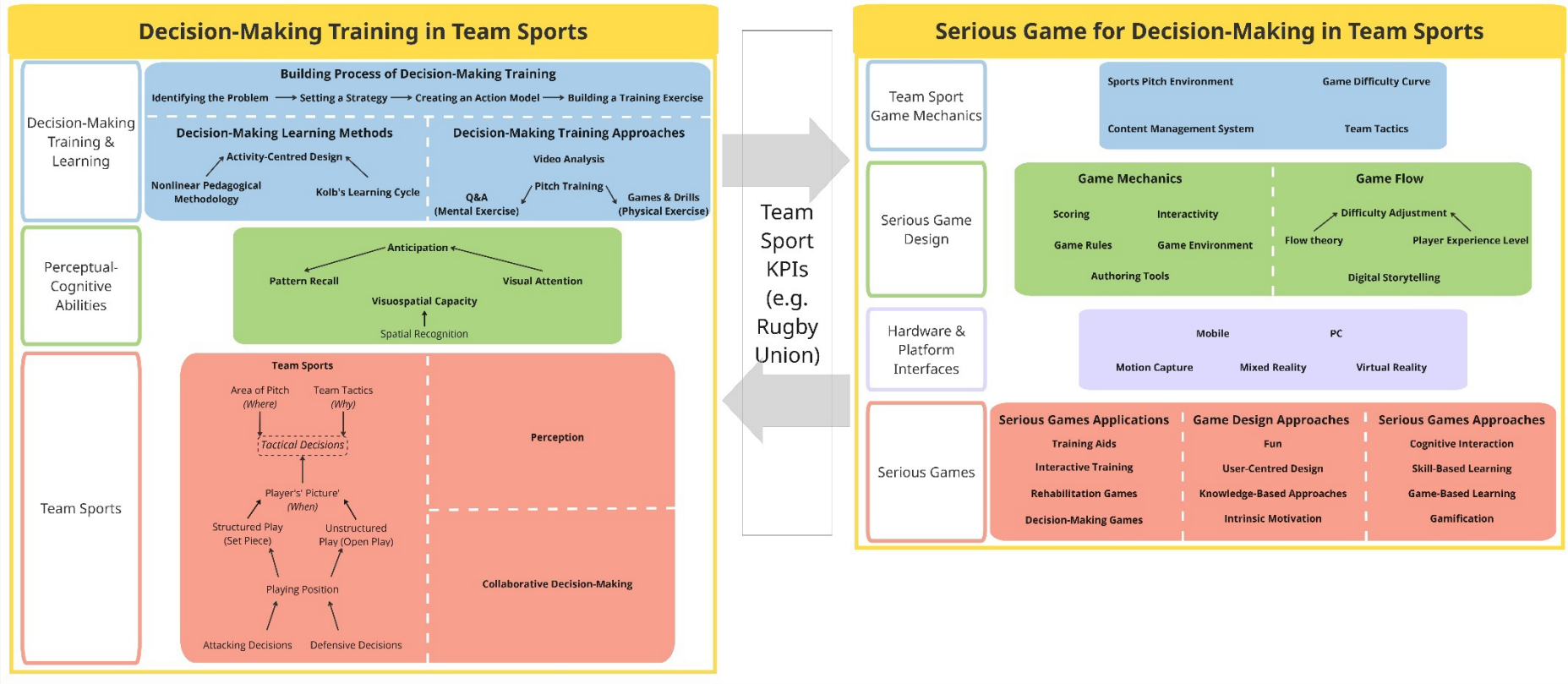

Figure 4.1: Headlights: Conceptual Framework (Post Phase 1)

4.4. Chapter Summary

In this chapter, the first phase of this initial user study was carried out. This was conducted as individual interviews with the key participant group recruited in the previous chapter. The purpose of this first phase of interviews was to act as the Identification of Requirements of any Serious Game training aid for Rugby Union. Each interview was conducted on a 1-2-1 basis and recorded.

The key findings of these interviews were added to the existing Headlights: Conceptual Framework, and some of the findings reinforced the importance of existing themes within the framework. In some areas, such as *Hardware & Platform Interfaces*, specific accessibility was raised by the participants that highlighted the *Mobile* platform as the most accessible for the intended user group of rugby players. In addition, the participant group identified *Attacking Decisions* and *Defensive Decisions* as key to ensuring rugby relevance of a game training aid. *Pass, Kick, Carry* was identified as the key decisions being able to be made by a player in an attacking situation, with *Tackling, Rucking, Defensive Line* being the decisions being able to be made in defensive situations. These decisions are linked together, and to Tactical Decisions by the context of *Playing Position*, which was also identified in the interviews. Finally*, Spatial Recognition* was also added to the Conceptual Framework, with a direct link to the key *Perceptual-Cognitive Ability* of *Visuospatial Capacity*.

In the next chapter, a refined Research Artefact will be created for the purpose of ensuring a rugby-specific context for the first design of a High-Fidelity Prototype, which will be presented to the same key participant group. This will be used as a 'storyboard' style prototype, which will then be followed by a second phase of interviews to collect feedback. This will further ensure a user-centred design in developing a Serious Game for Rugby Union in the subsequent chapters.

Chapter 5: Study 1, Phase 2: High-Fidelity Prototype & Design Framework Feedback

The purpose of the first user study in this research is to identify the key requirements for a Serious Game to act as a training aid for the sport of Rugby Union. In previous chapters, a key participant group was recruited and interviewed to provide the initial feedback and requirements on what such a Serious Game would need to act as a training aid. The findings from Phase 1 of this study in the previous chapter formed the key themes that were used in this chapter to develop a High-Fidelity Prototype. This was created at the end of the Phase 1 interviews and presented for feedback as a 'Storyboard' for the Serious Game to the key participant group for Phase 2 in this chapter. Intervening early in the development of a Serious Game, taking key concepts from Subject Matter Experts (the key participant group) and presenting a storyboard in this way are verified methods of ensuring a Serious Game is User-Centred in its design [93]. This chapter details the development of the High-Fidelity Prototype, as well as the next phase of user study conducted with the key participant group, to find the Design Framework Feedback to be used for the implementation of the game prototype for use by rugby union players.

5.1. Phase 2: Procedure

Based upon the findings of the initial interviews of Phase 1, the Headlights: Conceptual Framework was refined into a Research Artefact for the specific purpose of acting as a design framework for a game 'storyboard', a High-Fidelity Prototype. This was then created for presentation during Phase 2 of interviews with the stakeholder group. Key stakeholders were presented with this prototype to gather feedback from interview. This was presented as a 'player journey' to the stakeholder group, whilst using the training aid game from the perspective of a rugby player who is a back or forward (as appropriate to the key stakeholder's background). A full list of the questions asked in the interviews can be found in Appendix B.

The same key participant group from the previous chapter was again used for this phase of interviews. Following this round of interviews, the interview transcripts were coded and analysed, as with Phase 1. This would identify key themes that came from the result of this phase, for consideration to implement any changes to the game storyboard prior to implementation of the final game prototype for this research. New themes and concepts that did get discussed during this phase were further considered for addition to the original Conceptual Framework as well as the Research Artefact if of significant importance.

5.2. Research Artefact Design

As part of the design process towards creating a working prototype Serious Game training aid for Rugby Union players, a Rugby Union specific Research Artefact was designed based on the Headlights: Conceptual Framework to conceptualise the framework into an interactive Serious Game. The purpose of this first user study is to ensure any game designed is made tailored with Rugby Union athletes in mind, as is therefore following a User-Centred Design. Therefore, this artefact was used to act as the framework in the creation of a High-Fidelity Prototype. The artefact ensured that the design of this prototype would be relevant, with the key participant group interviewed in the previous chapter being interviewed again to provide feedback on this design. The concepts from the artefact are further explored in the findings of the previous chapter, as well as within systematic literature review chapter previously. The Headlights: Conceptual Framework had two key sections; Decision-Making Training in Team Sports, as well as Serious Game for Decision-Making in Rugby, with Rugby Union KPIs providing the link between these sections, therefore the research artefact followed the same format. Both sections had different sub-sections, which was also replicated for the Research Artefact. The Research Artefact has two distinct sections: *Decision-Making Training in Rugby Union*, and *Serious Game for Decision-Making in Rugby*. These map to similarly named sections of the Headlights framework. The Research Artefact created to contextualise the sport of Rugby Union in relation to the Headlights: Conceptual Framework can be found in Figure 5.1.

5.2.1. Decision-Making Training in Rugby Union

This section has 3 sub-sections: *Decision-Making Training & Learning*, *Perceptual-Cognitive Abilities*, and *Rugby Union*. These represent the same 3 sub-sections as found on the Conceptual Framework.

Decision-Making Training & Learning sub-section, there are also 3 themes: *Building Process of Decision-Making Training*, *Decision-Making Learning Methods*, and *Decision-Making Training Approaches*. These also replicate the same themes found within the Conceptual Framework.

- *Building Process of Decision-Making Training* theme has 4 linked steps to creating such training. Identifying the Problem, and Setting a Strategy are the first two of these steps, which represent the same steps from the framework. The third step, Design a Game Mode, represents the Creating an Action Model step from the framework, with the Game Mode for a Serious Game being the Action Model. The final step in the framework, Building a Training Exercise is contextualised for a Serious Game training aid by Creating a Game Scenario.

- *Decision-Making Learning Methods* theme is represented in the same format in the Research Artefact, with Activity-Centred Design being the key method link, a Serious Game would be one such activity used in learning for this research.

- *Decision-Making Training Approaches* within the Research Artefact contains two concepts, the first being Visual Interactive Rugby Simulation. This represents the existing methods of training decision-making within the sport of rugby union as it will contain visual presentations of the pitch for a Serious Game training aid (such as a representation being used within the game scenes). This replicates Pitch Training from the Conceptual Framework, as does the creation of any game-related scenarios which use rugby tactics and contains moving players within the pitch. These would be found within Pitch Training, as Games & Drills (Physical Exercise) as in the Headlights framework, and are represented by Visual Interactive Rugby Simulation within the Research Artefact. In addition, the Research Artefact also contains a theme in this sub-section for Interactive Q&A with Feedback Loop. This represents an interactive user training method, where players are asked to answer questions as a form of mental exercise. This concept represents the Q&A (Mental Exercise) within the conceptual framework. These two concepts provide the context for the development of a Serious Game for rugby union.

The **Perceptual-Cognitive Abilities** sub-section of the artefact contains 4 different abilities of this type: *Visual Attention*, which is linked to *Anticipation*, which also links to *Pattern Recall*. These are linked to the visual skills of an athlete to see, recognise and anticipate scenarios before them and recognise patterns. In addition, the *Visuospatial Capacity* is also represented within the Research Artefact, and ability that athletes use to understand the spatial relationships between objects – linked to this is *Spatial Recognition* as identified in the previous chapter by the key participant group. All of these Perceptual-Cognitive Abilities are seen as contextually significant for Rugby Union players, and as such are represented within the Research Artefact. Therefore, they will be considered within the design for the High-Fidelity Prototype.

In the **Rugby Union** sub-section of the artefact, two themes are represented: *Perception*, and *Rugby Scenario*. Perception represents the same theme within the Conceptual Framework, whilst *Rugby Scenario* represents the Team Sports theme of the same sub-section in the framework.

- *Perception*, the way in which a scenario within a Team Sports match is represented and understood by a given athlete, is represented within the Research Artefact as a theme. This represents the same theme within the Conceptual Framework.

- *Rugby Scenario* represents the Team Sports theme from the Conceptual Framework. Within this theme the *Tactical Decisions* framework is present, as it is in the Conceptual Framework. This represents the factors considered by any rugby player in order to make decisions. This framework has multiple factors that contribute and are linked to the *Tactical Decisions* made by a player, including:

    - *Area of Pitch (Where)* can influence which Tactical Decisions are made by a player, within this sport being the area of the rugby pitch a scenario is taking place. As this is also an important consideration for decisions within Rugby Union, it is found within the Research Artefact. This is also represented by the Conceptual Framework by the same concept.

    - *Team Tactics (Why)* are the specific patterns of play a team will seek to execute as part of a pre-arranged plan for any given match. This is represented in the Research Artefact and links to the *Tactical Decisions* made by a player, in the same manner it is represented within the Conceptual Framework.

    - *Player's Picture (When)* also contributes to the *Tactical Decisions* in this framework and is therefore present within the artefact. This is represented in the same manner from the Conceptual Framework, containing the same linked concepts such as *Structured Play (Set Piece)* and *Unstructured Play (Open Play).* In addition, *Playing Position* is linked to this and will therefore influence the decisions made in a Rugby Union match – linked to this is the types of decisions that can be made by a player in both attacking and defending scenarios in the sport: *Pass, Kick, Carry* in the artefact represents *Attacking Decisions* from the Conceptual Framework, whilst *Tackling, Rucking, Defensive Line* represents the *Defensive Decisions* concept in the framework. Both of these concepts contextualise the decisions that can be made by an athlete within the given sport of Rugby Union for this artefact.

The *Simulated Collaborative Decisions (NPCs)* theme within the sub-section within of Rugby Union in the Research Artefact represents *Collaborative Decision-Making* from the Conceptual Framework. This is to contextualise the act of this type of decision-making within the context of a Serious Game for Rugby Union – with NPCs being able to replicate the decisions made by other players during a match.

5.2.2. Serious Game for Decision-Making in Rugby

This section of the Research Artefact contains 4 sub-sections: *Rugby Game Mechanics*, *Serious Game Design, Hardware & Platform Interfaces*, and *Serious Games*. These represent the 4 sub-sections of the conceptual framework, with Rugby Game Mechanics providing rugby-specific context to the mechanics considered.

The **Rugby Game Mechanics** sub-section of the artefact contains the concepts which will give specific context to a Serious Game for the sport of Rugby Union, in the form of underlying game mechanics which tailors how any game of this type will play. It provides the contextualisation to the *Team Sports Game Mechanics* sub-section of the conceptual framework. The playing environment will be required within any game, so the *Rugby Pitch Environment* represents this within the research artefact, giving rugby-context to *the Sports Pitch Environment* concept within the conceptual framework. The difficulty of any game will also need to be implemented for any Serious Game, therefore the *Game Difficulty Curve* concept in the artefact represents the same concept from the conceptual framework. The way in which a game handles the content that runs for the player will also need to be implemented, so the *Content Management System* concept is present in the research artefact as it is in the framework. The pre-arranged patterns of play that any team within a team sport uses during a match is significant context to training skills such as decision-making in athletes – therefore, *Rugby Team Tactics* is used in the research artefact to give rugby-specific context to the *Team Tactics* concept found within the conceptual framework.

The **Serious Game Design** sub-section of the Research Artefact contains two themes, *Game Mechanics* and *Game Flow*. These represent the same themes of this section within the conceptual framework:

- *Game Mechanics* are the fundamental requirements any game will require to be designed, regardless of context. These will also be required for a game designed for Rugby Union. Therefore, *Game Mechanics* is in the same format for the artefact as found within the conceptual framework. This includes the same concepts from the framework *of Scoring, Interactivity, Game Rules, Game Environment,* and *Authoring Tools*.

- Within the *Game Flow* theme of the artefact, *Rugby-Related Scenarios* is introduced. This represents the concept of *Digital Storytelling* from the conceptual framework – giving the game a specific context for the sport of Rugby Union, with scenarios that can be designed for any prototype using this context. This theme also has the concept of *Difficulty Adjustment*, which defines how the game influences the difficulty based *on Player Experience Level*. The *Flow Theory* of a game also dictates how difficult a game should as this relates to the immersion experienced by players. These concepts are linked together in the research artefact, and represent the same concepts found within the conceptual framework.

Hardware & Platform Interfaces were discussed during interviews with the key participant group of the previous chapter – these participants identified that Mobile platforms are the most accessible for the intended users of Rugby Union athletes. Therefore, Mobile is represented in this sub-section for the Research Artefact and can be identified by the same name within the conceptual framework.

The **Serious Games** sub-section within the Research Artefact contains 3 themes: *Serious Games Applications, Game Design Approaches*, and *Serious Games Approaches*. These represent the same 3 themes found in this sub-section for the conceptual framework due to being contextually relevant to the development of any prototype training aid for rugby:

- The *Serious Games Applications* theme contains concepts that explore the different relevant uses of these types of games within the sporting context of Rugby Union and training decision-making. Therefore, this theme within the artefact focused on *Training Aids*, *Interactive Training*, and *Decision-Making Games* representing the same concepts as the conceptual framework for the research artefact.

- *Game Design Approaches* in the research artefact contains 4 concepts that detail different ways in which a Serious Game of this type can be designed. Serious Games are designed to meet specific user needs, where teaching new skills is the primary purpose of the game. *Fun* is important to increasing participation in using such games, so this as well as *User-Centred Design* are present within the artefact, as they are in the conceptual framework. *Rugby Expert Knowledge* in this theme represents the *Knowledge-Based Approaches* concept found within the conceptual framework. What motivates players to play such games will also need to be considered for any game design, therefore*, Intrinsic Motivation* is present in the artefact as it is within the conceptual framework.

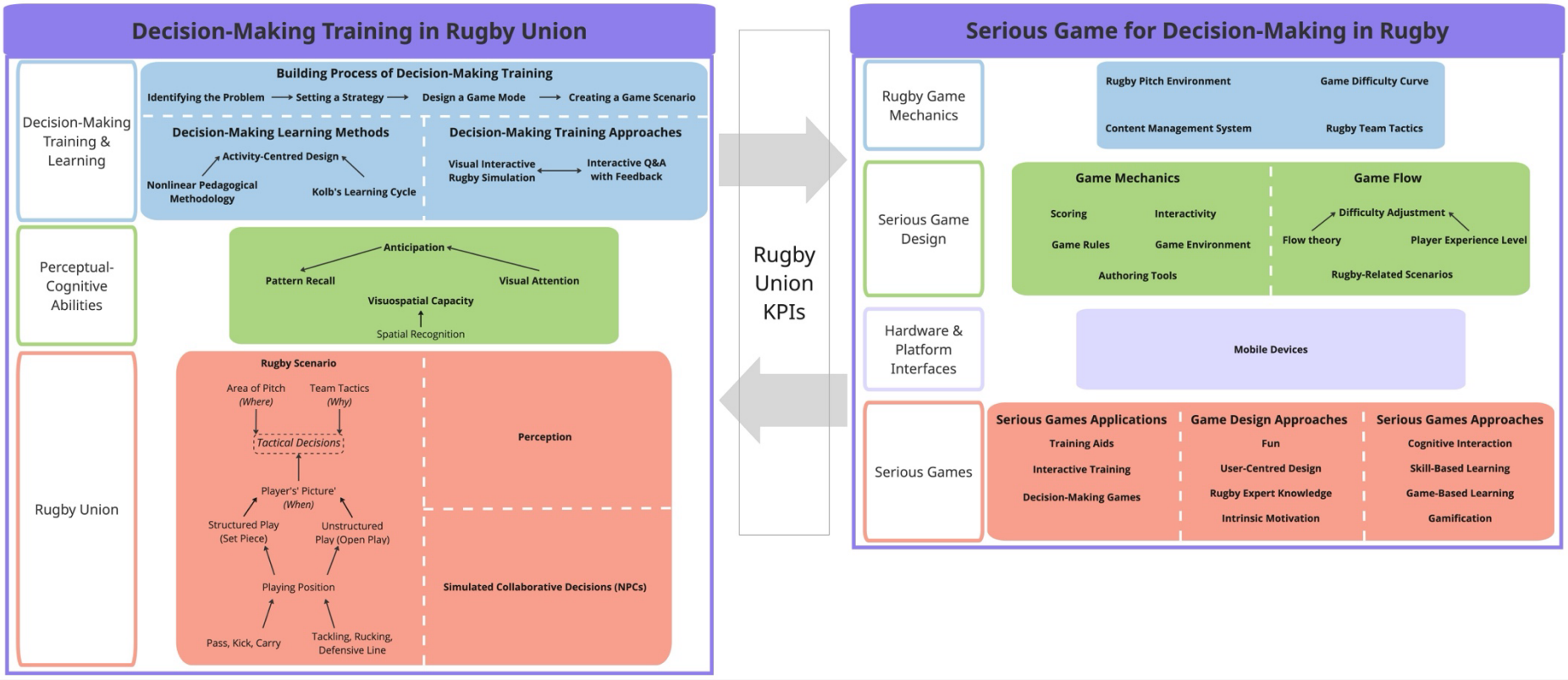

Figure 5.1: Research Artefact (Post Phase 1)

- *Serious Games Approaches* within the research artefact contains 4 concepts: *Cognitive Interaction, Skill-Based Learning, Game-Based Learning,* and *Gamification.* These concepts are representative of the same concepts within the conceptual framework, presented in the same format.

5.3. High-Fidelity Prototype Development

With an initial Headlights: Conceptual Framework developed from the Systematic Literature Review, a refined Research Artefact to act as a design framework, as well as feedback from key participants gathered from the interviews in the first phase of this research, a High-Fidelity Prototype was created. The purpose of this was to give an initial game design from the findings of both the literature and the interviews. The first version of this prototype was developed with the Research Artefact of the key findings from the initial interviews as well as the literature review. Feedback was then gathered in the next phase of interviews with the same key participant group for this user study. Feedback was used to further develop the High-Fidelity Prototype, Research Artefact and Conceptual Framework. These would provide the basis for the development of a working research prototype game.

The High-Fidelity Prototype was initially designed to act as an interactive storyboard that would give an indication of the design of the fully developed training aid and was produced using PowerPoint to achieve this after the completion of phase 1 interviews, as described in the previous chapter. The prototype initially asked for the player's rugby union playing position and experience with the intention of tweaking the gameplay to the users' answers. The player intro screen and player rugby experience selection screen can be found in Figure 5.2.

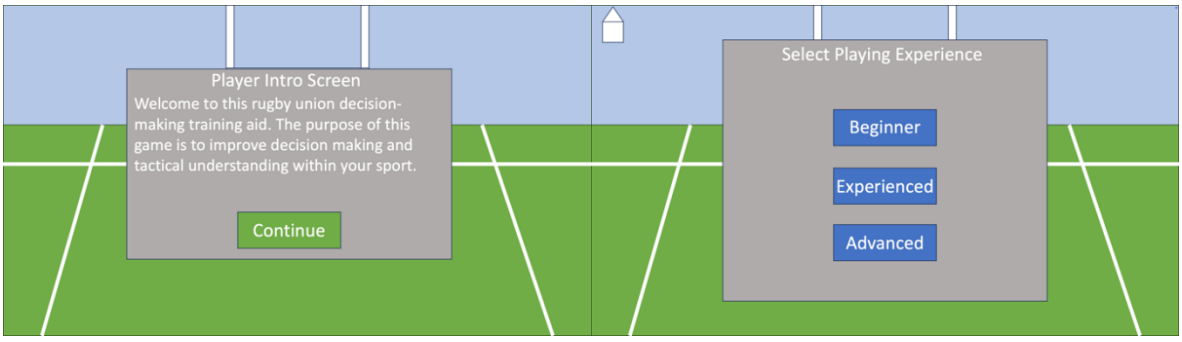

Figure 5.2: High-Fidelity Prototype player intro screen and rugby playing experience selection

The prototype had 3 distinct 'Game Mode' sections which aimed to encompass all decision-making elements of rugby union: scenario *Decision-Making*, *Tactical* awareness, and *Positional* decision-making. The prototype had a fully interactable user interface to give the impression of a developed

Serious Game training aid where users could select different options and look at their environment to aid in their decision-making. There was also two Camera Perspectives within the prototype, 1st Person (for the decision-making section) and 3rd person (for both the tactical awareness and positional decision-making sections). On the conclusion of playing scenarios within a Game Mode, a player feedback screen is also given to the players to give some information on the choices that were made. The player can select any Game Mode to play in any order, this operates as a *Content Management System,* where the player is given the appropriate scenarios to play from their choice in the game, within the prototype this operates as a Game Mode Selection Screen. As a further addition to this, a Home button is also present within the prototype, to allow the player to return to the start screen to select different Game Modes. The game mode selection screen and an example of a player feedback screen can be found in Figure 5.3.

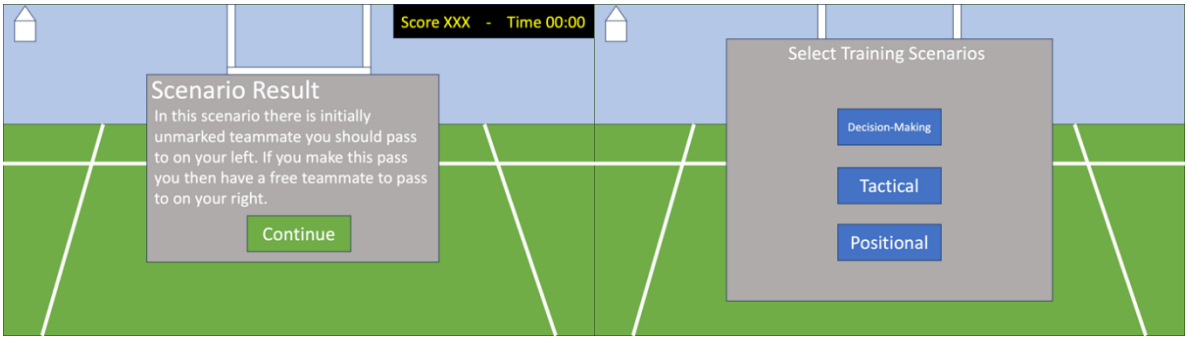

Figure 5.3: High-Fidelity Prototype game mode selection and feedback screen

Prior to the start of each Game Mode, a user-introduction screen is given to inform the player of how to play each of the Game Modes, this acts as a tutorial, a common method used in game design methods. Within the *Decision-Making Game Mode*, an attacking scenario was created where the player was given a scenario where there was an attacking 'overlap' – a common decision needing to be made in attacking situations in the sport. The scenario for this mode is presented in a 1st person camera perspective, and the player pass the ball in either direction, as well as carry the ball as the current ball carrier or kick the ball forward. This replicates the *Pass, Kick, Carry* options identified by the key participant group in the previous phase of research. The player can also look either left or right to better see the options available to them prior to deciding which option to take. The Decision-Making Game Mode intro screen, as well as an example of the scenario presented to the player is demonstrated in Figure 5.4.

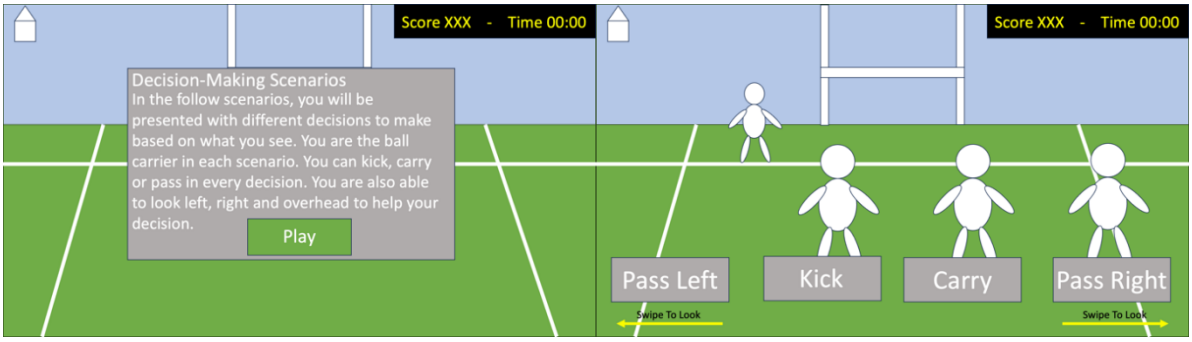

Figure 5.4: High-Fidelity Prototype scenario intro screen & decision-making game mode example

To replicate a *Game Difficulty Curve*, a *Sequential Decision* was added to this game mode with the original purpose to show that some scenarios for a fully developed training aid may require multiple decisions to be made, making the game more challenging for experienced players. This was received positively by the key participant group in future feedback. For the scenario in the High-Fidelity Prototype, the ideal result of decisions made by the player is to identify the overlap and space in both decisions and pass correctly to the free players. At the end of the scenario, a feedback screen displays to inform the player on if they made the correct decisions. An example of the Sequential Decision found in the Decision-Making Game Mode can be found in Figure 5.5.

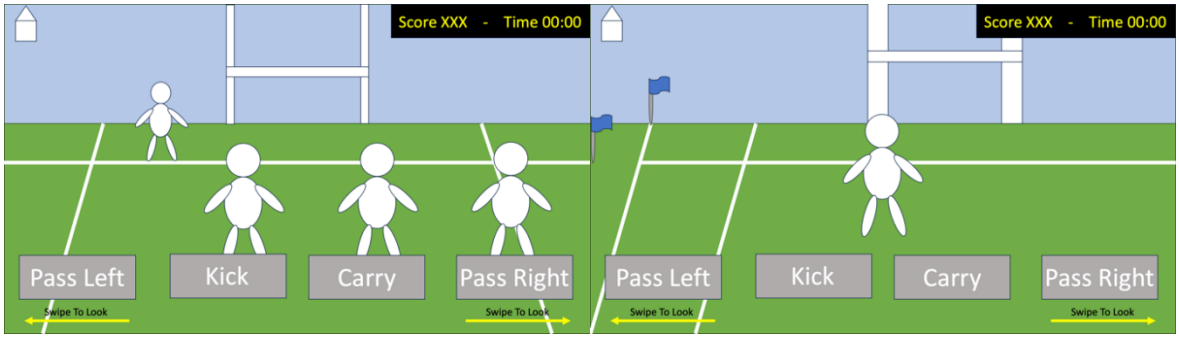

Figure 5.5: High-Fidelity Prototype sequential decision-making example

The *Tactical Game Mode* presents the player with a scenario where they have a 'birds eye view' of the scenario, an overhead 3rd person perspective. The purpose of this is to use the skill of Pattern Recall identifying the patterns of play and make a correct decision. In this scenario a timer is present that gives the player a fixed amount of time prior to a screen appearing that will give them a *Multiple-Choice Option* to make for the team they are playing as in the scenario. The overhead camera perspective for the initial view of the scenario the player is given, as well as the multiple-choice option given to the player in this game mode can be found in the examples in Figure 5.6.

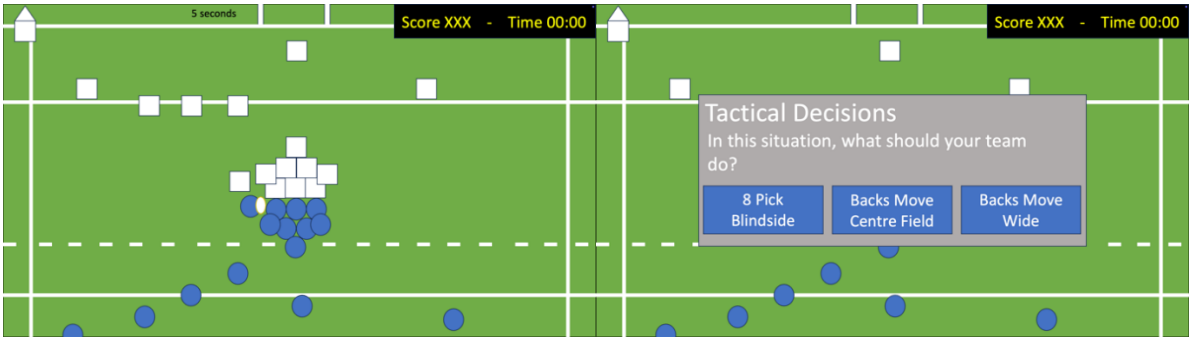

Figure 5.6: High-Fidelity Prototype tactical game mode examples, initial view and multiple choice decision

The scenario for the prototype focused on a centre-field scrum, where the ideal result is to select to use the short, blind side option to give their team a wider pitch to attack in the next phase of play. Before the feedback screens appear, the player is shown the result of the decision they have made in the given scenario, the purpose of this is to aid understanding for the feedback. An example of the decision result that is presented to the player as well as a following feedback screen for the tactical game mode can be found in Figure 5.7.

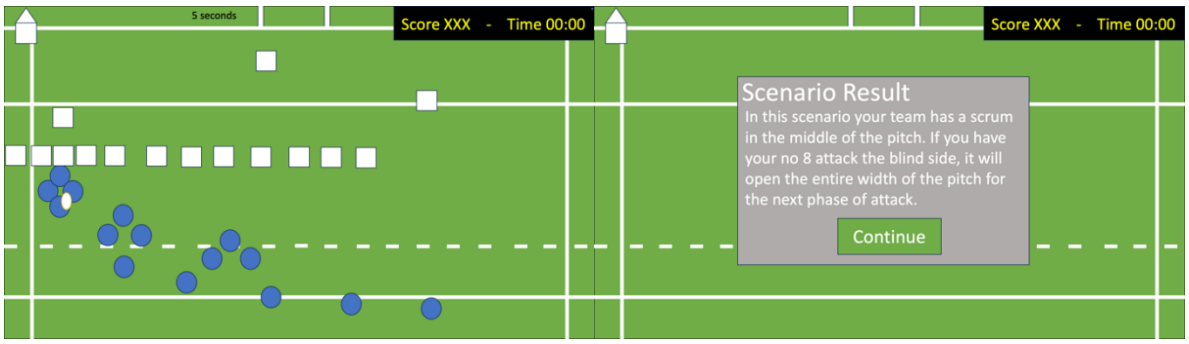

Figure 5.7: High-Fidelity Prototype tactical game mode examples, decision result view and feedback screen

Finally, within the *Positional Game Mode* the player first picks their *Playing Position* from a list grouped by backs and forwards positional groups. These positions and groups are the commonly accepted positions found within the sport. The position selection screen example in the prototype can be found in Figure 5.8.

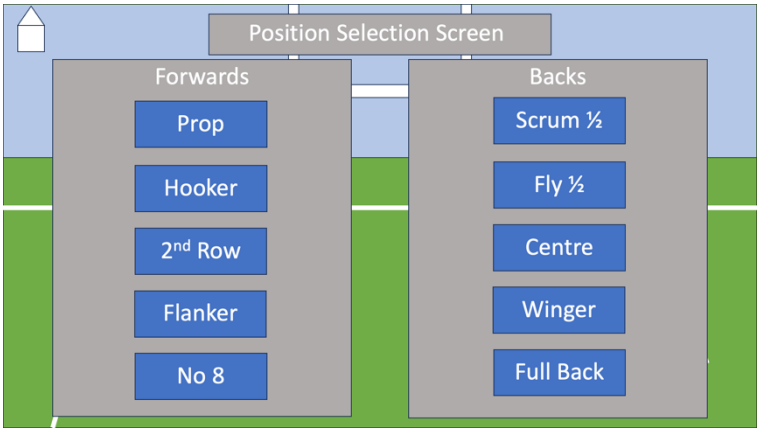

Figure 5.8: High-Fidelity Prototype position selection screen example, positional decision-making game mode

Depending on which position selected – the player will either be given a scenario to decide what to do for their positional group of forwards or backs, in a specific situation. Both scenarios used came from a set play lineout, The back's scenario being closer to the middle of the pitch, with more space to attack, and the forward's decision being near the try line to attempt to score. An example of the different scenarios given to the player based upon the position they select is found in Figure 5.9.

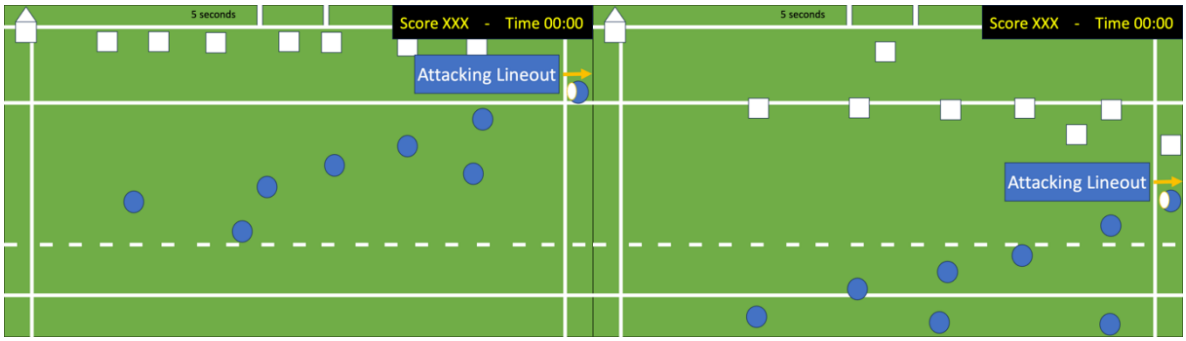

Figure 5.9: High-Fidelity Prototype positional decision-making game mode example, initial player view, forwards (left), backs (right)

For both scenarios, again a timer was present to give the player time to scan the scenario to make an informed decision. This method of the game presenting an appropriate scenario for the player again operates as a *Content Management System* within the game. Similarly to the *Tactical Game Mode*, the player is also shown the result of the decision they have made before the feedback screen appears. The different multiple choice options given dependent on which positional group the player selects for this game mode can be found in Figure 5.10.

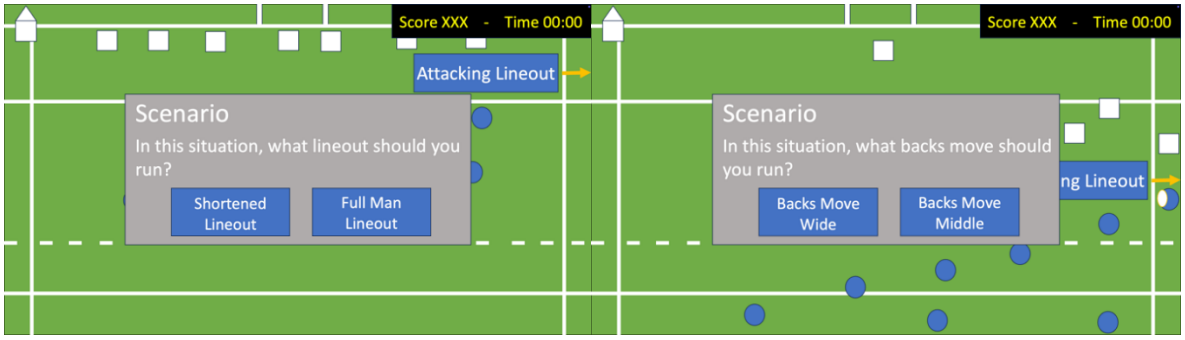

Figure 5.10: High-Fidelity Prototype positional decision-making game mode example, multiple choice options, forwards (left), backs (right)

5.4. Phase 2 Findings

Based upon the findings of the Phase 1 interviews, as well as the background research literature review, a 'game storyboard' was created to act as a High-Fidelity Prototype. The key findings identified from Phase 1 provided additions and refinements to the development of the conceptual model, which was initially created from the systematic literature review. The High-Fidelity Prototype is the result of the considerations of this refined conceptual framework. This prototype was presented to each key participant taking part in the participant group to gather feedback through the interview questions. The purpose of this interview phase is to further refine the conceptual model with this feedback, which will then be used to create a final game design for the research prototype that will act as a rugby union training aid. The prototype provided to the participant group for feedback was interactive so to give the participants a feeling of how the final game could look and feel.

The interviews were all carried out on a 1-2-1 basis with the researcher interviewing each participant digitally via video call. All calls were recorded, with transcripts produced and edited for each call. Following the interviews these transcripts were then open coded following a qualitative data analysis methodology. Whilst analysing the transcripts, a list of thematic codes from the key themes of the interviews were produced.

During this stage of interviews, the following key themes were identified. The below table shows the number of participants who mentioned each area, the number of references made to each key theme and the area within the conceptual model of this research these themes would fit within. An importance "weight" was given to each of the themes identified. This scale was between 1-5, with 1 being completely irrelevant, 3 being of a fair amount of importance, and with 5 being vitally important to take forward within the research. The summary of the findings from the Phase 2 interview transcripts can be found in Table 5.1.

Table 5.1: Summary of Phase 2 Code Findings

Category	Area in Conceptual Model	Weight	Instances Mentioned
User Input	New Area	4	5
Sport Experience Level	Game Design	5	9
Player Feedback	Game Design	4	5
Camera Perspective	Game Design	3	10
Sequential Decisions	Decision Making	3	5

User Input

User Input looks at the different ways information can be inputted by different users into a Serious Game. Any Rugby Union player that performs well within a match must be able to recognise and understand tactical patterns of play [15]. The Systematic Literature Review looked at previous research where Rugby Union coaches from a range of levels were interviewed with all agreeing that tactical awareness was an important consideration for decision-making skills of players [24]. Previous research also identified that coaches could develop a training framework to improve decision-making by inputting different constraints into decision-making training [19]. In this phase of interviews, the participant group identified similar themes of User Input in two ways: *Coach Input* and *Player Input.*

When asked if the *User Input* for such a training aid should be *"coach driven",* Participant 1 commented that *"It is yeah, definitely, because there'll be different reasons behind it".*

Comments were centred around coaches having their team's own tactics being used within any training aid, so having their input would be crucial to success of this. In addition, by ensuring a training aid can consider *User Input* in these ways, the research prototype can ensure that a user-centred approach is clearly followed. The importance of a user-centred design is key to the success of this research, so this theme was given a Weight of 4 out of 5. Both *Coach Input* and *Player Input* was added to this new area of the Conceptual Framework due to this.

Sport Experience Level

The key participant group also identified the player's *Sport Experience Level* during this phase of interviews. One key element of Game Design methodologies that was identified within the literature review was the *Game Difficulty Curve*. Previous research identified that by pacing the 'flow' of a game and carefully increasing the difficulty curve, player engagement increases as well as skill retention

[91]. A consideration for designing the difficulty of the training aid prototype will need to be how difficult the game is based upon the player's individual rugby playing experience. The High-Fidelity Prototype that was created for this phase of interviews took this into account by asking each user their individual rugby playing position and experience. This is intended to tailor the playing experience for each player.

Given that the High-Fidelity Prototype used a timer to tailor the difficulty of the decisions, Participant 2 commented that the thinking time required by a rugby player can be different given the Sport Experience Level of the user: *"Yeah, I think there's probably something in that a really experienced fly half versus a beginner fly half are gonna have very different time to think.".* This can be used to change the Game Difficulty Curve in further development of a full prototype training aid.

During the interviews, *Sport Experience Level* with a specific *Rugby Experience Level* context was picked up on by 4 of the 5 participants, with 9 references to rugby experience level throughout. Comments were positive about this implementation and added that this could be further tailored to other game mechanics within the prototype, such as the number of sequential decisions being made by the player within the training aid as well as the time allowed to make these decisions. For these reasons, this was seen as a key consideration for the further development of the prototype for this research and therefore given a Weight of 5 out of 5. This was therefore added to the Conceptual Framework. The specific *Rugby Experience Level* was added to the Research Artefact to represent the *Sport Experience Level* as a sporting context of this.

Player Feedback

Player Feedback screens were implemented within the High-Fidelity Prototype at the end of each gameplay scenario to give the player a form of feedback on the decisions they had made. The intention of this was to replicate feedback found in existing training methods such as *Video Analysis* to improve *Tactical Decisions* by players.

Combining Player Feedback in this way for those that enjoy visual learning with such a training aid that the High-Fidelity Prototype represents was also positively received, with the Participant 3 commenting: *"The visual aid is probably a lot more beneficial to someone like especially me because I said I learned through visual rather than told."*

Player Feedback Screens were mentioned 5 times during the interviews, with 3 different participants mentioning them. Whilst comments did say these could be clearer for players for a more developed prototype, as commented by Participant 3: *"making it a bit more clear. Yeah, maybe. just like a bit more clear, just a little bit more clear in that aspect".* The importance of these screens were clearly important for the further development of a training aid, with more clarity on the screens required. This was therefore given a Weight of 4 out of 5.

Camera Perspectives

Camera Perspectives, the visual way in which the users are presented with an environment will need to be considered within the design of a Serious Game for the purposes of acting as a training aid for Rugby Union players. *Camera Perspectives* within games can be presented in different ways, so for this purpose, the High-Fidelity Prototype that was presented to the key participant group had 3 different *Camera Perspectives* presented for feedback; a *1st Person* camera, a *3rd Person* camera, as well as a *Bird's Eye View* camera:

- *1st Person* cameras in games show the user the game environment and scenarios from the perspective of the initial character, as though they were viewing it themselves. For the High-Fidelity Prototype, this was a camera type that was used for the individual *Decision-Making Game Mode.* Participant 2 did feedback that this view did have limitations in terms of seeing the full view of the scenario from a player's perspective: *"The the first person's you've got the ball player as use kind of swiped. Round it almost looked as though the players were in front of you.",* when asked if it required a wider field of vision, which could be shown in a different perspective, the participant added: *"Yeah. Just got that a little bit wider.".*

- *3rd Person* cameras give the player a view of a scenario from a fixed distance from the characters, often behind and/or slightly above the character they are playing as. This was not initially used in the High-Fidelity Prototype but will be considered for the development of the working prototype, based on feedback. As highlighted, some of the limitations of field of view from *1st Person* could be addressed with this for future development.

- *Bird's Eye View* camera angles give the player a top-down perspective of the gameplay environment and it's characters. This is also a common camera angle used in Video Analysis techniques. As identified in Phase 1 Findings, this was identified as useful to give a 'big picture' perspective of the pitch, aiding with understanding of *Tactical Decisions*. It does not though

show decision-making in a player-by-player perspective, i.e., 1st Person. Both camera angles were used within the High-Fidelity Prototype for the purpose of ascertaining the impact of being able to use both in a training aid. Participant 1 commented: *"I like the birds eye view. I think that's something that we don't ever get to see as players. Well, yeah, ever really. Unless you're a professional".*

These *Camera Perspectives* were used to try to combine user experience with existing training aids such as video analysis tools. Therefore, this prototype was developed to incorporate both to attempt to address this issue of the limitations of *Video Analysis*, whilst also including *Camera Perspectives* that replicates the best aspects of it. The participant group was very positive about the combination of these within the High-Fidelity Prototype, with 4 of the 5 participants referencing this.

Players can also change their view during the individual *Decision-Making Game Mode*. This includes a Look Left and Look Right option to best simulate the ability to look or 'scan' as a player in the match. Outside of the interviews, feedback was gathered to ascertain if the game should use a *Timer* to introduce a pause when the player changes these views, to allow for information to be processed prior to a decision being made. This was received positively, with all participants agreeing this would be a positive change for the prototype.

Participant 1 commented on this change being a positive one: *"I think pause so it gives the person time to reflect, but then could there be like a 5 second pause? almost like a timer?"*
Participant 4 also recommended that this pause could be tied to the *Game Difficulty Curve: "I think having it pause would be good if you have a difficulty setting. Maybe not a full pause but maybe a timed delay?".* This could be achieved by tailoring it based on a player's *Rugby Experience Level.*

The participant group made comments further combinations of this mix of camera perspectives, with the player being able to switch between them being desirable. This represented a new concept of *Mixed Camera Perspectives* for use within the Serious Game training aid, which could, in turn, be considered within the *Game Difficulty Curve* – more experienced players may not have such flexibility as a less experienced player.

Mixed Camera Perspectives were also proposed as a possible improvement during the interviews, with Participant 1 putting forward one solution: *"Could we have, you know, on the storyboard*
Half the page is, the bird's eye view and the other half of the page is actually first person".

For further prototype development therefore, more *Camera Perspectives* will be implemented to allow this concept to develop, such as adding *3rd Person* perspectives. This theme during the interviews was important to ensure the prototype was on the right path with its design, and so the Weight of this theme was given a rating of 4 out of 5. *Camera Perspectives* and the types of camera, as well as *Mixed Camera Perspectives* were therefore added to the conceptual framework and the research artefact as a result.

Sequential Decisions

Sequential Decisions looks at decision-making being carried out in multiple instances within the same scenario. Previous research identified within the Systematic Literature Review stage of this research looked at how a coach group previously identified that rugby player decision-making needs to be impacted by a player's ability to adapt to a 'changing picture' of what is happening on the pitch [24]. Within a game of rugby union, this can include decisions being made quickly and in quick succession. The High-Fidelity Prototype that was presented for feedback in this phase of the research had 3 different *Game Modes*, with a tactical decision-making section requiring players to make multiple decisions based on selecting a type of set piece to carry out in each area of the pitch, and where the play should be focused after executing that set piece. The participant group reacted positively to this implementation, with 4 of the 5 participants referring to this.

Participant 5 liked the use of *Sequential Decisions* currently, but commented this could be implemented further: *"What would you do phase 2 phase 3? Cause you could have that and you wouldn't have to necessarily have that much as much. Live action as the decision making one for example. The storyboard you could really go into a hell of a lot of depth on rugby.".* The participant would also comment that coaches could use such a training tool to improve *Tactical Decisions* with such *Sequential Decisions: "a coach might load a tactical situation with. The outcome that he's after or the most desirable outcome. Do you know what I mean? So, how, what, decision does that player make, how quickly does it get him to that desirable outcome?".*

Participant 3 also commented positively on the use of *Sequential Decisions,* particularly the benefit for all *Rugby Experience Level's*: *"I like the fact that it's gone right. You've picked that decision. That's the right decision you've made. However, you've not scored just yet, so you might have to make another decision. So rather than just a single decision-making opportunity, it's making you think a lot more*

rather than just like a single thought. So that's really good for beginners all the way through to advanced.".

Sequential Decisions could be further implemented within a more developed training aid and could be based on the identified *Rugby Experience Level* of the player. This is therefore an important consideration for the final training aid, whilst already partially being implemented within the High-Fidelity Prototype, it could be further developed. This was added to the conceptual framework for consideration and given a Weight of 3.

5.5. Phase 2 Conclusion

After the second round of interviews with the key participant group, the Headlights: Conceptual Framework was again further developed from the Phase 2 findings. The initial framework was developed initially during the systematic literature review, then altered from the results of the previous Phase 1 study. The framework was altered to include new concepts which emerged from the interviews with the key participant group, which acted as feedback to the initial High-Fidelity Prototype that was developed in this chapter. The findings in the interviews included means of *User Input*, as well as *Player Feedback*. It also included the functionality for the game prototype to include *Sequential Decisions* as well as *Sequential Levels*, tailored for player difficulty and experience. The framework therefore also had a *Rugby Experience Level* element added for this reason. The participant group also identified game mechanic subjects such as *Camera Perspectives* to be used in any game prototype, particularly *Mixed Camera Perspectives*. The updated Headlights: Conceptual Framework, as well as the updated Research Artefact from the findings of Phase 2 can be found in Figure 5.11 and Figure 5.12 respectively.

During the second phase of interviews, participants identified that a form of *User Input* should be implemented as part of the training aid prototype. Comments focused on how feedback between players and coaches could assist with specific team tactical understanding. Therefore, a *User Input* theme was added to the conceptual framework, with an item for Coach Input and Player Input. As part of the High-Fidelity Prototype, feedback screens were given to players to give a measure of how successful they were in any given scenario. This form of feedback was well received by the participant group and encouraged to give further detailed feedback. Therefore, *Player Feedback* was added to the conceptual model within the Game Design theme.

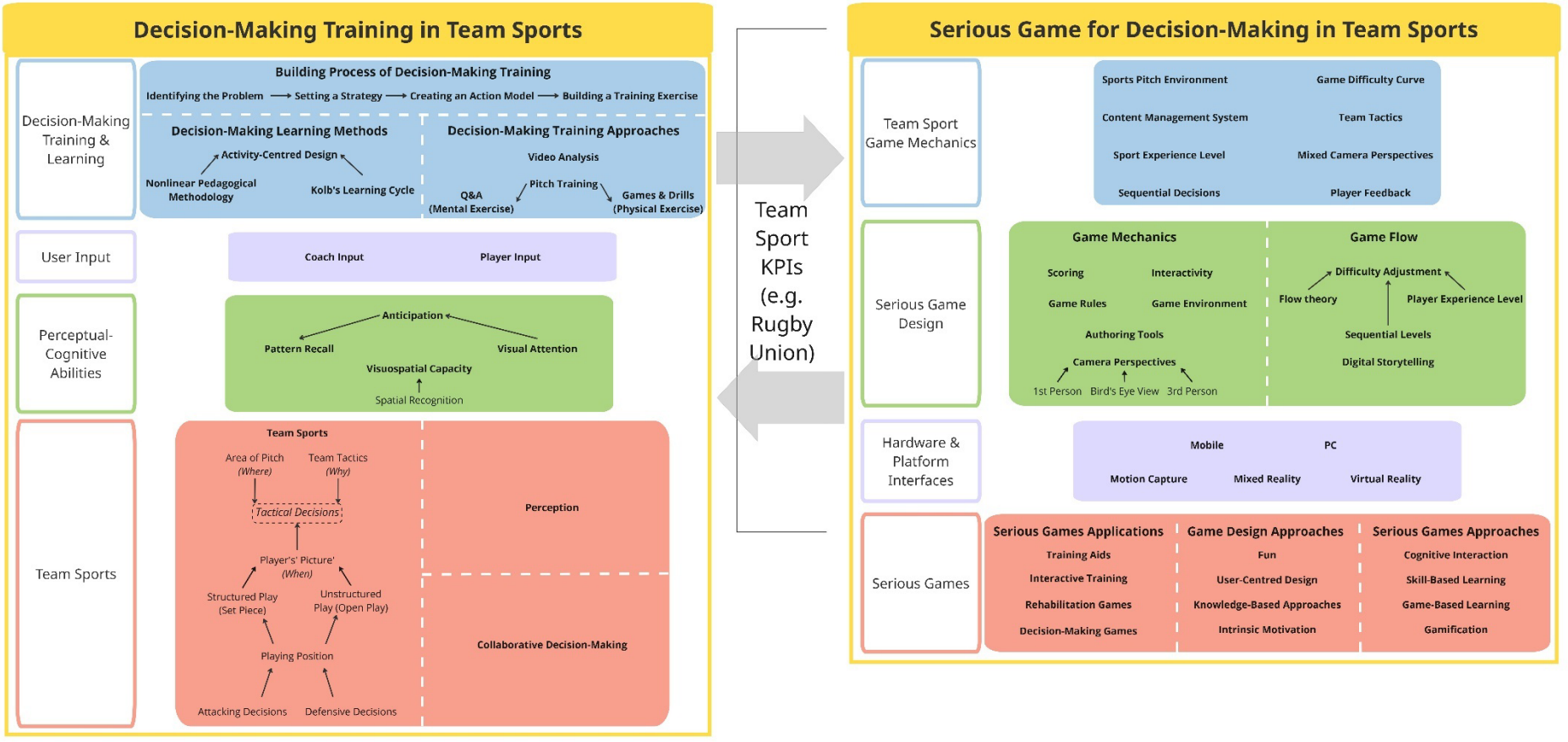

Figure 5.11: Headlights: Conceptual Framework (Post Phase 2)

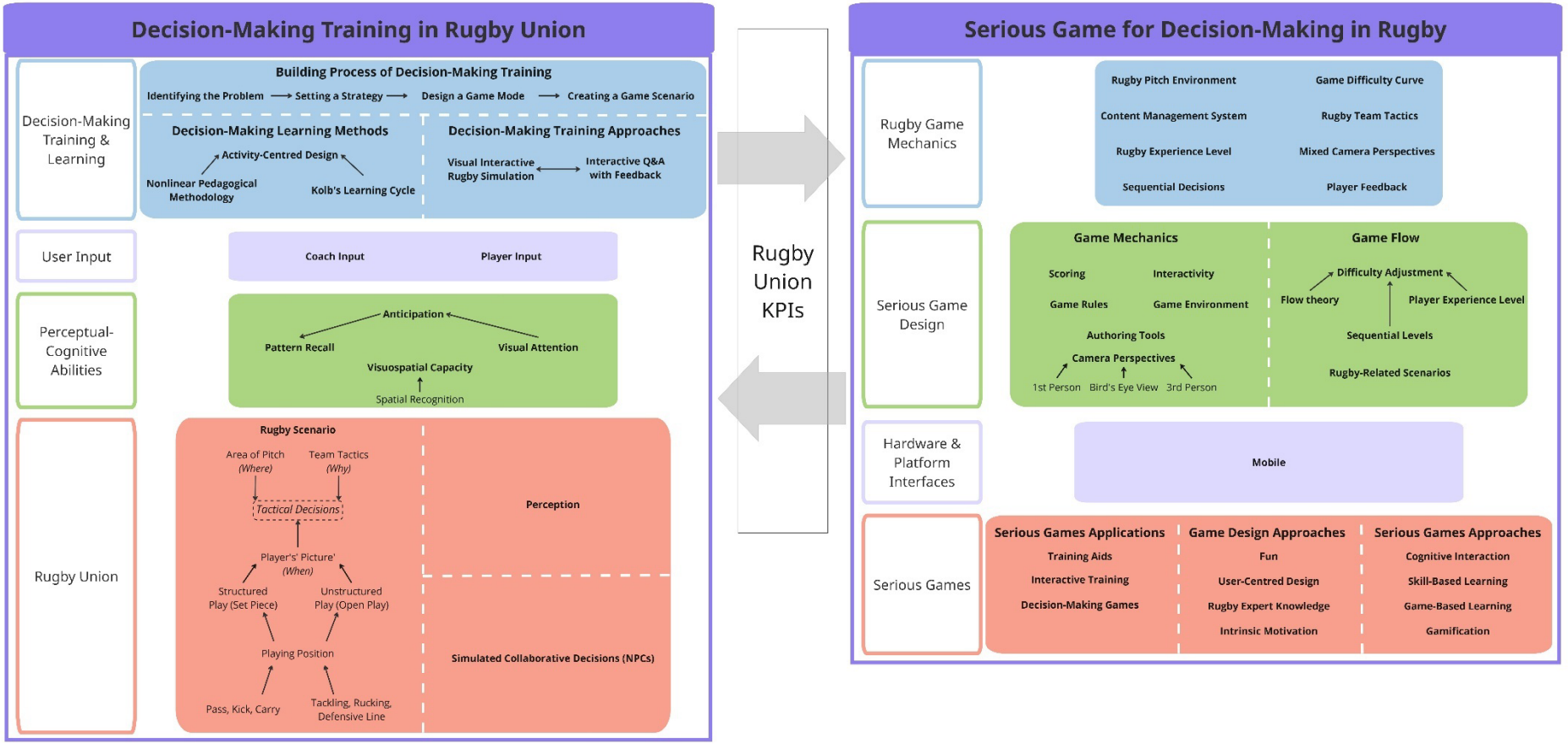

Figure 5.12: Research Artefact (Post Phase 2)

As part of discussions on specific areas of the High-Fidelity Prototype, the participants within the key participant group identified that *Sequential Decisions* could add a lair of difficulty to the training aid which could be tailored based upon the Rugby Experience Level of the player using the training aid. Making multiple decisions attributes to the player's 'picture' of what is happening in front of them, which could contribute to the tactical decisions made by individuals. This was added to this item as part of the Decision-Making theme within the conceptual model. As a further consideration of *Sequential Decisions*, *Sequential Levels* could be added to the training aid to further increase the difficulty curve for more experienced Rugby Player's. This was identified during the second phase of interviews and could offer more challenge to users of the training aid. Therefore, this was added to the Game Design theme within the Conceptual Framework. During the second phase of interviews, the High-Fidelity Prototype allowed players to choose their *Rugby Experience Level*. The participants interviewed responded well to this and highlighted that it could be used to tailor various aspects of the game difficulty curve with a direct impact on core mechanics within the training aid. Therefore, this was added to the conceptual model as part of the Game Design theme, linked to the *Game Difficulty Curve* item.

The High-Fidelity Prototype presented users with two different *Camera Perspectives* whilst using the training aid: 1st person and 3rd person perspectives. The aim of this addition to the prototype was to replicate the best aspects of Video Analysis techniques whilst resolving some of its limitations. Response to these perspectives were positive among most of the participant group with some highlighting these could be more integrated to offer *Mixed Camera Perspectives*. Therefore, these two perspective types were added as well as a *Camera Perspective* item to the Game Design theme of the conceptual model. In addition to the different *Camera Perspectives* presented to the key participant group with the High-Fidelity Prototype, participants highlighted in the interviews that these perspectives do not necessarily have to exist in separate areas of the training aid from each other and these perspectives could be combined in some areas. Therefore, *Mixed Camera Perspectives* where also added to the conceptual model. In addition, feature improvements were suggested by the participant group outside of the interviews for *Camera Perspectives* – for when a player changes their view a pause was implemented to allow players to process information.

5.6. Chapter Summary

In this chapter, a refined Research Artefact was created to act as a design framework for the initial High-Fidelity Prototype. This prototype was created as an interactive storyboard and presented to the same key participant group as the previous chapter. This group was interviewed following being shown this prototype and the interviews acted as feedback.

Initial feedback upon presenting the participant group with this prototype during phase 2 interviews focused on the *Rugby Experience Level* altering the *Game Difficulty Curve* of the prototype. This also could add to the *Sequential Decisions* being made within the training aid to add complexity. Feedback on the *Camera Perspectives* was positive with comments encouraging the mixing of these perspectives where possible, resulting in *Mixed Camera Perspectives*. The findings from this phase of interviews were used to further develop the Headlights: Conceptual Framework, with key findings for this research being also added to the Research Artefact.

These developments will be used to implement a working prototype game for phase 3 of interviews. In the next chapter, this working prototype game will be designed and developed using these assets. The prototype will then be presented to the same key participant group for further feedback and again ensuring that a User-Centred Design approach is followed at every stage of development of the Serious Game for training Rugby Union players.

Chapter 6: Study 1, Phase 3: Prototype Design, Development & Evaluation

In the previous chapter, a research study was conducted by interviewing a key participant group from the sport of rugby union to ascertain the key themes and concepts for a training aid game to address to improve the cognitive abilities and decision-making skills of a player within the sport. These core concepts were initially found and developed during the initial literature review of this research, with the findings of this forming the initial conceptual model. The previous chapter's interviews allowed the identification of the core concepts that are most important to a training aid game for the sport of rugby union, allowing the development of a refined research artefact, as well as a high-fidelity prototype to show the participant group, to act as an initial design concept for the training aid to be developed.

In this chapter, a research prototype was developed using the findings of these previous chapters and the conceptual framework, the refined research artefact as well as the high-fidelity prototype. The purpose of this prototype will be to be used as a training aid for the sport and have a positive impact on the skills identified. The game prototype was then presented to the key participant group for a final phase to the user study with the further feedback implemented to ensure user-centred design for the final game prototype.

6.1. Phase 3: Game Architecture & Prototype Design

The purpose of Shieldwall: Rugby, is to be a Proof-of-Concept Prototype is to be a Serious Game that can be used as a training aid for Rugby Union players to be able to train skills such as their decision-making. To achieve this, the previous study identified key requirements and themes to be used in such a training aid which formed the Conceptual Framework for this research, with a refined Research Artefact exploring the key themes required specific to a Rugby Union training aid. The High-Fidelity Prototype that was developed in the previous chapter during the interviews with the key participant group identified 3 distinct sections that a training aid for rugby union should address: individual decision-making, tactical decision-making, and positional decision-making. The participant group did however feedback that the final video game training aid would require further scenarios for defensive decision-making to also be included. Therefore, the scenarios that were created for the High-Fidelity Porotype as well as a new defensive decision-making scenario were included within the final design for the proof-of-concept prototype, Shieldwall: Rugby. First, the core gameplay for the prototype was designed. Shieldwall: Rugby was then created using the Unity game engine. Unity was selected as the

engine of choice due to its compatibility with mobile devices, which was key to accessibility of the target audience, rugby union players, as identified in the interviews in the previous chapter. The previous study also identified that the training aid should be accessible to as many players as possible, and to achieve this the game should be available for mobile devices. The game was designed and created for *Mobile* devices, and used the Unity Game Engine for this reason for development as this game engine was identified as being able to meet the portability requirement to mobile devices.

The overarching game design architecture will therefore be discussed in this chapter. This design explored Gameplay Mechanics, the Game Modes, the Scenario Context, Environment & Aesthetics, Gameplay Features as well as Player Profile & Stats for Shieldwall: Rugby. This design architecture is shown in Figure 6.1.

6.1.1. Player Profile & Stats

For the core game design of Shieldwall: Rugby, it was important to ensure that the game was User-Centred in its approach to be able to train the desired decision-making skills for the sport of Rugby Union. Therefore, following a TURF methodology (Tasks, Users, Representation & Function), as established by literature search in a previous chapter, Shieldwall: Rugby must consider the users' needs [57]. It will do this by using the Playing Position and Rugby Experience Level of the user to tailor the training aid to match their skill level and positional needs. The player will input this information at the start of using the training aid and will be able to alter it at any time whilst using the game via the Home Screen. Examples of the initial start screen as well as the home screen given to players can be found in Figure 6.2. The information given by the player will alter the Scenario Context given to the player, by giving the player scenarios relevant to their Playing Position. In addition, the Rugby Experience Level will alter the Game Difficulty Curve of the game, giving an experience challenge relevant to their experience of the sport, making the training aid more relevant to all skill levels of players using it.

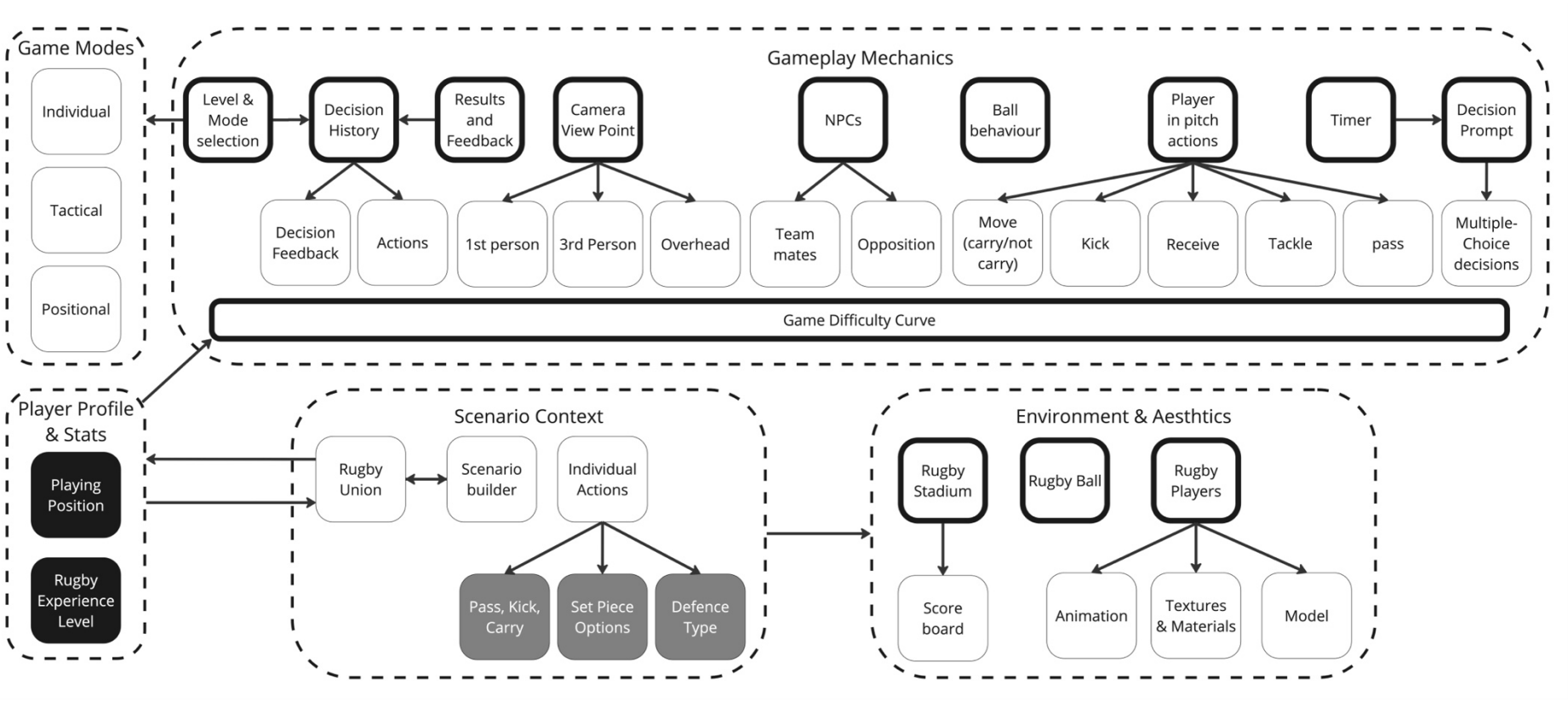

Figure 6.1: Shieldwall: Rugby, Core Game Design Architecture

Figure 6.2: Shieldwall: Rugby, Game Start Screen (Left), Home Screen (Right)

Playing Position

Following a TURF methodology, it is important to consider the specific user's needs for using a Serious Game – in the case of Shieldwall: Rugby, the rugby player and anything specific to them for using the training aid, such as their Playing Position for the sport. Rugby Union is a sport which has different positions in two Positional Groups, all which have unique roles. The Positional Groups have specific relevance and on-field tasks in both structured (Set Piece) plays, and unstructured (Open Play) plays. Because of this, for Shieldwall: Rugby the player will select their position at the start of using the training aid, which was initially presented in the High-Fidelity Prototype in the previous chapter's study. The player can change the position selected during gameplay via the Home Screen. These positions are given a Positional Group of Forwards and Backs, both of which will load a positional-specific scenario for the Positional Decision-Making Game Mode when selected. This will add to the Rugby Union Scenario Context of the game by using positional-specific scenarios. Table 6.1 illustrates positions in rugby union, whilst Figure 6.3 shows the Playing Position selection screen within Shieldwall: Rugby.

Table 6.1: Shieldwall: Rugby Playing Position & Positional Groups

Positional Group	Position
Forwards	Prop
	Hooker
	Second Row
	Flanker
	No. 8
Backs	Scrum Half
	Fly Half
	Centre
	Winger
	Full Back

Figure 6.3: Shieldwall: Rugby Playing Position selection screen

Rugby Experience Level

A key consideration for ensuring that the prototype Serious Game training aid is User-Centred is to consider their experience in playing the sport of Rugby Union. This was initially considered for the High-Fidelity Prototype, which asked the experience level of the user, the game player, upon beginning the game. The Key Participant Group reacted positively to considering this aspect for game play, with tailoring of scenarios to be implemented based upon the experience level. Feedback outside of the interviews also commented that this should be able to be altered after the initial selection is made. The difficulty levels established for Shieldwall: Rugby were Novice, for beginners to Rugby Union, Advanced which is aimed at those with at least some experience in the sport, and finally Expert for the more well-experienced players, perhaps playing at higher levels within the sport. These different experience levels alter the Game Difficulty Curve within the training aid. This is done by altering the in-game speed of play, with more experienced levels running at a faster speed with less analysing time available to players before making decisions in-game. The Playing Experience selection screen for Shieldwall: Rugby can be found in Figure 6.4.

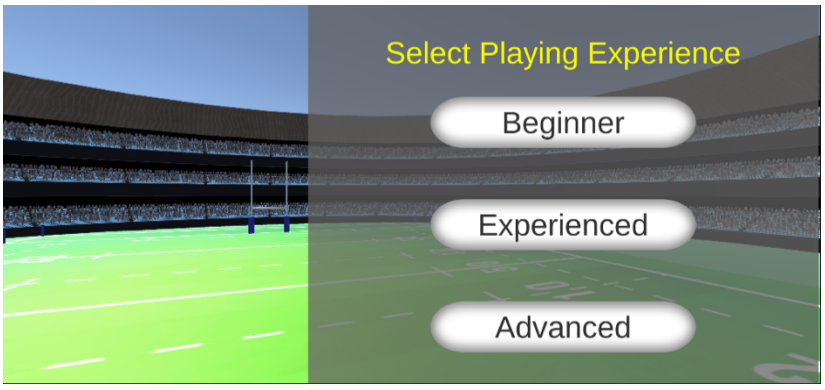

Figure 6.4: Shieldwall: Rugby, Rugby Experience Level selection screen

6.1.2. Scenario Context

To train decision-making in an impactful way as a training aid, Shieldwall: Rugby required specific contextual scenarios to be used that are relevant to the sport as well as the skills to be trained such

as decision-making. As Shieldwall: Rugby is designed to be a training aid for the sport of Rugby Union, specific sport-related context will be applied such as creating specific Game Modes that use rugby-related scenarios. These are formed from the key findings from the previous study were a key participant group fed back on an initial High-Fidelity Prototype that used such scenarios. In addition, previous studies identified within Chapter 2's literature review also identified that by using player input data in this way, a Serious Game could be better tailored to the player by given them specific scenarios [79]. These scenarios provide the training aid the Rugby Union context required for the Shieldwall: Rugby Prototype. These Rugby Union Game Modes within the prototype also use information about the user, the player in terms of their Playing Position and Rugby Experience Level to select the most appropriate scenarios as well as to manage the Game Difficulty Curve, to improve the impact of the prototype.

To give content to the player that is appropriate to their selected Playing Position and Rugby Experience Level, i.e. the Player Profile & Stats, a Scenario Builder was used to create the scenarios used within the 3 Game Modes of Shieldwall: Rugby. Scenarios were created initially from feedback given in the previous study by the key participant group, with further feedback from the High-Fidelity Prototype used to continue to tailor the scenarios used. Within each of these scenarios, players have Individual Actions they can take depending on the scenario they face – there are 'attacking' options such as Pass, Kick and Carry, Set Piece Options, as well as selecting Defence Type to be used. These decisions provide context to the scenarios created for Shieldwall: Rugby with a Rugby Union background for the training aid. This section will discuss how the Scenario Context for the sport of Rugby Union was created for the Shieldwall: Rugby prototype in these ways. Figure 6.5 provides a visualisation of the underlying game concepts that make up Scenario Context within the Shieldwall: Rugby game architecture.

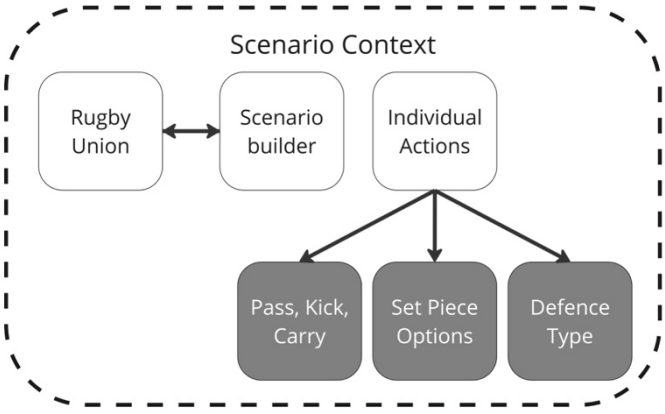

Figure 6.5: Shieldwall: Rugby Scenario Context game architecture

Rugby Union

To ensure that the Shieldwall: Rugby prototype has relevance to the subject it is aiming to be used for, *Rugby-Related Scenarios* will need to be used. This will ensure that the prototype is immersive, which is a desirable game element for a Serious Game's design [95]. A core feature of any game is establishing a Game's Rules, by using the sport of Rugby Union, the game rules are established by using the rules of the sport for the game. Initially, the High-Fidelity Prototype used in the previous chapter distinguished scenarios to be used in each gameplay section, this was further refined to include defensive decision-making scenarios because of the feedback received. Each scenario follows the gameplay rules of the sport of Rugby Union, which includes 15 characters on both the player's team and opposition. Providing the Rugby Union specific context by means of gameplay scenarios will ensure that the Serious Game has its desired learning outcomes for the sport. The Scenario Builder will be used to create and manage the scenarios that the player accesses while playing the game.

On starting the game, players are asked to select a "Rugby Experience Level" between beginner, advanced or experienced. They are also asked which position they play within the sport. These choices are made to ensure relevant scenarios are given to the player who is using the training aid, as well as tailoring the Game Difficulty Curve of the game based upon their experience. The choices made here are used to ascertain the Player Profile & Stats. These choices influence the scenarios selected for each of the 3 Game Modes, with the difficulty curve setting the speed of the scenarios, giving players less time to analyse and make decisions if they are more experienced, to enhance learning.

Scenario Builder

For any Serious Game, the context of what the game aims to train for players is important – this is given as Rugby Union context for the Game Modes within Shieldwall: Rugby. Scenarios were built using the Unity Game Engine. The relevance of the scenarios selected were verified by the previous study where a Key Participant Group were presented these in the form of an initial High-Fidelity Prototype for feedback. This feedback was used to further tweak the scenarios created. 3 Game Modes are present in Shieldwall: Rugby – Individual, Tactical and Positional Decision-Making. Each game mode has custom-built scenarios with both attacking and defensive scenarios present. Players are asked to make decisions on Individual Actions within each scenario, to make this game interactive for players to use. Whilst it was decided that it was not in-scope to have a custom Scenario Builder available to coaches for the purposes of the research prototype, this could be a future consideration for the development of a more usable Serious Game for the sport of Rugby Union in the future. This could allow coaches to input custom scenarios based upon their own team's tactics, which could

further improve usability – such Content Management Systems were identified during the literature review chapter of this research [21].

Individual Actions

As Shieldwall: Rugby is intended to be a Serious Game training aid, it will need to have interactive elements to engage the target audience, Rugby Union players. Players will make decisions within the Shieldwall: Rugby Serious Game through Individual Actions on each scenario. To achieve this in an interactive way, the player will be given different Individual Actions which they can choose to use within the game prototype. Rugby Union is a sport in which a player can take different Individual Actions which require a decision to be made, both in an attacking a defensive context whilst also making these decisions for Set-Piece (structured) plays. Within the previous study, the participant group identified that when a player has the ball in possession, they can choose to Pass, Kick or Carry the ball. This was replicated for decision-making scenarios where the player is in the attacking team. Players can also make different tactical Set-Piece Options for what their team should do given a specific situation in a rugby match (i.e. the Players' Picture; area of the pitch etc). Finally, within Shieldwall: Rugby there is also a choice of Defence Type's the player can select as part of the actions they take within the game scenarios. These Individual Actions are all presented to the player in the game by User Interface elements, such as question and answer boxes, or buttons to select a specific decision to make, as seen in the Individual Decision-Making Game Mode.

In attacking scenarios, players will be given the option to Pass, Kick, or Carry the ball. For defensive scenarios, the player will be asked which type of defence that they should run. Tactical decisions will give the player of the different types of set piece play their team could run and ask them which decision would be the best to run. These options will display in two different ways in the Shieldwall: Rugby prototype. For the Individual Decision-Making section, players will have all options available on-screen in a heads-up display and will be able to decide until their in-game player is "tackled" by the defence. For Tactical and Positional Decision-Making, the player will be shown a scenario, and asked to decide by a pop-up box that will display all options as selectable buttons. Individual Actions will therefore provide the interactive elements to Shieldwall: Rugby. This is desirable as previous literature reviews have shown that Serious Games with interactive mechanics act well as a support to learning [96].

6.1.3. Environment & Aesthetics

As established in the previous chapter's literature review, a Serious Game is a game-based learning tool used to teach and train skills. The success of such Serious Games can often be impacted by the immersion experienced by the player, with such factors as the Environment & Aesthetics within the game, this has been shown to improve the interactivity experienced by the player [97]. Previous research on Serious Games has also shown that players who felt immersed in the game environment also had high engagement, particularly when user interactivity, is also high [98]. This section will discuss the considerations and design implemented to create an Interactive and Immersive prototype for Shieldwall: Rugby by considering the Environment & Aesthetics of the game's design. These will be established using a Rugby Stadium, Rugby Ball, and Rugby Players (as models) within the game. All game environment assets were created or attaining in 3D, to best create real world immersion. In addition, a stadium asset was also imported to replicate a professional playing environment for the sport of Rugby Union. This section discusses how these game environment features were implemented within the Shieldwall: Rugby prototype to improve the Serious Game's immersion. Figure 6.6 provides a visualisation of the underlying game concepts that make up Environment & Aesthetics of the Shieldwall: Rugby game architecture.

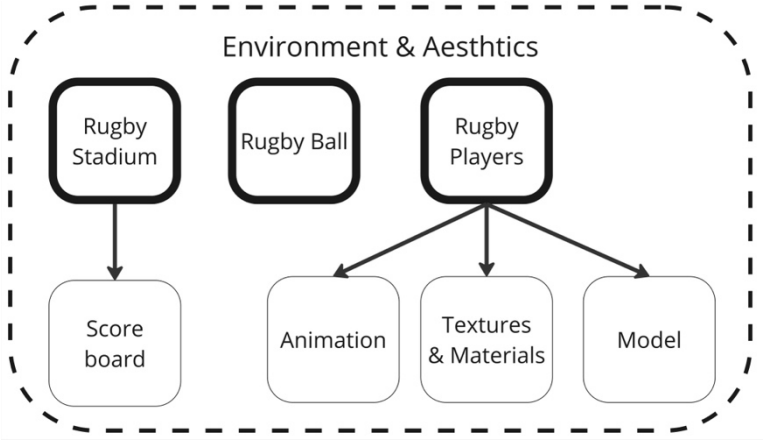

Figure 6.6: Shieldwall: Rugby Environment & Aesthetics game architecture

Rugby Stadium

As already established, immersion is a key component for creating interactive and engaging gameplay within a Serious Game. For Shieldwall: Rugby, we have already considered using rugby-relevant decision-making scenarios as the core gameplay for the player. However, to ensure immersion for the players, a rugby-specific environment should be used. Therefore, for Shieldwall: Rugby a virtual environment replicating a rugby pitch and match was created within the chosen game engine. This will include art assets for realistic human rugby player characters, as well as models replicating a real-world rugby pitch including line markings and flags. All relevant Pitch Furniture for a rugby pitch will

also be included in the final environment, including posts and flags. Some of these assets will be created within the game engine. In addition, rugby matches also use Scoreboards to keep track of both team's score during a match. Therefore, a Scoreboard is also present throughout all game modes and within each scenario that the player plays whilst playing Shieldwall: Rugby. Figure 6.7 shows the game assets that were created within the Shieldwall: Rugby prototype to replicate a Rugby Stadium game environment.

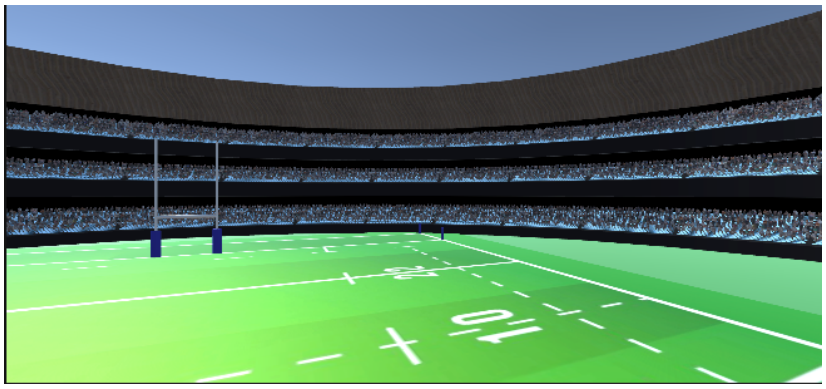

Figure 6.7: Shieldwall: Rugby, Rugby Stadium game assets

Rugby Ball

The sport of Rugby Union is a contact sport in were two teams play against each other and the winner is the team that scores the most points during a match. The teams compete for possession of a Rugby Ball, which is used to score points by tries and conversions [7]. As already discussed, immersion is key to improving the impact of a Serious Game. Therefore, a 3D model Rugby Ball was used in the creation of Shieldwall: Rugby to emulate the match ball used within the sport. This model was imported as a free asset and can be seen in all 3 of the Game Modes, where the player will either be in possession of the ball, or their team will be defending against opponents who have the ball. At any one time, there is only one ball present within the game, replicating a Rugby Union match which uses one ball during gameplay. Figure 6.8 illustrates an example of the Rugby Ball model used in Shieldwall: Rugby.

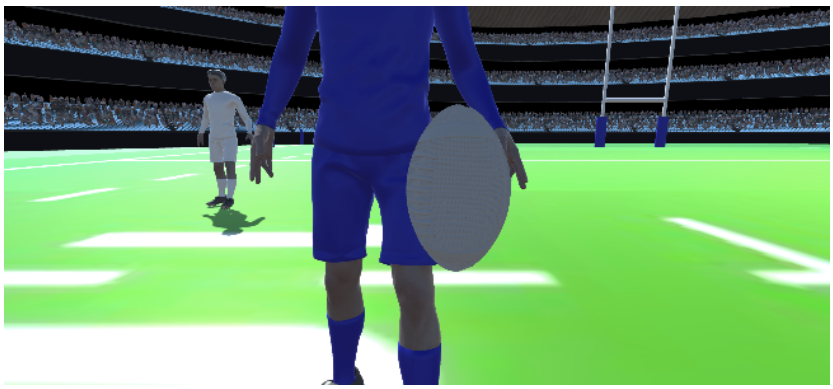

Figure 6.8: Shieldwall: Rugby, Rugby Ball model example

Rugby Players

To enhance the immersion of the Shieldwall: Rugby prototype, 3D human sports player models were used to simulate Rugby Players within the game. Models were obtained that best replicated Rugby Players in a match, with changeable colours on the materials of the playing kit worn by these models to replicate two competing teams. Models came attached with Textures & Materials that best replicated life-like assets with changeable colour options for the kits. Blue and White were used to distinguish the different playing kit colours of the player's team, and the opposing team. These colours were kept consistent across all Game Modes. Future development of the Shieldwall: Rugby prototype could allow a settings menu that allows changing of team colours to allow for greater accessibility, but as this is an initial prototype, this was not implemented for this research. All models also required Animations that replicated life-life movements of player's playing a Rugby Union match. Therefore, animations of running, passing, kicking, tackling, being tackled, as well as standing idle were used that worked with the 3D Rugby Player models. These animations were coded to trigger in each Game Mode when the player was viewing a scenario, and when they made the appropriate decisions. An example of the game asset models used to replicate Rugby Players within Shieldwall: Rugby can be found in Figure 6.9.

Figure 6.9: Shieldwall: Rugby, Rugby Players Models

6.1.4. Gameplay Mechanics

For Serious Games, Gameplay Mechanics relates to what a game player can do within a game, and how they experience the gameplay [99]. As ascertained by the literature search earlier in a previous chapter, there are multiple mechanics required for a Serious Game for a team sport such as Rugby Union. An initial High-Fidelity Prototype was used in the previous study to best replicate these mechanics and identify which were the most desired for the Shieldwall: Rugby prototype development, with participants giving feedback on different areas of the potential training aid. Following this method of mechanic identification ensured a user-centred design approach when it came to the gameplay mechanics, which will improve the user experience of Shieldwall: Rugby as a fully developed prototype.

A Game Difficulty Curve will manage how difficult the game is for players, which will be dictated by the Player Profile & Stats, being the Playing Position and Rugby Experience Level the player selects at the start of the game. Different Camera Perspectives that allow the player to view the game environment will be included across all Game Modes. There will also be Timers, which will control how long a player can analyse a scenario and make decisions within. Non-Playing Characters (NPCs) that the player will interact with in a rugby context will also be present to best create an immersive Rugby experience that replicates the real-world sport, these will be shown on two teams like with a match. To control which content is played next in Shieldwall: Rugby, a Level & Game Mode Picker will also be present for players to interact with in the prototype. Giving players insight into how areas for improvement was identified in the previous study as key for a decision-making training aid within the sport, therefore Decision History will give the player a chance to look at the decisions they made, and there will also be scenario Results & Feedback screens present within all Game Modes. To ensure the Serious Game is immersive in how players in the game move, there will also be Player in Pitch Actions that replicate rugby match movements and decisions. Finally, the Ball Behaviour of the Rugby match ball will also be implemented. This section will discuss how these Game Mechanics were designed for the Shieldwall: Rugby proof-of-concept prototype. Figure 6.10 provides a visualisation of the underlying game concepts that make up Gameplay Mechanics of the Shieldwall: Rugby game architecture.

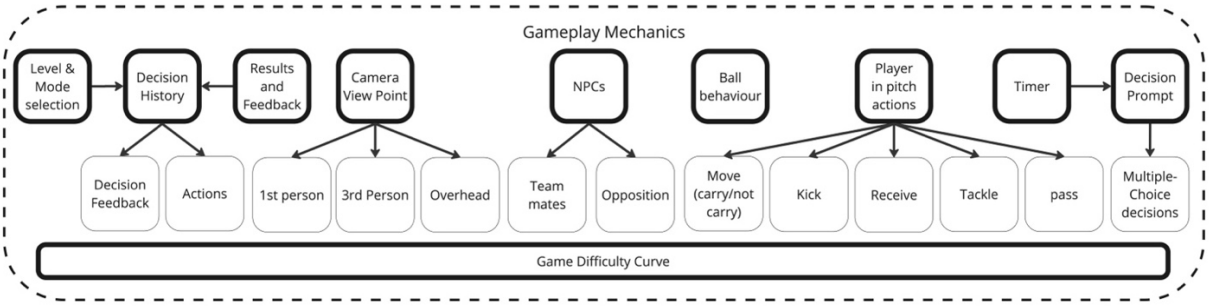

Figure 6.10: Shieldwall: Rugby, Game Mechanics game architecture

Game Difficulty Curve

The difficulty of any game is an important factor in the learning process of how to play a game – encouraging players to improve their skills at playing the game, controlling this by a Game Difficulty Curve can control how steep such a learning curve is [100]. Studies have found that using above real-time video-based training can significantly improve the accuracy and response time of athletes in other team sports [13]. On starting Shieldwall: Rugby, players set their Player Profile & Stats by selecting their Rugby Experience Level and Playing Position within the sport. Using this experience level selected, those players that identify as more experienced within the sport of Rugby Union will

have an increased Game Difficulty Curve, by increasing the in-game world time. This would mean that players would have less time to analyse the scenarios and make decisions, meaning a more difficult experience. In addition, players will be able to alter the difficulty by changing this experience setting when on the Level & Game Mode Picker screen.

Three different difficulty levels were created for the training aid prototype, following conventions in game design where each level will moderately increase the difficulty level. By doing so, increasing the difficulty level based upon skill level, a Serious Game can improve player engagement and skill retention [91]. The Game Difficulty Curve being controlled in this way impacted the Timers used in the different Game Modes of Shieldwall: Rugby, reducing the time to analyse scenarios if a player identified as more experienced at the sport. The difficulty levels created were Novice, Advanced and Expert. The game world speed associated to each rugby union Experience Level within Shieldwall: Rugby can be found in Table 6.2.

Table 6.2: Shieldwall: Rugby, Game Difficulty Curve Experience Levels - Game World Speeds

Experience Level	Game World Speed
Novice	100%
Advanced	125%
Expert	150%

Camera Perspectives

To create any Serious Game, there needs to be in-game Camera Perspectives for the player to view the in-game environment. In Shieldwall: Rugby, there are multiple different camera points of view, giving the player Mixed Camera Perspectives to view the game from. These were initially presented in 1st and 3rd person camera perspective for the initial High-Fidelity Prototype used in the previous study of this research. This received positive feedback from the key participant group when presented but was identified that more "birds' eye" views, i.e. Overhead Camera Perspectives would be impactful for viewing the full Players Picture of the pitch.

Therefore, these 3 camera perspectives were implemented for prototype. There are 3 different Game Modes within Shieldwall: Rugby, each with custom-made scenarios for the player to play – Individual, Tactical, and Positional Decision Making. Within the scenarios of each game mode there is a Camera Perspective present. Within the Individual Decision-Making Game Mode, the player is initially presented scenarios from a 3rd person perspective, just behind the ball carrying attacking player. This game mode has different choices to change this camera angle to best replicate an individual making

on the pitch facing decisions to make. There are look left and right options, which take the player into a 1st person perspective showing the field of vision to the direction of the ball carrier selected. Examples of these Camera Perspectives within the individual Decision-Making Game Mode can be found in Figure 6.11.

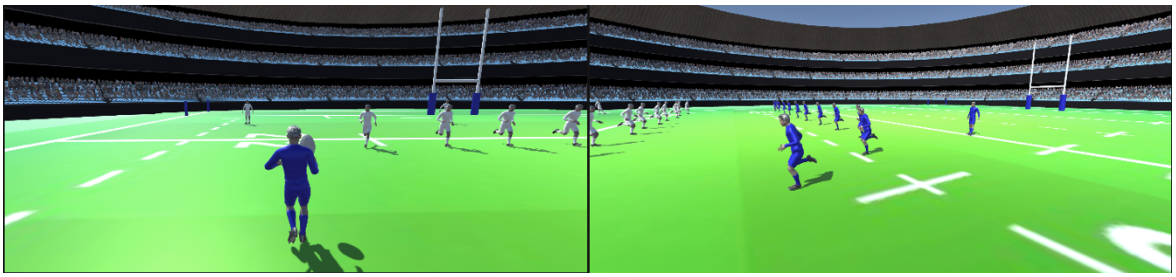

Figure 6.11: Shieldwall: Rugby, Individual Decision-Making Game Mode, 1st (right) and 3rd (left) person Camera Perspectives

There is also an Overhead button which when selected shows the overhead "bird's eye" view of the pitch, giving a wider Player Picture to the player to analyse the scenario. When any of these camera options are selected, the camera changes to that perspective for a limited time, dictated by the Game Difficulty Curve, and pauses the scenario to allow the player to analyse what they see. The camera then resets to the original camera perspective in 3rd person behind the ball carrier, and the scenario resumes. For both Positional and Tactical Decision-Making Game Modes, the player is given the scenarios in the Overhead Camera Perspective. This is because decisions made are related to the overall team decisions, so a wider Player's Picture was required – this was verified by the High-Fidelity Prototype in the previous study, where the participant group positively received this camera perspective being used for these gameplay modes. An example of the overhead, Bird's Eye View camera used in Shieldwall: Rugby in multiple game modes can be found in Figure 6.12.

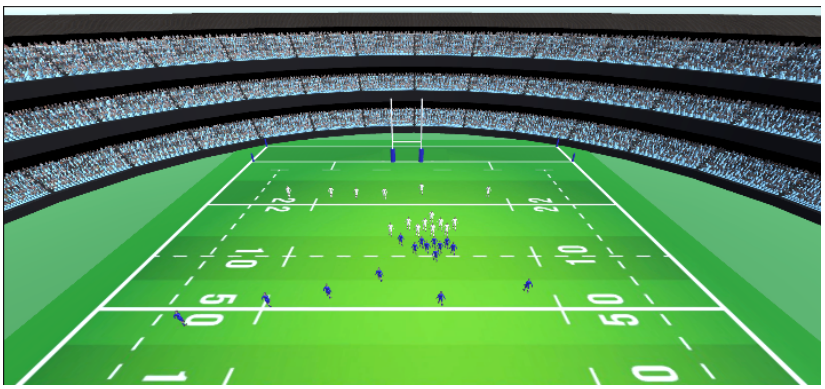

Figure 6.12: Shieldwall: Rugby Overhead Camera Perspective, 'Bird's Eye View'

Timers

Within 2 of the Game Modes in Shieldwall: Rugby (Tactical and Positional Decision-Making), there are Timers present that activate when a player accesses certain scenarios. These timers allow for players

to be able to analyse the scenario they are presented with and act as countdown timers with preset values. A first Timer in any given scenario they are present will begin its countdown on the beginning of the scenario. Once the time expires, it will trigger a prompt which will give contextual information and ask players to make decisions based on the scenario they've just seen. During this timer, in-game models will be moving to replicate a Rugby Union match, to give the player an immersive experience replicating the sport. The amount of time the player is given to analyse a scenario by these timers is controlled by the Game Difficulty Curve, which alters the in-game time based upon a player's Rugby Experience Level, chosen by the player. There are 3 difficulty levels based upon a player's experience – novice, advanced and expert. The novice timer is by default 5 seconds, with advanced and expert reducing this time to increase the difficulty curve by reducing the amount of time a player can analyse a scenario before being prompted to make decisions.

When a timer in these scenarios expires, a Decision Prompt displays asking the player a question based upon them deciding from the scenario they have just been given. This is displayed as a box on the User Interface. These prompts will take the form of Multiple-Choice Decision Prompts – players will have different options to choose from based upon the scenario they are given. In scenarios that require multiple decisions, i.e. Sequential Decisions, the scenario will have multiple timers present – all of which will remain at a consistent time to allow for the same amount of analysis to take place by the player prior to making another decision. The next Timer in order of the gameplay scene will be triggered to begin counting down as soon as a player has made the prior decision. The Scenario Analysis Time's given to the player based upon their selected rugby union Experience Level can be found in Table 6.3.

Table 6.3: Shieldwall: Rugby, Experience Level's and Scenario Analysis Time

Experience Level	Scenario Analysis Time
Novice	5 seconds
Advanced	3.75 seconds
Expert	2.5 seconds

Non-Playing Characters (NPCs)

To best replicate a real-life Rugby Union match, for the purposes of creating an immersive Serious Game training aid for the sport, there will need be Non-Playing Characters (NPCs) present within the training aid game. These characters will mimic the behaviour of rugby players within all Shieldwall: Rugby game modes. Accepting such uncontrolled behaviour is a part of any game design, which adds to the player's immersion with the game environment [101]. These NPCs were first introduced in the

previous studies' High-Fidelity Prototype, with representations of both the Player's team (Teammates) as well as Opposition players. Participants identified when shown this initial prototype which options to use related to Teammate and Opposition positioning on the field, when giving a more accurate Player's Picture. Rugby Union is a sport played with 15 players on both teams, in numerous different positions around the field. For Shieldwall: Rugby therefore, all scenarios were created with 15 players on either side and represented with 3D models with appropriate animations representing their Player in Pitch Actions during gameplay. Examples of the Non-Playing Characters (NPCs) found in Shieldwall: Rugby can be found in Figure 6.13.

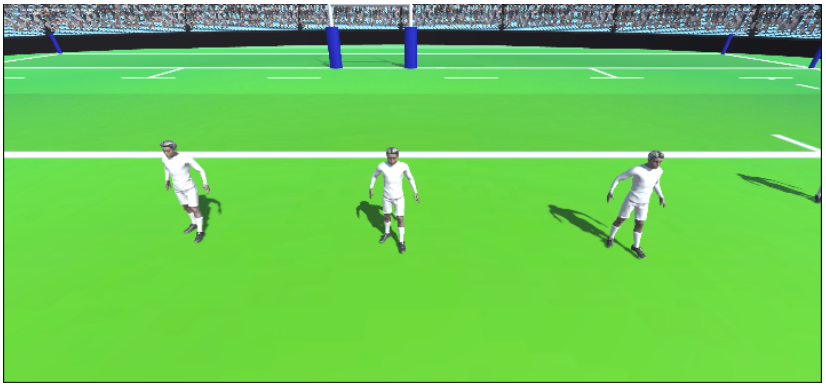

Figure 6.13: Shieldwall: Rugby, Non-Playing Characters (NPCs)

Level & Game Mode Picker

For the Shieldwall: Rugby research prototype, there will be 3 distinct Game Modes that the player can select to play, Individual, Tactical and Positional Decision-Making. There is also a section of the game that allows the player to access their Decision History of their playthroughs. To access these sections of the game, a Level & Game Mode Picker was implemented that could be accessed by the player via a Home Menu screen. The scenarios that are loaded as 'Levels' in each Game Mode are dictated by the players' choice of Rugby Union Playing Position – scenarios are tailored to this to ensure that they are relevant to the player using the training aid.

This screen is returned to on the conclusion of gameplay of any of the 3 Game Mode's scenarios, and the player can also choose to access this screen during any of the scenarios if they wish. On this screen, the player is also able to alter their Playing Position and as well as Rugby Experience Level. This means that if a player finds that they have selected a choice that is not appropriate for them, they will be able to alter it during gameplay. Changes will impact the Game Difficulty Curve as well as the scenarios that are loaded for each Game Mode when selected. The High-Fidelity Prototype used in the previous study had a Level & Game Mode Picker which allowed players to access each established Game Mode in this manner, which allowed the participant group to understand effectively how to access each. The

Home Screen acts as the Level & Game Mode Picker within Shieldwall: Rugby, this screen can be found in Figure 6.14

Figure 6.14: Shieldwall: Rugby, Home Screen, Level & Game Mode Picker

Decision History

Within Shieldwall: Rugby's 3 Game Modes, players are required to make different decisions, based upon the scenarios they are presented with. These decisions are evaluated for their impact on the scenario, with an ideal result in each based on the decisions made. At the end of every scenario, players are given Results & Feedback to analyse their performance, to ensure that a player can always access feedback and evaluate the decisions they have made, there is a Decision History section of the training game that gathers information on player performance. The information will contain the players Actions (i.e. the decisions they made) in each gameplay scenario, and it will also gather the Decision Feedback, whether the decisions the player made were deemed correct. This section gathers this information from each scenario played by the player and provides recommendations for areas of improvement for the player, which are tied to the 3 Game Modes of Individual, Tactical and Positional Decision-Making. This allows the player to identify which areas to target improvement, and as this is a Serious Game designed to be a training aid for Rugby Union players, this ensure a usable training aid that is user-centred. During the previous study, the key participant group with Rugby Union backgrounds identified that a prototype should include forms of feedback, so having this section of the game will allow players to see all the feedback given. This section of the game is accessible from the Level & Game Mode Picker, which is accessed on the Home Screen.

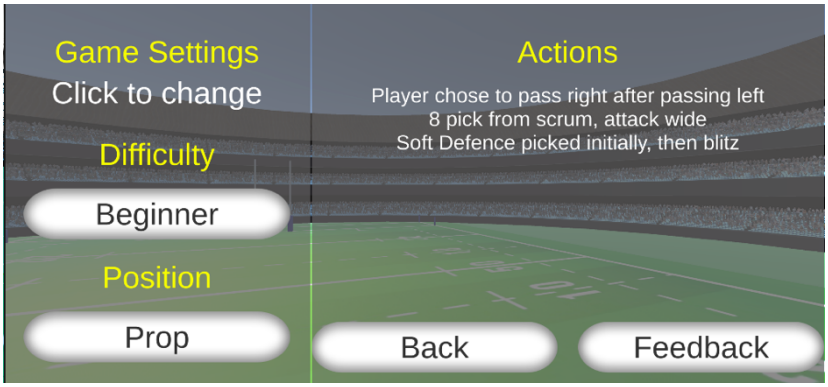

Figure 6.15: Shieldwall: Rugby Decision History screen

Results & Feedback

Within each of the 3 Game Modes in Shieldwall: Rugby, players are given different scenarios with Rugby Union context that asks the player to make decisions based upon the scenario they are faced with. These are doing for attacking and defensive scenarios, and the player has a mixture of scenarios from unstructured open play, and structured set piece plays, to replicate a real-life rugby match. As the prototype is designed to act as a training aid, feedback is required to be given to players who use the training aid on the decisions they have made, as seen in other training aids such as Video Analysis [102]. The High-Fidelity Prototype gave scenario results and player feedback in the form of a screen at the end of each gameplay scenario assessing the decisions made and providing this feedback. This was picked up in the previous study by the key participant group as a positive way of showing player's feedback whilst using the training aid. Therefore, these screens were implemented for Shieldwall: Rugby, with each scenario giving specific Results & Feedback to the player based upon the decisions made. This information was stored for the Decision History section of the game so that players could access their feedback history, to identify areas for improvement. Examples of the Results screen from a gameplay scenario, as well as the Feedback screen can be found in Figure 6.16.

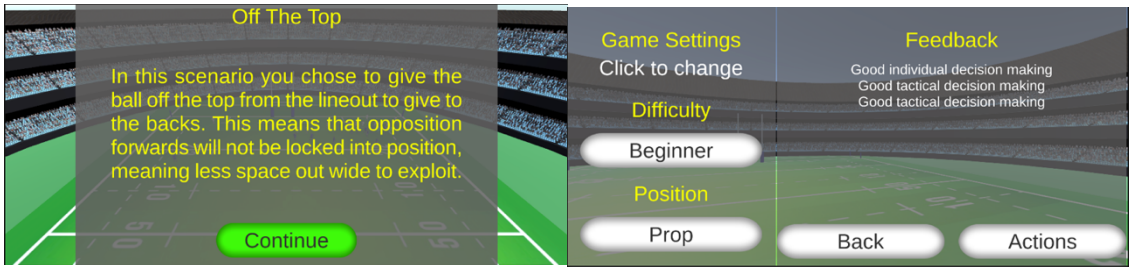

Figure 6.16: Shieldwall: Results & Feedback screens

Player in Pitch Actions

As identified in the Environment & Aesthetics section, immersion is a vital part of a Serious Games' design to improve its impact and usability. 3D models of Rugby Players were identified within this section to be used to best simulate a real-world Rugby Match and should be used for both the player's

team (Teammates) and opposing team (Opponents). To make this truly life-life though, movements were added to each character within Shieldwall: Rugby, to best emulate a rugby match. Therefore, Move (both with the model carrying the ball and without the ball), Kick, Receive, Tackle and Pass movements were implemented. To ensure they were as life-like as possible, animations were added to each character model for both teams and programmed to trigger where appropriate. Examples showing the in-game character movements for Player in Pitch Actions can be found in Figure 6.17.

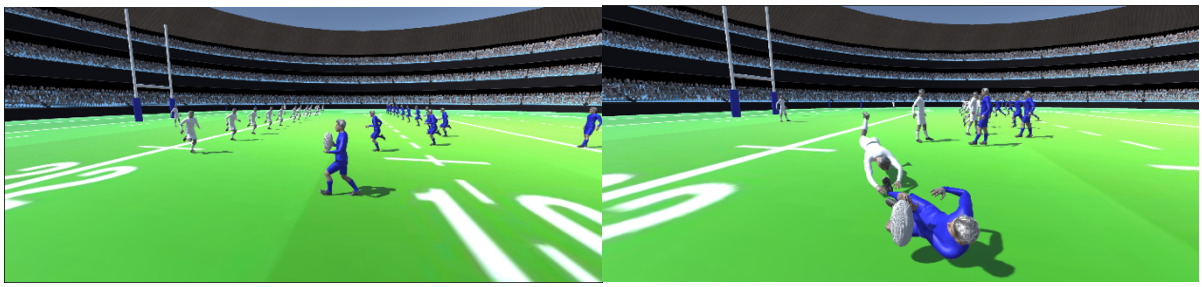

Figure 6.17: Player in Pitch Action Move (left), and Tackle (right)

Ball Behaviour

A Rugby Union match uses an oval ball which teams compete for control of during the game. This was identified as a key aspect to add to the Environment & Aesthetics of Shieldwall: Rugby to ensure an immersive experience. The ball model was added, so how this ball interacted with the game world in each scenario was also implemented. This Ball Behaviour was unique to the decisions a player makes in each Game Mode. The ball moves based on decisions, for example, when passing a specific direction, the ball will move to a teammate in that direction. If the player opts to Kick the ball, the ball will move ahead of their player character towards an Opponent's try-line. The ball is present in all 3 Game Modes, with the player controlling the specific movement of the ball for the Individual Decision-Making mode. Meanwhile, for the Tactical and Positional Decision-Making, the player makes team decisions from an Overhead Camera (birds eye view). The ball moves in relation to the choices made and the scenario, with all players in the player's team and opponents, reacts to these appropriately.

6.1.5. Gameplay Features

To develop Shieldwall: Rugby as fully functional training aid prototype for Rugby Union, specific Gameplay Features were implemented that were not tied to the specific Conceptual Framework for this research. Such features are commonplace within video games and were shown were possible in the previous studies' High-Fidelity Prototype to ensure relevance. These features a player Login screen, Navigation to allow interaction with the game, as well as in-game Lighting to allow the player to see their gameplay environment.

A feature that is used in video games is Login screens, which allow the player to create a specific profile and retain information such as settings, as seen in the Player Profile & Stats design. Whilst this was not implemented for Shieldwall: Rugby, it would be desirable to retain information on the player using the game for easier retention of the player to keep using the training aid. This research only required the players to use Shieldwall: Rugby for one training session, so a basic Login screen was introduced with a Welcome screen, as well as screen to obtain information on the player for Player Profile & Stats, which takes the form of a Rugby Experience Level and Playing Position Selection screen's, examples of which can be found in Figure 6.18 and Figure 6.19 respectively.

Figure 6.18: Shieldwall: Rugby Login Welcome screen

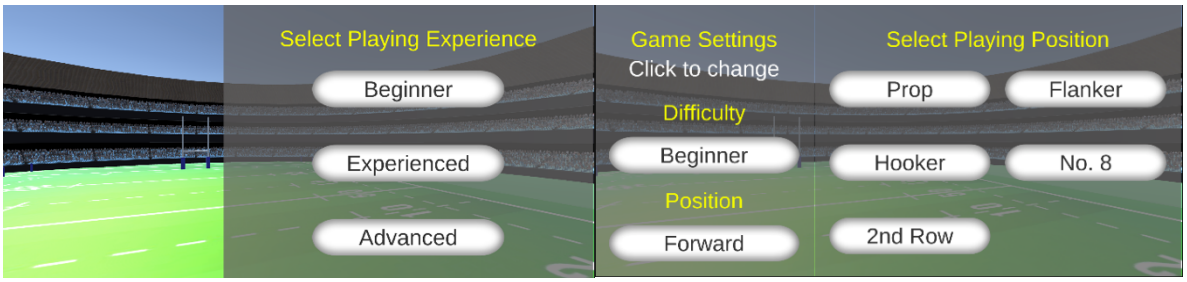

Figure 6.19: Shieldwall: Rugby Rugby Experience Level & Playing Position Selection screens

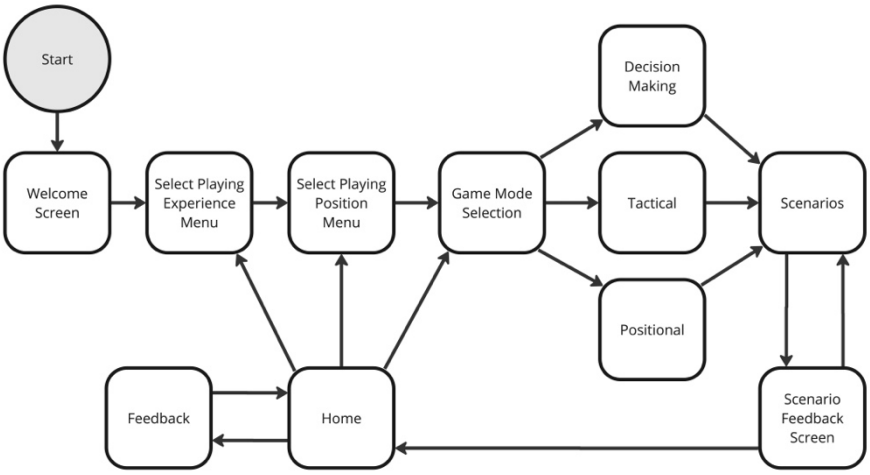

Figure 6.20: Shieldwall: Rugby player's Navigation Pathway

To use the prototype, the player will require a form of Navigation to use the game and interact with the different gameplay mechanics. Shieldwall: Rugby was designed to be accessible as possible, particularly on mobile devices as identified by the key participant group in the previous study. As such, touch mechanics were used for all Navigation features – which primarily used User Interface buttons to control players and decisions being made in all the prototype's game modes. The player's Navigation Pathway that can be found in Shieldwall: Rugby can be found in Figure 6.20.

Any game will also require Lighting to allow the player to see their game environment. For Shieldwall: Rugby this was replicated as best as possible to match real world lighting, so that it replicated a rugby union match being played in the day. The lighting system within Unity was used to implement this as it was already judged to be a realistic asset. An example of the in-game Lighting present in Shieldwall: Rugby can be found in Figure 6.21

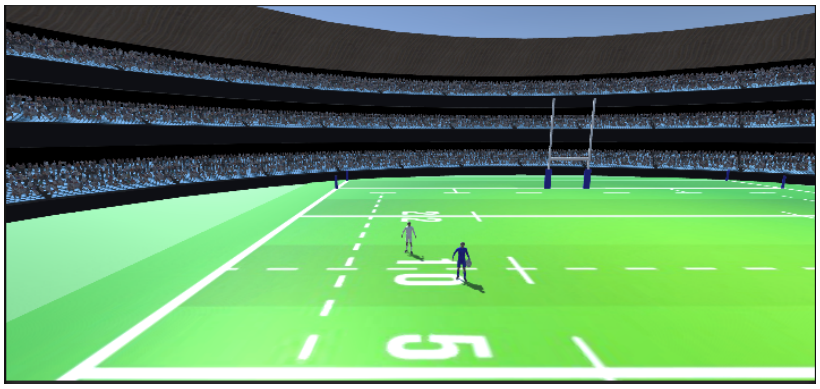

Figure 6.21: Shieldwall: Rugby in-game Lighting

6.2. Phase 3: Prototype Development

As a result of the initial Literature Review carried out for this research, key themes and concepts were identified that were relevant to developing a training aid for rugby union players. This training aid was to improve the decision-making and cognitive abilities of these players. These key themes and concepts formed the basis of an initial Conceptual Framework, that was further added to and developed during each phase of Stage 1 of the research. Interviews with key stakeholders within the sport of Rugby Union were carried out to better understand the needs of such a training aid. Key concepts and themes were added as identified during this process, with the most relevant forming a Research Artefact. This artefact was the initial basis for a Game Storyboard, that was presented to same participant group for feedback, which again was further developed as feedback was received. This storyboard was used as the initial design framework for the working Game Prototype. Development of this prototype began after the feedback on the storyboard was analysed for phase 2 of the initial research stage. On conclusion of Phase 2 interviews, work on the prototype began and the game was implemented using the Unity game engine. Unity was selected due to its capability of

developing a game that can be used on mobile devices, which was identified by the key participant group as an important accessibility need for the identified target audience, rugby union players.

6.2.1. Game Modes

The initial High-Fidelity Prototype had 3 distinct gameplay modes. An individual decision-making scenario, which was an attacking-based decision with the players' team in possession of the ball. A tactical decision-making scenario which asked the player to pick a specific team tactical move to execute. Finally, it also included a positional specific scenario which required a decision from the player, with the player selecting which their playing position prior to beginning the scenario. The Game Prototype followed this initial storyboard during this phase of development, with gameplay scenarios for each of the 3 sections created. Existing art assets were imported through the Unity store, with the purpose of creating an environment replicating that of a rugby union match, therefore a pitch and stadium was created and human characters used with two distinctly different colour clothing to act as a team's playing kit, as seen in team sports such as rugby union. For each section of the game prototype, full 3D models of players and the playing pitch were used, and feedback was given on the conclusion of each scenario to the player to evaluate how the player did in each, as well as give any points to improve on with their decision-making. To ensure a User-Centred design approach was followed, scenarios were created that ensured contextual appropriateness to the sport of Rugby Union, which is a sub-section within the Research Artefact under the *Decision-Making Training in Rugby Union* section of the artefact, this includes the themes of *Rugby Scenario*, with all of its concepts, as well as *Perception* that links to *Perceptual-Cognitive Abilities*, as well as the *Simulated Collaborative Decisions (NPCs)* that are made during gameplay. All of these were considered for the creation of each scenario of all game modes. An extract of this sub-section can be found in Figure 6.22.

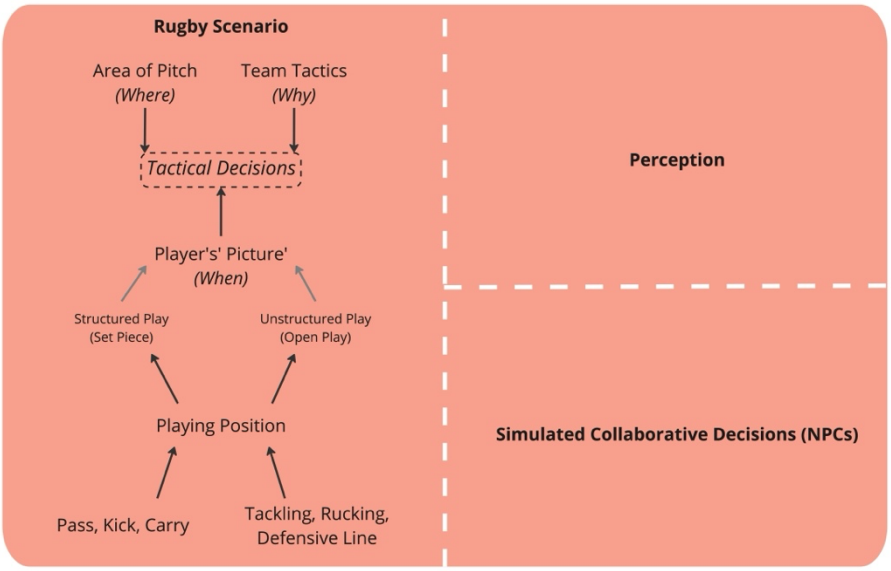

Figure 6.22: Research Artefact extract, Rugby Union sub-section

Individual Decision-Making

During a rugby match, rugby players will often have to make individual decisions on how to act. For all scenarios created for Shieldwall: Rugby, *Rugby-Related Scenarios* need to be created. Decisions can be made in *Unstructured Play (Open Play)*. Decision-making on an individual basis was identified as a key skill for Rugby Union players during the literature review section of this research, and in the previous chapters' study, the importance of developing these skills was identified as a key consideration for a training aid for the sport. Players will often make these decisions based on the *Player's 'Picture'* that they see on the pitch in front of them and can involve the use of their *Perceptual-Cognitive Abilities* such as *Spatial Recognition,* which was identified as key skills by the key participant group in the previous chapter's interviews. *Spatial recognition* is directly linked to a player's *Visuospatial Capacity*, which is how they identify the space between objects – which was raised during the literature review chapter. Another factor in decision-making in rugby that was to be considered for the proof-of-concept prototype was the nature of the sport requiring players often to have to make *Sequential Decisions* during a phase of play, which the key participant group in the previous study also highlighted. These key design considerations are summarised in Table 6.4. To ensure the prototype is user-centred, a player's Rugby Playing Experience should be considered. As Shieldwall: Rugby is an interactive training aid in the form of a Serious Game, game's Difficulty Curve was designed so that a player has a more challenging experience if they are more experienced player. The Unity Engine generates a game world time, which is altered depending on the experience level the player selects at the start of the game – meaning the scenarios for this section are at a greater speed if a player is more experienced. These experience level speeds are discussed in section 6.1.4.

Table 6.4: Key design considerations for Individual Decision-Making game mode

Research Artefact	Concept Used in Shieldwall: Rugby
Serious Game Design	Rugby-Related Scenarios
Rugby Union	Unstructured Play (Open Play)
Rugby Union	Player's 'Picture'
Perceptual-Cognitive Abilities	Spatial Recognition
Perceptual-Cognitive Abilities	Visuospatial Capacity
Rugby Game Mechanics	Sequential Decisions
Rugby Game Mechanics	Game Difficulty Curve

To incorporate these key themes within the prototype training aid, initially a High-Fidelity Prototype was developed to present to the key participant group in the final phase of the previous study for feedback. This included a specific individual decision-making section which included linked game mechanics to implement within the game training aid. Using an initial High-Fidelity Prototype was used in this way to demonstrate how the final game would look and feel for players, to ensure the validity of the design with a user-centred approach. For *Attacking Decisions,* the key participant group highlighted that a ball carrier in a game can make 3 choices for any decision – whether to *Pass, Kick, Carry* the ball. This was developed into a decision-making mechanic by means of giving multiple choices to the player representing this. Additionally, to give a true *Players 'Picture'*, i.e. a view of the pitch and scenario, this section included different game perspectives; a look 'left' and 'right' of the ball carriers' view, a look 'forward', as well as an overhead, *Bird's Eye View* camera, which replicates commonly used camera angles in other training aids such as video analysis. Using different *Camera Perspectives* such as this was developed because of the theme of *Mixed Camera Perspectives*, which was identified in Phase 2 of the previous chapter's interviews with the participant group. These player multiple choice options of *Pass, Kick, Carry*, as well as the Look options are shown in Figure 6.23, as well as the *Bird's Eye View* overhead camera perspective.

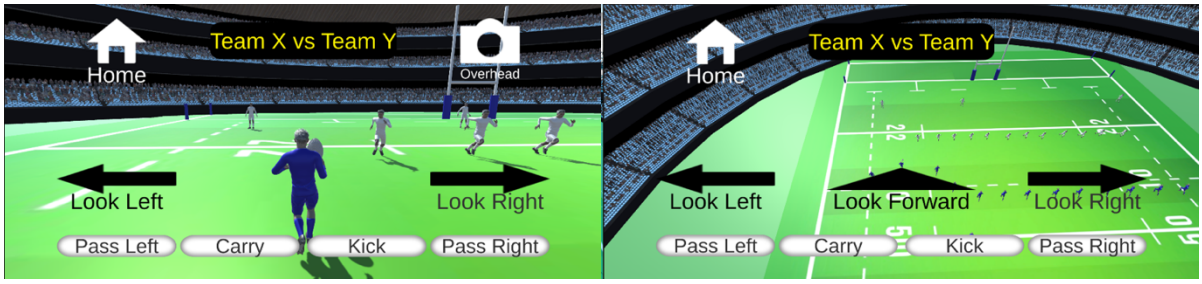

Figure 6.23: Shieldwall: Rugby Individual Decision-Making Game Mode, Pass, Kick, Carry and Look options (left), Bird's Eye View Overhead Camera (right)

To ensure a user-centred approach, *Rugby-Related Scenarios* being used for each area of the training aid prototype game was identified as a key theme. As such, an *Attacking Decision* of a player overlap – where an attacking team has more available players to give the ball to in a phase of play than a defending team has defenders available to mark and tackle each player, was used. This scenario was identified in the initial literature review of this research. The player acts as the ball carrier throughout the scenario and is initially carrying the ball in a wide area of the pitch, with a player on their team beside them (left) to pass to who is unmarked who would be the ideal player to pass to in the first instance. The player acting as a ball carrier, moving forward on a 'ball carrier line', also has teammates to their right who run 'decoy' lines which act to draw defenders, keeping the unmarked player free from defensive pressure. The ball carrier line and decoy lines were established as essential to 'Attack Plays' in *Unstructured Play (Open Play)* in the previous study. The player is given the initial decision to make, with a time limitation imposed as a defensive team advance towards the ball carrier – if the player takes too long to decide they will be tackled, and the scenario will end with feedback presented. This feedback screen is shown in Figure 6.24

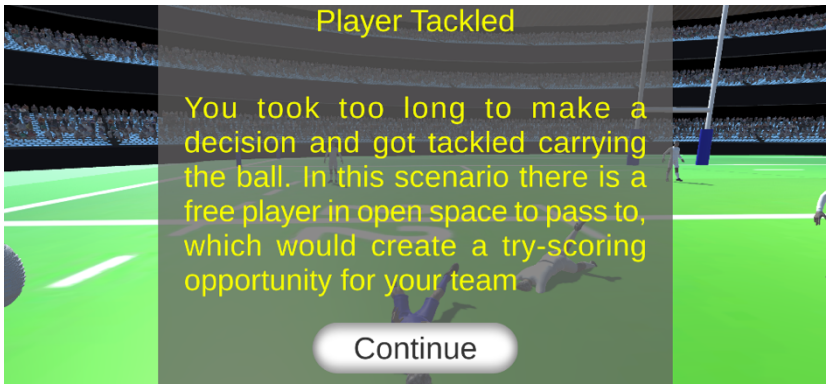

Figure 6.24: Shieldwall: Rugby, Individual Decision-Making Game Mode, Player Tackled feedback screen

The player can choose to *Pass, Kick, Carry* the ball in this situation – if they choose to kick, carry or pass to a marked player (right), the scene will continue showing the result of this decision with feedback also presented. The same feedback is presented for the carry option as the feedback shown

for the player taking too long to decide – both decisions result in the ball carrier being tackled so have the same impact. The feedback screens for these decisions can be found in Figure 6.25.

Figure 6.25: Shieldwall Rugby, Individual Decision-Making Game Mode, Pass Right (left) and Kick (right) feedback screens

If the player opts for passing to the unmarked player, the scenario gives the player control of the new ball carrier, who then is given a similar choice, but this time with an unmarked player to their right to pass to, who will continue to score a try if this option is selected. This 2nd *Sequential Decision* example is shown in Figure 6.26. The kick and carry options are still available to the player in this scenario, if those are selected a similar feedback screen for both will display as with the initial decision. This extra decision within the scenario gives the player *Sequential Decisions* to make for this scenario, a key theme from Phase 2 of the previous study.

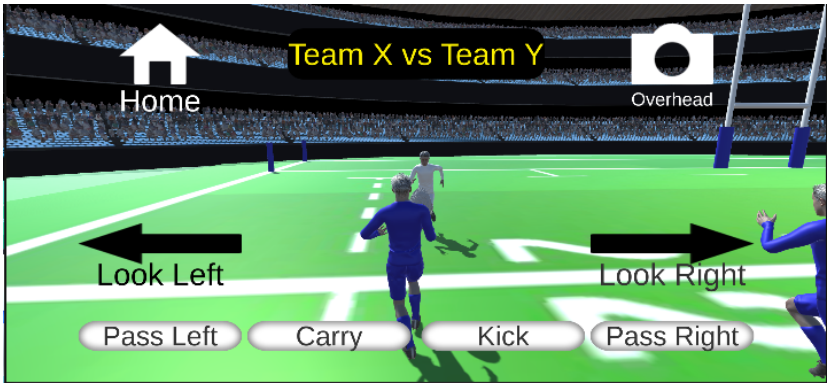

Figure 6.26: Shieldwall: Rugby Individual Decision-Making Game Mode, 2nd Sequential Decision example

At the end of this scenario, the player is given feedback on the choices they have made. If they identified successfully the unmarked players to pass the ball to, the feedback reiterates these positive choices to the player as shown in Figure 6.27. Meanwhile if the player is tackled or fails to identify these unmarked players to pass to, the feedback makes recommendations for improvement. This feedback was identified as a key theme during the previous study, as a key consideration within the Game Design requirements of the prototype.

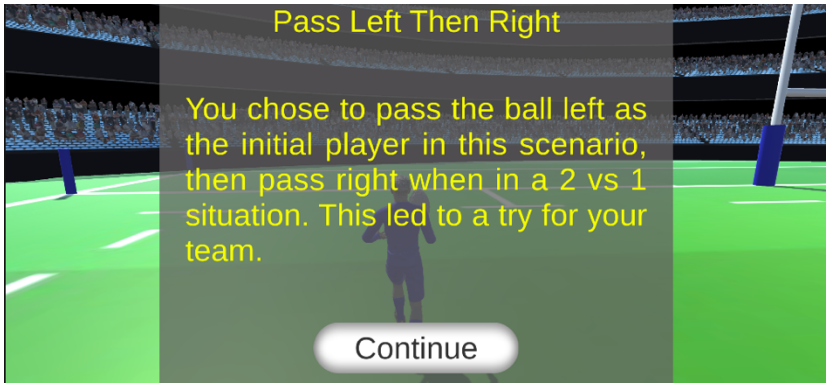

Figure 6.27: Shieldwall: Rugby, Individual Decision-Making Game Mode, correct Sequential Decisions feedback screen

Tactical Decision-Making

Rugby Union involves *Structured Play (Set Piece)* types such as scrums and lineouts, as well as *Unstructured Play (Open Play).* During a match, players on a team will be required to make decisions based upon their team's established game plan, or *Tactical Decisions*. As established by the Headlights: Conceptual Framework and within the Research Artefact created in previous chapters, the decisions a player can often make depends on the *Player's 'Picture'*, what they see during a situation within a match. *Perceptual-Cognitive Abilities* such as *Visuospatial Capacity* and *Pattern Recall* were identified in previous chapters as key for rugby union players – so scenarios were created which requires the player to be able to identify spaces and patterns within attacking and defensive scenarios and select the right tactical option. As with the other game modes, scenarios created within this Game Mode must be user-centred in design approach, so they are *Rugby-Related Scenarios*, and as with the other game modes, *Sequential Decisions* are made. These key design considerations for this game mode are listed in Table 6.5. The *Game Difficulty Curve* for these scenarios is managed by the game world time, which is a feature of the Unity Engine. Before playing this section of the game, the player using the training aid is required to select their *Rugby Playing Experience,* which alters the speed of this game world time – i.e., a player who selects a higher experience level, will find the scenarios play faster than someone who selects a beginner experience level. This was discussed further in section 6.1.4.

Table 6.5: Key design considerations for Tactical Decision-Making game mode, Shieldwall: Rugby

Research Artefact	Concept Used in Shieldwall: Rugby
Serious Game Design	Rugby-Related Scenarios
Rugby Union	Tactical Decisions
Rugby Union	Unstructured Play (Open Play)
Rugby Union	Structured Play (Set Piece)
Rugby Union	Player's 'Picture'
Perceptual-Cognitive Abilities	Pattern Recall
Perceptual-Cognitive Abilities	Visuospatial Capacity
Rugby Game Mechanics	Sequential Decisions
Rugby Game Mechanics	Game Difficulty Curve

In the previous chapter's Phase 1 and Phase 2 of a study was carried out with key participants from rugby union to develop the framework for a rugby union training aid. A High-Fidelity Prototype was created to be used as an initial design overview for this proof-of-concept prototype created in this chapter. This initial High-Fidelity Prototype included a section of the game for improving *Tactical Decision-Making*, where a player was given an overview of a *Structured (Set Piece)* play, particularly a centre field scrum, and asked what decision a team should make. This was implemented for Shieldwall: Rugby, where the player will be given an introduction screen (acting as a Tutorial for the game mode) explaining how the player should interact with the scenario, followed by the scenario taking place. Initially giving the player time to analyse the scenario before a decision prompt appears. This introductory screen and initial overview of the scenario given to the player are shown by Figure 6.28.

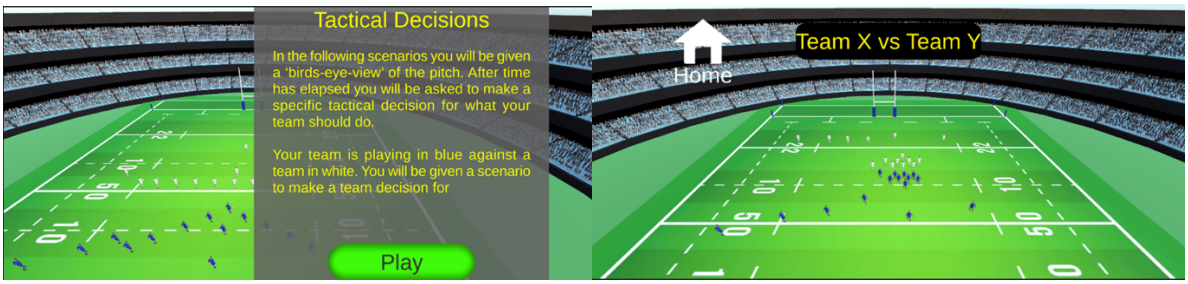

Figure 6.28: Shieldwall: Rugby, Tactical Decision-Making Game Mode, Intro screen (left) and initial player scenario view (right)

To ensure the Shieldwall: Rugby proof-of-concept prototype met its intended use, the game was developed using a user-centred approach, which was the purpose of using these previous key participant interviews to establish the design framework of the High-Fidelity Prototype. The interviews also establish key rugby union related themes that the prototype should incorporate to be impactful

as a training aid for players. As mentioned above, *Rugby-Related Scenarios* were used for this section of the game to make sure the decisions being made were relevant to those using the game as a training aid, this is why an attacking and defensive tactical decision was used in this way. In addition, players are given multiple choice options for both scenarios. For *Attacking Decisions,* the player is asked which type of tactical move the team should execute from the scrum – an attack with a forward player into the space on the 'blindside' to open the full pitch to attack, an attack up the middle of the 'open side', or a wide move on this same side. The optimal choice for the player to make initially here is to use the blindside attack, and if they chose to do this the scenario will show the result of this decision, followed by a *Sequential Decision* to make. Alternatively, the scenario shows the result of the choice made and completes with feedback given to the player on why they should choose to use the blindside attack. The initial decision prompt for the player shown in this game mode, as well as the resultant view of this decision are shown in Figure 6.29.

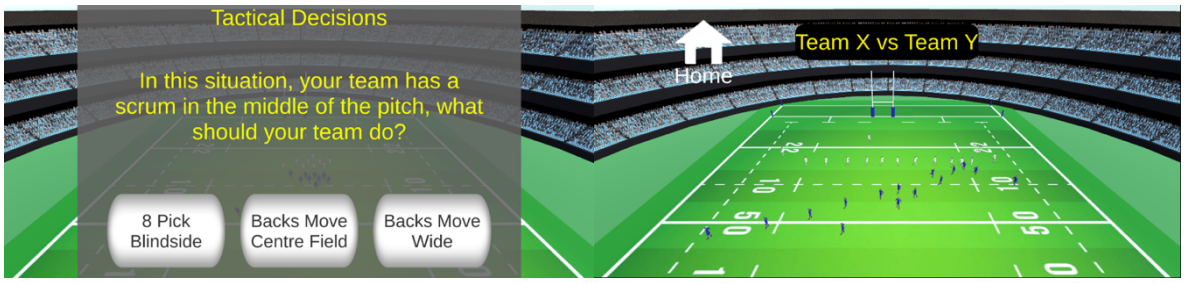

Figure 6.29: Shieldwall: Rugby Tactical Decision-Making Game Mode, initial decision prompt (left), 8 Pick Blindside result view (right)

The High-Fidelity Prototype was shown to the key participant group for feedback, where they identified that there should also be a form of defensive decision-making included in this game mode for *Tactical Decisions*. The final proof-of-concept prototype therefore was altered from the initial design to include an additional *Defensive Decision* where the player is asked which type of defence to use given their team's position on the pitch. A 'soft' defence where a team moves to meet an attacking team at a gradual pace, or a 'blitz' defence where the defensive team attempts to rush the attackers quicker and put them under more pressure. These types of defences which are tactical decisions of a team were established during the key participant interviews in the previous chapter.

For the defensive tactical scenario, the player is also given a multiple choice option – they are initially presented with a scenario where their defensive team is short of defensive players, with the attack having an unmarked player (also called an 'overlap'). The player is given a tactical choice of which type of defence their team should use in this situation, blitz or soft. If they chose to use the optimal soft defence choice, which allows defensive players to react to the additional attacking player, they are then given a Sequential Choice to make in defence, where they can either blitz or go soft. The

relevance of these Rugby-Related Scenarios was confirmed by the key participant group during the development of the the Shieldwall: Rugby prototype. As with the previous scenario, the initial view of the *Defensive Decision* is given to the player to analyse before a decision prompt appears after a set amount of time, as shown in Figure 6.30.

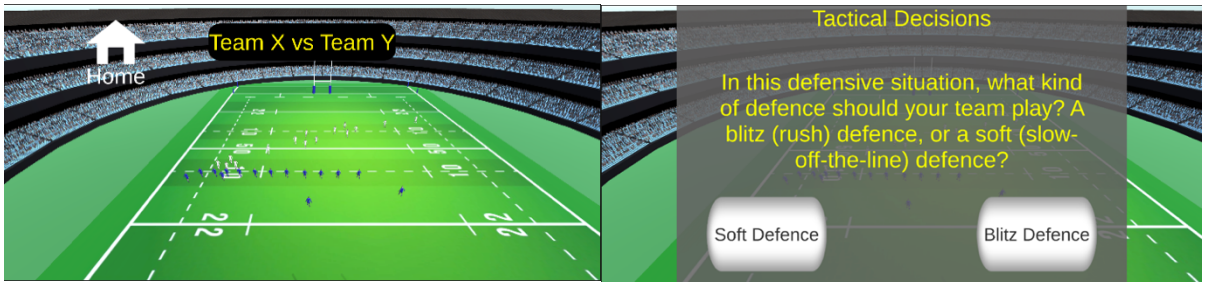

Figure 6.30: Shieldwall: Rugby, Tactical Decision-Making Game Mode, initial player view Defensive Decision (left), decision prompt (right)

For both tactical decisions, the player can also be given *Sequential Decisions* to make within the scenario. This is to best replicate Rugby-Related Scenarios, as rugby players often must make multiple decisions within a phase of play in a match. These were identified by the key participants as essential to the success of any training aid made for the sport and examples of these for both the Attacking Decisions and Defensive Decisions are shown in Figure 6.31, where the resultant view of the first decision made by the player is first shown, followed by the decision prompt.

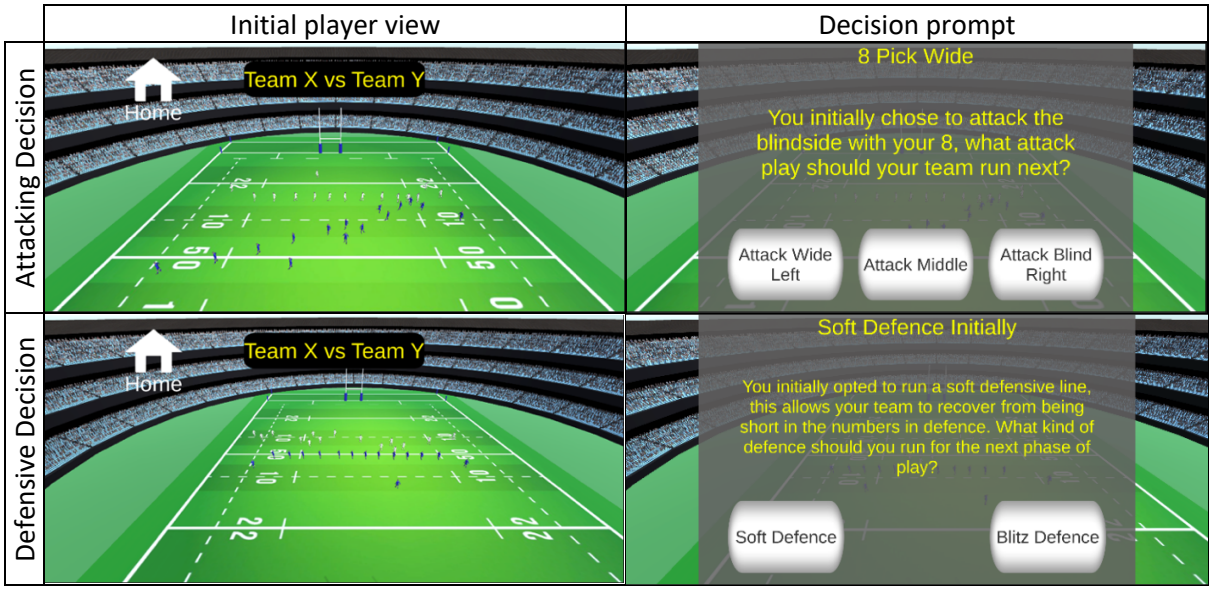

Figure 6.31: Shieldwall: Rugby, Tactical Decision-Making Game Mode, Sequential Decision

At the end of each scenario, the player is given feedback on the decisions they have made. If they correctly identified the space to attack to in the first scenario, the feedback reiterates that this was a good choice, this positive reinforcement is also given if they select to use the more passive ‘soft' defence initially in the defensive scenario. If the player makes different choices, the feedback will tell

the player choices they could have made to have a more desirable outcome. This style of feedback was initially used during the High-Fidelity Prototype development and was positively received by the key participant group in the previous chapter's study, so was used for the proof-of-concept prototype. The feedback screens for the player successfully choosing optimal options for both scenarios is shown in Figure 6.32.

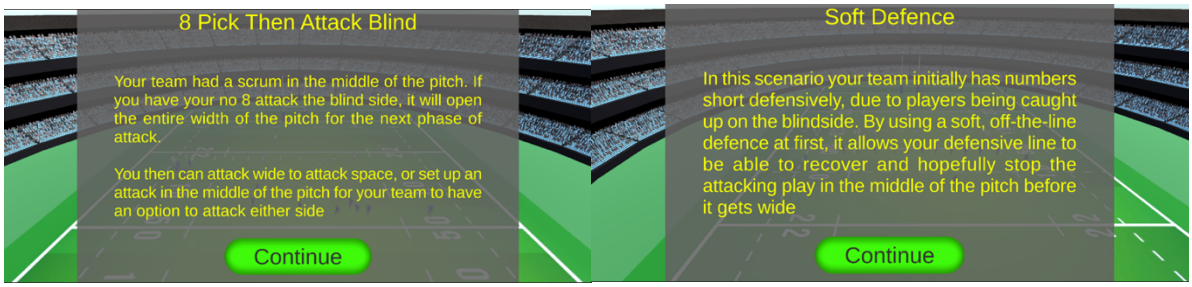

Figure 6.32: Shieldwall: Rugby, Tactical Decision-Making Game Mode, optimal decision feedback screens, Attacking Decision (left), Defensive Decision (right)

Positional Decision-Making

For the *Positional Decision-Making Game Mode*, as with the other Game Mode's, all scenarios within the mode must be created that are relevant to the sport – therefore *Rugby-Related Scenarios* were created. As Rugby Union is a team sport, there are different *Playing Position's* that a player can play – all of which often require different tactical decisions to make depending on the position. In the previous chapter's study, positional decision-making was identified as a key theme for consideration of development of a training aid, such as the Shieldwall: Rugby. The participant group interviewed identified that there are often "key decision-makers" that are position specific, be it of a forward's position in a "lineout" caller, or a backs position where playmaker roles such as fly halves often make position-specific decisions. As such, the High-Fidelity Prototype created a section of the design for a training aid where positional decision-making can be trained with scenarios given to a player as with other game sections, but to be tailored based on the *Playing Position*. As such, the Shieldwall: Rugby prototype asks the player to input their playing position prior to using this section of the game – selecting a backs or forward's position gives the player a *Structured Play (Set Piece)* to analyse and asks them to select a 'correct' option that their team should execute given the *Player's 'Picture'* (position of the pitch, type of play etc). Recognising patterns, or *Pattern Recall,* was established as key *Perceptual-Cognitive Ability* for Rugby Union players in recognising such set-piece patterns during the systematic literature review chapter. For both positional groups, the scenarios designed were presented to the key participant group for feedback to ensure that a user-centred approach was followed in the Shieldwall: Rugby prototype's implementation. Where appropriate, *Sequential Decisions* were also added to the scenarios in this game mode, as this was a key finding from the participant interviews in previous chapters. The time they are given is tailored to the player experience

level, which is selected on starting the game – the more experienced they are, the less time they will have before making their decision, which means that the *Game Difficulty Curve* is tailored based upon their experience, ensuring a user-centred approach, this concept is discussed further in section 6.1.4. These key design considerations for this game mode are listed in Table 6.6.

Table 6.6: Key design considerations for Positional Decision-Making game mode

Research Artefact	Concept Used in Shieldwall: Rugby
Serious Game Design	Rugby-Related Scenarios
Rugby Union	Playing Position
Rugby Union	Structured Play (Set Piece)
Rugby Union	Player's 'Picture'
Perceptual-Cognitive Abilities	Pattern Recall
Rugby Game Mechanics	Sequential Decisions
Rugby Game Mechanics	Game Difficulty Curve

Similarly to the *Tactical Decision-Making Game Mode*, when the player has selected to play the *Positional Decision-Making Game Mode*, an introductory screen will appear prompting the player instructions on how to play and interact with the scenarios they are about to be given within the training aid. This acts as a tutorial for the Game Mode and is given to player's no matter which position they select. After this screen, the player will also be given a scenario to analyse before a decision prompt is given. To ensure Playing Position is highlighted to the player for relevance, the specific playing positions selected by the player are highlighted during gameplay of this Game Mode. Examples of both the introductory screen and initial scenario player view can be found in Figure 6.33.

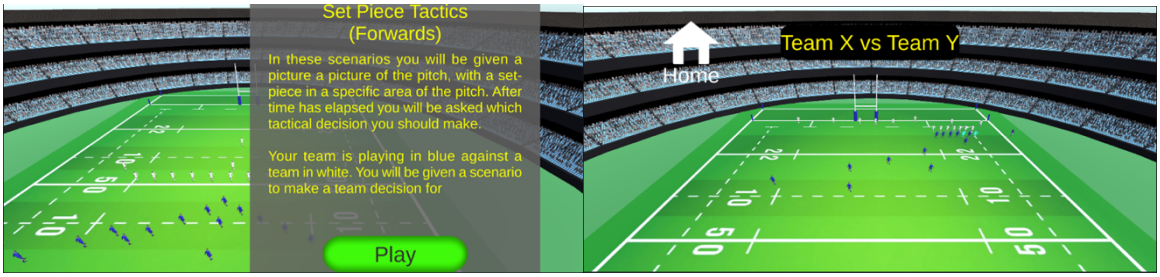

Figure 6.33: Shieldwall: Rugby, Positional Decision-Making Game Mode, Intro screen (left) and initial player scenario view (right)

If the player is from a forward's *Playing Position*, they are given a scenario where their team has an attacking lineout, just short of the opposition's try line. They are asked if they should use a 'full lineout' (i.e. all forward players involved in the set piece) or if they should us a shortened option (some forwards join the back line). This initial decision prompt is shown in Figure 6.34.

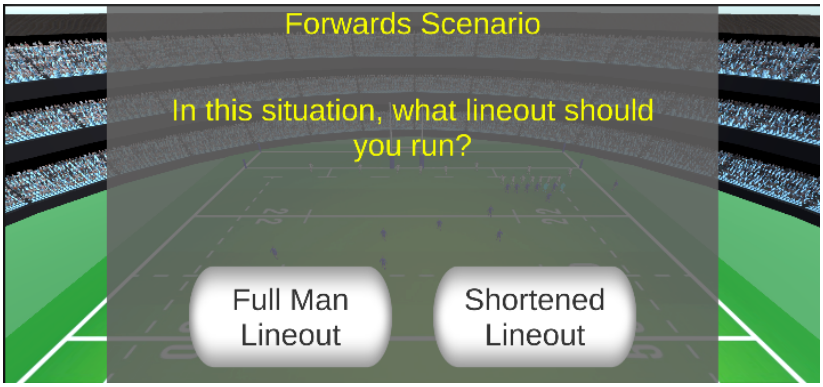

Figure 6.34: Shieldwall: Rugby, Positional Decision-Making Game Mode, initial forward's decision prompt

The player is then given a *Sequential Decision* to make, a theme identified as key to a rugby union training aid by the key participant group in the previous chapter, so this was incorporated into this design. After making an initial decision, the player will be given a view of the result of their decision, a time will elapse, and a second decision prompt will appear. In this scenario, the player should choose to keep all opposition forwards locked into position by using the full lineout option and then selecting a driven maul. This means that the backs in the team keep the most amount of space available for subsequent plays. The key participant group concurred with this option when given the prototype for feedback. They are then asked if the lineout should play the ball "off the top" (immediately to the backs for a wider play) or if they should catch and drive the ball towards the line as a "driven maul". The scenario will show the result of each decision made by the player before continuing. The player view from the initial decision, as well as the subsequent Sequential Decision is shown in Figure 6.35.

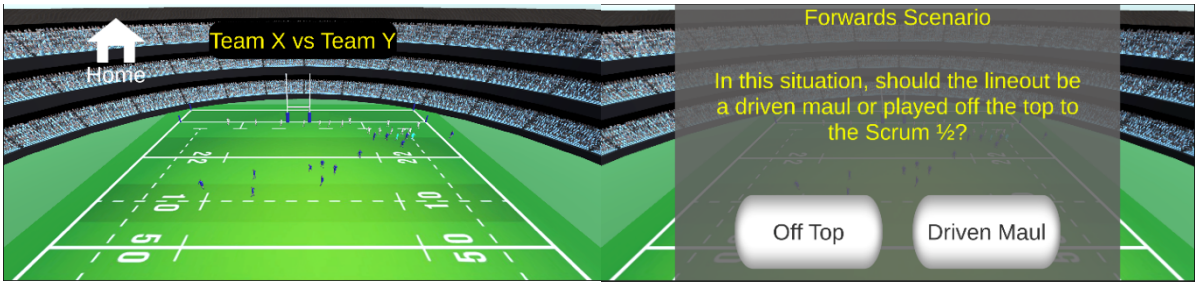

Figure 6.35: Shieldwall: Rugby Positional Decision-Making Game Mode, player view post initial decision (left), subsequent decision prompt (right)

If the player has identified themselves as playing a back's position, they are given a multiple-choice question on what type of play the backs should run, with two 'carry' options of a move to target the middle of the pitch, or wide of the pitch – they are also given an option to kick the ball. This is to best replicate the *Pass, Kick, Carry* options given to rugby union players in attacking plays in the sport, as identified in the previous study. In both running options, the player sees the ball 'passed' for a

teammate to carry. The desirable option for the player to select in this option is to use the backs move to target the middle of the pitch, leaving both sides open to being attacked in the next phase of play. The key participant group confirmed this would be the most desirable outcome when given the initial prototype to feedback on. The scenario will show the result of the decision made by the player before continuing. The initial player view for the back's scenario and decision prompt is shown in Figure 6.36.

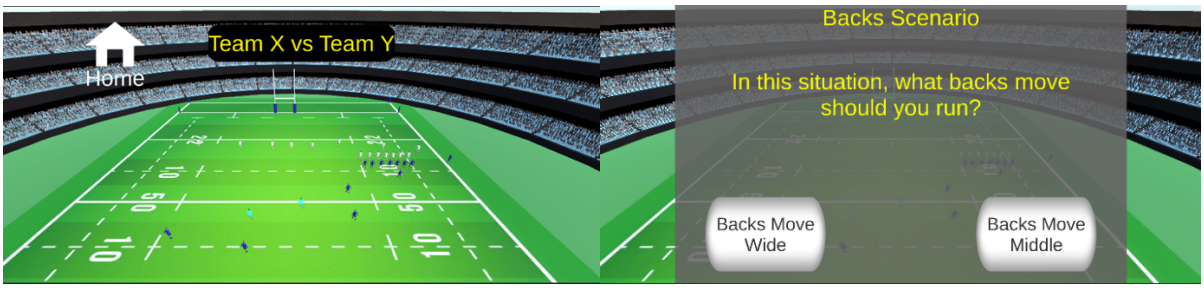

Figure 6.36: Shieldwall: Rugby, Positional Decision-Making Game Mode, initial back's player view (left), and decision prompt (right)

The player receives appropriate feedback based upon their responses to each scenario at its conclusion, similarly to other Game Modes in Shieldwall: Rugby. This occurs for both positional group's scenario's regardless of choice, with feedback tailored to the position selected. This feedback is displayed as a feedback screen giving the player detailed feedback on what was the desired outcome as well as the most optimal decision. Examples of these feedback screens for both positional groups are found in Figure 6.37.

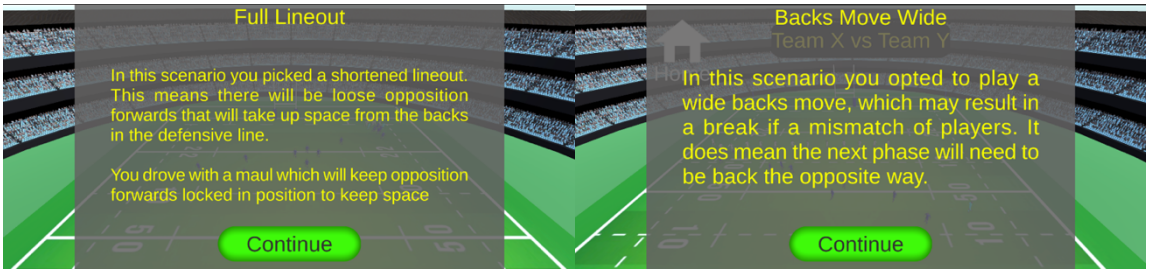

Figure 6.37: Shieldwall: Rugby, Positional Decision-Making Game Mode, optimal decision feedback screens, Forwards (left), Backs (right)

6.3. Phase 3: Prototype Evaluation

Based upon the findings from Phase 2, the feedback in the interviews was used to implement any changes required with the initial game storyboard presented to the participants. Feedback was also used from this phase of development to make modifications to the research's Conceptual Framework as well as Research Artefact. The final version of these elements was used to implement a working game prototype which had the purpose of being a training aid for rugby union players to develop their cognitive abilities and decision-making skills. Prior to this phase beginning, a Game Prototype was

designed and developed with the Research Artefact and Game Storyboard. This was designed using the Unity game engine, which has the capability of developing a game that is usable on mobile devices. During interviews, it was ascertained that the game should be accessible on such devices, so the prototype was developed with this in mind to continue to follow a user-centred approach, as the participant group identified this as a specific need for the target audience.

6.4. Phase 3 Procedure

For this final phase of the first stage of the research, the key stakeholder group were presented with this working prototype and asked questions to gather final feedback to further improve the game's design. By using this approach, the research prototype that would be created would be user-centred, by using the expert opinions of the key stakeholder group to ensure the usefulness, usability, and satisfaction with the designed prototype. This follows user-centred approach of a TURF framework model [57]. A full list of the questions asked can be found in Appendix C. The same key participant group was used for this final phase of interviews as was used in Phase 1 and Phase 2 in previous chapters. All interviews were recorded and carried out on a 1-2-1 basis.

6.5. Phase 3 Findings

As a result of the previous research phase of this study, the findings from the Phase 2 interviews were used to create a Proof-of-Concept Prototype (development discussed in the next chapter) for use as a Rugby Union training aid. The main purpose of this phase of the study is to gather feedback on the 1st version of the prototype, and to implement any final changes before running a subsequent study on measuring the impact and usability of a Serious Game training aid for the sport. This phase also acted to add any final additions to the Conceptual Framework as well as the Refined Research Artefact.

The interviews were all carried out on a 1-2-1 basis with the researcher interviewing each participant. All calls were recorded, with transcripts produced and edited for each call. Following the interviews these transcripts were then open coded following a qualitative data analysis methodology. Whilst analysing the transcripts, a list of thematic codes from the key themes of the interviews were produced.

During this stage of interviews, the following key themes were identified. The below table shows the number of participants who mentioned each area, the number of references made to each key theme and the area within the conceptual model of this research these themes would fit within. An importance “weight” was given to each of the themes identified. This scale was between 1-5, with 1 being completely irrelevant, 3 being of a fair amount of importance, and with 5 being vitally important

to take forward within the research. A summary of the Phase 3 findings from the interview transcripts can be found in Table 6.7.

Table 6.7: Summary of Phase 3 Code Findings

Category	Conceptual Framework	Weight	Instances
Prototype Feedback	Defensive Decisions, Multiple Choice Options	5	35
Visual Learning	Decision Making Learning Methods	4	2
Interactivity	Game Mechanics	5	4
Serious Game Design	Serious Game for Decision-Making in Team Sports	4	40

Prototype Feedback

Prior to this phase of interviews, the key participant group were all individually given access to the developed research prototype so that they can give *Prototype Feedback* during their interview. The purpose of this was to continue to follow a user-centred design approach to the development and allow for changes to be made prior to carrying out the next user study. As such, *Prototype Feedback* was a key theme that emerged in these interviews with a total of 35 mentions throughout the interviews and all participants contributing feedback. Key areas for improvement of the prototype focused on was *Defensive Decisions,* as well as some *Multiple Choice Options* present within some of the *Game Modes* of the prototype:

- *Defensive Decisions* were a theme that developed during Phase 1 of the interviews. However, the High-Fidelity Prototype was designed and implemented without a specific scenario for this area of the sport. As the research prototype initially took its design from this High-Fidelity Prototype, there was no *Defensive Decisions* present in Shieldwall: Rugby. This was highlighted by Participant 2 In the interviews: *"We can now train our decision making in attack. How can we do it in our defensive set?".* Therefore, a scenario for *Defensive Decisions* was developed as part of the *Tactical Game Mode* after the interviews were carried out. The participant group was shown this after it was developed and all responded positively to this scenario. Participant 2 commented: *"Really like that as a defensive scenario. Seeing the whole picture and then making that game call is going to be really beneficial coaching our defensive leaders."*. Participant 3 also responded positively to the new scenario, but commented that Sequential Decisions could also be included for this scenario: *"Yeah I think it's a good option to have. My feedback relatively remains the same. Making that 1 decision is quite easy to do, but it would be great if there was then the next phase added in"*. Therefore, this scenario was then further tweaked to include *Sequential Decisions*, with a *Defensive Line* decision requiring to be made.

This *Defensive Decisions* scenario was also added at the end of an *Attacking Decisions* scenario, representing *Sequential Levels* within the research prototype.

- In the research prototype presented to the key participant group, some expected *Multiple Choice Options* within the sport of Rugby Union, for *the Pass, Kick, Carry Attacking Decisions* options were not presented as would be expected. This was fed back by the participants, particularly from those of the Backs playing and coaching positional background. This was due to the Positional scenario for player's that selected a Backs position did not initially include a Kick option for the situation. This option was therefore added after this phase of interviews to improve the training aid Serious Game, filling the needs of the player and ensuring user-centred design as a result. Participant 3 commented on the missing option for the scenario: *"Yeah, because like if I see this here, I see no full back in behind, chances are if I get that ball quick off of there because it obviously moves quick. So I understand this is a prototype, but I would see this and maybe go, oh, we can maybe get a little (kick) up the middle."*. To ensure the training aid best meets the needs of rugby players, this missing option was added to the scenario after the interviews were concluded.

To ensure that the research prototype followed a user-centred design approach throughout all stages of development. Changes were made to the prototype following the interviews being carried out. Following this approach was of high importance, therefore given a Weight of 5. Changes made included adding certain *Multiple Choice Options* to existing scenarios with kick added to the Positional Decision-Making game mode for backs positions as shown in Figure 6.38, as well as creating a new *Defensive Decisions* scenario which is discussed in section 6.2.1.

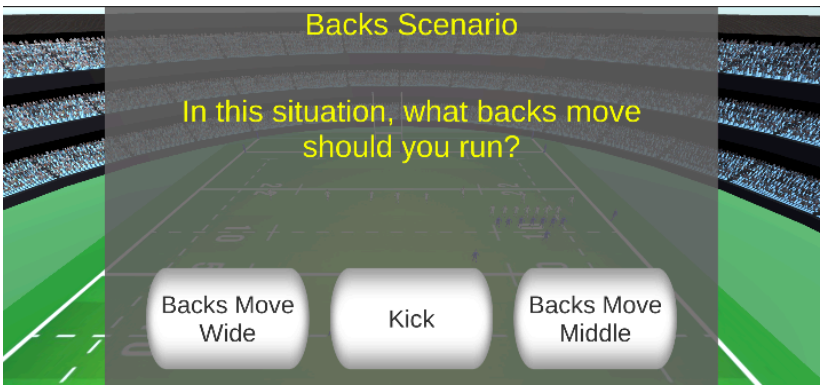

Figure 6.38: Shieldwall: Rugby, altered Backs Positional Decision-Making scenario prompt

Visual Learning

Visual Learning is the process of learning by means of giving a learner the information in a visual format, often found within Serious Games. During the previous phase of interviews, one participant commented that they best learned as a visual learner. In this phase of interviews, it was commented that the serious game training aid was itself a Visual Learning method.

Participant 5 raised this, and commented that they would use such a training aid for player's in their team: *"Yeah, I would If there was a tool like that, I would definitely with a few players I can think of right away, particularly who have just kind of joined the team that could really do with a kind of visual learning aid like that. And just to pick up some of the more kind of basic details of rugby, that they may be lacking at the minute, but training is maybe too quick or, you know, they're too tired or things like that. So yeah, 100% I would have players on that right away".*

During this phase of interviews, 2 participants raised *Visual Learning* methods. As this was also mentioned in the previous phase of interviews, its importance became clear, so this was given a Weight of 4 and added to the conceptual framework as well as the research artefact.

Interactivity

Interactivity, the way in which a player engages with a game such as the research prototype training game was mentioned in different ways during this phase of interviews. For the research prototype was achieved in by a *Player Engagement Cycle*, involving *Player Input, Triggers,* and *Reactions:*

- The *Player Engagement Cycle* in Serious Games relates to the ways in which players attach themselves to the game. Players can be motivated to engage in different ways with such games, and this was raised by participants within the interviews, with it noted that training in this way can engage players in different ways to existing training methods such as *Video Analysis*. Participant 2 commented on this: "Because obviously video analysis is great when you're looking in, but chances are you're all going to pick out the same things, but one of you is going to say it first. So, a lot of the team are going to then sit relatively silent if we're doing big group sessions. Whereas in this, if everyone could just get out the phone and we put a scenario out and then everyone puts in their answers, puts in their whatever. There's that kind of bit of interactivity which keeps players engaged while also kind of coaching and going, oh, what, why did you see carry as the right option?". For the training aid, the *Player Engagement*

Cycle is achieved in 3 ways: by *Player Input, Triggers,* and player *Reactions*, all of which were received well during this phase of interviews:

- *Player Input* is the ways in which the player can control the game elements within the research prototype. This input contributes to the *Player Engagement Cycle* within the prototype. The input is achieved by giving the player selectable options and interactive elements that control the game's scenarios as well as Content Management System to select those scenarios. The positives of allowing players to interact by Player Input in this way was highlighted by the key participant group during the interviews. Participant 5 commented on the interactive choices made within the training aid via Player Input: *"It's interactive mainly. It's live It's not just words on a screen. So, you have to you have to make decisions quickly as well.".* Choices within the scenarios come from *Triggers* that comes from unfolding scenario events, which gives the player choices to make based on their *Reactions* to such events.

- *Triggers* are the in-game events which are designed to capture the attention of the player within the research prototype and encourage *Reactions*. For the prototype, these Triggers involve non-playing characters (NPCs) carrying out rugby related scenarios for the player to react to. The Triggers prompt *Multiple Choice Options* which have two forms – controlling a character which reacts to a choice by the player, or through a screen which prompts the player to make a choice based on the scenario they have just seen. These *Multiple Choice Options* presented by these Triggers were received positively by the participant group, with 3 of the group mentioning them during interviews with 6 references. Participant 2 commented on the effectiveness of these with possible future additions adding to the depth of the training aid: "then the kick pass carries, probably the options. And then I guess as you build further scenarios into it, you'll get those those kind of things built in, which would be good because obviously at the moment passing is kind of the option there".

- *Reactions* are the chosen *Player Input's* that are a direct result of the *Triggers* presented by the game, in this case the research prototype. *Reactions* for the prototype are the decisions that are made within each game mode, which results in *Interactivity* within the *Player Engagement Cycle*, meaning the game has the required *Interactivity*. The participant group highlighted that decision-making within the

prototype achieved the required level of *Interactivity*, with Participant 5 commenting that they felt the Reactions prompted by the decision-making time was appropriate for the training aid's target audience: *"So you have to you have to make decisions quickly as well. That reactive time of, of a player on a pitch is what's kind of important. And committing to a decision quickly and decisiveness can be, can be the biggest killer of a lot of situations".*

The way in which the player controls game elements by means of *Interactivity* for the research prototype was achieved by a *Player Engagement Cycle*. This involved creating *Player Input, Triggers* and *Reactions* within the game which the participant group received positively when asked within the interviews. 3 participants referenced *Interactivity* during the interviews, with 4 references to this. As *Interactivity* was identified within the systematic literature review chapter as important to improving player immersion and engagement with a Serious Game, this was given a Weight of 5. The *Player Engagement Cycle* itself was also added to the research artefact to represent the *Interactivity* element of the conceptual framework.

Serious Game Design

Serious Game Design within the conceptual framework represents the underlying *Game Mechanics* and *Game Flow* concepts required for the creation of such a game as Shieldwall: Rugby. During the design and implementation of the Shieldwall: Rugby research prototype, design decisions were made to attempt to consider the specific needs of the users – rugby players using the prototype as a training aid. The concepts found within the conceptual framework were given relevant rugby-related contextualisation's within the game, and included: *Scoring, Game Rules, Game Environment,* and *Authoring Tools.*

- Instead of using traditional *Scoring* mechanics found in games, it was decided that primarily players would ascertain how well they did in any given gameplay scenario by *Decision Feedback* screens.

- *Game Rules* that define how a player can play a game were set by the rules of the sport, so for this case *Rugby Union Laws* which are enforced by referees in any given match.

- The *Game Environment* was designed to best replicate a Rugby Union match. Therefore, a *Rugby Stadium, Rugby Ball,* and *Rugby Players* were used to do this in a 3D game environment.

These are the 3 components to create such an environment so added as concepts to the research artefact specifically.

- *Authoring Tools*, how scenarios can be entered and changed within a game is instead represented by *Coach-Driven Content.* This is due to participants identifying during interviews that allowing coaches to enter specific information such as team tactics would be relevant for players.

These design decisions for the research prototype were made with the user's needs in mind, to ensure relevance and suitable immersion with the game by ensuring rugby-related relevance. This proved to be positive in the views of the participant group, as when all were asked if they would recommend the prototype as a method of learning, all 5 commented that they would. In addition, there was no feedback from the participants that these considerations should be changed for future development of the prototype. These contextualisation's were therefore used within the research artefact to represent their relevant concepts, and this area was given a weight of 4 out of 5, with ranging levels impact for each concept.

6.6. Phase 3 Conclusion: Refining Artefact framework

After the 3rd phase of interviews with the key participant group, the Headlights: Conceptual Framework was again further developed from the Phase 3 Findings, as well as the Research Artefact. The framework was developed during the systematic literature review, with Phase 1 and Phase 2 Findings developing this further, and a rugby-specific Research Artefact initially developed during Phase 2. During Phase 3, a working research prototype, Shieldwall: Rugby, was also designed and developed based upon this artefact, as well as the High-Fidelity Prototype designed and developed during Phase 2 of this user study. The results of this round of interviews led to *Prototype Feedback*, which resulted in changes being made to improve the satisfaction of the prototype, ensuring a *User-Centred Design*. These changes included the addition of *Defensive Decisions* as well as more *Multiple Choice Options* to the prototype. Additionally, the interviews saw the concept of *Visual Learning* being added to the conceptual framework – as well as contextualisation's of the framework for the research artefact, which included *Interactivity* being represented by a new *Player Engagement Cycle* (which includes *Player Input, Triggers* and *Reactions*). The feedback from the participants also reaffirmed design decisions made during the prototype development *representing Serious Game Design* concepts – this included *Scoring* being represented by *Decision Feedback*, *Game Rules* being represented by *Rugby Union Laws*, the *Game Environment* had 3 components added representing the make-up of the

chosen environment (*Rugby Stadium, Rugby Ball,* and *Rugby Players*), and finally *Authoring Tools* was represented by *Coach-Driven Content*. These representations were added to the relevant areas of the research artefact.

During the Phase 3 interviews, *Prototype Feedback* was gathered to make improvements to existing Shieldwall: Rugby prototype. The participant group highlighted that the prototype required scenarios to represent *Defensive Decisions*, as the initial prototype had not included such a scenario. This was designed and implemented, with the same participant group shown the result for feedback which was met with positive responses. The scenario was added within the *Tactical Decisions Game Mode* to replicate *Defensive Line* decisions to match a team's specific tactics. Additionally, the participant group raised that some *Multiple Choice Options* which they expected for some of the prototype scenarios were not present – specifically the option to *Kick* on *the Positional Game Mode* for Backs positions. This was therefore added. These changes were implemented to ensure that Phase 3 continued to follow a *User-Centred Design* methodology in the design and creation of the Shieldwall: Rugby research prototype.

Visual Learning was identified by the participant group as benefit to using a visual learning tool such as the serious game research prototype, Shieldwall: Rugby. This concept was raised in the previous phase of interviews by one participant, but in this phase, it was raised by multiple as a key benefit to the prototype. *Visual Learning* was identified as a keyway of learning for rugby union players in these interviews so therefore, this was added to the Headlights: Conceptual Framework.

Interactivity was considered for the Shieldwall: Rugby research prototype, as a serious game acts as an interactive training aid. By ensuring that the game is engaging for players by achieving a good level of *Interactivity*, it is ensured that a *User-Centred Design* approach is followed. During the interviews, it emerged that Interactivity within the prototype was achieved by a *Player Engagement Cycle*. This cycle has 3 components – *Player Input, Triggers,* and *Reactions* which make up the 3 ways *Interactivity* is achieved in Shieldwall: Rugby. The participant group responded well in the interviews when feeding back on the prototype, therefore this cycle and the 3 concepts were added to the research artefact as the contextualisation of the *Interactivity* concept from the conceptual framework.

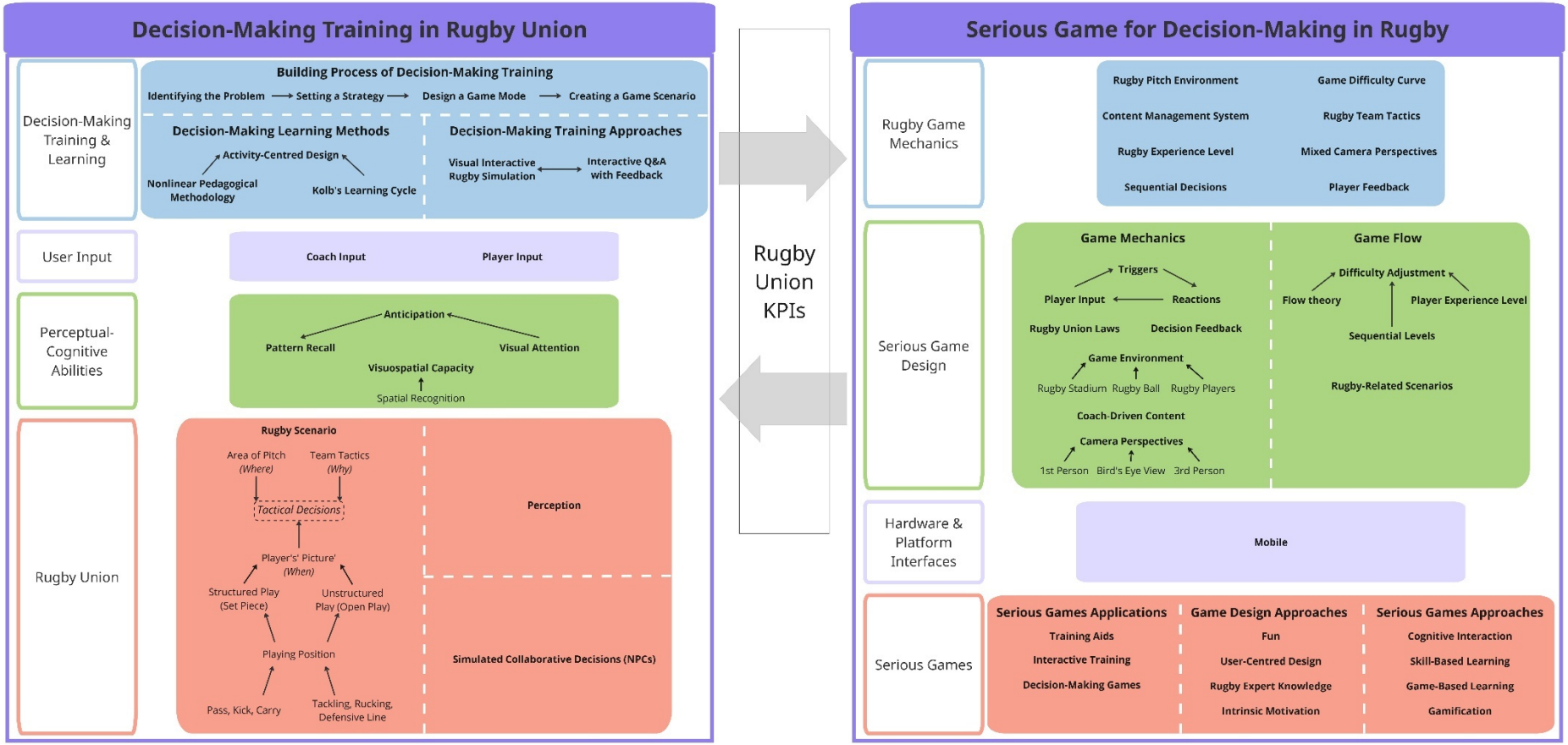

Figure 6.39: Research Artefact (Post Phase 3)

Serious Game Design concepts were also raised during this phase of interviews, giving feedback on the research prototype that was presented to the key participant group. During the design and implementation of Shieldwall: Rugby, design decisions were made to best represent the concepts within the theme of *Game Mechanics*, in the sub-section of *Serious Game Design* within the Headlights: Conceptual Framework. *Scoring* was represented by *Feedback Screens*, *Game Rules* were represented by *Rugby Union Laws*, the *Game Environment* consisted of 3 components (*Rugby Stadium, Rugby Ball, Rugby Players*), and *Authoring Tools* were represented by *Coach-Driven Content*. Feedback from the participant group was positive on the prototype, with all participant's stating they would recommend the method of learning. Therefore, these representations were added to the research artefact to contextualise the conceptual framework specifically for the sport of rugby union, as shown in Figure 6.39.

6.7. Chapter Summary

During Phase 3 of this user study, a research prototype, Shieldwall: Rugby was designed and created to act as a prototype training aid for Rugby Union players, based upon the findings of Phase 1 and Phase 2 of this study. This prototype was presented to the same key participant group that were interviewed during the first two phases, with feedback gathered during the interviews. The resulting feedback was then used to make further changes to the research prototype to ensure a user-centred design approach at all stages of development.

The key participant group gave general Prototype Feedback, with some missing scenarios and features which were then implemented on Shieldwall: Rugby. The group also highlighted *Visual Learning* techniques as used within Serious Games such as the prototype; therefore, this was added to the conceptual framework. Themes on *Interactivity* also emerged during the interviews, leading to the contextualisation of this concept as a *Player Engagement Cycle* for the research artefact. In addition, the participant group also commented on the implemented prototype's *Serious Game Design*, with the choices that were made to this also providing context for concepts within this theme from the conceptual framework, to be conceptualized for the research artefact.

In the next chapter, a 2nd user study will be conducted which will be focused on Analysing Prototype Usability & Impact. A new Participant Rugby Club, with Participant Coaches and Participant Players will be recruited to take part in this study to investigate if the proof-of-concept prototype proves this research's hypothesis.

Chapter 7: Evaluating Prototype Usability & Impact

In the previous chapter, a proof-of-concept research prototype training game was designed and developed using the findings of the 1st research study and the initial literature review. This prototype used the Headlights: Conceptual Framework and Research Artefact to ascertain the key design elements required for a rugby union training aid to be implemented that would have a positive impact on the players using it for training decision-making and perceptual-cognitive abilities.

In this chapter, this impact will be assessed in two ways. A participant rugby club, with a group of senior men's and women's rugby union players were recruited, as well as their coaches to take part in this study. The study will have two parts – firstly the research group of players were given access to the research prototype to use as a training aid, after which they were asked to fill in a usability questionnaire. The players then took part in their regular team training session, whilst the coaches recruited monitored their performance during the session and assessed them by proxy during individual coach interviews after the conclusion of the training session. By following this research methodology, the usability and impact of the Shieldwall: Rugby research prototype was measured, therefore answering the initial research questions as identified in Chapter 2.

7.1. User Study: Analysing Prototype Usability & Impact

Based upon the findings from Stage 1 of the research, a refined Research Artefact of key themes for the development of a training aid for Rugby Union players to develop their decision-making and cognitive abilities was refined, from the initial Conceptual Framework, which was developed during the initial literature review. This Conceptual Framework and the Research Artefact was added to in each phase of Stage 1, with the findings being used as a basis to develop, at first a High-Fidelity Prototype, and then subsequently, a working Game Prototype that was presented to the participant group for feedback during Stage 1. The purpose of Stage 2 of the research was to analyse the impact and usability of the created prototype by investigating its impact on a group of Rugby Union players.

The aim of this user study is to analyse the performance of the decision-making and cognitive abilities of a rugby union player by giving them access to the research prototype and assessing their performance following this. This will be monitored against a control group to understand fully the impact of using the game as a training aid. A rugby union club was identified to participate in the research, which came from the contacts of the principal researcher. The impact and usability of the prototype was monitored in the following ways:

1. Usability test with the research group to understand how usable the game as a training aid was using the Post-Study System Usability Questionnaire (PSSUQ) (Players)
2. Conducting interviews with expert coaches of the research group, to ascertain the improvement of player decision-making and cognitive abilities (Coach)
    a. Assessing the impact of the prototype on rugby players through using coaches as proxy users. This will be achieved using semi-structured interviews as the method.

The study was approved by Brunel University of London, College of Engineering, Design and Physical Sciences Research Ethics Committee, Reference Number: 49794-LR-Sep/2024- 52910-1.

The purpose of this study is to answer the research questions set out in Chapter 2:

RQ1: Can Serious Games be used for training Decision-Making in Team Sports?

RQ2: Would players and coaches engage with games as a training tool?

To answer these questions three hypothesis have been formed in relation to these research questions. This study aims to measure the usability and impact of the Shieldwall: Rugby research prototype, therefore answering RQ1 and RQ2. These hypotheses are listed with their associated research questions in Table 7.1.

Table 7.1: Research Hypotheses and associated Research Questions (RQ)

	Hypothesis	RQ
H1	Players find the Shieldwall: Rugby prototype engaging	RQ1, RQ2
H2	Coaches find the Shieldwall: Rugby prototype a usable training aid	RQ1, RQ2
H3	A Serious Game training aid makes a positive impact on the players from a coach perspective	RQ1

7.2. Participant Groups

For the purposes of this research, a group of participants were recruited to undertake Stage 2 of the research. This research stage has a purpose of analysing the Shieldwall: Rugby research prototype, created in the previous chapter, and ascertain the usability and impact of the prototype on decision-making and perceptual-cognitive abilities of rugby union players. The creation of the prototype followed a user-centred design methodology, the benefits of which is that user productivity with the final designed prototype will be improved, as well as improve user satisfaction and training speed [56]. As it was designed for Rugby Union players, participants for this stage of research were recruited from the sport, using the contact networks of the principal researcher. This stage of research uses coaches of the participant players to

assess the impact of the prototype by proxy, by interviewing coaches to understand the impact on participant rugby players who had access to the game prototype. Therefore, to ensure the coaches best knew the expected performance levels of each player, coaches and rugby union players from a specific Participant Rugby Club were recruited to take part in Stage 2 of the research. Coaches and players were recruited from this club who are involved in both the Men's and Women's Senior teams of the club, with players coming from all playing position background. Coaches were recruited from both teams within the club.

To undertake the study, a participant club from the sport of rugby union was recruited from within the contact network of the principal researcher. This club was identified and recruited with an appropriate number of men's and women's senior players with the club, with a playing team for both, which holds regular training sessions with coaches for each team. Players identified within the playing squad to take part in the research have a variety of different playing experiences within the sport. These measures are to ensure that the research study best looks at the impact of a serious game training aid for the sport in a way that is representative of the wider sport. By using a single rugby club, it allowed for the research to be carried out in an efficient manner with the players of the same team using the research training aid prior to their session, and the coaches being interviewed on conclusion of the training.

Participant Rugby Players

As part of the study, a research group of participant rugby union players were recruited from the participating rugby club. This group represented players of a range of different playing experiences from both the men's and women's senior playing team within the club. The group was giving access to the research prototype prior to a regular team training session, and asked to complete a recognised usability questionnaire, the Post-Study System Usability Questionnaire (PSSUQ) to assess the usability of the research prototype. During the following training session after this, the participating rugby coaches assessed any improvements in the player's decision-making and cognitive abilities during the training session, commenting on this during the coach interview section of the study. Players were also recruited across a variety of playing positions in the sport, from both backs and forwards positional groups.

Participant Rugby Coaches

Within the participating rugby club, senior coaches were recruited to take part in this study from both the senior men's and women's teams. The purpose of this is to assess by proxy any improvements made in cognitive abilities and decision-making skills by the participating rugby player group during a training session for the team, held after the players were given access to the research prototype training aid game.

Coaches were recruited from both teams and represented coaching expertise in both backs and forwards positional groups, to best assess improvements across all positions within the participant group. Interviews were conducted on a 1-2-1 basis with each coach after the training session, with the coaches asked to comment and give scores to improvements across all areas identified by the research prototype. The coaches were also asked to assess the number of participant players they seen improvements from.

7.3. Procedure

The study for this chapter was carried out in two parts. Firstly, using the proof-of-concept prototype rugby union training aid, a group of participant rugby players were recruited and given access to this prototype, prior to their regular team training session. 30 participants in total were recruited, with a mixture of men's and women's senior players with a range of playing experience levels. They were given the prototype to play through all scenarios, and prior to then taking part in their training session, they were asked to complete a Post-Study System Usability Questionnaire, to assess their satisfaction and the usability of the research prototype developed. Player participants were then monitored by their usual team coaches during the training session, where they were assessed for improvements to their decision-making and cognitive abilities. These coaches were then interviewed following the session on an individual basis to comment on the impact they perceived by their players. In total, 4 coaches were recruited to take part in this part of the study. All participants were recruited from the same participating rugby union club.

Player Usability Test

Using the Game Prototype that was developed during Stage 1 of the research, a group of participant rugby union players were identified and given access to the game to use as a training aid prior to a regular training session for their team. Each participant was given full access to the game to use, with their gameplay monitored and recorded. After playing the game, each participant was given a usability questionnaire to complete, the Post-Study System Usability Questionnaire (PSSUQ) to validate the usability of the prototype as a potential training aid. The participants would then take part in their regular team training session, where their performance will be monitored by their coaches. This follows similar research approaches where a usability evaluation questionnaire was used to measure the impact of a Serious Game [78].

Participants from the rugby club were monitored, with coaches taking the subsequent training session given a list of which players participated in the research to monitor their training performance against those that did not, who will operate as the 'Control Group', for the purposes of this research. Each participant will be asked the following questions and to rate the prototype on a scale of 1-7, with 1 being

strongly disagree, and 7 being strongly agree. A full list of all the questions asked can be found in Appendix D.

Coach Interviews

The Game Prototype that was developed during Stage 1 of the research was given to a group of participant rugby union players to use prior to taking part in a regular team training session, ran at their associated rugby club. The players had full access to all elements of the Game Prototype and were asked to complete a usability questionnaire prior to taking part in their training. These training sessions were monitored by the normal coaching team for these players, with coaches aware of which players took part in the research as the participant group, and the players who did not, who are acting as a control group to measure impact. Both the senior men's and women's teams with the participant rugby club took part in the research. This means that the impact of a game prototype on both male and female players in the sport of rugby union was measured to see if it improved their decision-making and cognitive abilities.

The coaches where then interviewed on an individual basis, after the team training session had finished. Coaches were used in this fashion as a proxy assessment of the impact of the prototype, as used in other Serious Game research with games designed with a User-Centred approach, as with this research [29]. During the interview's questions, like with the previous research stage, were open-ended. Interviews will be carried out with coaches after research participants have carried out their usability testing, and coaches have been able to assess any potential improvements to participants decision-making and cognitive abilities in a training environment. All interviews were recorded and transcribed, with codes establishing key themes from the interviews. Coaches were asked to rate the impact of the prototype on both decision-making and cognitive abilities, as well as on each area of the game prototype (individual decision-making, tactical and positional decision-making). A full list of the questions asked of each coach can be found in Appendix E.

7.4. Findings

This study was conducted in two parts. First, a Player Usability Test to assess the usability of the Shieldwall: Rugby prototype, using a version of the Post-Study System Usability Questionnaire (PSSUQ), a validated means to measure system usability. This was given to participating rugby union players after they were given the Shieldwall: Rugby prototype to use prior to a regular team training session. Coach Interviews were then conducted after this training session to assess the impact of the prototype by proxy. Interviews were conducted on a 1-2-1 basis and recorded, with the transcripts coded. The findings for both parts of this study are therefore analysed in two sections, the Player Usability Test, and the Coach Interviews.

The purpose of this study is to validate the 3 hypotheses set out in section 7.1, which would therefore answer the research questions as established in Chapter 2. RQ1 relates to if a Serious Game such as Shieldwall: Rugby can be used for training decision-making in a team sport such as rugby union, whilst RQ2 asks if players and coaches would engage in such a training aid.

7.4.1. Player Usability Test

To ascertain if the research game prototype is a usable training aid for rugby union players, a participant research group of athletes within the sport was recruited to participate in a usability test. Participants were given access to the game prototype to play prior to taking part in their team's regular training session. On finishing playing with the game prototype, they were asked to complete a validated questionnaire, the Post-Study System Usability Questionnaire (PSSUQ) which contains questions on their satisfaction using the game, ease of use, accessibility, game information, learning to play the game, as well as gameplay functions and capabilities. Each participant for each question in the PSSUQ was asked to rate their satisfaction on each area, using a Likert scale of 1-7, with 1 being "Strongly Disagree", and 7 being "Strongly Agree". The PSSUQ measured the perceptions of the final prototype game on Overall System Satisfaction (Question 1), System Quality (Question 2-8), Information Quality (Question 9-12) and Interface Quality (Question 13-16).
Table 7.2 shows the list of questions from the version of the PSSUQ used during this study, with the associated Research Questions they sought to answer.

A 16-item version of the PSSUQ was used, as previous studies have found that questions 3, 5 and 13 of the original 19 item are optional and can be removed with no significant impact, saving research time [103]. 30 participant rugby union players were recruited and took part in this study, with each having access to the Shieldwall: Rugby prototype to use as a training aid, prior to completing a PSSUQ. The mean responses for all questions within the PSSUQ are shown in Figure 7.1.

Table 7.2: PSSUQ Questions and associated Research Questions

	PSSUQ Question
1	Overall, I am satisfied with how easy it is to use this game.
2	It was simple to use this game.
3	I was able to complete the tasks and scenarios quickly using this game.
4	I felt comfortable using this game.
5	It was easy to learn to use this game.

6	I believe I could become productive quickly using this game.
7	The game gave error messages that clearly told me how to fix problems.
8	Whenever I made a mistake using the game, I could recover easily and quickly.
9	The information (such as online help, on-screen messages, and other documentation) was clear.
10	It was easy to find the information I needed.
11	The information was effective in helping me complete the tasks and scenarios.
12	The organization of information on the game screens was clear.
13	The interface of this game was pleasant.
14	I liked using the interface of this game.
15	This game has all the functions and capabilities I expect it to have.
16	Overall, I am satisfied with this game.

Overall System Satisfaction (Question 1): On a 1-7 Likert scale such as the one used for this study, a value of 4 would be deemed the average score. On Overall System Satisfaction (Question 1), the participants gave a high satisfaction (Mean = 5.83, SD = 0.79), indicating that the participants received the prototype well. Additionally, in all areas of the PSSUQ, the mean score for each section was above this average score indicating Shieldwall: Rugby had a high satisfaction among its users.

System Quality (Question 2-8): In terms of System Quality the participants also scored the Shieldwall: Rugby prototype highly (Mean = 5.75, SD = 0.61), indicating that the research group felt that the prototype was usable for its intended purpose. It's worth noting that Question 2, "It was simple to use this game" scored highly (Mean = 6.10, SD = 0.66) as well as Question 4, "I felt comfortable using this game" (Mean = 6.03, SD = 0.76). This would indicate that the participants found the prototype usable as a training aid, one of the aims of prototype's development and the purpose of this research. It's worth noting that participants gave a lower-than-average mean score for Question 7, "The game gave error messages that clearly told me how to fix problems", the variance in deviation was also higher for this question than the average for the section (Mean = 5.10, SD = 1.47). This was also true for Question 8, "Whenever I made a mistake using the game, I could recover easily and quickly" (Mean = 5.10, SD = 1.49). Gameplay scenarios as designed did not give an immediate mistake recovery option, which likely led to this being rated lower than other areas for this section of the PSSUQ. It was identified in the previous studies' interviews that rugby union scenarios may not always have 1 specific correct option, so tailoring the scenarios in the training prototype to have more possible positive outcomes may improve this score. By improving these areas further, the views of the System Quality for the rugby union training aid game prototype could be improved further, meaning a more impactful training aid.

Information Quality (Question 9-12): The participant group also gave a positive average score to the research prototype for Information Quality, with a mean score of 5.80 (SD = 0.73). This would indicate that the participant rugby players found that information being presented by means of a video game is effective when using it as a training aid. Whilst the score is positive, there was a larger than average deviation and lower than mean score for Question 10, "It was easy to find the information I needed" (Mean = 5.77, SD = 1.10) as well as for Question 11, "The information was effective in helping me complete the tasks and scenarios" (Mean = 5.57, SD = 1.10). This would indicate that whilst the participants still viewed this area of the prototype positively, by improving the information given to players within the game, and by making the prototype more user-friendly, the satisfaction could be further improved. These questions within the PSSUQ addressed the information available to players in the Shieldwall: Rugby prototype, as well as such information being able to assist players in required task completion (such as training needed skills for the sport such as Perceptual-Cognitive Abilities).

Interface Quality (Question 13-16): Finally, the Interface Quality section of question also received high satisfaction among participant responses, with a mean score of 5.66 (SD = 0.88). Whilst all scores were above average, Question 15 "This game has all the functions and capabilities I expect it to have" was a lower-than-average mean score for this section (Mean = 5.50, SD = 1.43). This could be due to the prototype requiring further integration with specific rugby union's team's tactics to be more impactful as a training aid, something that was noted by the subsequent coach interviews part of this study, as well as in the interviews with key participants in the previous study when ascertaining the key requirements for a training aid in the sport. Having team tactics more identified within the prototype would likely improve this score. Overall, participants did rate the training aid game high in satisfaction, with the final question for this section, "Overall, I am satisfied with this game" receiving a higher-than-average mean score for the section of 5.83. The positive scores throughout this section indicate that prototype was usable as a prototype for these participant rugby union players, with room to improve these scores further if team tactics are further incorporated within the prototype.

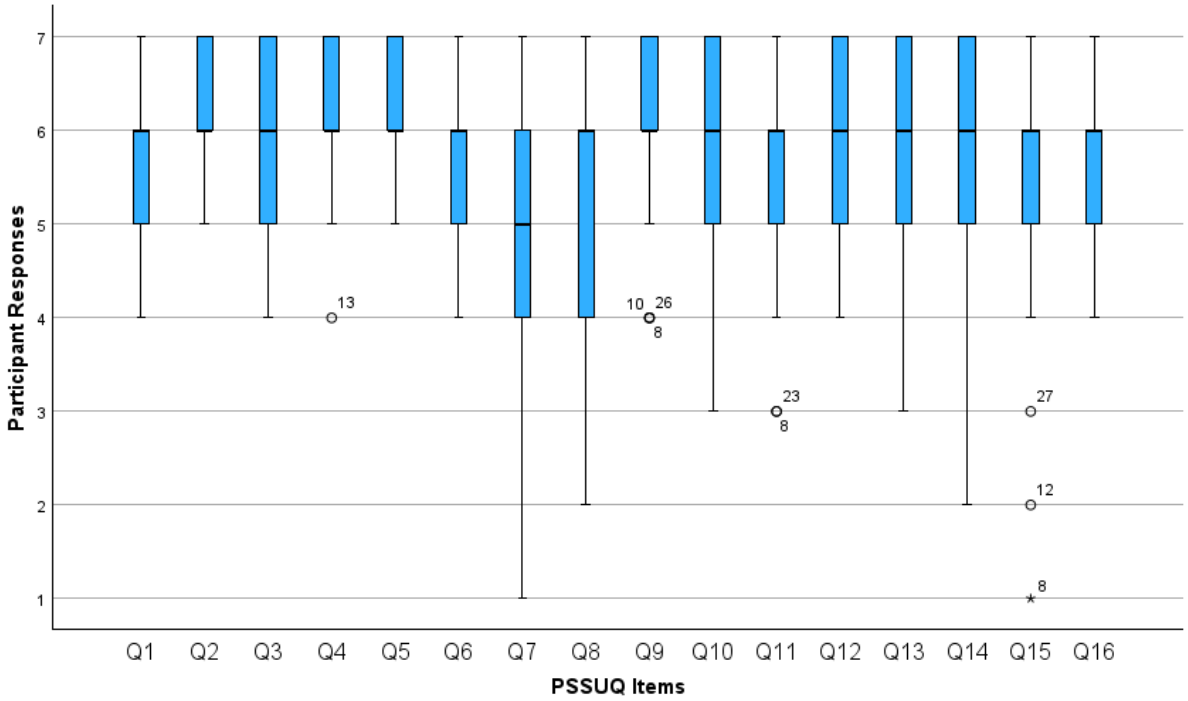

Figure 7.1: PSSUQ Mean Responses by Question

Significance Tests

Once all participants had taken part in the research, and filled in their PSSUQ evaluation, a normality test was run on the results of each question to distinguish if the data collected was normal. The results were shown to be normally distributed; therefore, a t-test was subsequently carried out. The t-test was run to determine if the mean scores for each section of the PSSUQ (Overall System Satisfaction, System Quality, Information Quality and Interface Quality) were statistically significant when compared to the total mean value of the responses. Running these tests showed that the mean score of each section remained consistent, and that the scores were shown to be statistically significant due to a significance score of less than 0.001 on each area. Hence the results of the PSSUQ study are statistically significant and therefore, it is possible to prove H1.

Table 7.3: PSSUQ Statistics Summary

PSSUQ Area	N	Mean	Std. Deviation	Std. Error Mean
Overall System Design	30	5.83	0.791	0.145
System Quality	30	5.7571	0.61434	0.11216
Information Quality	30	5.8083	0.73309	0.13384
Interface Quality	30	5.6667	0.88895	0.1623
Total	30	5.7521	0.59756	0.1091

Table 7.4: One-Sample t-test

	t	df	Significance		Mean Difference	*95% Confidence Interval of the Difference*	
			One-Sided p	Two-Sided p		Lower	Upper
Overall, I am satisfied …	40.368	29	<.001	<.001	5.833	5.54	6.13
System Quality	51.329	29	<.001	<.001	5.75714	5.5277	5.9865
Info Quality	43.396	29	<.001	<.001	5.80833	5.5346	6.0821
Interface Quality	34.915	29	<.001	<.001	5.66667	5.3347	5.9986
Total	52.723	29	<.001	<.001	5.75208	5.5289	5.9752

7.4.2. Coach Interviews

To better understand the impact of a Serious Game being used as a training aid for rugby union players, coaches of a participating rugby union club were interviewed to gather their opinions on the impact the research game prototype had on players involved in the team they coach. This prototype was developed in Stage 1 of the research and was given to participants of various levels of playing experience from relative beginner to very experienced players. Coaches were recruited for these interviews from both the men's and women's senior playing teams and were chosen to be interviewed to act as a proxy assessment of the impact the game training aid had. Prior to accessing the prototype, players took part in a regular team training session, and coaches were interviewed after these sessions and asked questions on the training aid impact. A total of 4 coaches were recruited for this part of the research. All coaches were asked open-ended questions on the areas of prototype impact, impact on decision-making skills as well as perceptual-cognitive abilities. On each area, the coaches were asked to rate the impact of the prototype on a scale of 1-10.

Prototype Impact

By using a video game training aid, it is hoped that there will be a positive impact on decision-making and cognitive abilities of the participant group of rugby union players, who used the prototype created for this

research. Players taking part in this research took part in a regular team training session prior to using the prototype. The coaches that took the sessions then rated the impact they felt that the prototype had on the players involved. The table summarising each coach's impact rating by proxy of the participant rugby players, as well as average score summaries can be found in Table 7.5. Each was asked to rate the overall impact on a scale of 1-10, the four coaches gave an average score to the prototype of 7.25 out of 10, with the highest score being 8, and lowest being 6. Coaches were then asked to rate the impact of the prototype on their player's *Individual Decision-Making, Tactical Decision-Making,* and *Perceptual-Cognitive Abilities.*

All scores given for this were positive, with Coach 1 who gave the lowest score still reflecting: *"could definitely see that improving"*, indicating that the prototype could improve Its impact further with adjustments.

Coach 3 also commented that further improvements could be made to improve the impact score further: *"tweaks or improvements, if we could look at scenario based against our game plan, that question bank being aimed at how we're playing and how we're looking to deliver on a pitch and it would easily bump up",* this reflection identified that if the training aid looked at a specific team's tactics, it would have a greater direct impact on the players using it.

Coaches also commented on the positive impact it had on players who are seen as key decision makers withing a team, Coach 1 commented that they observed participant players seeing an immediate impact: *"getting more vocal, getting more involved, definitely organising the line out a bit more so yeah, it was good to see them. You know, get a bit more confidence from using the game".*

All coaches agreed that of the players that used the prototype, they seen an impact on at least half of the players in the subsequent training session. The coach for the women's team identified out with the interview that they had a higher number of less experienced rugby union players, when compared to the player's group for the men's team, which is noteworthy as they also rated the number of players that the prototype had a positive impact on higher at 75%, whereas the coaches for the men's team rated this an average of 50%. This would indicate that the prototype may be more impactful for less experienced rugby union players. Subsequently, the coaches were asked later in the interviews to rate the impact the prototype had on the research participant rugby players who used the game for induvial and tactical decision-making, as well as their cognitive abilities. All coaches gave these areas a positive average score, underlining that they felt the prototype had a direct impact on the players they worked with in the training session after use of the video game training aid – both individual and tactical decision-making scored an

average of 7 out of 10 between the 4 coaches, with cognitive abilities receiving an average score of 7.67. All coaches also added that the number of players they seen a direct impact on for these areas was 50% and above. These positive scores for all areas identified, as well as the high number of players it had an impact on as identified by their coaches, indicate that the research prototype did meet its intended use of improving decision-making and cognitive abilities, with coaches also underlining that this could be improved with specific team-based scenarios.

Overall, the research prototype was viewed as having a positive impact by the coaches who were interviewed after carrying out a regular team training session, with the group of players that had used the research game prototype prior to the session. The coaches also felt that they had seen improvements by many the players who used the prototype, at least over half. When asked, coaches also felt that each area the research prototype intended to improve, decision-making and cognitive abilities, also were improved by the research players. This means that the coach group felt that the intention of the research prototype video game was a success. Coaches also commented that the scores for impact could also be improved with specific prototype scenarios tailored for their team.

Table 7.5: Coach Interview Impact Summary Table

	Prototype Impact		Individual Decision-Making		Tactical Decision-Making		Perceptual-Cognitive Abilities	
Coach	**(1-10)**	**%**	**(1-10)**	**%**	**(1-10)**	**%**	**(1-10)**	**%**
1	6	50	7	50	7	50	7	50
2	8	50	8	50	5	50	8	50
3	7	50+	6	50+	7	100	8	70
4	8	75	8	75	9	100	8	40-75
Average	**7.25**	**50.00**	**7.25**	**50.00**	**7.00**	**66.67**	**7.67**	**56.67**

Individual Decision-Making

A rugby player's decisions on the field can often impact the success of their team, improving this skill was identified by the literature review as well as by the key participant group in the earlier study of this research. The participant group there identified that an individual rugby player can make decisions both in attack and defence, with attacking decisions centring around a player's decision to carry, kick, or pass the ball when in possession. As such a custom scenario was used in the prototype where a player was given these options in a match situation and asked which option to take. The key participant group also identified

that improving sequential decision-making would be key to improving the skills of these players, so the scenario had multiple decisions for the player to make. Players were given the prototype to use prior to a regular training session, and the coaches interviewed for this study were asked to rate the impact of the prototype on the participating player's individual decision making. All coaches gave a positive score to the prototype for improving decision-making, with an average score of 7 out of 10 for the 4 coaches interviewed. 3 of the 4 coaches said that decision-making improved for 50% and above for the participating players, with 1 coach saying they seen an impact on 75%. This coach was for the women's team participating in the research, who the coach commented outside of the interview that there were more less experienced players within their playing squad. In addition, often in a game of rugby union a player must make specific decisions based upon their individual playing position, this was identified by the literature review and backed up by the key stakeholder group in interviews for the previous study. As such, the game prototype also asked each player for their playing position and gave them a scenario to make a specific decision based upon this, to improve positional decision-making skills. The high scores that the prototype received for its impact as well as improvement of individual decision-making reinforce that the prototype was successful in improving these skills, as rated by the coaches.

Comments by the coaches focused on these improvements, Coach 1 commented that: *"they made better decisions. And we'd probably see that transition into on the pitch".* In addition, this coach also identified improved confidence from key decision-makers: *"they were getting more vocal, getting more involved, definitely organising the line out a bit more".*

Also highlighted was that the use of sequential decisions within the scenarios also had an impact. Coach 3 said that: *"I think when you look around scenario-based pieces that understand in what they're doing, why they're doing it, what they're looking at, second, third phase, all comes from talking through discussion understanding and that definitely helps".*

Overall, the research prototype was seen by the coaches interviewed to be impactful for Decision-Making Training in Rugby Union, as it was seen to improve individual decision-making. Particularly effective was its impact on positional-relevant decisions as well as asking the participant players to make sequential decisions, as this best imitates a game of rugby union. Among the players that had access to the game prototype as a training aid, the coaches thought this improved decision-making for a high number of players, over half of those who used it. The prototype was also seen to be more impactful to a group of players with less experience of the sport. This means that the video game training aid was successful in improving the individual decision-making of the players who used this research prototype.

Tactical Decision-Making

Rugby Union is a team sport, and as such, individual players are often required to make decisions in a match which considers their specific team's tactics, or Tactical Decision-Making. They will need to make these decisions given the context of the *Player's "Picture*" of a match, i.e. position of the pitch and the on-going changing situation. This was identified within the literature review of this research as well as by the key participant group in the previous study. Because of this, a specific area of the game was developed that asked the players to make decisions based on their team's tactics given a match situation. To understand the impact of this, the coaches were asked about this during the interviews after the participating players had used the video game training aid and taken part in a regular team training session. The coaches rated the impact of the research prototype on the tactical decision-making of the participant players an average of 7 out of 10, with the highest score being a 9, and lowest being a 5, with the coach giving this lowest score identifying that by having their team's "set plans" could be better adapted for the training aid. The coach who gave the highest score was the coach for the women's team, who had a higher number of less experienced players taking part in their training sessions, which they mentioned off-interview. The coaches rated that the average number of participant players that the prototype had a direct impact on for tactical decision-making was an average of 66.67%, with two coaches saying that it impacted half of their playing group, and the other two coaches saying that it directly impacted all their players who are key decision makers on the pitch.

Coaches commented that because the prototype impacted a key decision-maker, that then impacted the other players in the team. Coach 4 referenced a specific decision-maker, and how this then led to peer-to-peer learning during the interview: *"for the scrum half it was 100% definitely, and then like I say that sort of worked its way out to the rest of the team."*

Coach 3 commented that the impact of the prototype was to improve understanding for key positions on the park that make such tactical decisions: *"That more fits with your lineout leaders and those guys understanding like you said, where on the park, what we're trying to effect as a team, what their options are and then where we go to from that second and third phase and tying in with the 1/2 backs and the decision makers in the backs then. It's a good thing".*

They also added that the additional exposure to such a training aid improved their understanding of the team's tactics. *"It's a good thing isn't it, just give him a little bit more exposure to picking and understanding what they're trying to do".*

In summary, the research prototype contained a specific tactical scenario for participant players to make Tactical Decisions based upon understanding with their team's tactics. This directly had a positive impact on those players exposed to the training aid, with coaches who took the training session after players used the training aid game saying that over half of the players taking part seen an improvement to their understanding. In addition, the prototype also was seen to be beneficial to players who are seen as key decision makers of a team on the pitch, with all these roles being seen as having a positive impact by the coaches who mentioned them. Overall, this means that the prototype has been useful at training these skills, as was desired during the game's design and implementation for tactical decision-making.

Perceptual-Cognitive Abilities

The mental side of rugby union, with its perceptual-cognitive abilities such as visual attention and pattern recall were identified as key abilities that a rugby player needs to develop to improve, as shown in the literature review. The research prototype was designed to be able to be used as a training aid to improve key cognitive abilities such as pattern recall and visual attention, with the prototype having custom scenarios which used these skills, such as scenes with an overhead view and asking the player to identify which tactical decision the team should execute. Because of this, the participant coaches were asked to evaluate the improvements of their playing group who had access to the research prototype. On a scale of 1-10, the four coaches rated the impact of the prototype on cognitive abilities an average of 7.67, with all coaches assessing that an average of over 50% of the participating players had a direct positive impact on. One coach felt this could range up towards 75% of those players, which is worth noting that this coach works with the women's team, were they identified there was more less experienced players in this group than the men's playing group.

The prototype was seen by the coaches as being a useful tool for cognitive abilities, Coach 3 commented on skills being trained such as Pattern Recall: "*understanding where on the pitch and what we're trying to do as a team can all be affected by that scenario-based app and then you can now build on that".*

Game difficulty Curve features, such as adjusting the amount of time given to players to process game scenarios was seen as a positive as well, which can be further tailored based on rugby experience level, with Coach 1 commenting that they saw this on the training pitch after the players used the prototype: *"I think they were getting into position quicker and there definitely wasn't as much thinking time required and they were able to make the right decision with a bit more pressure and a bit more time".*

The training aid prototype was seen as a useful tool for training perceptual-cognitive abilities outside of scheduled team training sessions, particularly useful within the amateur or semi-professional game where time can be limited, as identified in the literature review. Coach 2 commented that training such skills would benefit some players for that reason: *"can't always make training while they're using this, they can go through all the elements during the weeknights and then when it come to training, they know exactly where to fit in when the coach calls right lineouts I want tempo or a one cancel, so they know exactly what we're on about".* They then went on to reference that training pattern recall would benefit players due to improving Tactical Decisions: *"especially to some of the guys that don't can't always make training while they're using this, they can go through all the elements during the weeknights and then when it come to training, they know exactly where to fit in when the coach calls right lineouts".*

To conclude, the coaching group of participants that were interviewed for this study seen a clear positive impact on the players they coached who had access to the research prototype, prior to taking part in their team training sessions. Over half of those who used the prototype seen an improvement, and coaches commented on visual scanning, reaction times, as well as pattern recall. They also identified that such a training aid would be beneficial outside of their normal team training sessions, and the higher percentage impacted of those in the playing group with less experienced players shows that such an aid would be more beneficial to newer rugby union players. This means that the research prototype was successful in being able to improve the cognitive abilities of the participant players, in the views of the coaches who were asked about the performance of these players in their training session.

Comparison with Existing Training Approaches

To understand the impact of a Serious Game as a potential Training Aid for rugby union players, the participant coaching group were asked during the interview's questions on the existing Training Aids they use for the purposes of training decision-making and cognitive abilities within their playing group. The purpose of this was to compare existing training aids for the sport in terms of the rating impacts the coaches gave them with Shieldwall: Rugby. Pitch Training was deemed as an essential training method so was not compared, whilst coaches commented that classroom-style sessions were seen as an extension of Video Analysis. Therefore, this comparison compared Shieldwall: Rugby to Video Analysis in terms of the coach rated impact, the summary table of these scores can be found in Table 7.6. All coaches interviewed identified that Video Analysis was a key tool that was already used within their team's. When asked to rate the impact of Video Analysis as a training aid, 3 of the 4 coaches rated this positively, scoring an average of 7.25 out of 10 for impact on players. This matched the 7.25 average score given by the same coaches for the impact that the research game prototype had on the participating players during the subsequent training session, after players used the prototype.

Table 7.6: Training Aid Comparison of Coach Impact Ratings

Coach	Shieldwall: Rugby	Video Analysis
1	6	8
2	8	8
3	7	9
4	8	4
Average	**7.25**	**7.25**

Coaches commented that the score could be improved for the Shieldwall: Rugby training aid, Coach 3 said that by further improving the prototype based on an individual Team Tactics, this could improve its impact score: *"look at scenarios based against our game plan, that question bank aimed at how we're playing and how we're looking to deliver on the pitch".*

Developing the research prototype further, to be tailored to Team Tactics, or even to identify coaching points from other teams who a team may be facing were both identified in previous stage of research by the key participant group. This further tailoring could therefore improve the research prototype's impact score which could make it a more useful training aid than other existing aids. 2 of the 4 coaches did identify that the impact of the video game training aid was lower than that of existing methods such as video analysis, however they did agree that with improvements the impact score of the game training aid would be improved. Both coaches were working with the men's team which had a greater number of experienced rugby union players participating in the research. It was noted after the interview by the coach of the women's team that video analysis struggles to have an impact on less experienced rugby players as a training aid, a consideration made during the literature review of this research. As the women's team had more less experienced rugby player participants, the coach for this team rated the game prototype considerably higher than video analysis, with the game receiving an 8 for impact, and video analysis receiving a 4. It has been noted in both Stage 1 and 2 of this research that a video game training aid would be possible to tailor for less experienced players, which is a difficulty identified with existing video analysis tools. This is backed up by the score the women's coach also gave to the research prototype for the number of players they seen a direct impact on in their training session, rating the prototype at impacting 75% of players, whereas for the men's group the average rating for this was around half of the participants.

To conclude, coaches scored similarly for impact for the serious game training aid as the impact of tools such as video analysis. Considering comments on impact for less experienced players, this could solve an existing problem with video analysis as a training aid, in the form of a Serious Game training aid for rugby

union players. In addition, the impact of the game training aid could be improved with specific tailoring of in-game scenarios to be more relevant to a specific team's tactics.

7.5. Study Conclusions

In this chapter, the research prototype, created in previous chapters because of the literature search and previous study, was used to ascertain if a video game training aid can be used to improve the decision-making and cognitive abilities of rugby union players. This was done by recruiting a participant rugby club, with a men's and women's senior playing team as well as coaches that regularly work with these teams. The prototype was assessed in two ways – firstly by giving a research group of these rugby players access to the prototype and asking them to complete a validated usability test, the Post-Study System Usability Questionnaire (PSSUQ). After using the prototype, the players then took part in their regular training session, and coaches were then interviewed to ascertain the improvements made to decision-making and cognitive abilities. These coaches provided a proxy assessment of the prototype used as a measure of its impact on the research group of participant players.

The player usability test was carried out by firstly giving participating rugby union players access to the research prototype developed in the previous chapter of this research to play as a training aid. This was done prior to their regular team training session so that coaches could then assess the players for any improvements to their decision-making and cognitive abilities. Players were given a Post-Study System Usability Questionnaire (PSSUQ) to complete to assess the prototype game on Overall System Satisfaction (Question 1), System Quality (Question 2-8), Information Quality (Question 9-12) and Interface Quality (Question 13-16). Scores for each question were given on a Likert Scale of 1-7. Across each section, the participating rugby players scored the Shieldwall: Rugby prototype positively, with a total mean score of 5.75 for all sections, with a deviation of scores of 0.59. The scores for each question where also ran through normality and significance tests, which showed normal and significant results. This means that this Player Usability Test showed that the prototype was usable for its purpose as a rugby union training aid from the perspectives of the participant rugby players. This means that H1 is validated due to players finding the prototype engaging during this test.

The game was designed in a user-centred manner, so these positive scores show that the intended use was achieved, and the significant data results from the subsequent tests verified this. Notably, there was a variance of scores in areas such as game mechanic functionality (Question 15) which can be attributed to the prototype requiring further tailoring to a specific's team's tactics to achieve better usability. There was also room to develop the prototype in error correction and feedback (Question 7 & 8). The scenarios implemented did not have more than 1 "correct" decision for the player to make, with no way for the

player to follow up a poor decision with a “good” decision. Implementing scenarios with multiple different outcomes could improve the score for these questions further. Despite these variances, players still rated each of these questions above the average of 4 for the scale used, meaning they still viewed these areas of the game positively, but with room for improvement.

During the coach interviews stage of this study, coaches were asked to assess the impact of the research prototype on the participating rugby players who took part in their subsequent training session. Across all areas asked, the prototype training aid received positive scores for impact, achieving a 7.25 out of 10 overall, getting the same score for individual decision-making, a 7 out of 10 for tactical decision-making and an average of 7.67 for cognitive abilities. Coaches said that at least 50% of those players taking part in the research seen a direct impact in all areas, with even more players seeing improvements in the team with more less experienced players (75%). The high impact scores, as well as the high number of players effected, would indicate that coaches reached a consensus that these skills were improved by using such a training aid. In addition, coaches commented that key decision makers within their team seen a direct positive impact from using the training aid, particularly for improving tactical decision-making. Coaches were also asked about other training aids, such as video analysis which rated similarly to the prototype video game training aid. The coaches identified that the prototype also has potential for improvements to enhance its impact, such as more specific scenarios for players as well as tailoring of scenarios to a specific team’s tactics. Overall, the comments and ratings by the coaches indicate that the research prototype had its desired effect of improving decision-making and perceptual-cognitive abilities of the rugby players who used it, whilst also being a more useful tool for less experienced players, an issue identified with existing training aids such as video analysis within the literature review. This means that coaches found the Shieldwall: Rugby prototype as a usable training aid for the rugby players in their team, and that it had a positive impact on the players from their perspective – this validates both H2 and H3.

With H1, H2 and H3 validated, this means that these hypotheses can be used to answer the research questions set out in Chapter 2. The question of if a Serious Game of this kind can be used for training decision-making in a team sport such as rugby union (RQ1) is answered due to players finding the Shieldwall: Rugby prototype engaging (H1), coaches found that the prototype was usable as a training aid (H2), and the game made a positive impact from the perspective of the coaches (H3). In addition, the question of whether players and coaches would engage with such a training tool (RQ2) was proved by the validation of the hypothesis that players would find the prototype engaging (H1) as well as coaches again finding the prototype usable (H2).

7.6. Chapter Summary

In this chapter, a study was designed and carried out to answer the research questions set out in Chapter 2. The purpose of this was to ascertain if a Serious Game such as Shieldwall: Rugby could be used for training decision-making in a team sport such as rugby union, as well as if players would engage with such a training tool.

To answer these questions, 3 hypotheses were formed:

- Players find the Shieldwall: Rugby prototype engaging (H1)
- Coaches find the Shieldwall: Rugby prototype a usable training aid (H2)
- A Serious Game training aid makes a positive impact on the players from a coach perspective (H3)

The study was conducted in two parts a Player Usability Test in the form of a 16 questions PSSUQ, as well as Coach Interviews to assess the Shieldwall: Rugby impact by proxy. The participating player group found the prototype usable based upon their positive responses – this meant that it was engaging to them, validating H1. Interviews with the coaches found that the prototype was usable as a training aid and made a positive impact on the participating players, validating H2 and H3. With all of these validated – this answers the research question that a Serious Game can be used to train decision-making in a team sport like rugby union, as well as the question that players and coaches would engage with this training tool.

Chapter 8: Discussion

In this chapter the thesis is concluded with a summary of the thesis, followed by discussing the key contributions throughout this research. The chapter concludes by a discussion on the limitations of the research and future work considerations.

8.1. Summary of Thesis

Initially a systematic literature review was carried out in chapter 2, where a total of 71 conference papers and academic journals were accepted from the initial literature pool using the PRISMA protocol. This literature review established the key perceptual-cognitive abilities and decision-making strategies which contribute towards the success of rugby union players, within the context of Serious Games. This therefore achieved objective 1 of the research. From this, an initial conceptual framework was created from the literature findings, resulting in the first version of the Headlights: Conceptual Framework, contributing towards achieving objective 2. The findings from this chapter contribute towards answering research question 4; decision-making strategies and Perceptual-Cognitive Abilities that a serious game requires to act as a training aid are established from the literature.

In chapter 3, a first user study was designed. The purpose of this was to follow a user-centred design methodology in the creation of a design framework for a research prototype for the creation of a serious game training aid for team sports such as rugby union. This involved the identification of a key participant group to interview at 3 different phases of development of the prototype: Pre-Implementation, Design Framework Feedback, and Post Implementation Feedback. This would contribute towards identifying the needs of such a training aid such as the skills and strategies needed by rugby union athletes (objective 1), as well as further developing the conceptual framework (objective 2). A study carried out in this way followed a thematic analysis methodology and followed in the subsequent chapters.

The first phase of this study was then carried out in chapter 4, with the initial findings from this adding further understanding the needs of the intended users for the prototype, as well as further adding to the conceptual framework. The key participant group was interviewed during each phase of the study, beginning in this chapter with the transcripts from this coded. The participants used in all phases beginning in this chapter were experts within the sport, ensuring a user-centred design methodology was followed. This added to achieving objective 2, as well as completing the findings for objective 1. The findings from this phase of interviews, with the initial systematic literature review in chapter 2, form the answer to research question 4 as the perceptual-cognitive abilities and decision-making strategies required for rugby union players to use a serious game training aid in this context are established.

Using the initial findings of the previous phase of the study in the last chapter, a high-fidelity prototype was developed and presented as a 'storyboard' to the key participant group in chapter 5. This was designed based on a created Research Artefact which was created as a contextualisation of the conceptual framework for use in creating a serious game for the sport of rugby union. The high-fidelity prototype was presented to obtain Design Framework Feedback from the expert participant group, with a subsequent interview forming the second phase of the user study. The findings from this again added developed the conceptual framework and subsequently the research artefact as well. This initial design and feedback began the design process towards the development of a proof-of-concept prototype as well as further developing the conceptual framework in addition to the research artefact, therefore contributing to the completion of objective 2 and 3. This contributes towards answering research question 3 as it presents the design framework, the research artefact, of how a serious game training aid for rugby union.

In chapter 6, the findings of the previous chapter were used to design and create the initial Shieldwall: Rugby research prototype that was presented to the key expert participant group for feedback to further develop this. The prototype presented received feedback in the form of another round of interviews with the participants where the transcripts were coded to provide crucial findings to further improve the prototype. This ensured the user-centred design methodology was followed at all stages of development of Shieldwall: Rugby prototype. This design and creation of the serious game prototype meant that objective 3 was achieved by this chapter and followed a RAD methodology. This further contributes towards answering research question 3, implementing a serious game training aid prototype for rugby union.

The Shieldwall: Rugby prototype was then tested using a user study which was consisted of 2 parts: A usability test with a participant research group of rugby players to understand how usable the game as a training aid was using the Post-Study System Usability Questionnaire (PSSUQ), and then conducting interviews with expert coaches of the research group, to ascertain the improvement of player decision-making and cognitive abilities by assessing the impact of prototype by proxy. The prototype was initially given to the players to use prior to a regular training session, they then completed the PSSUQ test, took part in their training session where coaches assessed the impact during the session. After this, each coach was then interviewed with the transcripts coded similarly to the previous study in the prior chapters. The findings from this found that the prototype was usable and engaging for rugby players and coaches as well as showing that such a serious game can be used as a training aid for a team sport such as rugby union. This study evaluated the design of the prototype, which was based upon the conceptual framework and

contextualised research artefact, thus achieving objective 4. By showing the impact of the prototype, this also answered research question 1 and 2; a Serious Games can be used for training Decision-Making in Team Sports, and players and coaches engage with games as a training tool.

8.2. Contributions

Throughout this thesis, contributions have been made to achieve the 4 objectives set out in chapter 1. These key contributions are found in Table 8.1. The next sections will present these contributions in order of importance. During this thesis, a first-of-its-kind Headlights: Conceptual Framework was presented that established the required strategies and skills that underpin decision-making and its training within team sport, as well as the serious game design considerations required for training skills such as decision-making in a team sports context. The thesis also contextualised this framework by creating a research artefact for the sport of rugby union from the conceptual framework, which led to the creation Shieldwall: Rugby research prototype. The thesis also used a User-Centred Design Methodology, an iterative and multi-phase development cycle that engaged experts from within the team sport of rugby union to create a usable prototype for its intended users.

Table 8.1: Summary of research contributions

Contribution	Objective	Research Questions
Headlights: Conceptual Framework	Objective 1	RQ3, RQ4
Research Artefact & Shieldwall: Rugby	Objective 2 & 3	RQ3
User-Centred Design Methodology	Objective 4	RQ1, RQ2

Headlights: Conceptual Framework

The Headlights: Conceptual Framework is the primary contribution made in this research, which achieves objective 1 by designing a conceptual framework of the key concepts involving decision-making in team sports, as well as within the context of a serious game. This is the first structured framework to link decision-making in team sports with serious game design. From this, a training aid can be made for team sports as it was for rugby union within this research. Headlights creates a structured list of concepts that future designers can use to consider what is needed to make a training aid of this type impactful. This framework therefore allows other researchers and industry practitioners to be able to design and implement a similar framework for other team sports, by identifying the key considerations for such designs to be created. This allows future research to be carried out on its impact in a wider field of team sports, as well as allowing the exploration of new methods to be used for training aids such as the created Shieldwall: Rugby research prototype, as well as in the exploration of different training aids.

The framework establishes the key decision-making training & learning strategies, the user input sources, the perceptual-cognitive abilities, as well as team sport concepts that underpin Decision-Making Training in Team Sports. This framework established which of these concepts must be considered when developing a training aid such as a serious game. By doing this, this section of the framework can be used in future research and development of training aids that seek to train these skills. By doing so, future work on such a training aid answers the questions of which perceptual-cognitive abilities are required to support and improve decision-making in a team sport context, such as that found in rugby union which previously did not have existing research to answer. The conceptual framework identifies the key concepts for each area to be considered by researchers and designers which can allow for a contextualised design framework, as implemented within the research artefact of this thesis to create the Shieldwall: Rugby prototype.

The framework also identifies the key considerations towards creating Serious Game for Decision-Making in Team Sports. Whilst there is previous research into improvement of skills through such games in the field of sport such as basketball [61], this did not identify a full design framework. The Headlights: Conceptual Framework does this, with the key sub-sections and themes identifying the underlying Team Sport Game Mechanics required, the Serious Game Design methodologies, the Hardware & Platform Interfaces that can be used for such a training aid as well as the actual Serious Games background (their Applications & Approaches, as well as the Game Design Approaches used in these game types). This allows for a serious game of this type to be applied for other team sports, as this thesis showed that by following of the user-centred design methodology, a serious game can be designed and created from a contextualised version of the framework – in this case the research artefact that was used to provide a specific rugby union context. With this design methodology, an expert key participant group from the sport of rugby union also ensured that all the required concepts were covered within the framework. The process demonstrates how the framework can be operationalised: first as a general design tool and then adapted into sport-specific applications through expert input. This framework identifies the key concepts and skills such as perceptual-cognitive abilities required for a serious game training aid for the sport, and provides such a framework for what a game should look like – this answers research question 3 and 4.

Research Artefact & Shieldwall: Rugby

The Research Artefact provided the contextualisation of the Headlights: Conceptual Framework which provided a design outline, which then led to the implementation of the Shieldwall: Rugby prototype. By using this step process to design and implementation from the underlying theory, the final serious game followed a user-centred design which prioritised the needs of its users – and on analysis and assessment

was shown to be an impactful training aid. By going through this process within the thesis, it has led to the first working serious game designed for training decision-making within the sport of rugby union. This also means it is the first game of its kind created from the initial Headlights: Conceptual Framework. Chapter 7 validated this game design and implementation pipeline, going from conceptual framework to research artefact context to an implemented serious game prototype, by showing the impact and usability of Shieldwall: Rugby among participant rugby union players. By validating this process, it demonstrates a pipeline for the development of future games of this kind for researchers and designers.

The creation of the Research Artefact achieves objective 2 by creating the design framework for the serious game to train decision-making in rugby union. The artefact itself was created to contextualise the concepts identified within the Headlights: Conceptual Framework, specifically for the sport of rugby union. By creating such an artefact, it shows how future design and research can take the conceptual concepts from such an abstract framework and make a sport-specific design outline for an intended team sport. It showed how specific game mechanics and design can be given this sporting context, with specific tactical elements such as the rugby specific Player's Picture being able to be identify which considers a player's position and a team's tactical strategies. By co-creating this artefact during the 1st thesis study with an expert participant group, this artefact also ensured its relevance to the sport.

The development of the Shieldwall: Rugby prototype achieved objective 3 of this thesis, by developing such a prototype. This is proof-of-concept prototype which used the research artefact as a design framework shows how the contextual elements from such an artefact can then be implemented within a serious game, taking these concepts and framing them within 3 distinct game modes for Individual, Tactical, and Positional decision-making. It also shows that using the context can provide sport-specific scenarios such as those created for those game modes for rugby union. By using the key participant group as well, it also shows how future designers and researchers can create a feedback loop for improving a developed serious game training aid. Shieldwall: Rugby also shows that the shortcomings of existing training aids such as video analysis can be overcome with the use of a serious game, by creating a 3D virtual environment which can be implement decision-making scenarios and tailoring them for all sporting knowledge backgrounds using game mechanics and design methodologies. The creation of the serious game training aid in the form of Shieldwall: Rugby, and its validated impact and usability provide a clear framework for how a training aid of this kind should look and play. This answers research question 3 as established in chapter 2.

User-Centred Design Methodology

A User-Centred Design Methodology was used throughout the design and implementation of the Shieldwall: Rugby prototype. This methodology ensured the needs of the intended users was followed, identifying key requirements. These needs were considered at each stage of the design process cycle, with the aim of this methodology to create systems that increase user productivity with the designed application, their satisfaction as well as decreasing user training time which has been shown previously by existing research [56]. By following this methodology, it validates it as a way in which to design and develop a serious game. This was done in this thesis in a 3-phase study which interviewed a key participant group throughout of rugby union coaches and players at each stage of development:

- **Phase 1:** A first interview was carried out to the establish the key training needs and requirements for players of the sport of rugby union within any training aid, which further developed the initial conceptual framework (established by the systematic literature review) and developed a conceptualised research artefact from this for the sport of rugby union.
- **Phase 2:** An initial High-Fidelity Prototype was created and presented to the group for feedback, which in turn refined the underlying conceptual framework and contextual research artefact.
- **Phase 3:** A final prototype, Shieldwall: Rugby was presented to the group and improved because of their feedback.

This methodology and its resultant prototype were assessed in chapter 7 by given the developed game to a group of participant rugby players, who then completed a player usability test. The impact on the players was then also assessed by proxy by their team coaches who were interviewed after a regular training session, following the use of Shieldwall: Rugby. This assessment found that the training aid game was usable by players, engaged with by coaches, as well as having a positive impact on the player group. This means that the User-Centred Design Methodology used achieved objective 4 of this thesis by providing an evaluated game prototype, as well as refinements being made to the conceptual framework and contextual research artefact during development.

By successfully creating a usable and impactful game prototype, this means that this methodology is a validated pipeline for future researchers and designers to design and create similar serious game training aids in the future. It also shows that this methodology can be used to create impactful software for fields such as team sport, which meets its intended needs of its users. In addition, it shows that a multi-phase approach with a key participant group can be used to improve usability and impact in the serious game design pipeline. In addition, by applying a user-centred design methodology to design and create the

Shieldwall: Rugby prototype, as well as validating this with the two user studies', this answers research question 1 and 2 as identified in chapter 2 – this is because it shows that a Serious Games can be used for training Decision-Making in Team Sports, as well as showing that both players and coaches engage with games as a training tool.

8.3. Research Limitations

Whilst this research developed a usable and impactful serious game prototype for rugby union, there were specific limitations on the research. 30 participant players were used within the usability and impact study in chapter 7, which whilst showing by proxy assessment there was an impact on this group and that they found it an engaging and usable training aid, this number of participants is not large enough to generalise to wider populations such as the wider network of rugby union players and coaches. However, the study findings do provide validity and significance, where larger case studies could be used to provide further insight in parallel with this. Further research should look to use a wider participant base, as well as participants from different performance levels such as at the elite level. As this assessment was also carried out by proxy, it was from the coach's perspective. Hence, the findings do not include a longevity study and one-to-one assessment of individual players. Yet, in sports the coach assessment of impact and improvement is standard practice and a common substitute.

In addition, whilst men and women players across various experience levels were used in the study, only one club was used with participants. The impact could be further assessed by providing the Shieldwall: Rugby prototype to other clubs across different performance levels of the sport to measure impact. This could also apply to clubs from different nations as the impact could be different based on this. Whilst specific alterations to the game were made based upon Rugby Experience Level such as the Game Difficulty Curve, having the wider base of player performance levels can provide further refinement to this, increasing its impact.

Whilst not in scope of this project, a sport psychologist was not used within the expert key participant group within the 1st user study. Future contributions by such an individual could be considered to assess the psychological impact of such a serious game training aid, as well as further inclusions on from this field within the prototype. Whilst the studies showed there was an impact already on the rugby players that used it, having further additions from a psychological background could only improve this further.

Additionally, whilst the developed Headlights: Conceptual Framework created a general framework towards creating a serious game for decision-making in team sports, it has only been shown to be usable

and impactful in one sport, rugby union, within this study. Future work could explore its use for other team sports, which can be achieved by using the same validated design and implementation pipeline identified in this thesis – taking the conceptual framework, creating a contextual research artefact and therefore implementing a serious game training aid based on this.

8.4. Future Research & Development

This section will address the ways in which research into the areas covered by this thesis could be approached in the short, medium and long-term future, as summarised in Table 8.2. There are 3 domains for which future work research and development will be considered*: Serious Games in Team Sports*, *Serious Games as a comprehensive training aid for Team Sports*, and *Artificial Intelligence (AI)*. Future work on the *Serious Games in Team Sports* focuses on the further development of the use of such a serious game within sports at different performance levels and across different sports. *Serious Games as a comprehensive training aid for Team Sports* establishes the future work in expanding the features of such a game-based training aid, improving the user experience, impact as well as immersion with the training aid. Finally, *Artificial Intelligence (AI),* looks at the advances made in this technology and how it can be applied and used within a training aid of this type for athletes and their skills.

Table 8.2: Summary of Future Research & Development

Domain	Short-Term Future	Medium-Term Future	Long-Term Future
Serious Games in Team Sports	Expanding the artefact to similar team sports to rugby union	Incorporate elite-level performance	Creating a multi-experience-level, multi-sport platform
Serious Games as a comprehensive training aid for Team Sports	Content Management, Collaborative decision-making training	Expanding training to physical skills, cognitive capacities, and communication	Fully immersive training experiences
Artificial Intelligence (AI)	Dynamic difficulty adjustment AI techniques	Content (scenario and tactics) generation	AI coach

Short-Term Future

Within the short-term, immediate future of research into the domain of Serious Games in Team Sports, research should look to expand on the existing conceptual framework by looking to similar sports to create a new artefact for, further validating the framework for more than just the sport of rugby union. Further

validation and measurement of the impact of such artefacts could be measured by researching such training aid's impact with a wider group of participants, across multiple levels of performance, as well as in multiple different countries. This exercise of providing contextualisation across other sports, as well as measuring the impact of the result would underline the overall importance of the Headlights: Conceptual Framework for use as a design framework for creating a Serious Game for Team Sports to train athlete's decision-making skills.

In the short-term, improvements could also be made to the training aid, to ensure that Serious Games as a comprehensive training aid for team sports like rugby union capture all the required skills and functionality required. This would further ensure user-centred design is followed by making improvements such as adding a further form of Content Management – as coaches during the studies identified that tailoring specific scenarios for their players would allow specific tactical and targeted skills training. This could improve the engagement in such a training aid for both players and coaches. In addition, further features could be added to include Collaborative Decision-Making, which was identified by the key participant group during the 1st user study of this thesis. This would allow teammates to be able to make decisions together, replicating further a real-life team sport. This again would improve immersion and expand the usability of the serious game training aid. Additionally, feature improvements such as improving accessibility through in-game settings could improve the usability of future training aids.

And finally, within the domain of Artificial Intelligence (AI), new developments in using adaptive AI could further improve such mechanics and design features already found in the serious game training aid developed within this thesis. Such features as the Game Difficulty Curve could be tailored by AI to be more responsive to the player using them. This would improve immersion, adding to the Game Flow of the serious game [66].

Medium-Term Future

In the medium-term, future research work within the domain of Serious Games in Team Sports should look to be able to fully incorporate elite-level performance, with the additional considerations for this level of athlete fully considered within a user-centred design methodology. This level of performance sport has athletes performing at a higher level than those used during this thesis, which means they will be of a higher skill level. So, to ensure a training aid game is usable and engaging to this group, alterations to existing game architecture will be required particularly on the Game Difficulty Level. To achieve successful Flow Theory, challenge of the game should not be too far advanced of player skill so that it causes frustration. Therefore, balancing challenge with skill level is an important consideration when designing

the game for this level of athlete [25]. Elite-level performance will also require further understanding of the sport within a game training aid, so this will need to be fully developed, such as much deeper team tactics, or superior perceptual-cognitive abilities.

Within the same time frame for the Serious Games as a comprehensive training aid for Team Sports domain, developments in research should consider the expansion of the skill sets training in such aids to include physical skills, cognitive capacities as well as communication. Whilst some research has looked to explore the relationship of using such virtual environments and games to improve other skills such as motor skills in basketball players [5], these studies have yet to establish the true extent of how such physical skills could be improved in their use. The underlying perceptual-cognitive abilities that underpin decision-making was explored in this research, however there was not a specific focus on improving these through the gameplay specifically. Furthermore, psychology could be used in further developments of such a serious game, with sport psychologists becoming a part of their development. This could be achieved through the addition of further hardware and technologies out with the most accessible used in this research (mobile) to more immersive technologies such as virtual reality. This has already been used in training team sports such as basketball [27]. In addition, communication skills were identified as key skills in both user studies for rugby union players to develop during interviews. An investigation into integrating this type of training within the serious game training aid could be explored.

Finally, AI could be used in future work in the medium-term to improve the impact and usability of training aids of this kind. During interviews, and within the short-term discussion, it has been established that there should be an involvement of coaches to custom-create content to ensure greater engagement with the training aid. AI could be used as a means of generating further content, such as creating new scenarios for the player or further tactical decisions to improve understanding.

Long-Term Future

By using the conceptual framework to create validated artefacts and subsequent training aids within the short term, and then subsequently fully incorporating elite performance sport within the medium term – the long-term development of this research could focus on the creation of a multi-experience-level training aid within an integrated multi-sport platform. By creating a multi-experience-level aid, truly all experience levels within a sport could be considered and ensure the relevance of such technology to all athletes. One of the weaknesses identified by existing technologies was to ensure its relevance to all athletes no matter what level, as video analysis was identified as being more suited to expert athletes. The role of performance analysis as well is a mentally demanding one, and not available to all sports or club's dependent on funding

levels [10], [11]. By creating such a multi-sport platform, this could ensure the benefits of using such training would be able to reach a wider audience of sport athletes no matter what their sport is, giving a means to overcome difficulties with existing training aids. By creating an ecosystem for multiple sports, such a platform could identify transferable skillsets between sports, particularly if an athlete is changing to a new sport – idea sharing would also be possible between these sports, with sports being able to identify new ways to train skills based upon findings in another sport that is relevant to theirs.

Long-term, Serious Games as a comprehensive training aid for Team Sports should look to become even more engaging and immersive to the intended user – the athletes. Using a user-centred design methodology such as that in this research can improve this, as shown during the user studies conducted. As technologies become more available or new ones emerge, using such a methodology well ensure that a fully immersive training experience would be possible. By expansion of skill sets to be included within a serious game training aid as identified in the medium-term goals, and with the improvements by adding collaboration to decision-making training as well as more extensive content management in the short-term, the long-term future work can use these to continuously improve immersion. This could lead to a vast array of skills and custom experiences being created within future training aids. Previous research has shown that by increasing interactivity and immersion within a serious game in ways such as this, the game flow experienced also increases which improves the experience for the player [30][66], so future work in the long term should aim to be more interactive and immersive.

As technology also improves, with further improvements expected in the domain of AI, future work should seek to utilise these advancements in technology to further the impact of training aid prototypes in team sports. With content creation being a goal for the medium-term, as well as game difficulty adjustments being short-term future work goals, a means of coaching with all the feedback mechanisms you would expect of a real-life coach could be the future for the AI development of training aids in sport such as serious games. The training aid feedback developed in this research was identified by the key participant group interviewed in the first study as a positive means to give feedback in the training aid – with custom AI generated content being created, AI could also provide feedback in the style a coach would to respond to scenarios, replicating real-life coaching and further improving the immersion with the serious game training aid. By using AI in this way, AI Coaches could become personalised to the individual player, something that can prove challenging in real life team sport coaching, particularly in sports such as rugby which is played with a larger number of players in a team.

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Chapter 9: Appendix A: Key Participant Questions, Phase 1

The following questions were asked in this interview phase to each participant. Each question was open-ended, with interviews recorded and transcribed.

Section 1 Questions:

1. What is your background in Rugby Union?
2. What is your current role within Rugby Union?
3. Thinking about decision-making training for rugby players, what training aids are you aware of for Rugby Union players who wish to train these skills?
4. Thinking about decision-making training, in what ways do you currently think rugby players train decision-making strategies within their teams' tactics?
5. Thinking about cognitive ability training for rugby players, what training aids are you aware of for Rugby Union players who wish to train these skills?
6. Thinking about cognitive ability training, in what ways do you currently think rugby players train their cognitive abilities?
7. What limitations are there with the current use of training aids in Rugby Union?

Section 2 Questions:

1. Thinking about decision-making training for rugby union players, what tasks in a rugby match do players undertake that a training aid should seek to address?
2. Thinking about cognitive ability training for rugby union players, what tasks in a rugby match do players undertake that a training aid should seek to address?
3.
    a. What key decisions are required to be made by a rugby union player, regardless of position?
    b. What key decisions are required to be made by a rugby union player in their given position as a forward/back (as appropriate to stakeholder background)?
4. Are there any position-specific scenarios that should be addressed with a training aid?

Chapter 10: Appendix B: Key Participant Questions, Phase 2

The following questions were asked in this interview phase to each participant. Each question was open-ended, with interviews recorded and transcribed.

Questions:

1. Based upon the themes of Phase 1, explore the concepts behind the storyboard design presented (this question will be formed further from feedback in phase 1)
2. What did you like best about the design?
3. What did you like least about the design?
4. Can you recommend any changes to improve this design?
5. Would you recommend this way of learning to others?
6. Any other comments?

Chapter 11: Appendix C: Key Participant Questions, Phase 3

The following questions were asked in this interview phase to each participant. Each question was open-ended, with interviews recorded and transcribed.

Questions:

1) Based upon the themes of Phase 1 & 2, explore the concepts behind the prototype presented (this question will be formed further from feedback in phase 1 & 2)
2) Thinking about cognitive abilities, does the game fulfil the training needs of a rugby union player in a forwards/back (as appropriate for the stakeholder interviewed) position?
3) Thinking about decision making skills, does the game fulfil the training needs of a rugby union player in a forwards/back (as appropriate for the stakeholder interviewed) position?
4) What did you like best about the game?
5) What did you like least about the game?
6) Can you recommend any changes to improve this game?
7) Would you recommend this way of learning to others?
8) Any other comments?

Chapter 12: Appendix D: Player Participant Questionnaire

The following questions were asked to all rugby player participants in the form of a digital questionnaire:

1) Overall, I am satisfied with how easy it is to use this game.
2) It was simple to use this game.
3) I was able to complete the tasks and scenarios quickly using this game.
4) I felt comfortable using this game.
5) It was easy to learn to use this game.
6) I believe I could become productive quickly using this game.
7) The game gave error messages that clearly told me how to fix problems.
8) Whenever I made a mistake using the game, I could recover easily and quickly.
9) The information (such as online help, on-screen messages, and other documentation) provided with this game was clear.
10) It was easy to find the information I needed.
11) The information was effective in helping me complete the tasks and scenarios.
12) The organization of information on the game screens was clear.
13) The interface of this game was pleasant.
14) I liked using the interface of this game.
15) This game has all the functions and capabilities I expect it to have.
16) Overall, I am satisfied with this game.

Chapter 13: Appendix E: Rugby Coach Interviews

The following questions were asked in this interview phase to each participant. Each question was open-ended, with interviews recorded and transcribed.

1. Do you think that the research prototype used by the players helped to improve during the following training session? How? In what aspects?
    a. Scale of 1-10 how would you rate the impact
2. Did using the prototype see these players improve in utilising skills such as pattern recall or visual attention during the following training session?
    a. Scale of 1-10 how would you rate the impact
3. Did using the prototype see these players improve in utilising skills such as individual and team tactical decision-making? Did they make better decisions based upon their individual playing position?
    a. Scale of 1-10 how would you rate the impact
4. What are your current methods for building the same skills? How does the prototype's impact compare to it?
    a. Scale of 1-10 how would you rate the impact
5. Any other comments?