Design and Implementation of a Low Cost Virtual Rugby Decision Making Interactive

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Abstract. The paper describes the design and implementation of a novel low cost virtual rugby decision making interactive for use in a visitor centre. Original laboratory-based experimental work in decision making in rugby, using a virtual reality headset [1] is adapted for use in a public visitor centre, with consideration given to usability, costs, practicality and health and safety. Movement of professional rugby players was captured and animated within a virtually recreated stadium. Users then interact with these virtual representations via use of a low-cost sensor (Microsoft Kinect) to attempt to block them. Retaining the principles of perception and action, egocentric viewpoint, immersion, sense of presence, representative design and game design the system delivers an engaging and effective interactive to illustrate the underlying scientific principles of deceptive movement. User testing highlighted the need for usability, system robustness, fair and accurate scoring, appropriate level of difficulty and enjoyment.

Keywords: Perception and action · HCI · Game design · Interactive · Sport

1 Introduction

This paper describes the design and implementation of a rugby side step interactive for use in an education and heritage visitor centre in Belfast, N.Ireland. This interactive is based on ground breaking deceptive movement research conducted by [1] and allows users to attempt to virtually block animated rugby players running towards them. The virtual rugby players are carrying out different side steps (deceptive movements) of varying levels of difficulty. The paper will briefly describe the research and the design of the system with reference to the psychological principles underpinning the work.

Original work by Brault et al. [1] explored how coordinated body movement can be used to not only communicate action intention but also to deceive an opponent. The researchers made use of an interactive VR environment to present real body movement (deceptive and non-deceptive), captured from real rugby players using motion capture. These body movements were then used to animate virtual rugby avatars that make side-step movements to try and beat a defender. Participants were asked to predict the final running direction of the virtual attacker (See Fig. 1). An analysis of the participants' responses showed that expert players focused more on the visual information that specified true running direction (i.e. the avatar's centre of mass) compared to the novice users

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who tended to focus more on the deceptive movement signals (upper trunk yaw and out-foot placement) that fooled them into thinking the avatar was running in the opposite direction. Further, it was found that experts waited significantly longer before making a decision. This delay in movement initiation allowed experts to pick-up more visual information which in turn allowed them to be more accurate in their decisions. It should be noted, however, that this delay was possible due to the superior action capabilities of the experts (i.e. their ability to cover the distance quicker than novices). This cutting edge experiment made use of expensive virtual reality equipment and a large laboratory space to fully immerse the participant in the virtual environment. The current work highlighted in this paper, aims to transpose the essence of the aforementioned research into an interactive that can be employed in a public space with the associated limitations in complexity, practicality and cost of the equipment used.

Fig. 1. Original work by Brault et al. [1]. (A) Participant wears custom VR backpack. (B) Deceptive MOCAP animation of French rugby players within Virtools. (C) Participant moves to intercept the virtual player. (D) Makes use of Intersense IS-900 tracking with Cybermind Visette45 HMD.

The interactive aimed to provide a physical and cognitive experience of a key component of the game of rugby (namely blocking an attacking player), while additionally, illustrating the importance of the dynamics of human movement in signaling action intentions. Meaningful participation for visitors in a museum setting is challenging [2]. In order to provide such meaningful participation fundamental psychological research was adapted to engage, entertain and educate the user.

2 Design

Psychological principles underlying design choices will be outlined, followed by a description of the system designed.

2.1 Egocentric Viewpoint

In order to measure perception and action we need a methodology that can adequately and accurately recreate this perception/action loop from the player's perspective (e.g. head mounted cameras [3]). In other words, we need to use technology that allows us to recreate an athlete's (egocentric) 3D viewpoint of an unfolding sports related event that can be updated in real time. An egocentric viewpoint is essential to provide players with the relevant information necessary to act in a natural manner. In the original work a head mounted display combined with a low latency tracking system was used (Cybermind Visesette45 with an Intersense IS-900 ultrasonic positioning system). This methodology has been adapted for use in other context such as cricket bowling, gap perception in rugby and goal-keeping [4–7]. However, in adapting the work for use in a visitor centre setting, use of such equipment was cost-prohibitive and does not lend itself to long-term practical use. Furthermore, it does not allow other visitors to share the experience in a satisfactory way, with head mounted display ego-motion resulting in a very jittery image. To overcome these limitations a large screen was used to present the action, geometry sized to provide a one to one mapping of movement in the real world to movement in the virtual display. This provided a perceptual window of the virtual stadium, where the virtual player could be perceived as moving towards the visitor playing the game. A Microsoft Kinect camera system was used to update the viewpoint in real-time with the image moving left or right as the visitor moved. Although the projection was not in 3-D, having a depth cue such as motion parallax generated by the ego-motion of the visitor, offered a much more compelling experience.

2.2 Immersion

Immersion is related to the technical capability that a system has. It aids sense of presence but is distinct in that it relates to technical specification. The system designed for the visitor centre acknowledged that the technical specification of the original work would need to be reduced but that this does not necessarily have to impact on the sense of presence perceived by the user. i.e. there may be a low level of immersion but a high level of presence.

2.3 Sense of Presence

Sense of presence is highly related to immersion, although a discrete concept, defined by [8] subjective perception in which an individual's experience is generated by technology but that that experience is perceived without acknowledging the role of the technology i.e. an individual is present in a virtual experience but feels that it is real in some subjective sense. It has been argued that VR systems provide the potential, through improving, technology to immerse an individual and provide a sense of presence. However, sense of presence is not solely defined or constrained by the complexity or technical capability of the hardware used. As previously discussed, a reduced technological solution was deemed most appropriate in the context of use. Therefore a number of factors were combined into the design to improve the sense of presence based on the factors highlighted in the work of Schuemie et al. [9].

- Immediacy of control: The Microsoft Kinect makes use of a camera-based system to estimate body position and as such the user does not need to wear any additional sensors. With this minimum abstraction between movement and movement-based feedback, an immediacy of control was provided.
- Anticipation: It was paramount to capture the real movement of players as the provision of naturalistic performance provides the best source of information to allow players to anticipate direction of travel. With sufficient control, immediacy and anticipation, perception of movement also contributed to the sense of presence.
- Mode of control: The user interface was purposefully simplified to avoid any complicated gestures. This included reducing any initial input to the system via player selection or otherwise. Rather than make use of gestures to control the game, a simple button press was used to start the interactive. Further, calibration was included within the game mechanic and hidden from the end-user. Interaction was only provided via body movement (stepping side to side) in a natural manner.
- Modality of Information and multimodal presentation: Information was provided for both the visual and auditory sensory channels to draw the user more into the interactive. The stadium was recreated and actual sounds from an Ulster rugby game were captured. Realistic game commentary and feedback were recorded from a well-known sports commentator and embedded throughout the game to further enhance the user experience. Clear sound and visual information were also combined to provide clear playing instructions and provide performance feedback during game play.
- Environmental richness: High-resolution models of known objects (e.g. Kingspan stadium), realistic player avatar movement and recognisable stadium sounds all contributed to an environmentally enriched experience.
- Reduction of distraction features: The experience was designed to provide an augmented reality i.e. the player movement in the real world has an effect on the virtual world laid out. This was enhanced through the use of grass flooring which stretched from the real world through to the virtual pitch. Further, the game is played within a semi-enclosed space, reducing outside distraction and drawing the visitor into the interactive experience.
- Meaningfulness of the experience: The experience attempts to provide a means of interacting with professional rugby players, watching their real movement while attempting to block them as they attempt to deceive and pass. Essentially, the meaningfulness of the experience should relate to the real world [A]. The system provided the capability to do so with players reporting that they felt immersed within the experience, albeit without any physical contact.
- Realistic performance: Sense of presence was enhanced through the presentation and measurement of real performance of both virtual character and the player (i.e. performance feedback score (block = 10 points, half-block = 5 points, miss = 0 points) at the end of each trial).

2.4 Representative Design

An important factor when designing a system is to maintain an interactive relationship between an organism and his/her environment so that the behaviour observed in an experimental context mirrors, as closely as possible, the behaviour observed in a realistic sport setting [10]. The concept of representative design introduced by Brunswik emphasised the need to have experimental tasks that allow the player to pick up perceptual information that specifies a property of the environment actor system [11, 12]. The system made use of real captured movement to ensure that behaviour elicited would closely match those found in a realistic sporting setting.

2.5 Perception and Action

Related to representative design, is the notion of perception and action coupling. Gibson said that "We must perceive in order to move but we must also move in order to perceive" [10]. In the context of sport, players are active (rather than passive) perceivers who continuously engage in exploratory behaviours that allow them to pick up important information to guide their decisions about when and how to act. In other words, their behaviour emerges from their egocentric perception of what the environment affords at a given moment in time (active perception) and what the actor is capable of doing (action capabilities) [13]. The system maintains the perception-action loop, allowing players to act upon the perceived heading direction. A mere button-press would miss this important concept. Decision-making emerges from the constraints in the player-environment interaction. Affordances emerge as a player interacts with the system. This unfolding dynamic allows each player to obtain a unique performance, based on their own action capabilities. This perception-action loop should be maintained through mapping of movement in the real world in the virtual [14].

2.6 Functional Fidelity

In a review by Miles et al. [15] noted that the most important factor for using virtual reality technology in a sporting context is functional fidelity. Research suggests that picture realism is not a determining factor when trying to use virtual reality technology to elicit realistic sporting behaviours [16, 17]. Rather, it is the extent to which the user can interact with the environment and respond as they would in the real world that predominates [18]. However, work by Vignais et al. [19] highlights that visual fidelity can play a factor with a need for sufficient communication of the simulated movement within an animation. An observer's own movement (action) must be incorporated into changes in the display (perception). By maintaining this aspect from real-life, the perception/action loop experienced will be carried over from real to virtual and the level of behavioural realism, or functional fidelity, in a virtual environment will be significantly increased [20]. Functional fidelity includes aspects such as accurate representation of player movement, time and place appropriate interaction which maintains real time response, captured via natural interaction with the environment and replication of the physical properties of those interactions.

2.7 System Design

Game Design. The operational definition of a computer game as defined by Pauli et al. is playful interaction with a computer which involves an effort to overcome unnecessary obstacles [21]. There are many benefits of game playing: Enjoyment and pleasure, sense of structure, motivation, activity, flow since games are adaptive, learning as games have outcomes and provide feedback, ego gratification, excitement, creativity, emotion and social learning [22]. Flow experience is defined as consisting of eight fundamental elements [23]. These are that a task can be completed, that there is an ability to concentrate on the task, that there are clear goals and immediate feedback to facilitate this, that a sense of control over actions emerges which is effortful but achievable, that concern for self disappears but emerges more strongly after the task is complete and that the sense of duration of time is altered. Flow has been identified as a major reason for the attractiveness of a game [24]. They state that dual-flow is required to keep a player in a state of flow. This comprises of the dual flow of attractiveness and effectiveness. Good game design comes out of four main principles: the designer, context, participants and meaningful play [25]. Building on this, Salonius-Pasternak and Gelfond suggested that effective game design should meet the needs of its intended audience in terms of expectations and characteristics of the audience [26]. The audience was defined as young people from age six upwards with a wide range of exposure to rugby. With these considerations in mind, the aim was to provide an informative, realistic but playful movement game interactive to illustrate the aforementioned psychological components involved in deceptive movement in rugby. The following sections describe the design and implementation of the interactive based on the game design concepts discussed.

Game Mechanics. To play the interactive users must attempt to block an approaching virtual player. A total of six different players perform a pre-recorded deceptive movement to either the left or right side of the user. The user attempts to block the virtual player by anticipating the correct running direction and then moving to the correct side. The game algorithm determines if a full, half or no block has occurred by detecting the user body position relative to the avatar as the avatar passes the user. Performance feedback is given after each attempted block and a final score is presented to user at the end of the six trials.

Scoring. Scoring was based on a 0 (no tackle), 5 (partial tackle) and 10 (full tackle) point scale. Initial conception was based on scoring related to a higher number of body markers but this proved to have little impact on the end score achieved and complicated the scoring dynamic. Rather only six tracked components were taken into account to determine if there was a collision between the virtual player and the user. These were left, right and centre shoulder, left, right and centre hips. A half block was scored if the user collided with the virtual player bounding box (See Fig. 2) with either the left or right hip and/or left or right shoulder (depending on the correct end running direction) while a full block was scored if the centre of the user's body collided with the virtual player. This provided sufficient complexity and granularity of score to provide a range of scores for each play of the interactive. The scoring system chosen focuses on providing effective, simple feedback based on clear objectives to maximise engagement and motivation [27]. Additionally, a focus on simulation misses an opportunity to engage the player's fantasy and as such pure accurate simulation was adapted to allow for better user engagement. This simplification of the collision detection algorithm avoided a complex interaction between the user's various body parts and those of the virtual player i.e. in real-life it becomes important to consider whether an arm or leg and associated contact points, among many other factors, would result in a successful tackle. This gamification of this rugby playing scenario allowed for non-rugby experts to engage more readily with the interactive. Score therefore could not be equated to rugby playing ability. Instead, this interactive looks only at whether a successful movement decision was made with a successful stopping tackle being filled in via user fantasy.

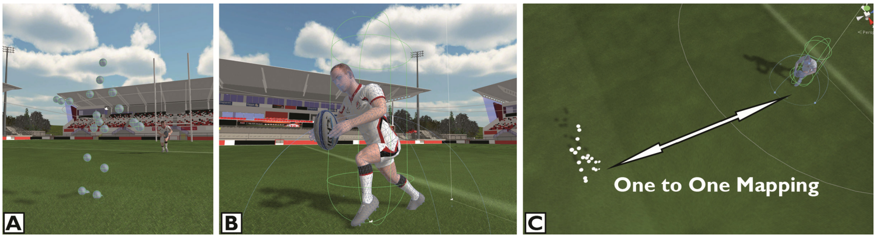

Fig. 2. (A) Kinect Points (blue dots) which represent the user's body segments. (B) Simple bounding box on the virtual player to inform collision detection between the user and the virtual player. (C) One to one mapping between the physical and the virtual space. (Color figure online)

Player Movement. Player movement within the game was detected using a low cost movement sensor (Microsoft Kinect V1) (See Fig. 2). This hardware provided sufficient speed of movement detection and processing (25 fps) to allow for the detection of the player's movement response in real-time. Although the Microsoft Kinect can detect multiple users, it was decided to simplify control by always detecting the last player in the predefined playing space. Although the Microsoft Kinect allows for gestural control, it was decided to minimise complex interactions within the interactive by ignoring this functionality. This meant that users were not required to learn any calibration movements or use gestural control to navigate the game environment. Movement was reduced to a one-to-one mapping of movement in the virtual space and detected displacement in the physical game playing space. As mentioned above, a reduced set of body points were also used to simplify scoring and to ensure that a wide range of body sizes and morphologies could be tracked. The tracked positions were head, shoulders (mid, left and right) and hips (mid, left and right) with side-to-side movement being mapped via detection of the user's head position. By in turn mapping this movement to a virtual camera a motion parallax effect was produced which enhanced both the sense of movement and immersion in the game. In agreement with Isbister and Mueller, the game provided feedback on the end result of the movement, i.e. whether a block was made or not, rather than on the quality of the actual movement itself [28]. This ambiguity allowed for the sensor to provide sufficient feedback while allowing individual users to use a range of different movements to achieve similar results. Within the context of the interactive, this type of tracking provided sufficient complexity to allow for the user's accurate detection of deceptive movement without adding other more sport specific factors such as correct body position required for a real rugby tackle.

Sound Design. As previously mentioned, audio was recorded by a well-known commentator. A script was provided with a series of responses to various game actions. The commentator was also asked to adapt the script accordingly to ensure his own unique style of presentation was captured. This was then edited with Adobe Audition to create clear, volume-levelled audio for use in-game. Throughout the game a random selection of appropriate audio segments were used to ensure players did not become fatigued by repeated audio, with the instructions, the only consistent component. Audio was used to entice players, clearly explain rules of the game, provide positive reinforcing feedback during game play and provide a summary at the end of each game session. Stadium ambiance was captured during a regular season game to capture crowd chants and supporter band songs.

Visual Presentation. As mentioned above, consideration was given to the presentation of the interactive, making use of a low-cost head mounted display. However, this was ruled out to reduce health and safety risks (VR sickness, movement in a virtual space with physical constraints, loose wiring), the inability for other users to simultaneously share the experience and also due to costs (hardware maintenance and durability, initial hardware investment). Curved projection was also considered but ruled out, due to costs, space limitations and weighting of improved experience versus a flat screen. Additionally, passive 3D projection was considered to aid immersion. However, this was ruled out for several reasons. Firstly, the nature of animations produced with regard to speed and time on screen would not benefit from 3D presentation. Secondly, users would be required to wear 3D glasses which were deemed impractical in an unmanned exhibition space. Thirdly, the interactive was designed to be viewed simultaneously by other visitors and therefore 3D projection would have appeared blurred without everyone wearing passive glasses. The space dedicated to the interactive was defined prior to consultation with the design team. As such, there was limited fixed space, within which to fit an interactive. That being said, the play space was designed to optimise the visual display screen to encompass and immerse the player within the interactive. A screen of size of 3.5 m × 2.625 m was installed to produce as large an image as possible that would span the entire play area (wall to wall and floor to ceiling). A Panasonic PT-EX510, fitted with short throw lens, was used to display images.

Physical Layout. The play space measured a total of 3.5 m × 3.95 m. Within this, a dedicated action zone was demarcated via floor markings and lighting control (See Fig. 3). This helped the user to position himself/herself in the ideal playing position. There was initial concern that the player would not reposition themselves at the centre of the game-play area at the end of each movement. However, the players, in the majority of cases automatically repositioned themselves in the centre of the game area with an inherent understanding of how the game worked and how placement in the centre would best optimise their chances of success. A run-off space either side of the main game zone was incorporated to ensure physical risk to players was minimised while they engaged with the interactive [28]. Artificial grass flooring was used to extend the perception of the virtual pitch out into the physical space, increasing the level of presence within the virtual environment. In order to cater for the greatest range of user characteristics careful consideration was given to the positioning of both the player tracking sensor (the Kinect) and the projector. The play space was limited by the capabilities of the Kinect Sensor (1.2 m - 3.5 m) and the physical limitations imposed by the space available in the visitor centre.

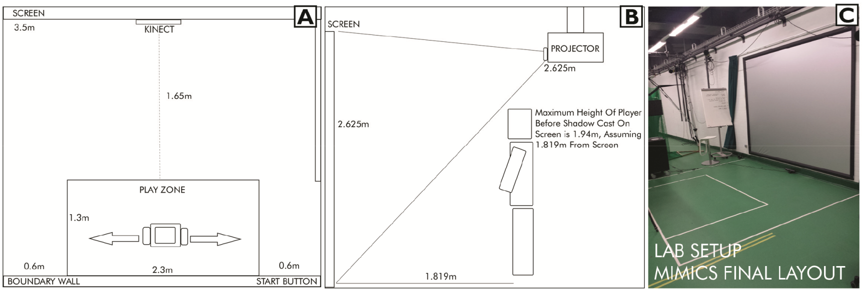

Fig. 3. Physical layout of the play space. (A) Overhead view of the space (B) overhead front projection (C) final physical space layout mocked in the movement innovation lab

Front-projection was used and therefore the possibility of a shadow being cast on screen by a user needed careful consideration. Optimum placement was made to allow players ranging in height, from 0.6 m to 1.93 m, to play the game. Those that fell outside this range could still play although body tracking became less reliable as body segments began to fall outside the tracked volume and a shadow was cast on the screen for those greater in height. A virtual representation of the player on screen was considered but it was decided to use the real-world one-to-one mapping to provide players with a sense of position i.e. the player position was not manipulated to fit the game mechanic.

Virtual Player Likenesses. Player likenesses were recreated by South West College making use of Autodesk Maya. Reference images of player faces were captured during motion capture sessions and sample shirt images were used to add player clothing. Anthropometric measurements were taken of every player to include head, neck, chest, waist, bicep, calf and thigh circumference alongside weight, height and length of main body segments. These were then incorporated into each model to closely match the real rugby player's dimensions. Each player had a skeleton attached. Models were saved in the fbx file format and imported into Unity, following standard naming conventions (See Fig. 4). Motion capture was carried out over a number of sessions making use of 22 Qualisys Motion Capture cameras (Oqus 3 and Oqus 3+) arranged to capture a 6 m × 10 m action space (See Fig. 4). Joints and body segments were markered-up providing a total of 56 passive reflective markers on each player. Their motion was then captured while carrying out a number of set movements which included walks, jog, run, idle, celebration, deceptive and non-deceptive side-steps. Side-steps were carried out against an opponent to aid timing and encourage realistic movement. Multiple trials were captured and from these a subset was selected for labelling and conversion into animation files. Labelled files were imported into Autodesk Motionbuilder software tied to an actor and subsequently to the custom 3D player likeness. For animations requiring additional length, the player's own run was merged and hand adjusted to create a seamless complete animation. Finally, finger position was manipulated for each player to ensure a rugby ball appeared to correctly sit in-hand during the virtual animations of the deceptive movements (side-steps). Each movement lasted approximately four seconds. By capturing the professional rugby player's real movements, it was possible to capture a number of deceptive movements. These deceptive movements are unique to each player and involved different relevant orientation/reorientation parameters, medio-lateral displacement of the center of mass (COM), foot, head, upper trunk, and lower trunk yaw; and upper trunk roll as described in the precursor work [1]. Essentially, by use of false exaggerated parameters of movement combined with postural stabilisation, each rugby player was able to produce deceptive movements that could deceive a defender with varying levels of success. These varying levels of success were harnessed to create an interactive that catered to a large range of capabilities.

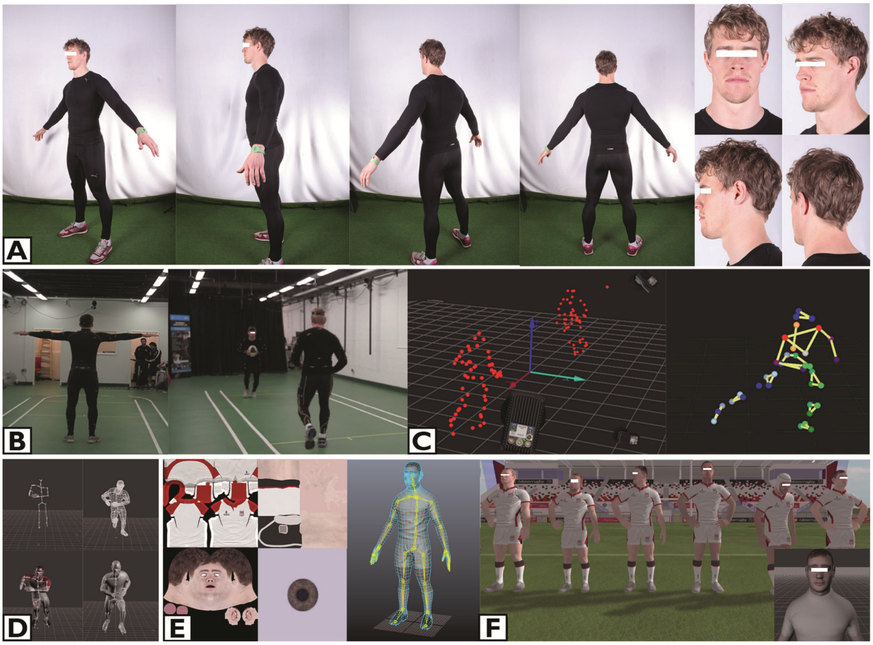

Fig. 4. Player likeness. (A) Reference photography of all players. (B) MOCAP using Qualisys. (C) Data cleanup and labelling. (D) Mapping in Autodesk Motionbuilder. (E) Texturing for normal, specular and diffuse. (F) In-game player rendering

3D Environment. The 3D environment consisted of a recreation of the Kingspan Stadium, Ulster Rugby (See Fig. 5). Initial architecture concept had been developed within Google SketchUp by Ulster Rugby Architecture and Design Contractors. This model was imported into Unity 3D and further refined to include necessary elements such as rugby posts, stadium hoardings, flood lights, home and away player seating, field markings etc.

Fig. 5. Final interactive (A) Nevin Spence Centre with the bottom panel showing a visitor playing the interactive (B) user interface instruction elements (C) final virtual player depictions within the interactive

User Interface. The user interface (See Fig. 5) was designed to fit within the larger visitor centre design motif (Mather and Co.) and was developed in-house to provide clear visual and textual guidance to users. This was combined with auditory instructions to ensure that all users could quickly interact. The instructions chosen aimed to be clear and concise while providing sufficient information for any user to begin play without need for additional assistance. In addition use of iconography was made to ensure that users were given a visual indication of actions required.

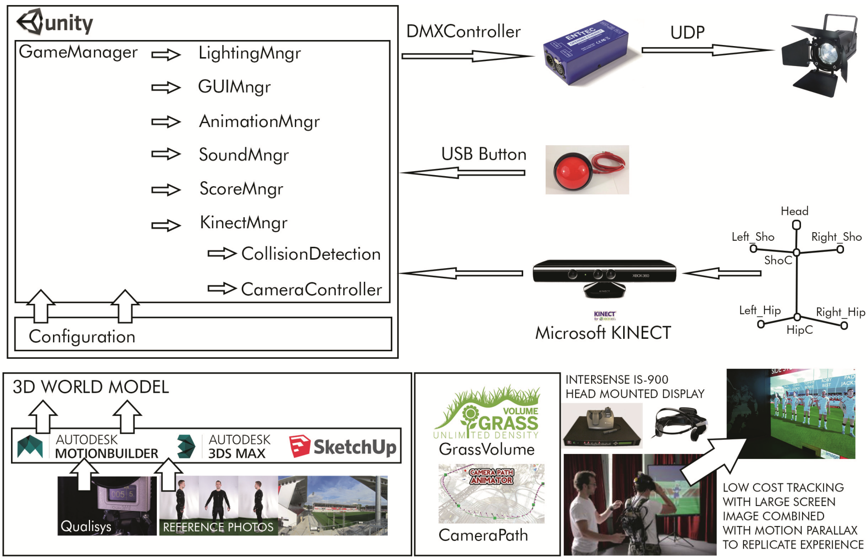

Fig. 6. System elements that enable the interface with the external hardware elements

System. The system was developed using the game engine Unity Professional 4.0. Third party assets were used which included grass pitch (VolumeGrass), stadium flyover camera manager (CameraPath) and the Microsoft KinectWrapper V1.7 Unity plugin. The program consists of a main manager class which handles game mechanics and is supported by a number of specialised classes to handle player animation, player collision, audio, user interface and lighting interface (See Fig. 6). A custom Unity plugin was written to communicate over UDP with a DMX Control unit to control lighting (fading, flashing, colour change). Configuration parameters were provided to control the game which included timing (audio, in-game, idle components), sound volume, lighting configuration (speed, intensity, colour), scoring metric and default user position relative to the virtual environment. A Microsoft Windows 7 PC (Intel core i7, Nvidia GT700 series card, 16 Gb RAM) was used to run the program connecting to a Microsoft Kinect V1 via USB. A USB start button was used to trigger game start.

3 User Testing

Previous research has shown that virtual deceptive movement can be shown to a user and can illicit natural behaviours in response to those stimuli, albeit within an experimental laboratory settings. However, in adapting the original research work for a visitor centre interactive there were a number of unknowns that required user testing. Testing was carried out in a cyclical manner with input from both end users and subject matter experts (VR, Rugby, Exhibition Design). Testing was carried out via prototyping, in-lab (Movement Innovation Lab, Queen's University of Belfast), in large-scale public testing (Make it Digital, Northern Ireland Festival event, BBC BlackStaff Studios) and in final production settings (Ulster Rugby, Kingspan Stadium, Nevin Spence Centre). Aspects considered during testing included:

3.1 Motion Perception Using Parallax Motion

Initial design proposed that user movement alone would provide sufficient connection between the virtual and physical environment. However, additional movement queues were required to engage the user and provide a perception of physical movement mapped into the virtual space.

3.2 Sufficiently Accurate Body Segment Detection

As the system made use of reduced segment tracking it was important to understand if users perceived this as acceptable within the confines of the game mechanics. The users perceived tackling as responsive and accurate to their own expectations of play. Further, testing highlighted the flexibility of body tracking used in that users of many different heights, wearing different types of clothing were sufficiently tracked to allow for gameplay throughout. The design essentially made use of the limitations of the Microsoft Kinect to help ensure relevant appropriate movement detection within the game confines

[28]. By allowing for ambiguity in movement and collision an appropriate balance was created to ensure users felt gameplay reacted in an expected way.

3.3 Unexpected Actions

Testing was paramount to understand unexpected or unplanned events that might occur during game use. Examples included users attempting to cheat the system (moving towards screen before virtual player runs past them), swapping users mid-game, a user helping another user to play (e.g. holding a younger player). Users did attempt to run forward within the play space to intercept the player before a deceptive movement was made. This was counteracted by creating a virtual zone, within which collision detection occurred. This minimised the effect of cheating the system.

3.4 User Experience of Virtual Tackle

This ties to the previous section but relates to the user experience of tackling and whether users perceived correctly that a tackle should have been made or missed. Initial testing was carried out in the laboratory using subject matter experts (experienced with VR systems, original system, experienced rugby players and coaches). This testing led to movement of fixed camera position relative to the z-direction in the virtual space. This meant that virtual player made their deceptive movement within screen space and then proceeded to virtually run past the physical point where the user was stood.

3.5 Level of Difficulty

Games should be challenging but not so much as to feel frustrating with [29] suggesting that there should be an attempt made to keep players in ‘flow’ which is a balance between challenge and ability. The level of difficulty of the movements was assessed through play-testing in-lab and in testing as part of the BBC Make It Digital Festival 2015. Initial design proposals considered balancing the game difficulty by combining a set of known player movements based on their average level of difficulty so as to provide a consistent level of difficulty to each and every user. However, during play-testing it became apparent that the level of difficulty was sufficiently set via randomisation of player movements that no further grouping of movements was required. Figure 7 shows the average score per virtual player for a total of 242 individual tackles, averaged over both, left and right final direction heading. The average score across all users for all virtual players is 5.8 (Std dev 2.9), indicating that, typically, users can make some connection with the virtual player. It is clear that players 3 and 4 were found to be more deceptive (and more difficult to block) as average scores are much lower (4.5 and 3 respectively). However, because every user faces deceptive movements from all six virtual players, the level of difficulty is sufficiently mixed to allow users to experience sufficient challenge while also rewarding play.

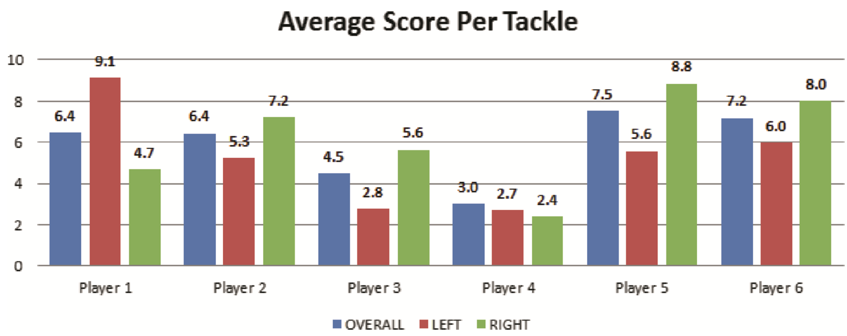

Fig. 7. Average score per tackle for each virtual player

Further, consideration was given to the level of difficulty as it applied to the physical capabilities of the user i.e. would a younger player find the interactive more or less challenging than an older user. It was found that both younger and older players found the interactive equally difficult. The physical movement required to block a player was minimal so the challenge lay in attempting to perceive and anticipate the final running direction of the player and act upon it in a timely manner. This allowed users from five years upwards to play. It is important to note that challenge and difficulty are intended in games but this does not mean that the style of interaction should be the overriding means of challenge [30]. The skills required to perform in-game were directly related to the perceived affordances made available to players. The interactive aimed to highlight the skill of the professional players involved and the skill required to anticipate or react to that deceptive movement by the user. Therefore, the game difficulty needed to remain fairly high. However, the game also aimed to provide an engaging yet enjoyable experience so a balance was struck via choice of user body position and collision detection to achieve a score.

3.6 Understanding Usability

Usability testing was carried out in the lab by (i) domain experts (interactive design subject matter experts, VR systems experts), (ii) several groups of younger users within a controlled lab environment (three groups of twenty users, ranging in age from eight to sixteen), (iii) three hundred plus users of all ages at the NI Science Festival and (iv) via a soft opening of the visitor centre for a period of three months. Instructions were made to be self-explanatory as the interactive would not be manned by staff. Further, the instructions provided sufficient visual information to allow play with or without hearing accompanying auditory instructions. Several hard of hearing users tested the interactive and were able to understand and play the game without any assistance. Each tackle was preceded by a graphic and whistle sound to prepare the user. As the interactive was part of a larger visitor centre tour, it was important that total playtime was not excessive to avoid bottlenecks. Input from experienced visitor centre concept designers suggested that the game should run for no longer than one minute and thirty seconds (note this varied slightly depending on duration of audio feedback).

Additionally, effect of fatigue was minimised by having a reduced run-time [28]. No explicit information was provided regarding how scoring worked; rather the users had an implicit understanding of whether they did or did not achieve a high score. The game rules could also be learnt effectively via user observation. This allowed users, even without instruction to play the game [28].

3.7 System Robustness

The system was expected to run on a daily basis for extended periods of time, without any support interference. Testing in-house and over an intensive period of three days at the BBC NI Science Festival indicated that the program could run for sufficient time without issue. Final lighting control was not known prior to final production installation. However, in-lab testing had highlighted appropriate ranges of lighting to ensure the Microsoft Kinect sensor would effectively pickup user movement.

3.8 User Engagement and Enjoyment

Engagement and enjoyment of a system is difficult to capture, particularly with a large range of expectations from novice users of all ages through to those experienced in playing rugby. Malone suggests that fun can be achieved via the inclusion of three components [31]. These are challenge, fantasy and curiosity. Challenge is created by the inclusion of a simple goal which should be practical or fantasy rather than the achievement of a skill in of itself. This allows for informative performance feedback regarding attainment of that goal. Fantasy is provided by inserting the user in the virtual rugby world and pitting them against professional players. Curiosity is defined as the motivation to learn independent of any goal or fantasy fulfilment and this can be achieved by sensory means, informational complexity or cognitively. Feedback is core to curiosity to help the player delve further into how to play the game. The scoring system employed is simple yet sufficient to provide this feedback. By including users (novice and expert) of all ages throughout the design process the interactive remained educational, instructive while entertaining as witnessed during extended play-testing with multiple users, requests for repeat play and via the visitor centre management report.

4 Discussion

The work highlighted that despite limitations in implementation; underlying design principles can be adopted to ensure that the important components of an interactive tool can be implemented to create an innovative interactive display. Presence is well understood so as not to be limited by the technological implementation and as such the work focused on the elements that could potentially increase levels of presence and end user engagement and enjoyment. Transformative work such as this is important to help illustrate scientific work within a relevant context to a broad range of users. This allows educators to use the fun elements of a visitor centre space as a jumping-off point to explore underlying scientific principles. The interactive design made use of low-cost components, which although have limitations, do have capabilities that allow for a suitable interaction. It provides an example of how fundamental research could potentially be adapted to be used in a non-laboratory setting.

As technology improves and also becomes more robust, there is the potential for the use of head mounted displays within public space areas. Hardware such as the Oculus Rift, HTV Vive and others can provide suitable interaction to produce other types of immersive, interactive public gaming. However, work is required to understand and improve the acceptance of such technology, particularly with regard to the desire for shared visitor experiences and the practicality of high usage within a visitor centre environment.

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